# THE NIGERIA ASSOCIATION OF HYDROLOGICAL SCIENCES (NAHS)

## PROCEEDINGS OF THE

# 11th

## ANNUAL CONFERENCE
## (CALABAR 2021)

## THEME:
# HYDROLOGY AND SANITATION IN A CHANGING ENVIRONMENT

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# FOREWORD

It is a great privilege to write the foreword to the Proceedings of the 11th Annual Conference of the Nigeria Association of Hydrological Sciences (NAHS). The tortuous journey to this conference started in 2019 immediately after the successful hosting of the 10th Annual Conference by Usmanu Danfodiyo University, Sokoto from the 21st to 24th October, 2019. The conference which was slated for October 2020 could not hold due to Covid-19 pandemic which grounded all academic activities globally and in all Nigerian Universities. In fact, at the close of 2020, we could only get seven (7) papers from contributors. Today, we are grateful that we have sixty-nine (69) solid papers from highly distinguished scholars, professionals and students in the current Book of Proceedings.

The theme of this year's conference **"Hydrology and Sanitation in a Changing Environment"** seems to have been prophetically chosen by the organizers. Indeed, the world has changed with the advent of the Covid-19 pandemic. The array of well-researched papers presented on the eight (8) sub-themes is reflective of the current interest of hydrologists in water, sanitation and hygiene.

One major highlight of the Calabar conference is the attraction of our neighbouring countries into NAHS. We therefore welcome with open arms our international participants from Ghana and Cameroon.

The choice of Calabar as host is not misplaced. Calabar is a coastal city sandwiched between two great rivers, 'the Kwariver and the Calabar river' with lovely hydrological features such as waterfalls, meander loops, in-land deltas, creeks and river estuaries. Calabar is thus the "hydrologist paradise".

We sincerely hope that the outcome of presentations, debates and discussions at the conference will proffer solutions to the challenges of water scarcity, sanitation, open defecation, flooding, surface and ground water management, entrepreneurship and job creation in the water sector of our Nation.

Finally, may I express my profound thanks and gratitude to all those who contributed both academically and financially to make this worthy academic enterprise a huge success.

Thank you.

**Professor Eze Bassey Eze**

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**LEAD PAPER 1**

# WATER RESOURCES MANAGEMENT IN A CHANGING ENVIRONMENT; THE FATE OF COASTAL CITIES IN WEST AFRICA

**Ishmael Yaw Dadson (Ph.D)**
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***Abstract***

*Environmental change has been a global issue since it affects every sector of our economies. It changes the constituent of environmental resources such as water, vegetation, air and soils, including the built environment. In West Africa, environmental change is a reflection of the spread of the Sahel, reduction in the volume and shrinkage of stream channels, soil impoverishment, change in rainfall distribution and amount as well as drought and high rate of evapotranspiration. In all these, humans are seen as both the cause and victims of such phenomena. It is therefore important to device strategies to manage environmental resources such as water to offset the consequences of environmental change. In this paper, emphasis is placed on issues emanating from environmental change and water resources with reference to coastal dwellers in West Africa. This is a concept paper, which traces the Changing Environment in West Africa with emphasis on water resources. The paper discusses the impact of changing environment on water resources, management of water resources, experiences of West African coastal city dwellers and coping mechanisms for water management. The paper concludes with some policy recommendations.*

## Introduction

Our global ecosystem is and has always been complex, dynamic, and in constant flux. Science tells us how natural forces of enormous power have shaped and reshaped Earth's surface, atmosphere, climate, and biota again and again since the planet's beginnings about 4.5 billion years ago. For most of the planet's history, those environmental changes were the result of the interaction of natural processes such as geology and climate, and were described on the geological time scale in epochs, spanning millions of years. When humankind appeared on Earth around 200,000 years ago the influence of human activity on the environment must have been small and localized. The influence of scattered small groups of people on the global ecosystem would have been overwhelmed by the forces of natural systems (Steffen and others, 2007).

Population growth accelerated over the centuries that followed until the planet was adding more than that 50 million people every year. Our planet is now home to roughly 7.8 billion people Population Reference Bureau, (2020), and we are adding 1 million more people roughly every 4.8 days (US Census Bureau, 2011). Before 1950, no one on Earth had lived through a doubling of the human population, but now some people have experienced a tripling in their lifetime (Cohen, 2003).

With hunting and the use of fire, later agriculture and urbanization, and eventually the industrial revolution and modern technology, the ability of humans to shape their environment also grew exponentially. In about 2000, Earth scientists coined a new word — Anthropocene — to describe a new epoch where "the human imprint on the global environment has become so large and active that it rivals some of the great forces of nature in its impact on the functioning of the Earth system" (Steffen and others, 2011). Many in the Earth sciences believe that epoch has begun and that humankind with its vast numbers and its power to change the face of the Earth is at risk of putting the Earth system out of balance and causing the collapse of natural systems that are essential for humans to thrive, perhaps even threatening the future of all humankind (CILSS, 2016).

With so many new families to feed, West Africa doubled the area covered by farms between 1975 and 2013. Vast areas of savannah, woodland, and forest landscape have been replaced or fragmented by cropland. At the same time villages, towns, and cities have grown in area — taking up 140 percent as much land as they had in 1975. In part, to make way for those farms and settlements, more than a third of the forest cover present in 1975 has been lost. In savannah and steppe landscapes of West Africa, drought, in some cases made worse by unsustainable land use practices, has degraded the vegetation cover contributing to a 47 percent increase in sandy areas. The future is unpredictable, but the trends of the past four decades projected into the future would be unsustainable. Conversion of the natural landscapes of West Africa to agriculture greatly reduces the natural biodiversity, and exposes the soil to wind and water erosion. The savannah, woodland, forest, and wetland ecosystems that are lost have some relatively tangible impacts such as the loss of natural ecosystem goods and services like wood for fuel and construction, honey, nuts, medicines, game animals, berries, and forage. There are also many important goods and services lost that are less visible such as biodiversity, carbon storage, water quality, water runoff versus infiltration, and regional climate functions. (CILSS, 2016).

Coastal zones, the narrow transition areas that connect terrestrial and marine environments, are our planet's most productive and valued ecosystems (Crossland et al., 2005). Sixty percent of the world's major cities are located in coastal zones, and 40% of the people on the planet live within 100km of a coastal zone (Nicholls et al., 2007). Within coastal areas, we see the tightly intertwined relationships between humans and coastal resources amplifying the most urgent questions of limits and equilibrium, sustainability, and development in our world today (Nwankwoala, 2015). A number of coastal dwellers experience water crises despite the fact that they live in the midst of enormous water bodies. This could be partly blamed on global environmental change. The purpose of this paper is therefore to explore the extent to which the changing environment is affecting our water bodies and its management with reference to the coastal cities in West Africa.

## Environmental Change

Environment in the view of Ajayi (1998) is the total surrounding of an organism in a given area including the physical and non-physical surroundings. Kwan, Lam and Ofoefuna (2011) see environments as the conditions of an organism's surroundings. Onuoha (2012) defined an environment as a set of conditions and forces which surround and have direct influence on the organization/organism.

Global Environmental Change (GEC) is a topical phenomenon in the scientific literature as evidence of its presence and impacts continues to emerge from different corners of the world (Turner et al. 1990, Vitousek 1994, Steffen et al. 2004, Zalasiewicz et al. 2008). The notion of GEC refers to a set of planetary-scale changes in the Earth System (Vitousek 1994, Zalasiewicz et al. 2011, Dirzo et al. 2014), spanning from large-scale changes related to the global geosphere and biosphere systems (e.g., nitrogen and carbon cycles, biodiversity loss) to changes at the local or regional scale and related specifically to human activities (e.g., waste production, extirpation of species, land use changes). The processes driving GEC result from complex articulations of human actions (IGBP 2004) as well as from biological and physical processes, sometimes resulting from the accumulation of even multiple localized processes (Turner et al. 1990).

Environmental change is the variation in the occurrence of some climatic factors; rainfall, temperature, light wind: biotic factors; predators, parasites, soil micro-organism, pest and diseases: and edaphic factors; soil pH, soil texture, soil structure etc. When environmental changes occur as a result of the actions of human and other natural phenomena, lives and properties are adversely affected. (Nwankwoala, 2015).In general, environmental change has been described by scholars as an integrative, all-encompassing, and even cyclical process (Sánchez-

Cortés and Chavero 2011, Habiba et al. 2012, Boillat and Berkes 2013), with significant social dimensions (Byg and Salick 2009, Petheram et al. 2010) and also alters the various components of the earth's system/the spheres Ajayi (1988).

**Changing Environment in West Africa**

West Africa, with an area of about 5,112,903km$^2$ or 1,974,103sqm and an estimated population of 411,813,234 in 2021, the sub region can be divided internally through its natural features. West Africa, like the rest of Africa, faces serious environmental challenges, including land degradation, deforestation, biodiversity loss and extreme vulnerability to climate change, Ozone Depletion, Greenhouse Effect and Global Warming. The forest vegetation is rapidly giving way to savannah, savannah is giving way to sahel, humid fertile soils are becoming hard pans, delta and wetlands are becoming silted, lakes are shrinking in size, etc. Environmental change in West Africa, like many parts of the globe, is mainly caused by anthropogenic effects. Some of the anthropogenic activities are indiscriminate felling of trees, bush burning, land and soil degradation, water contamination, emission of greenhouse gases and poor environmental management. These activities have dire consequences on the environment as has been revealed by some studies. Present day landscapes of the Guinean Region are mostly altered by human activity, particularly slash-and burn agriculture, so that the actual extent of Guinean forest is rather limited. Most of what remains has been modified by humans. The tree and wooded savanna are also extensive. Some authors consider that the forests have been replaced by "derived savanna," a mosaic of cropland, bush fallow, and secondary forest resulting from centuries of human influence (Keay, 1959). The Guineo-Congolian Region is the wettest in West Africa, this region is thought to have been mostly forested in the past, but today only a fraction of the land is forested.

The West African countries are also home to a population of over 7,500 African elephants, although many groups reside in northern savanna habitats outside the forest ecosystems (Mallon and others, 2015). The Upper Guinean forest ecosystem of West Africa, however, is one of the most critically fragmented regions on the planet. Indeed, only 68,500 sq km, or 10 percent of its original forest cover, remains. Much of this remaining forest is exploited for timber and does not represent intact habitat. Moreover, hunting and indiscriminate trapping are prevalent throughout the forest zone, and accelerating rates of animal harvest put increasing pressure on populations of primate sand forest antelopes. Similarly, hunting — whether for meat, trophies or sport — has resulted in a catastrophic decline of large mammals across the Sahel and Sahara zones in the north of the region (Durant and others, 2013; Mallon and others, 2015).

In Senegal, due to dam construction at Diama in Senegal and Manatali in Mali, for agricultural and electricity purposes, the Senegal River has lost biodiversity, with a resultant decrease in fish landing. In Senegal, the mangrove forests of the Saloum-Sine Delta sprawl across roughly 650 km2 of the coast of south-eastern Senegal. Parc National du Delta du Saloum provides protection to 760 km2 of forests and the surrounding areas, while 1800 km2 of the delta have been designated as a UNESCO Biosphere Reserve. Nevertheless, since the late 1960s it has been recognized that these forests have been dying. They have declined in both area and density by roughly 25 % since the early 1970s. This is generally attributed to a decline in rainfall over the past decades and overexploitation of water reserves which have changed the mix of salt and fresh water in the estuary, making it too saline for many trees (Cugusi and Piccarozzi, 2009, p. 47).

The tourism industry in Senegal has grown at an annual rate of around 10 % over the past 3 decades and now ranks as the second industry in terms of foreign exchange earnings 1 million US$ in 1995, and contributes about 3 % to GDP (ACOPS, 2002a). Most tourism developments are located on the coastal zone. Tourism is especially well developed along the South Coast and on the coast of Casamance. In the Saloum estuary, a big estuarine complex, tourism is one of the main activities, although it is not as developed as along the South Coast. There is an urgent need for improved planning and diversification (ecotourism, discovery, game fishing etc.) of the tourism sector. While attention is being given to the development of tourism, especially in coastal areas, far less attention is being given to the social and environmental impacts of tourism on the coastal zone (ACOPS, 2002a).

**Water Resources in West Africa**

Of all renewable natural resources, water is the most precious and it is a basic requirement in the sustenance of all forms of life, complementing our basic needs such as food as well as effectively contributing to socio-economic development. Water resources hold great economic potential for agriculture, tourism, irrigation, transport and industry (Nsubuga et al. 2014). It is near impossible to get immediate and or future replacement for most water uses unlike other resources.

West Africa is enriched with numerous surface water resources (rivers, estuaries, lakes, reservoirs), including major ones such as rivers Niger, Senegal, Gambia, Volta and Lake Chad. These rivers take their sources in tropically wet major groundwater basins and regions with considerable amount of annual rainfall (Fig. 1

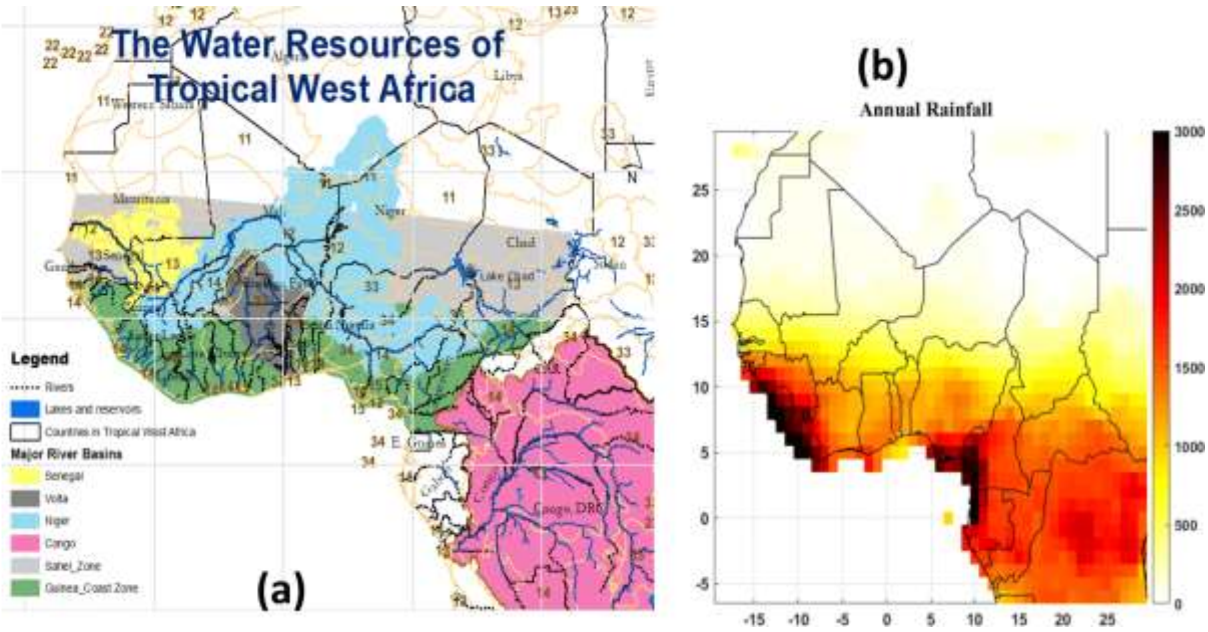



Fig 1: Some water resources in West Africa (Springer Nature, 2021)

Almost every country in the sub region can boast of some amount of water resources, be it marine, ground water, streams, rivers, lakes, wetlands and creeks among others. This notwithstanding, the region is afflicted by chronic deficits arising from the unequal distribution of rainfall and run-offs in time and space, the weak exploitation of the potential resources and poor management of existing resources. West Africa has a surface area of more than 5 million km2 and a population of more than 400 million inhabitants. The region is characterized by strong interdependence between its states for water resources. These resources represent a large potential, but the region continues to be confronted with situations detrimental for its development (West Africa Water Resource Policy, 2008; Worldometer, 2021).

One of the West Africa region's most striking features is the stark contrast between wet and arid zones.

This contrast is however attenuated by the configuration of the region's hydrographical network. Indeed, the region's major watercourses (Niger, Senegal, Gambia, and Lake Chad) have their sources in high rainfall areas, before flowing through the Sahelian zone, which experiences chronic rainfall deficits. Thus, these watercourses ensure an interzonal transfer of freshwater from wet

to arid areas. These transfers create a high level of water interdependency among West African countries. The 17 countries of the region share 25 transboundary rivers. The Niger river basin is

shared
by 11 countries against 8, 6 and 4 respectively for the Lake Chad Basin, the Volta River and Senegal River. The majority of West African countries have a dependency ratio of more than 40%2 (Niasse, 2005).

**Key water resource issues facing Africa**

There are many resource-side issues facing Africa. Among these are:

1. Multiplicity of trans-boundary water basins, eg 9 for Niger, 6 for Volta and 5 for L. Chad
2. High spatial and temporal variability of rainfall. Spatial variability within countries, between countries and sub regions or climates
3. Growing water scarcity – high rainfall as against drought in some areas
4. Inadequate institutional and financing arrangements – low financing and unsustainable investment. Management at different levels
5. Inadequate data and human capacity – paucity of data on water resources
6. Inadequate development of water resources;
7. Depletion of water resources through human actions

**Impact of the Changing Environment on Water Resources**

West Africa's coastal areas host about one third of the region's population and generate 56 percent of its GDP (Croitoru, et al 2019). They are home for valuable wetlands, fisheries, oil and gas reserves, and high tourism potential. However, these areas are affected by severe pressures inter alia; rapid urbanization along the coast has increased the demands on land, water, and other natural resources; man-made infrastructure and sand extraction have contributed to significant coastal retreat; moreover, climate change and disaster risks are exacerbating these threats. As a result, coastal areas are undergoing alarming environmental degradation leading to deaths (due to floods, air and water pollution), losses of assets (houses, infrastructure) and damages to critical ecosystems (mangroves, marine habitat) (Croitoru et al 2019).

Increased droughts and high temperatures in the region indicate that more extreme events are expected which will affect water quality in different environments. Over 60% of countries in West Africa will be facing water scarcity by 2025 while almost 80% of surface waters are facing eutrophication (*Environmental Health Perspectivesn.d).* The situation will be aggravated by:

1. Increased temperatures as well as more erratic and variable rainfall during the present century, as more water will be lost to transpiration and evaporation. Areas with basement complex geology and lower rainfall are the most vulnerable to declining aquifer discharge.
2. Population growth rates in rural areas at about 3 percent per annum mean that twice as much drinking water will be required in 25 years. Urban areas relying on groundwater for drinking will be much more vulnerable due to rapid urbanization.
3. Technological changes probably pose the greatest threat to groundwater sustainability. While increased commercialization will definitely require more water (Climatelinks, 2014).

The West Africa region has experienced a marked decline in rainfall since the 1968-1972 period, from 15 to 30% depending on the area. The region's major rivers (Niger, Senegal, Volta) experienced concomitant decrease in average discharge: 40 to 60% (Niasse, M. 2005). If the trends in climate contexts that took place over the last three decades continue to prevail, West Africa will experience decreased freshwater availability. Compared to previous decades, it is observed that since the early 1970s, the mean annual rainfall has decreased by 10% in the wet tropical zone to more than 30% in the Sahelian zone while the average discharge of the region's major river systems dropped by 40 to 60%. This sharp decrease in water availability has been combined with greater uncertainty in the spatial and temporal distribution of rainfall and surface water resources (Oyebande et al, 2002; Niasse et al. 2004).

In sub-Saharan Africa, the occurrence of drought from the 1970s on has resulted in a decline in the flow rate of the largest rivers. For a 20% decrease in rainfall in comparison with the previous period (Nicholson et al., 2000), the average annual discharge of the largest rivers in the region (Niger, Senegal) fell by 40% (Paturel et al., 1997). Less dramatic rain shortage in recent years did not cause runoff to approach former averages (Bricquet et al., 1997; Mahe´ et al., 2000). Although the above-mentioned rivers have parts of their course in semi-arid, Sahelian countries, their contributing areas are located further south under much wetter, Guinean climate. Declining river flows have been reported for many humid watersheds in western and central Africa (Servat et al., 1997).

By storing freshwater during seasons and years of abundance and making it available when needed, dams are a means to address scarcity and unreliability of water and achieve a dependable water supply. By doing so, they often affect significantly the patterns and modalities of access to water and to other resources depending on it. Therefore, the multiplication of dams increases the pressure on water resources –which translates into increased withdrawals and the alteration of flow regimes as a result of the fragmentation of river courses. Dams also pose an issue of equity in access to water and associated resources. Depending on their size and location, they affect more or less profoundly the conditions of access and use of water resources at the entire basin level (Niasse, 2005)

The lakes of West Africa were also considerably affected by the drought events which have especially been persistent in the region during the past three or four decades. In particular, the inflow into the lakes dropped sometimes by as much as 50%. This is for example true of the Kainji Lake whose inflow in the first half of 1974 was down by as much as 50% and all year round downstream navigation could not materialize. In addition, the fish catch in the lake went down from about 28 000 t to only about 10 000 t. (Ojo et al 2003).

Other consequences of climate change and variability such as devastating floods include: the proliferation of floating weeds along watercourses, and the deterioration of water quality, etc. The proliferation of floating weeds (the water lettuce, water hyacinth, Typha, etc.) results from the general disruption of the climate in the region. This is particularly due to the reduced flow velocity in watercourses, temperature change as well as the deterioration of water quality. These weeds hinder fishing, navigation, the functioning of irrigation schemes and hydroelectric development. They also choke several water bodies of the region, including lakes and wetlands known for their biological diversity of global importance (Oyebande et al 2010).

"Coasts are experiencing the adverse consequences of hazards related to climate and sea level. Coasts are highly vulnerable to extreme events, such as storms, which impose substantial costs on coastal societies. Annually, about 120 million people are exposed to tropical cyclone hazards, which killed 250,000 people from 1980 to 2000. Through the 20$^{th}$ century, global rise of sea level contributed to increased coastal inundation, erosion and ecosystem losses, but with considerable local and regional variation due to other factors" (Nicholls et al., 2007, p. 317).

The Niger River is about 4,180 km long and passes through almost every climatic zone in West Africa. A vast inland delta has formed along its way in Mali, owing to the shallow slope of the river and sand accumulations that have obstructed its many channels. The Inland Niger Delta acts like a giant sponge, moderating the flow downstream and reducing the risk of flooding where the Niger arcs past Timbuktu in Mali's northern Sahel, sand accumulations push it southward. In Nigeria, the Niger River is joined by the Benue, its major tributary, which drains much of north-eastern Nigeria.

The Lake Chad Basin occupies a huge area, covering parts of Niger, most of Chad, Nigeria, Cameroon, and the Central African Republic. The catchment of the Chari and the Logone Rivers comprises the southern part of the Lake Chad Basin. They feed Lake Chad, which has shrunk to a small fraction of its 1960 size.

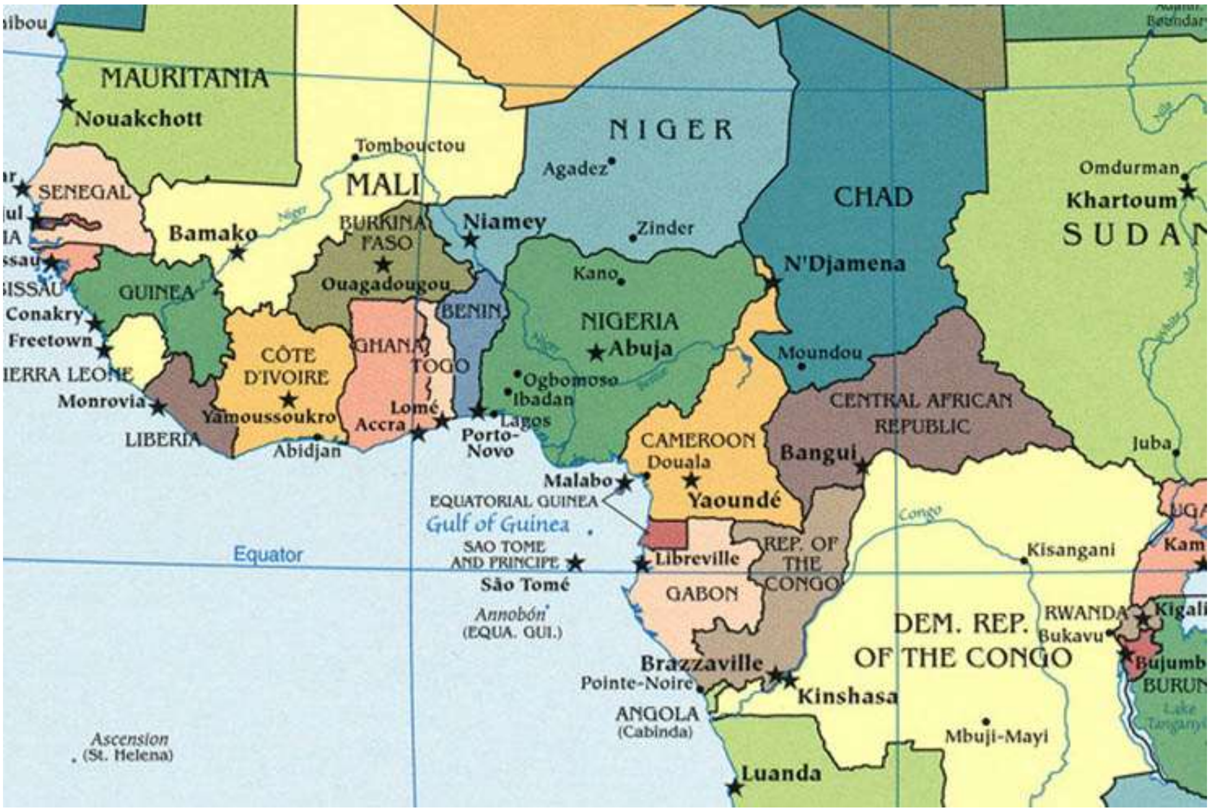
## Coastal Cities in West Africa

The West African coast, spanning from Mauritania to Gabon, cover 17 countries with a diversity of economic, political, and conflict situations. The 17 countries are Benin, Cape Verde, Cameroon, Côte d'Ivoire, Equatorial Guinea, Gabon, Ghana, Guinea, Guinea-Bissau, Liberia, Mauritania, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, The Gambia, and Togo. It stretches for about 5,700km (CSIS, 2021). These areas are of crucial importance to the region, as they include one third of its population and generate 42 percent of its GDP. The urban population, located mostly in these areas, is growing at an annual rate of 4 percent, which is almost twice the worldwide average. This rapid urbanization and net migration to the coast are already increasing the demands on land, water, and other natural resources. In addition, man-made infrastructure interrupting natural sediment flow (river dams, seawalls, breakwaters) and extraction of sand from beaches or dunes have led to significant coastal retreat in West Africa; the highest rates of retreat - in the order of 10 meters per year or more – occur near river mouths and harbor jetties, that is, in the most urbanized areas. Coastal degradation is leading to significant losses of assets (e.g. houses, infrastructure) and critical ecosystems (e.g. beaches, wetlands, mangroves), with negative impacts on coastal communities (WACA Res IP-CCA, 2018).

With one third of West Africa's population and source of 42 percent of its GDP, coastal areas are the region's socio-economic nexus. Population growth, and associated anthropogenic stressors have imposed enormous pressure on coastal resources, especially water. Moreover, the region is among the World's hotspots for climate change impacts. Many coastal African countries are vulnerable to sea-level rise, flooding and increased erosion, which pose immediate and long-term risks to livelihoods, assets and natural resources (WACA Res IP-CCA, 2018).

Moreover, West African coastal communities – particularly the poorest, whose livelihoods depend on natural resources – are increasingly vulnerable to climate change impacts. Every year, an average of 500,000 people in the region are threatened by floods and aggravated coastal erosion, resulting in significant losses, estimated at 2.3 percent of Togo's GDP in 2013 10 and 3.2 percent of Mauritania's GDP in 2014 11. In Senegal, flooding affects about 200,000 people annually, with impacts estimated at US$89 million per year on average; while the extreme floods in 2009 caused substantially higher damages in Dakar (US$104 million)12. Sea Level Rise (SLR) and expected extreme events like storm surges will be a major factor for coastal retreat at the regional level by the end of the century (WACA Res IP-CCA, 2018).


Senegal
The Gambia
Guinea-Bissau
Guinea
Sierra Leone
Cote d'Ivoire
Ghana
Nigeria
Liberia
Togo
Benin
Cameroon
Equatorial Guinea
Gabon
GULF OF GUINEA
Republic of the Congo
Democratic Republic of the Congo
Atlantic Ocean
Angola
CSIS
EUROPE, RUSSIA, AND EURASIA PROGRAM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Nouakchott
Tombouctou
MALI
NIGER
Agadez
CHAD
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Khartoum
SENEGAL
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BURKINA FASO
Niamey
Zinder
N'Djamena
GUINEA
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Abuja
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CÔTE D'IVOIRE
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Monrovia
Yamoussoukro
Lomé
Lagos
LIBERIA
Accra
Porto-Novo
CAMEROON
Bangui
Juba
Abidjan
Douala
Malabo
Yaoundé
EQUATORIAL GUINEA
Gulf of Guinea
Kisangani
SAO TOME AND PRINCIPE
Libreville
REP. OF THE CONGO
Equator
São Tomé
GABON
RWANDA
Kigali
Annobón (EQUA. GUI.)
DEM. REP. OF THE CONGO
Bukavu
Brazzaville
Pointe-Noire
Kinshasa
ANGOLA (Cabinda)
Mbuji-Mayi
Ascension (St. Helena)
Luanda

There has been a lot of concern about environmental dynamics and the implications for socioeconomic and socio-cultural activities in West Africa. In all these, the impact of environmental change and management of water resources is of great concern to policy makers and relevant stakeholders. With floods and droughts, desertification, soil erosion, and such other consequences of climatic variations and climate change, the issues of climatic variability and climate change and their impacts have been a topic of focus for the past three to four decades in the region. In particular, there has been increasing realization of the importance of water, and concern for water management for sustainable development. It is well known that in West Africa water is becoming increasingly scarce and more expensive to supply with more expertise and technological know-how required for planning, design and implementation than before. In addition, water can no longer be misused, abused or squandered without adverse consequences for the region. The water crisis no doubt requires attention, particularly in the event of impending climate change (Ojo, et al 2003).

In West Africa, there are several coastal communities whose livelihood usually revolves around the exploitation of biological resources in their environment. Besides, as in other parts of the world, the coastal area is preferred for urbanisation and industrialisation as well as amenities for recreation and tourism. This multiple-usage and its socio-economic benefits can lead to degradation and affect the quality of water. Cities—especially those with substantial poor populations—will face increasingly severe challenges in tackling the impacts of global environmental change (GEC), including the ability to improve ware quality. This applies strongly in Africa, one of the world's poorest regions (Nwankwoala, 2015).

Challenges faced by coastal dwellers in relation to changing climate and water resources include:

1. Low rainfall
2. Saline ground water
3. Sea erosion
4. Contamination of coastal waters
5. Disappearance of mangroves and coastal waters
6. Deep water table
7. Silted wetlands

Management issues need to be tailored at solving such problems. Aside the national water and sanitation improvement projects in some of the countries, most coastal dwellers have been adopting their own coping strategies to manage the situation.

**Coping Mechanisms for Water Management and Environmental Change among Coastal Dwellers in West Africa**

Africa's major economic sectors are vulnerable to current climate sensitivity, with huge economic impacts, and this vulnerability is exacerbated by existing developmental challenges such as endemic poverty, complex governance and institutional dimensions; limited access to capital, markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts.

These in turn have contributed to Africa's weak adaptive capacity, increasing the continent's vulnerability to projected climate change (Boko et al., 2007, p. 435). There follow some examples of adaptation carried out or being planned in each of the 5 regions.

In spite of the low adaptive capacity of Africa, people have developed traditional adaptation strategies to face the great climate inter annual variability and extreme events. This reinforces the observation that local people have perceived, interacted with, and made use of their environment with its meagre natural resources and changing climatic conditions in what could be seen as practical coping mechanisms.

In Gambia, adaptation measures to water stresses during droughts and high rainfall variability include irrigation water transfer and water harvesting and storage (Elasha et al., 2006). Protection measures for the Gambia coastal zone were estimated to cost between US$ 300,000 to US$ 400,000 in 1998 (ACCC, 2006b). Land value in the Gambia between Banjul and Kololi Beach Hotel is estimated at about US$ 217 million (ACCC, 2006b). Due to the high rate of erosion, individual hotels are undertaking protection measures for their own properties. Kairaba Beach Hotel for example has spent US$ 400,000 on sand bagging using geotextile sandbags whilst Senegambia Hotel spent about US$ 330,000 in 1998 to protect its beach by a sandbagging method (ACCC, 2006b). Kololi area in Gambia has undergone beach nourishment with 1 million m3 of sand, widening the beach by 120 m (ACCC, 2006b).

At Banjul Point to Toll Point eroded land has been reclaimed with about 2.7 million m3 of sand (ACCC, 2006b). Coastal protection structures include wooden groynes, beach refill, revetments and sandbags. For the Gambian coastline a total value of US$ 0.96 million was estimated to be at risk with the average total relocation cost is about US$ 12000 per km.

In Ghana, migration has been used as a method of adapting to climate change. Key policy responses to environmental migration include social protection support to migrants, as Ghana is doing with its northern development strategy; and considering rights-based resettlement for populations directly displaced by climate impacts, such as sea-level rise (EACC study team, 2009).

In Gambia, groynes are a major technique of beach stabilisation. Trunks of palm trees are jetted into the beach and tied together with timber. In the Gambia, the existing groynes in the area between Laguna Beach and Palm Grove Hotels and Banjul Point need to be rehabilitated. To reduce the flow of sand to the port and ferry terminal, a long and high terminal groyne need be constructed at Banjul Point between State House and Albert Market (National Climate

In Togo, groynes have been found to be very effective in stabilizing eroded beaches (National Climate Committee, 2003). Due to coastal erosion problems, coastal protection using breakwaters and groynes has been constructed along a 12 km coast between KpemeGumukope and Aneho (UNESCO-IOC, 2009).

Adaptation costs are calculated as though decision-makers knew with certainty what the future climate will be, when in reality current climate knowledge does not permit even probabilistic statements about country-level climate outcomes. In a world where decision makers hedge against a range of outcomes, the costs of adaptation could be potentially higher. Climate science tells us that the impacts will increase over time and that major effects such as melting of ice sheets will occur further into the future. Even so, the projections up to 2050 are more reliable than those beyond this period (EACC study team, 2009). Most regions use hard adaptation measures that require an engineering response rather than an institutional or behavioural response. Soft adaptation measures often can be more effective and can avoid the need for more expensive physical investment. Uncertainty about the exact nature of climate change impacts at the local and regional level, for example in terms of precipitation and storminess makes it difficult to fine-tune adaptation measures. Adaptation decisions will be taken under uncertainty (Agrawala and Fankhauser, 2008).

There are some adaptation measures that are easy to agree on, even in the face of uncertainty, such as those known as ‘win-win measures’. These are adaptations that are justifiable even in the absence of climate change. Measures to deal with climate variability, such as long-term weather forecasting and early warning systems, are examples (Agrawala and Fankhauser, 2008, p. 25).

Grand Popo and Ouidah lie on the western part of the Benin coastline and the areas are overall agricultural and peri-urban. There are a number of conservations areas, and the region has high potential for tourism. Mono estuary falls in this area, and the estuarine systems is interconnected with the sea via a narrow mouth. The areas have experienced higher frequency of storm surges, resulting in submersion of major parts of the beaches, hundreds of fishing shelters and houses of local communities. The expected SLR and extreme events will increase the incidence and intensity of coastal flooding affecting public infrastructures, fishing and other economic activities along the coast and health of the coastal ecosystems. Adaptation measures could include a comprehensive set of interventions (e.g. sediment management, dredging, stabilization/construction of estuary) and improvement in select public urban infrastructure based on further analysis (WACA Res IP-CCA, 2018).

The Eastern coast is an industrial area with multiple groynes, and is mostly eroding though there are a few accretion pockets. The area is subject to intense storm surges, and regular coastal floods causing destruction to dwellings, roads, ship groundings etc. Potential adaptation measures include managing and establishing natural protected areas to buffer critical road infrastructures in the eastern part of the national coastline. Cotonou is a major urban area with significant port infrastructure. It is at high risk of erosion. A number of groynes have been built to manage the erosion. The area also faces high storm surges and is at risk of coastal floods. Potential adaptation options include retrofitting or upgrading critical urban infrastructures to manage expected increase in flooding frequency and volume. Abidjan is the economic hub for Cote d'Ivoire and characterized by high population growth and uncontrolled urbanization. The areas are dominated by low slope, significant rainfall and low drainage capacity, which puts these areas at high risk for flooding. There is also lack of data for appropriate adaptation planning. Adaptation measures could include integrated flood risk management through improvement in drainage infrastructure, retrofitting existing assets and implementing improved structural codes in areas currently exposed to erosion and flooding to protect transport infrastructure (WACA Res IP-CCA, 2018).

In the city of Grand Bassam there is currently no sustainable connection between Ebrie lagoon and the Atlantic Ocean. High level of siltation has been obstructing efforts to open this access channel. Given the climate change risks of sea level rise and increased coastal and riverine flooding, the lack of connection will accumulate discharges, negatively affecting water quality. Adaptation measures include re-opening the Grand Bassam inlet, dredging and instalment of groynes combined with bank protections to block the longshore sediment transport to restore natural hydraulic conditions in the wider Grand Bassam. Nouakchott being below sea level, is at major risk of flooding due to expected sea level rise. Limited drainage networks and ruptures in the protective dunes increase the risks. Potential activities include improved hydrological planning/investment and conservation of natural ecosystems, with the aim of protecting vulnerable populations living on the lowest elevation along the coast (WACA Res IP-CCA, 2018).

The Senegal River Delta consists of sensitive ecosystems along with developed agro-pastoral hinterland of the river valley and the wetlands complex and land with low agricultural productivity in the lower delta. The coastal dynamics in the area is sensitive to any disturbance, including the changes in salinity, hydrology and increased erosion expected due to climate change. Potential adaptation options include improved development planning (minimizing impacts of roads and basic urban infrastructure development), improvement in management of transboundary sediment in the Senegal Delta, aimed at increasing the longshore sediment transport, and managing sand retention in Senegal river (WACA Res IP-CCA, 2018).

Casamance is an area highly eroded and impacts of climate change is expected to induce accelerated coastal erosion, loss of land and assets, floods, marine submersion, salinization and changes in the distribution and abundance of coastal and marine habitats and species. There have been no adaptation interventions at this high-risk area so far and communities have been relying on autonomous adaptation. Adaptation options for this site could include implementation of a mix of interventions (e.g. large-scale mangrove planting, groynes, beach nourishment, and salinization reduction), and climate-risk informed land-use planning on the river banks of Casamance, to protect communities and biodiversity rich ecosystems from coastal erosion and the permanent submersion due to SLR. To protect the livelihoods of local communities coastal fishing infrastructures could be retrofitted. There is also need for monitoring for salt water intrusion in surface water and understanding for appropriate adaptation measures (WACA Res IP-CCA, 2018).

Lagoons along the Togolese coast have high sedimentation which puts it at an increased risk of being inundated under climate change conditions, making close-by settlements and local assets such as fish processing and landing structures more vulnerable. Potential adaptation measures include investments in dredging, restoration of surrounding areas, and construction of diversion structures to increase the lagoon capacity for flood water.

Protection against the erosion and increased flood risk due to expected SLR could include implementation of hybrid solutions such as management of sediment transport, sand nourishment and hard infrastructures, to provide long term protection to highly eroded areas east of Lome Port (WACA Res IP-CCA, 2018).

Some of the adaptation and coping strategies at the various levels include:

1. Education/Awareness.
2. New Conservation Technologies.
3. Recycle Wastewater.
4. Improve Irrigation and Agriculture Water Use.
5. Water Pricing.
6. Energy Efficient Desal Plants.
7. Rain Water Harvesting.
8. Community Governance and Partnerships.

**Conclusion**

The impact of environmental change affects all productive resources but water bodies are among the most vulnerable. The spatial variations in climate and transboundary nature of some major rivers in West Africa make issues of water resource management a dicey one. Though West Africa is endowed with rich water resources, the coastal areas have challenges as salinity, contamination and low rainfall amount. Aside the national strategies, the coastal dwellers have devised their own local coping strategies to manage the issue of water crises. This notwithstanding, the low management capacity of the people still renders them vulnerable to the impact of environmental change with regards to water resources in coastal West African.

**Recommendations**

All efforts should be put in place to achieve the vision of SDG 6 to ensure availability and sustainable management of water and sanitation for all by the year 2030. In this regard, The shared water vision for Africa which ensures an equitable and sustainable use and management of water resources for poverty alleviation, socioeconomic development, regional cooperation, and sound environment envisioned by the ECA, AU and ADB should become the springboard for West African governments to achieve SDG6.

**References**

ACCC (2006). Inventory of coastal resources vulnerable to climate and shoreline changes in Cape Verde, The Gambia, Guinea Bissau, Mauritania and Senegal). Adaptation to climate change - responding to shoreline change and its dimensions in West Africa through integrated coast area management, 145 pp.

Advisory Committee on Protection of the Sea- ACOPS. (2002). Portfolio of project proposals for the Global Environment Facility project on Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa (GF/6010- 0016). Jointly undertaken with UNESCO-IOC, UNEP and GPA, 336 pp.

Agrawala, S., & Fankhauser, S. (2008). Economics aspects of adaptation to climate change: costs, benefits and policy instruments, 133 pp.

Ajayi, P.O.S. (1998). Comprehensive geography for secondary schools. Pp 178-184.

Boillat, S., & Berkes, F. (2013). Perception and interpretation of climate change among Quechua farmers of Bolivia: indigenous knowledge as a resource for adaptive capacity. Ecology and Society 18(4):21. http://dx.doi.org/10.5751/es-05894-180421

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R., & Yanda, P. (2007). Africa. Climate Change: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge UK, 433-467.

Bricquet, J.P., Bamba, F., Mahe. G., Tour ´ e, M., &Olivry, J.C. (1997). ´ Evolution r ´ ecente des ressourceseneau de l'Afriqueatlantique. ´ Revue desSciences de l'Eau 3: 321–337.

Byg, A., & Salick, J. (2009). Local perspectives on a global phenomenon. Climate change in Eastern Tibetan villages. Global Environmental Change 19:156–166. http://dx.doi.org/10.1016/j. gloenvcha.2009.01.010

CILSS (2016). Landscapes of West Africa – A Window on a Changing World. U.S. Geological Survey EROS, 47914 252nd St, Garretson, SD 57030, UNITED STATES.

Climatelinks (2014). Climate Change and Water Resources in West Africa: An Assessment of Groundwater Management

Cohen, J.E. (2003). Human Population: The Next Half Century: Science, v. 302, no. 5648, p.1172-1175, at http://dx.doi.org/10.1126/science.1088665.

Croitoru, L., Miranda, J.J., & Sarraf, M. (2019). The Cost of Coastal Zone Degradation in West Africa: Benin, Côte d'ivoire, Senegal and Togo.World Bank Group 1818 H Street NW Washington DC 20433
Crossland, C.J., Kremer, H.H., Lindeboom, H.J., Marshall Crossland, J.I., & Le Tissier, M.D.A. (2005). Coastal Fluxes in the Anthropocene: The Land–Ocean Interactions in the Coastal Zone, Project on the International Geosphere-Biosphere Programme Series. Global Change—The IGBP Series. Springer-Verlag, Berlin, 232 pp.

Cugusi, B., &Piccarozzi, M. (2009). Climate change and human mobility in Africa. A thematic literature and organisational review. Prepared for the International conference towards the G8 summit. CeSPI working papers 59/2009, 57 pp.

Dirzo, R., Young, H.S., Galetti, M., Ceballos, G., Isaac, N. J.B., & Collen, B. (2014). Defaunation in the Anthropocene. Science 345(6195):401–406. http://dx.doi.org/10.1126/science.1251817

Durant, S.M. et al (2013). Fiddling in biodiversity hotspots while deserts burn? Collapse of the Sahara's megafauna: Diversity and Distributions, v. 20, no. 1, p. 114-122, at http://dx.doi.org/10.1111/ddi.12157.

Economics of Adaptation to Climate Change (EACC) study team. (2009). The cost to developing countries of adaptation to climate change. New methods and estimates. The global report of the Economics of Adaptation to Climate Change (EACC). Consultation Draft, 102 pp.

Elasha, B. O., Medany, M., Niang-Diop, I., Nyong, T., Tabo, R., & Vogel, C. (2006). Background paper on impacts, vulnerability and adaptation to climate change in Africa for the African workshop on adaptation implementation of decision 1/CP.10 of the UNFCCC Convention. Accra, Ghana, 21-23 September, 2006, 54 pp.

Habiba, U., Shaw, R., & Takeuchi, Y. (2012). Farmer's perception and adaptation practices to cope with drought: perspectives from north western Bangladesh. *International Journal of Disaster Risk Reduction* 1:72–84. http://dx.doi.org/10.1016/j.ijdrr.2012.05.004

International Geosphere-Biosphere Programme (IGBP). 2004. Global change and the earth system. A planet under pressure. Springer, New York, USA

Keay, R. (1959), Derived savanna: derived from what: Bulletin d'IFAN Ser. A, v. 21, no. 42, p. 7-438.

Mahe, G., Olivry, J.C., Dessouassi, R., Orange, D., Bamba, F., & Servat, E. (2000). Relations eaux de surface-eauxsouterrainesd'unerivi ´ ere tropicale ` au Mali. ComptesRendus de l'Acad´ emie des Sciences—series IIa 330: 889–892.

Mallon, D.P., Hoffmann, M., & McGowan, P.J.K., (2015). An IUCN situation analysis of terrestrial and freshwater fauna in West and Central Africa: IUCN at http://dx.doi.org/10.2305/iucn.ch.2015.ssc-op.54.en

National Climate Committee. (2003). First national communication of the Republic of the Gambia to the United Nations' Framework convention on climate change. pp. 144.

NIASSE, M. (2005). Climate-Induced Water Conflict Risks in West Africa: Recognizing and Coping with Increasing Climate Impacts on Shared Watercourses. *Human Security and Climate Change.* An International Workshop Holmen Fjord Hotel, Asker, near Oslo.

Niasse, M., Afouda, A., & Amani, A. (2004). Reducing West Africa's Vulnerability to Climate Impacts on Water Resources, Wetlands and Desertification. Elements for a Regional Strategy for Preparedness and Adaptation. IUCN, Gland (Switzerland) & Cambridge (UK)

Nicholls, R.J., Wong, P.P., Burkett, V., Codignotto, J., Hay, J., McLean, R., Saito, Y. (2007). Coastal systems and low-lying areas.

Nicholson, S.E., Some, B., & Kone, B. (2000). An analysis of recent rainfall conditions in West Africa, including the rainy seasons of the 1997 El Nino and the 1998 La Nina years. *Journal of Climate, 13: 2628–2640.*

Nsubuga, F.N.W., Namutebi, E.N., & Nsubuga-Ssenfuma, M. (2014). Water resources of Uganda: an assessment and review. Journal of Water Resource and Protection 6:1297–1315. https://doi.org/10.4236/ jwarp.2014.614120

Nwankwoala, H. N. L. (2015). Causes of Climate and Environmental Changes: The need for Environmental Friendly Education Policy in Nigeria: *Journal of Education and Practice.Vol.6.*

Odido, M., & Mazzilli, S. (2009). African Oceans and Coasts. IOC Information Document, 1255, UNESCO Regional Bureau for Science and Technology in Africa, Kenya, 163 pp.

Ojo, O., Oni, F., & Ogunkunle, O. (2003). Implications of climatic variability and climate change on water resources availability and water resources management in West Africa: *Water Resources Systems—Water Availability and Global Change.* Lagos, Nigeria.

Onuoha, B. C. (2012). Business and Entrepreneurial Environments, A Nigerian Perspective. Port Harcourt: African Entrepreneurship Initiative.

Oyebande, L. & Odunuga, S. (2010). Climate Change Impact on Water Resources at the Transboundary Levelin West Africa: The Cases of the Senegal, Niger and Volta Basins. *The Open Hydrology Journal, vol 4, 163-172*

Oyebande, L., Amani, A., Mahé, G., & Diop, I.N. (2002). Climate Change,Water and Wetlands in West Africa: Building linkages for their Integrated Management. Working Paper. IUCN-BRAO. Ouagadougou. April

Paturel, J.E., Servat, E., Kouame, E., Lub ´ es, H., Fritsch, J.M., & Masson, J.M. (1997). Manifestations d'unevariabilit ` e hydrologiqueen Afrique de ´ l'Ouest et Centrale. In Sustainability of Water Resources under Increasing Uncertainity, IAHS Publication 240, International Association of Hydrological Sciences: Wallingford; 21–30.

Petheram, L., Zander, K.K., Campbell, B.M., High, C., & Stacey, N. (2010). 'Strange changes': indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia).

Sánchez-Cortés, M. S., & Chavero, E.L. (2011). Indigenous perception of changes in climate variability and its relationship with agriculture in a Zoque community of Chiapas, Mexico. Climatic Change 107:363–389. http://dx.doi.org/10.1007/ s10584-010-9972-9

Servat, E., Paturel, J.E., Lubes-Niel, H., Kouam ` e, B., Travaglio, M., &Marieu, B. (1997). De la diminution des ´ ecoulementsen Afrique de l'Ouest et ´ centrale. ComptesRendus de l'Acad´ emie des Sciences—series IIa 325: 679–682.

Steffen, W., Crutzen, P.J., & McNeill, J.R., (2007). The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature: AMBIO: A Journal of the Human Environment,v. 36, no. 8, p. 614-621, at http://dx.doi.org/10.1579/0044-7447(2007)36[614:taahno]2.0.co;2.

Steffen, W., Grinevald, J., Crutzen, P.J., & McNeill, J., (2011). The Anthropocene: conceptual and historical perspectives: Philosophical Transactions of the Royal Society A:Mathematical, Physical and Engineering Sciences, v. 369, no. 1938, p. 842-867, at http://dx.doi.org/10.1098/rsta.2010.0327.

Turner, B. L., Kasperson, R.E., Meyer, W.B., Dow, K.M., Golding, D., Kasperson, J.X., Mitchell, R.C., &Ratick, R.J. (1990). Two types of global environmental change: definitional and spatial scale issues in their human dimensions. Global Environmental Change 1:14–22. http://dx.doi.org/10.1016/0959-3780(90)90004-S

U.S. Census Bureau, (2011), International Database at http://www.census.gov/ipc/www/idb/worldpopinfo.php

UNFCC (2011). Ghana's second national communication. http://unfccc.int/ resource/docs/natc/ghanc2.pdf

Vitousek, P. M. (1994). Beyond global warming: ecology and global change. Ecology 75(7):1861–1876. http://dx.doi.org/10.2307/1941591

West Africa Coastal Areas Resilience Investment Project for Climate Change Adaptation (WACA ResIP-CCA). (2018). Green Climate Fund –Docomentation.

West Africa Water Resources Policy(WAWRP). ECOWAS in collaboration with UEMAO & CILSS, from iucn_wawrp.pdf.

WRC Ghana. (2015). Water resource managementand governance. http://www.wrc-gh.org/waterresources-management-and-governance/ ground-water-management

Zalasiewicz, J., Smith, A., Hounslow, M., Williams, M., Gale, A., Powell, J., Waters, C., Barry, T.L., Bown, P.R., Brenchley, P., Cantrill, D., Gibbard, P., Gregory,F.J., Knox, R., Marshall, J., Oates, M., Rawson, P., Stone, P.,  & Trewin. N. (2008). Are we now living in the Anthropocene? GSA Today 18:4–8. http://dx.doi. org/10.1130/GSAT01802A.1

**LEAD PAPER 2**

# APPLICATION OF REMOTE SENSING IN HYDROLOGY

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***Abstract***
*Remote sensing (RS) has the capability of observing several variables of hydrological interest over large areas on repetitive bases. This paper examines the relevance of remote sensing data in hydrology i.e in the areas of precipitation, soil moisture, surface water inventory, groundwater potential, flooding and basin characteristics. The traditional image classification algorithms for detection of water pixel, namely Normalized Difference Water index (NDW= Green – NIR/Green +NIR) Modified Normalized Difference Water Index (MNDW=Green-SWIR+SWIR etc) were useful in the mapping of Lake Chad, wetland mapping of Makurdi LGA in Benue state using Landsat ETM and Nigeria SAT-1, as well as Groundwater potentials in Jos North. The study reveals among others, that between 1973 and 2017, Lake Chad had depleted to about 75% in surface area. Similarly, wetland marix cross table indicated that 812.64 ha of wetland was lost between 1986 and 2012. The determination of groundwater potentials in Jos North revealed that borehole data obtained from 57 boreholes was used to validate the groundwater potential from which 63.16% coincided with the groundwater potential model.*

## Introduction

Water is fundamental to the existence of life and is one of the most critical resources. Hydrology, as the study of water on the Earth's surface, whether flowing above ground, frozen in ice or snow, or retained by soil; is inherently related to many other applications of remote sensing, particularly forestry, agriculture and land cover, since water is a vital component in each of these disciplines. Most hydrological processes are dynamic, not only between years, but also within and between seasons, and therefore require frequent observations. Remote sensing offers a synoptic view of the spatial distribution and dynamics of hydrological phenomena, which often unattainable by traditional ground surveys.

Remote Sensing applications are becoming more important because remote sensing techniques have the ability to measure spatial, spectral and temporal information as well as provide data on the state of the earth’s surface. It is also a rapidly changing domain with new sensors, platforms and applications techniques being developed to give hydrologists new data and views of the landscape (Rango, 1994 and Running et al, 1994). Remotely sensed observations are being increasingly used for regional and global monitoring of hydrological variables including; soil moisture, rainfall, water levels, flood extent, evapotranspiration or land water storage, as well as the forcing, calibration and assimilation into hydrodynamics, hydrological and hydro-meteorological models (Alsdorf et al, 2007; Rast et al, 2014).

At the National Centre for Remote Sensing Jos, remote sensing data have been very successful in extracting relevant hydrological information. The aim of this presentation is to demonstrate the use of Remote Sensing derived data in hydrological research and applications.

## Applications of Remote Sensing

Remote sensing is being applied in hydrology in the following areas with some practical examples from the National Centre for Remote Sensing, Jos.

i. Precipitation
ii. Soil moisture
iii. Ice and frost
iv. Surface water inventory, monitoring and mapping
v. Groundwater potential Evaluation
vi. Basin characteristics and morphometric analysis
vii. Flood routing, delineating and mapping

**Precipitation**

Precipitation is the key variable in the hydrological cycle. Conventionally, precipitation is measured using raingauge and it provides estimates of the amount of precipitation in the surrounding area. Remote sensing offers the possibility of observing precipitation in real or near-real time over relatively large areas and of complementing the conventional precipitation measurement. When a satellite is used for rainfall monitoring, the following factors are evaluated:
• The boundaries of areas affected by significant rain.
• Basin rainfall totals.
• Total rainfall accumulated from particular events.
• The short-term forecasting of rainfall.

**Soil Moisture Estimation**

Remote sensing offers a means of measuring soil moisture across a wide area instead of at discrete point locations that are inherent with ground measurements. RADAR is effective for obtaining qualitative imagery and quantitative measurements, because radar backscatter response is affected by soil moisture, in addition to topography, surface roughness and amount and type of vegetative cover. Keeping the later elements static, multi-temporal radar images can show the change in soil moisture over time. The radar is actually sensitive to the soil's dielectric constant, a property that changes in response to the amount of water in the soil. Users of soil moisture information from remotely sensed data include agricultural marketing and administrative boards, commodity brokers, large scale farming managers, conservation authorities, and hydroelectric power producers.

**Surface Water Inventory, Monitoring and Mapping**

Surface water bodies, such as rivers, lakes, and reservoirs are irreplaceable water resources for human life and ecosystems. Changes in surface water may result in disasters, such as flood or drought issues.
The size and distribution of surface water across the landscape is not uniform, making monitoring of these waters for quantity and quality difficult, time consuming, and expensive using field methods. Remote sensing techniques offer the potential to monitor the landscape effectively and efficiently to locate surface water and to measure parameters related to surface water location. This provides information such as volume, area, change detection and watershed analyses of surface water, using satellite images and shuttle radar topographic mission (SRTM). Spatio-temporal assessment of water depletion of Lake Chad from 1973 to 2017 (44years) was carried out. The research shows that the present day spatial extent of Lake Chad with its coverage is estimated at 3,789,52km sq and was observed to have depleted /shrunk to about 75 % in surface area with reference to the situation at 1973 as shown in Figure 1.

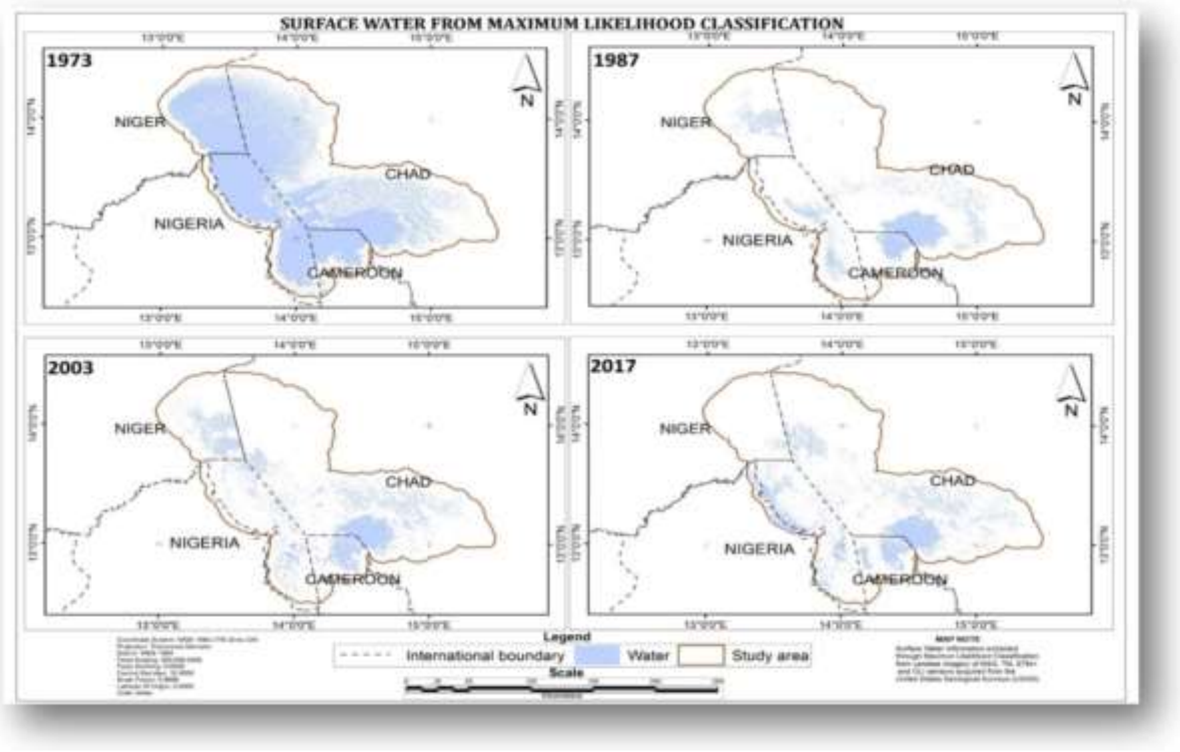


**Fig.1**: Classified surface extent of Lake Chad

**Wetland Inventory and Monitoring**

Wetland mapping is the first step in monitoring this important part of the ecosystem. Wetland management helps in reducing the effect from floodwaters and storm surges, sedimentation, pollution from upland drainage as well as in aquifer recharge. From conservation point of view, coastal habitat can be monitored using the technologies of remote sensing. The extent of wetland degradation resulting from anthropogenic activities such as agricultural activities, settlement and construction can be determined and monitored through remote sensing.

In the light of the above, specific attention is now directed towards the use of Earth Observation Satellite base information that can effectively manage wetlands. A study using remote sensing data and GIS to assess the condition of wetlands in Makurdi was carried out in order to describe the trends in land use and land cover due to changes in agriculture, sedimentation and settlement patterns over 26 years period. Landuse and landcover of the study area were generated through supervised classification of the various images sample sets of the supervised six classes (Water body, bare surfaces, Built up Area, Wetland, Forest and Farmland). The result showed a progressive reduction of the wetland over time as wetland marix cross table indicated that 812.64 ha of wetland was lost between 1986 and 2012. Changes in the static landcover are presented in Figure 2.

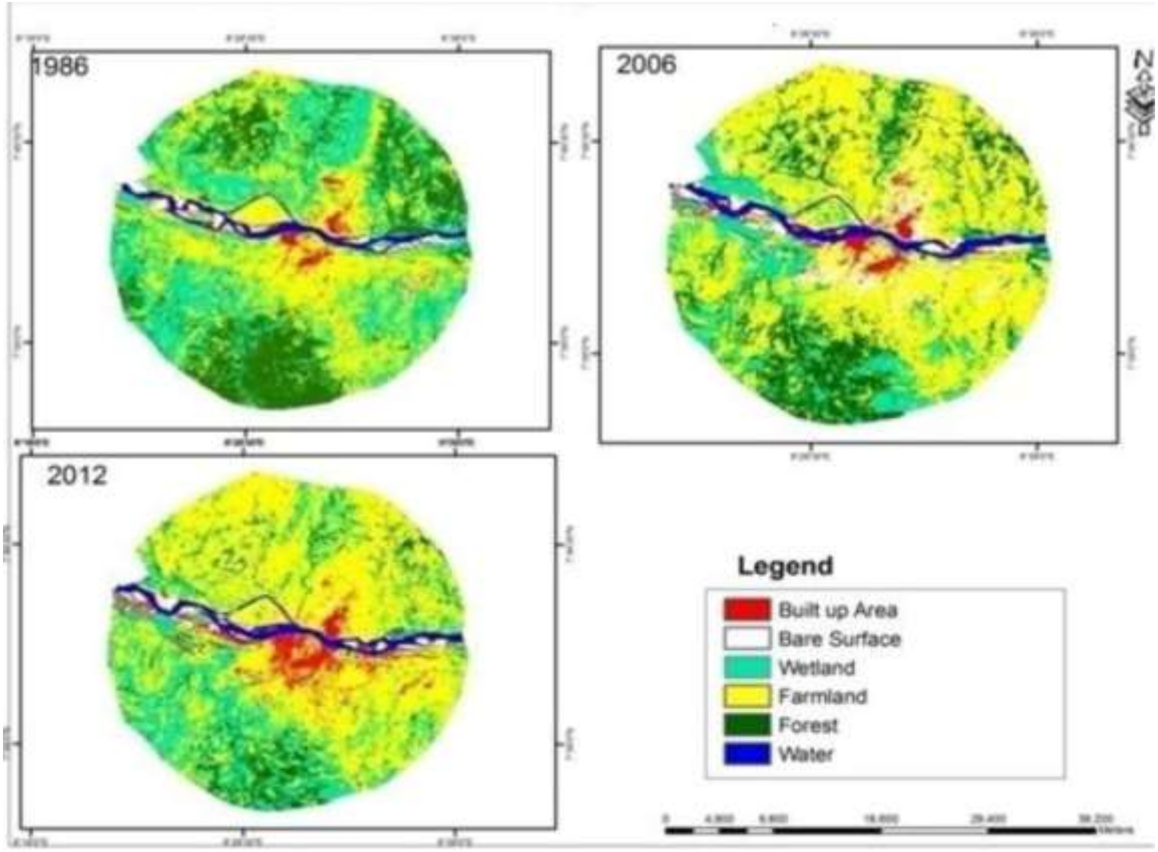


Fig. Fig. 2 Land use land cover of Makurdi from 1986 to 2012

**Groundwater Inventory Potential**

The concept of integrated remote sensing and GIS has proved to be an efficient tool in groundwater studies. Saraf, 1998 and Khan, 2002 demonstrated the use of Remote Sensing (RS) and Geographic Information Systems (GIS) in the exploration and assessment of groundwater in consolidated and unconsolidated formations in semi-arid regions. In like manner integrated investigation involving remote sensing and GIS and Analytical Hierarchy Process (AHP) in modeling groundwater potential zones within Jos North central Nigeria was carried out. Nigeria Sat-1, ASTER GDEM, topographic and geological maps of the study area were used to generate the various themes; lineaments, geology, drainage, geomorphology, surface water body and slope. Thematic weights were assigned to the various layers AHP. The groundwater potential model of the area was produced by integrating the different thematic layers using Weighted Index Overlay Analysis (WIOA) in ArcGIS. Five different potential zones were determined; very high, high, moderate, low and very low have been conducted with the objective of optimal results in sustainable ground water development in Jos North, plateau State, Nigeria. The determination of groundwater potentials in Jos North revealed that borehole data obtained from 57 boreholes was used to validate the groundwater potential from which 63.16% coincided with the groundwater potential model. Figure 3 shows zones of groundwater potential in the study area.

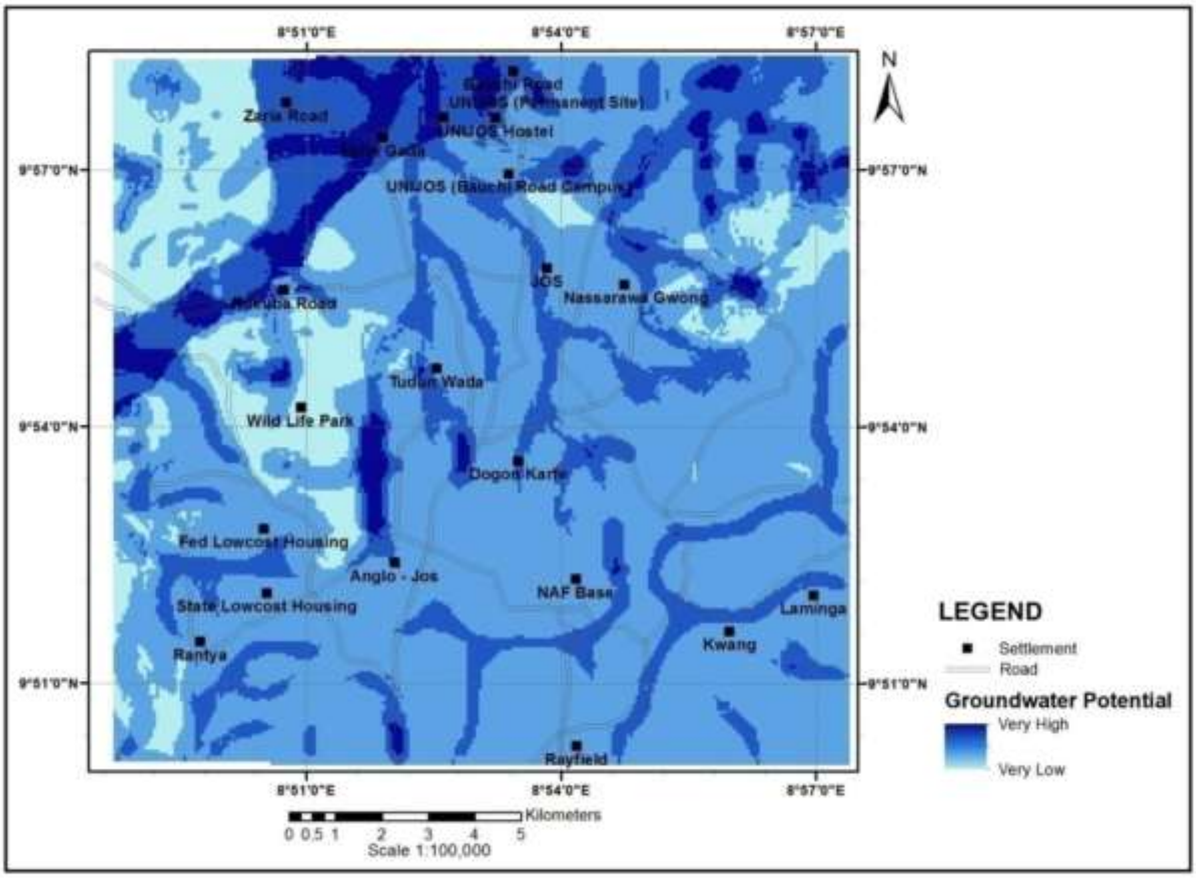


Fig.3 Groundwater potential of Jos North

**Summary and Conclusion**

The application of remote sensing is widely recognized as a tool in environmental management. It has been applied in various hydrological areas such as surface water management, groundwater management, precipitation, evapotranspiration, soil moisture, etc. The application of remote sensing in hydrology is increasing in practice due to its flexibility (manipulation and synoptic coverage) over a large area.

In conclusion, the advantages of this application over the conventional methods have made it more acceptable in the present dynamic world

**Reference**

Alsdorf, D., Rodriguez, E., & Lettnmaier, D. (2007). Measuring Surface Water form Space. *Rev.*

Khan, M. (2002). Use of Remote Sensing and Geographic Information System in the Delienation and Characterisation of Groundwater Prospect Zones. *Journal of Indian Society Remote Sensing*, *30* (3), 131-141.

Rast, M., & Johannessen, J. a. (2014). Review of Understanding of Earth's Hydrological Cycle: Observations, Theory and Modeling. *Surv. Geophysics* , 160-161.

Rango,A. (1994) Application of Remote Sensing by Satellite, Radar and other methods to Hydrology. Operational Hydrology Report N0. 39, WNO-NO 804.

Running, S.W., Justice, C.O., Salomonson, V., Hall, D., Barker, J., Kaufman, Y. J. ,Strahler, A.H., Heute, A.R., Muller, J.P. , Vandebilt, V. , Wan, Z.M. , Teillet, P. & Carneggie, D.

(1994) Terrestrial Remote Sensing Science and algorithms planned for EOS/MODIS. Int. Remote Sensing.

Saraf, C. (1998). Integrated Remote Sensing and Geographic Infromation System for Groundwater Explanation and Identification for Artificial Recahrge Sites. *International Journal of Remote Sensing, 19* (10), 1825-1845.

# SUB-THEME 1:

# WATER AND ENVIRONMENT LINKAGES

# IMPACT OF BALLAST WATER DISCHARGE ON THE CALABAR RIVER, CROSS RIVER STATE, NIGERIA

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**Abstract**

*The study investigated the impact of ballast water discharge on the Calabar River in Cross River State of Nigeria. The comparative study design which allowed for two sets of data (from ballast discharged and non-discharged areas) to be compared to determine the impact of ballast water on the quality of water was adopted for the study. Data on water quality parameters (including pH, DO, $BOD_5$, temperature, conductivity, turbidity, nitrate, nitrate, Mn, $Ca_4$, $SO_4$, $NO_2$, TSS, TH) were obtained. These data were obtained from primary source though in situ measurement and laboratory analysis. The purposive sampling technique was adopted in the study, because the locations of ships berth were identified by the researchers along the Calabar River course at Shoreline Jetty, Nigerian Port Authority (NPA), Export Processing Zone (EPZ) and Nigerian National Petroleum Cooperation (NNPC) Jetty. The control point, serve as ballast water non-discharged area and was located along the Adiabo bridge end of the river which is upstream of the ballast discharge area. Measurement was taken once a week, and particularly after ship discharges for over a period three (3) months to allow for the generation of sets of data with a sample size of 12 for each of the measured parameter. The results revealed significant variations between the Control Station and other stations. Using the dissolved oxygen as an example, $t = 1.63667$, $p > 0.001$; $t = 2.24167$, $p < 0.001$; $t = 1.74833$, $p < 0.001$; $t = 2.21417$, $p < 0.001$ for comparisons between Control Station with those of NPA, Ballast Tank, Shoreline and NNPC Jetty respectively. It was concluded that ballast water has negatively impacted on the quality of the Calabar River. However, the results further revealed that the level of impact was within the acceptable limits for water bodies used for domestic and recreational purposes. Continuous monitoring of the river quality by the relevant authorities to ensure that ballast water impact does not exceed the recommended limits was recommended.*

**Keywords:** Ballast water, Calabar river, comparative study design, water quality analysis

## Introduction

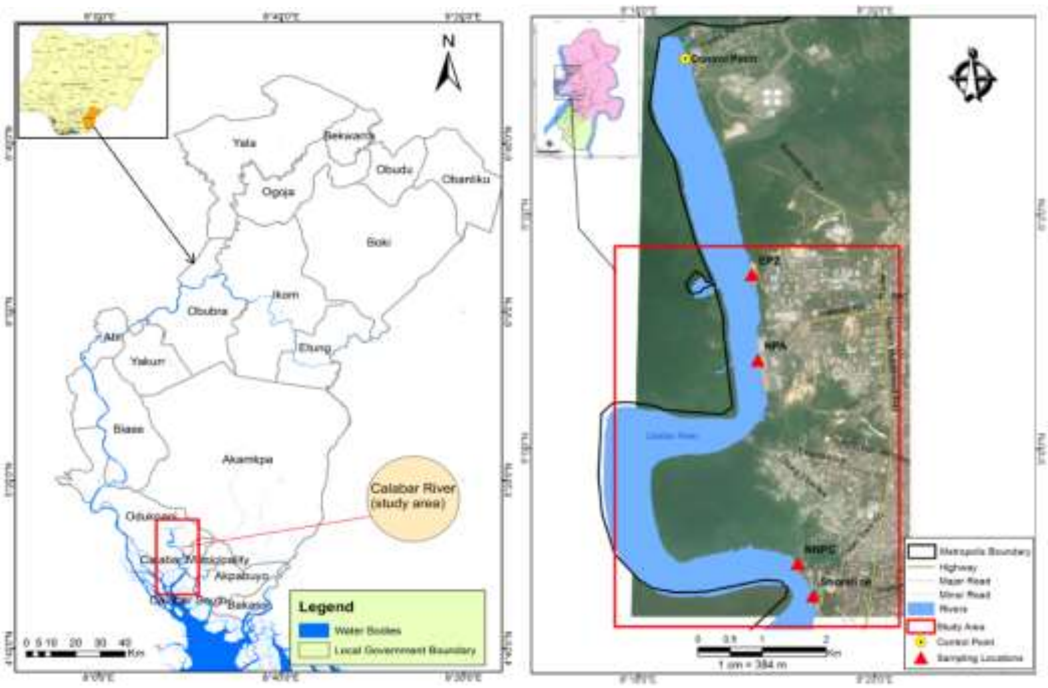
Shipping by sea is one of the largest industries in the world. Over 80 percent of the world's commodities are transported every day by ships and this is not without negative consequences. For instance, ballast water is used to compensate for an empty hull to weigh down the ship during movement. At the destination, the ballast water is then discharged into the sea (Carlton 2001). Ballast water has been recognized as waste water that is responsible for ocean pollution, the world-wide transfer of non-indigenous species, pathogenic bacteria and other pollutants of ballast water discharge. This poses serious environmental, ecological and economic threats to both coastal communities and marine environment in the world

The discharge of harmful aquatic organisms and pathogens found in ships ballast water from one port environment to another can have severe ecological and economic consequences, especially when they transform into marine pest. International Maritime Organization (IMO, 2016) has identified that discharge of ballast is one of the four greatest threats to the world oceans and waterways globally, and are always very difficult to control and almost impossible to eliminate once they are established in a new environment. This action does not only change the composition of water in the new environment, but also introduces new organisms which may become invasive.

In Calabar river ballast water is discharged by vessels indiscriminately. Such indiscriminate discharge has impacted the physico-chemical and bacteriological parameters of the Calabar river. However, the level of impact due to de-ballasting is not known. Hence, the study was carried out to investigate the impact of ballast water discharge on the Calabar river.

**Study Area Description**

Calabar River is a major river in Calabar metropolis, Cross River State. The river drains part of the Oban Hills in the Cross River National Park. The catchment under study is between Longitudes $8.316228^0$ and $8.323961^0$E of the Greenwich Meridian and Latitudes 4.977722 and $5.013778^0$N of the Equator. The basin is about 43 kilometers wide and 62 kilometers long with an area of 1,514 square kilometer (Eze & Efiong, 2010). However, the study was conducted around the water front of the Nigerian Port Authority (NPA), Calabar. FIG. 1 is a map of Cross River State, indicating Calabar Municipality, in whose bounds the study was be conducted. FIG. 2 is map showing part of Calabar Municipality where the study was carried out. The study was conducted around shoreline jetty, NNPC Jetty, EPZ Jetty, NPA terminals and Adiabo bridge end of the Calabar river.




**Research Methodology**

The researcher adopted a comparative study design (Kumar, 2014) which allowed for two sets of data (from ballast discharged and non-discharged areas) to be compared to determine the impact of ballast water on the quality of water (Ebin & Efiong, 2017). Data on water quality parameters (including pH, DO, $BOD_5$, temperature, conductivity, turbidity, nitrate, nitrate, Mn, $Ca_4$, $SO_4$,

$NO_2$, TSS, TH) were obtained. These data were obtained from primary source though direct field and laboratory measurements.

The purposive sampling technique was adopted in the study, because the locations of ships berth were identified by the researcher along the Calabar River course at Shoreline Jetty, Nigerian Port Authority (NPA), Ballast tank and Nigerian National Petroleum Cooperation (NNPC) Jetty (TABLE 1). The control point, serve as ballast water non-discharged area and was located along the Adiabo bridge end of the river which is upstream of the ballast discharge area.

**Table 1:** Sampling locations

| S/N | Sample locations | Longitudes | Latitudes |
|---|---|---|---|
| 1. | Shoreline | 8.323961$^o$ | 4.977722$^o$ |
| 2. | NNPC | 8.321931$^o$ | 4.983724$^o$ |
| 3. | NPA | 8.316228$^o$ | 5.013778$^o$ |
| 4. | Ballast Tank | 8.315005$^o$ | 5.024082$^o$ |
| 5. | Control point | 8.305219$^o$ | 5.055544$^o$ |

**Source:** Authors' fieldwork (2020)

Water samples were obtained from ballast water discharged and non-discharged areas of the Calabar River for laboratory analysis while in-situ measurement were done for the affected parameters using standard procedure (APHA, 2005). This was done once a week, and particularly after ship discharges for over a period three (3) months to allow for the generation of sets of data with a sample size of 12 for each of the measured parameter. This was done to allow for the use of small sample parametric statistical analysis (Students' T-test and one-way analysis of variance).

## Results and Discussions

### Description of water quality parameters across sampled stations

The measured water quality parameters for the five (5) stations were presented in tables and described based on their mean values (TABLE 2). For instance, DO the mean values recorded for the various stations are 4.22 for NPA, 3.62 for Ballast, 4.11 for Shoreline, 3.65 for NNPC Jetty and 5.86 for the Control station at Adiabo (TABLE 2). This means that the least mean value of DO was obtained in the ballast while the control point had the highest concentration of DO. Similarly, the mean values for $BOD_5$ are 1.51, 1.66. 1.35. 1.52 and 0.13 for NPA, Ballast Tank, Shoreline, NNPC Jetty and Control respectively (TABLE 2). The $BOD_5$ in the ballast water was the highest (1.66) while that in the control station was the least (0.13).

**Table 2:** Mean values of water quality parameters

| Parameter | Station | | | | |
|---|---|---|---|---|---|
| | NPA | Ballast Tank | Shoreline | NNPC Jetty | Adiabo Bridge end (Control) |
| DO (mg/1) | 4.2233 | 3.6183 | 4.1117 | 3.6458 | 5.86 |
| Temperature | 27.0225 | 27.3817 | 28.0942 | 26.9633 | 24.7708 |
| BOD5(mg/1) | 1.5092 | 1.6558 | 1.35 | 1.5167 | 0.1333 |
| Electrical Conductivity | 352.456 | 404.699 | 336.248 | 326.043 | 255.912 |
| NO3(mg/1) | 0.0521 | 0.0417 | 0.0647 | 0.0539 | 0.0255 |
| Turbidity | 41.2467 | 67.5808 | 47.9242 | 175.513 | 31.7825 |
| TSS(mg/1) | 6.8167 | 1.5458 | 4.3633 | 7.4692 | 2.4217 |
| NO2(mg/1) | 0.0511 | 0.3902 | 0.0568 | 0.0508 | 0.0183 |
| SO4(mg/1) | 0.4019 | 2.0543 | 0.7807 | 0.566 | 0.2081 |
| PO4(mg/1) | 0.0378 | 0.1583 | 0.0414 | 0.0619 | 0.0133 |
| TH (mg/1) | 8.5525 | 1.6192 | 7.7892 | 8.3575 | 1.4792 |
| Ca (mg/1) | 9.6325 | 16.6692 | 5.0825 | 7.6392 | 1.8125 |
| Chloride (mg/1) | 4.625 | 4.2167 | 1.6833 | 3.5925 | 2.6917 |
| NH4 (mg/1) | 0.0692 | 0.0517 | 0.02 | 0.0607 | 0.0037 |
| pH | 6.1842 | 6.6 | 6.0217 | 5.88 | 5.0733 |

**Source**: Authors' field and laboratory analysis (2020)

**Variations in water quality parameters across the study area**

The results from the analysis of variance (TABLE 3) indicate significant variations in the means of all measured parameters across the sampled locations in the study except for $NO_3$. Hence, the null hypothesis which states that, 'there is no significant difference in the mean values of water quality parameters obtained from ballast discharge points and non-discharge point (control station)in the Calabar river' was rejected for fourteen sampled parameters but retained only in one. These variations are also displayed in the means plots (FIGS. 3 – 17). However, a post hoc comparisons of individual measured parameters across the sampled stations provided deeper insights into the nature and source of the variations.

For example, the post hoc comparison of DO across the 5 sampled stations (TABLE 4) revealed that only the comparisons with the Control Station showed significant difference ($t = 1.63667$, $p > 0.001$; $t = 2.24167$, $p < 0.001$; $t = 1.74833$, $p < 0.001$; $t = 2.21417$, $p < 0.001$ for comparisons of

DO in the Control Station with those of NPA, Ballast Tank, Shoreline and NNPC Jetty respectively). Similar results were obtained for Temperature, $BOD_5$, Conductivity, turbidity, TSS, $SO_4$, $PO_4$, $Ca^{2+}$, Chloride and pH. This means that the sampled locations were significantly different from the control.

Independent samples test of water quality parameters between the control station and ballast tank consistently (except for TH) revealed that significant difference exists in water obtained from the two locations (TABLE 5). Water obtained from the control station consistently presents better quality than that of the ballast tank and the other three (3) measurement stations. It therefore means that ballast water from ships has negatively compacted on the quality of the river. The finding is consistent with literature (Elcicek, et al, 2013; Efiong, 2004; Efiong & Eze, 2004).

**Table 3:** Results of analysis of variance

| Parameter | Variance | Sum of Squares | Df | Mean Square | F | Sig. | Decision |
|---|---|---|---|---|---|---|---|
| DO | B Groups | 40.407 | 4 | 10.102 | 31.736 | .000*** | Rejected |
| | W Groups | 17.507 | 55 | .318 | | | |
| | Total | 57.913 | 59 | | | | |
| Temp | B Groups | 74.353 | 4 | 18.588 | 20.227 | .000*** | Rejected |
| | W Groups | 50.543 | 55 | .919 | | | |
| | Total | 124.896 | 59 | | | | |
| $BOD_5$ | B Groups | 18.702 | 4 | 4.675 | 234.514 | .000*** | Rejected |
| | W Groups | 1.097 | 55 | .020 | | | |
| | Total | 19.798 | 59 | | | | |
| Elec Cond | B Groups | 137992.944 | 4 | 34498.236 | 14.105 | .000*** | Rejected |
| | W Groups | 134520.867 | 55 | 2445.834 | | | |
| | Total | 272513.812 | 59 | | | | |
| $NO_3$ | B Groups | .010 | 4 | .003 | 1.160 | .338 | Retained |
| | W Groups | .124 | 55 | .002 | | | |
| | Total | .135 | 59 | | | | |
| Turbidity | B Groups | 166489.480 | 4 | 41622.370 | 18372.201 | .000*** | Rejected |
| | W Groups | 124.603 | 55 | 2.266 | | | |
| | Total | 166614.083 | 59 | | | | |
| TSS | B Groups | 326.945 | 4 | 81.736 | 4777.951 | .000*** | Rejected |
| | W Groups | .941 | 55 | .017 | | | |
| | Total | 327.886 | 59 | | | | |
| $NO_2$ | B Groups | 1.160 | 4 | .290 | 9.973 | .000*** | Rejected |
| | W Groups | 1.599 | 55 | .029 | | | |
| | Total | 2.759 | 59 | | | | |
| $SO_4$ | B Groups | 25.645 | 4 | 6.411 | 1267.015 | .000*** | Rejected |
| | W Groups | .278 | 55 | .005 | | | |
| | Total | 25.923 | 59 | | | | |
| $PO_4$ | B Groups | .152 | 4 | .038 | 119.261 | .000*** | Rejected |
| | W Groups | .018 | 55 | .000 | | | |
| | Total | .170 | 59 | | | | |
| TH | B Groups | 647.203 | 4 | 161.801 | 211.599 | .000*** | Rejected |
| | W Groups | 42.056 | 55 | .765 | | | |
| | Total | 689.259 | 59 | | | | |
| Ca | B Groups | 1495.283 | 4 | 373.821 | 90.037 | .000*** | Rejected |
| | W Groups | 228.352 | 55 | 4.152 | | | |
| | Total | 1723.636 | 59 | | | | |
| Chloride | B Groups | 67.752 | 4 | 16.938 | 290.721 | .000*** | Rejected |
| | W Groups | 3.204 | 55 | .058 | | | |
| | Total | 70.957 | 59 | | | | |
| $NH_4$ | B Groups | .038 | 4 | .009 | 19.731 | .000*** | Rejected |
| | W Groups | .026 | 55 | .000 | | | |
| | Total | .064 | 59 | | | | |
| pH | B Groups | 15.071 | 4 | 3.768 | 83.756 | .000*** | Rejected |
| | W Groups | 2.474 | 55 | .045 | | | |
| | Total | 17.545 | 59 | | | | |

*** Significant at the 0.001 level

**Source:** Author’s statistical analysis, 2020.

**Table 4:** Post hoc multiple comparison tests for DO

| (I) Location | (J) Location | Mean Difference (I-J) | Std. Error | Sig. |
|---|---|---|---|---|
| NPA | Ballast Tank | .60500 | .23033 | .158 |
| | Shoreline | .11167 | .23033 | .993 |
| | NNPC Jetty | .57750 | .23033 | .195 |
| | Control (Adiabo) | -1.63667* | .23033 | .000*** |
| Ballast Tank | NPA | -.60500 | .23033 | .158 |
| | Shoreline | -.49333 | .23033 | .344 |
| | NNPC Jetty | -.02750 | .23033 | 1.000 |
| | Control (Adiabo) | -2.24167* | .23033 | .000*** |
| Shoreline | NPA | -.11167 | .23033 | .993 |
| | Ballast Tank | .49333 | .23033 | .344 |
| | NNPC Jetty | .46583 | .23033 | .404 |
| | Control (Adiabo) | -1.74833* | .23033 | .000*** |
| NNPC Jetty | NPA | -.57750 | .23033 | .195 |
| | Ballast Tank | .02750 | .23033 | 1.000 |
| | Shoreline | -.46583 | .23033 | .404 |
| | Control (Adiabo) | -2.21417* | .23033 | .000*** |
| Control (Adiabo) | NPA | 1.63667* | .23033 | .000*** |
| | Ballast Tank | 2.24167* | .23033 | .000*** |
| | Shoreline | 1.74833* | .23033 | .000*** |
| | NNPC Jetty | 2.21417* | .23033 | .000*** |

*** Significant at the 0.001 level

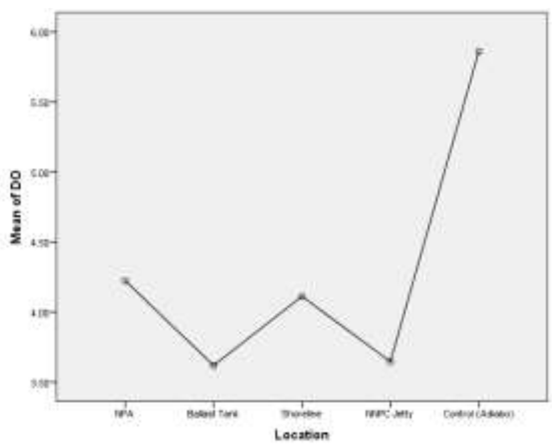



Fig.3. Means plot of DO across sampled points

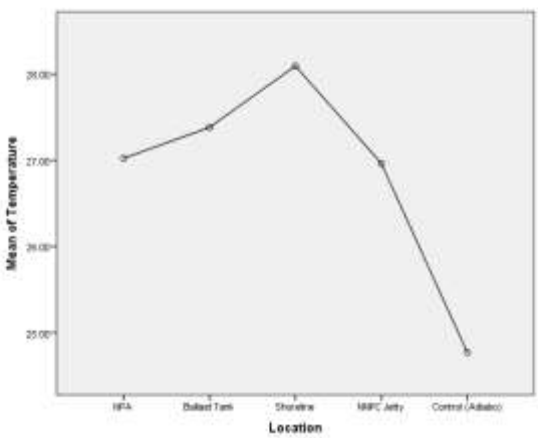



Fig.4. Means plot of temperature across sampled points

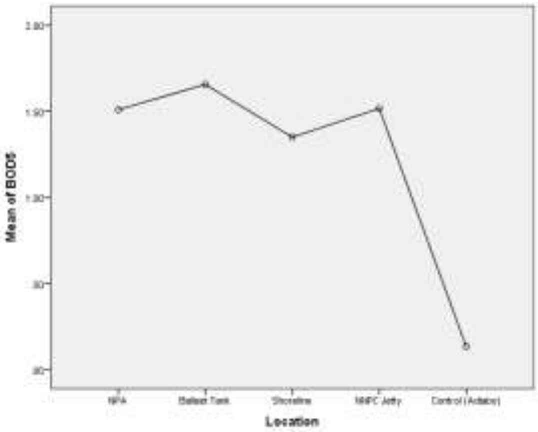



FIG.5. Means plot of $BOD_5$ across sampled points

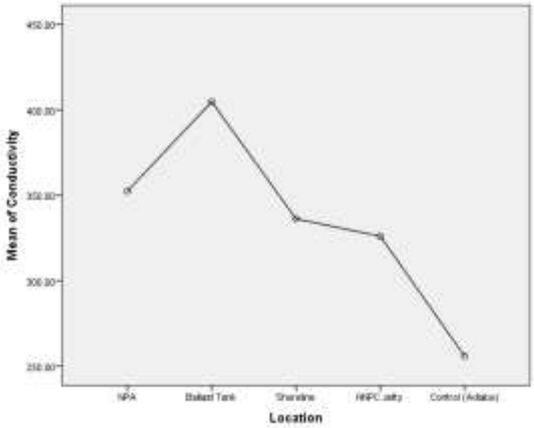



FIG. 6. Means plot of electrical conductivity across sampled points

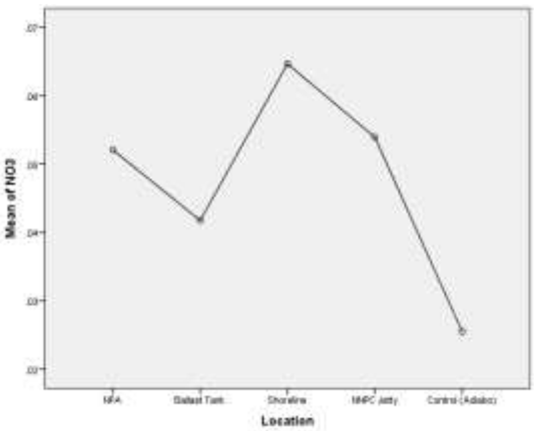



Fig. 7. Means plot of $NO_3$ across sampled points

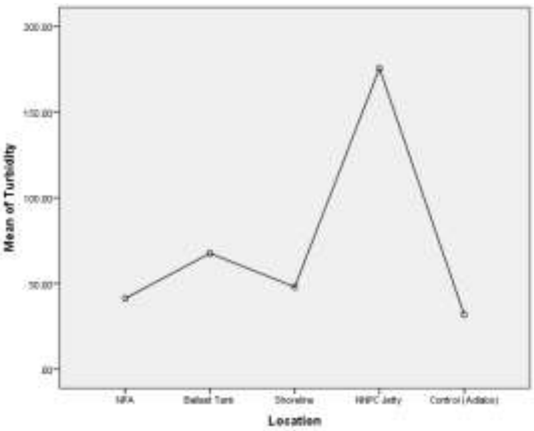



Fig. 8. Means plot of turbidity across sampled points

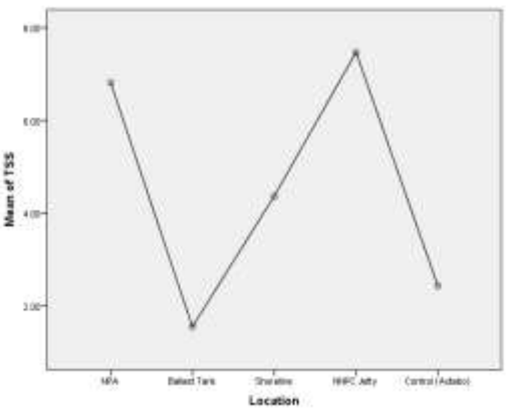



Fig. 9. Means plot of TSS across sampled points

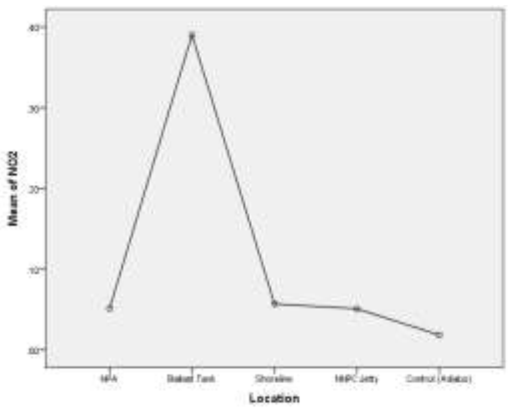



Fig. 10. Means plot of $NO_2$ across sampled points

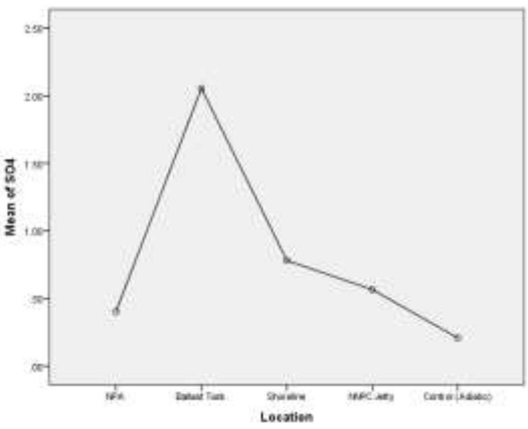



Fig. 11. Means plot of $SO_4$ across sampled points

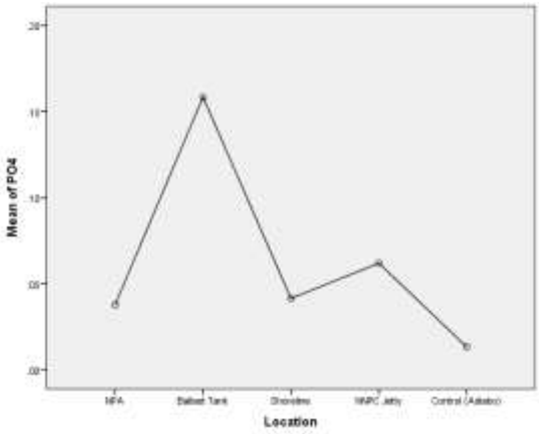



Fig. 12. Means plot of $PO_4$ across sampled points

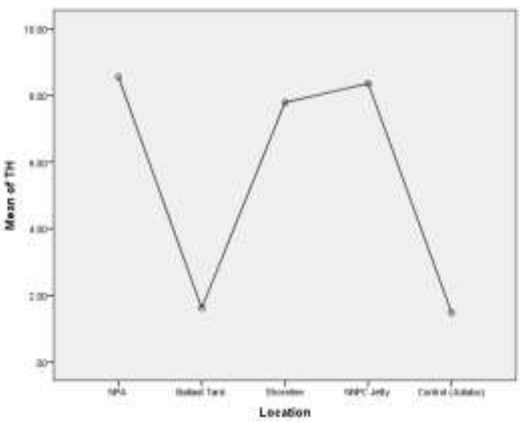



Fig.13. Means plot of TH across sampled points

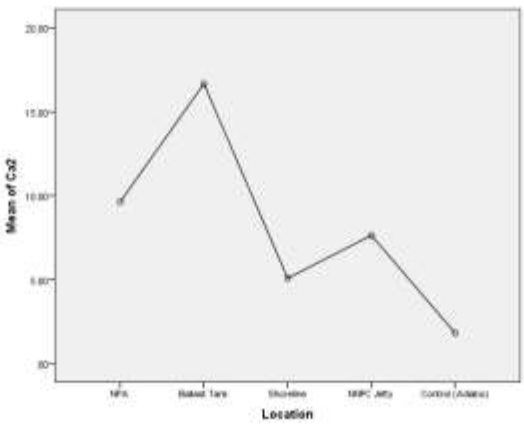



Fig. 14. Means plot of Ca across sampled points

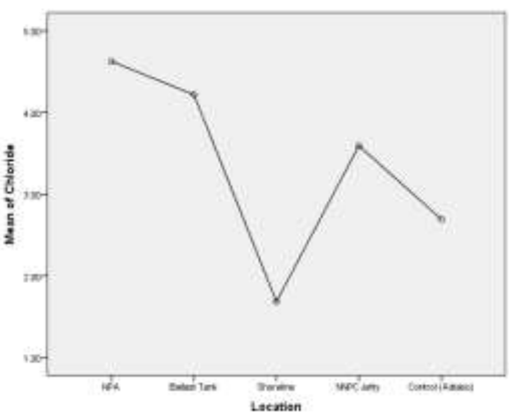



Fig. 15. Means plot of chloride across sampled points

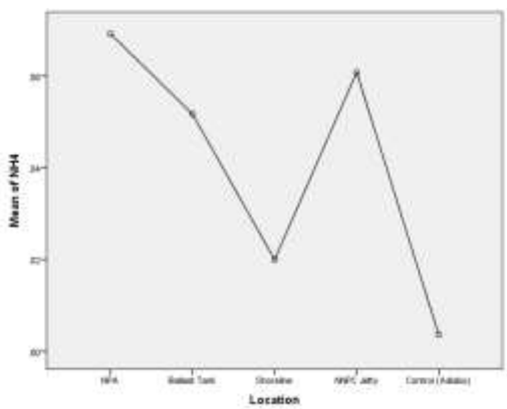



Fig. 16. Means plot of $NH_4$ across sampled points

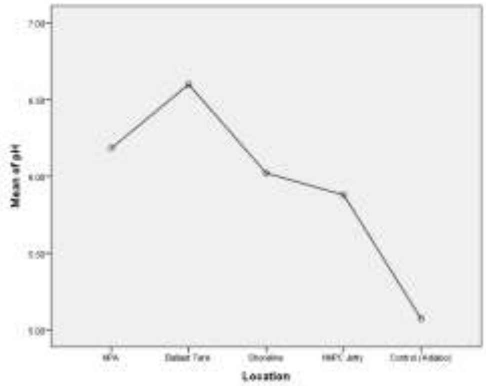



Fig. 17. Means plot of pH across sampled point

**Table 5:** Independent samples test between the Control station and Ballast Tank

| Parameter | Nature of variance | T | df | Sig. (2-tailed) |
|---|---|---|---|---|
| DO | Equal variances assumed | 7.973 | 22 | .000*** |
| | Equal variances not assumed | 7.973 | 20.955 | .000*** |
| Temperature | Equal variances assumed | 6.501 | 22 | .000*** |
| | Equal variances not assumed | 6.501 | 18.652 | .000*** |
| $BOD_5$ | Equal variances assumed | 33.071 | 22 | .000*** |
| | Equal variances not assumed | 33.071 | 19.219 | .000*** |
| Conductivity | Equal variances assumed | 6.977 | 22 | .000*** |
| | Equal variances not assumed | 6.977 | 21.295 | .000*** |
| $NO_3$ | Equal variances assumed | 10.515 | 22 | .000*** |
| | Equal variances not assumed | 10.515 | 11.739 | .000*** |
| Turbidity | Equal variances assumed | 98.717 | 22 | .000*** |
| | Equal variances not assumed | 98.717 | 19.747 | .000*** |
| TSS | Equal variances assumed | 10.403 | 22 | .000*** |
| | Equal variances not assumed | 10.403 | 11.192 | .000*** |
| $NO_2$ | Equal variances assumed | 3.379 | 22 | .003** |
| | Equal variances not assumed | 3.379 | 11.000 | .006** |
| $SO_4$ | Equal variances assumed | 2588.100 | 22 | .000*** |
| | Equal variances not assumed | 2588.100 | 15.115 | .000*** |
| $PO_4$ | Equal variances assumed | 13.459 | 22 | .000*** |
| | Equal variances not assumed | 13.459 | 11.547 | .000*** |
| TH | Equal variances assumed | .276 | 22 | .785 |
| | Equal variances not assumed | .276 | 11.001 | .787 |
| Ca | Equal variances assumed | 12.562 | 22 | .000*** |
| | Equal variances not assumed | 12.562 | 14.120 | .000*** |
| Chloride | Equal variances assumed | 16.513 | 22 | .000*** |
| | Equal variances not assumed | 16.513 | 14.958 | .000*** |
| $NH_4$ | Equal variances assumed | 12.260 | 22 | .000*** |
| | Equal variances not assumed | 12.260 | 11.051 | .000*** |
| pH | Equal variances assumed | 38.696 | 22 | .000*** |
| | Equal variances not assumed | 38.696 | 11.180 | .000*** |

*** Significant at the 0.001 level

** Significant at the 0.01 level

**Source:** Author’s statistical analysis, 2020.

**Conclusion and Recommendation**

The aim of the study was to investigate the impact of ballast water discharge on Calabar River, Cross River State, Nigeria. The study revealed significant contamination of the Calabar river by ballast water discharge by ships. Hence, ballast water has negatively impacted on the Calabar river. While the level of impact was still within acceptable limits of water quality for domestic and recreational purposes, continuous monitoring by appropriate agencies of government to ensure that the quality of the river water does not deteriorate as a result of ballast water discharge is strongly recommended.

**References**

APHA (2005) Standard methods for the examination of water and wastewater (7thed.). Washington DC: America Public Health Association 1134.

Carlton, J. T. (2001). Introduced species in U.S. coastal waters: environmental impacts and management priorities. Pew Oceans Commission, Arlington. Retrieved on 12th April, 2019 from http://www.pewoceans.org/

Ebin, O. I. & Efiong, J. (2017). Assessment of surface water quality in Yakurr Local Government Area, Cross River State, Nigeria. Proceedings of the 8th International Conference of the Association of hydrological sciences, 99-105.

Efiong, J. &Eze, B. E. (2004). Effluent discharge and stream discharge by a rubber factory. a case study of Field 20 stream in Odukpani, Cross River State.*African Journal of Educational Studies in Mathematics and Sciences*, 2 (2), 79 -89.

Efiong, J. (2004). *Rubber processing and water quality: the case study of PAMOL(Nigeria) Limited, Odukpani, Cross Rivers State.* An Unpublished M. Sc. Thesis, University of Calabar.

Elçiçek, H., Parlak, A. & Çakmakç, M. (2013). Effect of ballast water on marine and coastal ecology. *Cappadocia*, 18(20), 1-11.

Eze, E. B. & Efiong, J. (2010). Morphometric parameters of the Calabar river basin: Implication for hydrologic process. *Journal of Geography and Geology*, 1(2).

Geospatial Links (2020). www.geospatiallinks.com.ng).

International Maritime Organization (IMO) (2016).

Kumar, R. (2014). Research methodology: a step-by-step guide for beginners. Fourth edition. Los Angeles: Sage.

WHO (2005). Emerging issues in water and infectious disease organization, Geneva, Switzerland.

# EFFECTS OF PRECIPITATION EFFECTIVENESS INDICES ON THE YIELD OF SOME SELECTED ROOT CROPS IN TARABA STATE, NIGERIA

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***Abstract***
*Precipitation effectiveness indices is one of the important climatic indices that has a direct relationship with crop cultivation, they are relevant in measuring the quantity and period of available moisture utilized by plants, which is essential in appropriate crop selection for planning. It is against this background that this paper examines the relationship between the indices and yield of some selected crops, and then identified the critical indices that affect the yield of the crops in Taraba State. Precipitation indices and yield of Yam, Cassava and Irish Potato were the data used in this study. Daily and monthly precipitation records as well as yield of the selected crops were collected from Taraba State Agricultural Development Program (TADP). Both Precipitation indices and crops yield were subjected to stepwise regression to examine the effects of rainfall indices on the yield of the selected crops. Result of the study revealed that rainfall in June and hydrological ratio were selected as the critical indices affecting the yield of Yam at p=0.004 and 10.890 at 0.029 respectively for Yam yield variation in the state. It was also observed based on the result of the study that August rainfall is the critical PEI that has a positive effect of 0.013 to the yield of Irish potato in the state while June rainfall shows a negative effects to the yield of cassava in the state. In regards to this, it was concluded that hydrological ratio, June and August rainfall were the critical PEI affecting the yield of yam, Irish potatoes and cassava in the state, as such there is a need to inform farmers on the significant effects of these indices to crop yield. In addition, there is also a need for Government and non Governmental intervention to farmers in terms of farm input to improve their crop yield.*

## Introduction

Climate is one of the critical factors affecting crop cultivation and determines when to start planting, weeding, harvesting and storage of the crops. The important aspect of the climate that has a direct relationship with crop cultivation is precipitation effectiveness parameters (PEI) which can be calculated from rainfall record (Ezra *et al.*, 2020a and Haruna & Tasi'u, 2017). These parameters include mean annual rainfall, monthly rainfall distribution within the rainy season, numbers of rain days within the growing season, Onset date of rain, Cessation dates of the rains, Length of the Rainy Season (LRS), Hydrologic Ratio (HR), Seasonality Index (SI), number of consecutive dry days within the rainy season among others (Sawa & Adebayo, 2011). All these indices are referred to as the major climatic controller of crop yield in the tropical savanna region (Adebayo, 2000). They are relevant in measuring the quantity and period of available moisture utilized by plants, which is essential in appropriate crop selection for planning (Kimamo, 2019 and Moncunill, 2006). They also determine the type of crop to cultivate in a given area, the yield of the crop and farmers' profit (Ayoade, 2005 and Adebayo, 2010). Hence, dependence on total rainfall alone in determination of crops productivity is not sufficient because availability of soil moisture, time of occurrence of rainfall, it spread, intensity, frequency, and other rainfall indices strongly influence agricultural operations and yield potentials than the volume of rainfall received (Mostafa *et al.,* 2015 and Ezra *et al.,* 2020a). This is based on the fact that, the volume or mean annual rainfall doesn't influence the growth and yield of crops, instead the efficiency of the rainfall at different developmental stages of the plant growth and other rainfall indices that is highly significant to the growth and yield of crop (Ezra *et al.,* 2020a). For example, it was observed that the occurrence of 7- 14 non-rainy days within a growing season has demonstrated a major effect on final yields of crop (Barron, 2003). In addition, the onset, duration, frequency and cessation of rainfall within rainy seasons are very relevant rather than average and volume of the rainfall (Kimamo, 2019). Similarly monthly rainfall especially at critical stage of crop growth (vegetative and reproductive stage) is significant to the growth and yield of crop (Ezra *et al*., 2020a).

In Taraba state, several studies on the nature and extend of precipitation effectiveness indices and how it affects agricultural development of the state where presented and explained. For example, Ezra *et at*., (2020b) documented that, LRS in the area is decreasing and that will have a negative impact on crops based on fact that LRS which determines the duration of the rainy season is decreasing and that will not support the growth and yield of long maturing crops. They also documented that, there is a positive slope of Seasonality Index in the area which is clear evidence that the study area is getting drier annually. In other word, the study area is affected with shorter spread and steadiness of rainfall during the rainy season, making the area to be dry leading to poor crop yield. In the same vein, study by Angela and Fidelis (2013) revealed that rice farmers in the state are facing serious climatic challenges such as; stunted rice growth, widespread of pest and diseases, difficulties in predicting rice planting period, drying and withering of rice seedlings, delayed rainfall and too much heat which evaporates water from rice plant. It is against this background that this research was designed to examine the effect of precipitation effectiveness indices on yield of some selected crops in the state.

**Study Area**

Taraba State was carved out of the former Gongola State on 27th August 1991 by the then regime of General Ibrahim Babangida. The State is one of the Nigerian thirty-six (36) state which is located in North-Eastern part of the country and has a coordinate of latitude $6^o30^'$ and $8^o30^'$ North of equator and longitude $9^o00^'$ and $12^o$ $00^'$ East of the Greenwich meridian (Figure 1).

The area is made up of high plains which covered those parts of the Benue low lands lying above flood level but below 1000 ft contour line and include places around Karim Lamido, Jalingo, Sunkani and some part of Wukari while the high highlands are erosional in nature and are cut in sedimentary formations. River Benue is the major river in the state (Adebayo and Umar, 2020) while River Donga and Taraba are the other dominant river systems which flow across the Muri plains to drain the entire State together with the minor ones, such as the Lamorde and Mayo Ranewo (TYPA, 2009).

In terms of spatial pattern of the moisture variables, Ezra *et al* (2020b) documented that mean annual rainfall, onset of date of rain, cessation date of rain, hydrological ratio, relative humidity and LRS showed a similar distribution where the highest value of the variables was recorded around Sardauna, Ussa, Kurmi, Takum and Gashaka LGAs in the southern part of the state, while places like Karim Lamido, Lau, Ardo-Kola, Jalingo, Zing, and Yorro LGAs have the lower values of moisture parameters. This spatial rainfall implies that, the northern parts of the state around Karim, Lau, Sunkani, Jalingo, Zing and Yerro have a range mean annual rainfall between 1,034mm to 1,201mm while places around Gembu, Mayo Ndanga, Nguroje, Maisamari, Lissam Sambo, Tosso and Gadin have a mean annual rainfall between 1,640 and 1970mm. Onset date of rain, on the other hand, showed that rainfall in the northern part of the state around Karim, Lau, Sunkani and some parts of Jalingo start around $1^{st}$-$10^{th}$ May while the southern part of the State around Gembu, Mayo Ndanga and Nguroje experience start of rain around $16^{th}$-$31^{st}$ March. In a similar pattern, the cessation date of rain in the northern part of the state end between $1^{st}$-$10^{th}$ October but, lasted in the Southern part of the state between $1^{st}$ - $5^{th}$ November. Seasonality index, on the other hand, showed that, seasonality index in the northern region of the State showed a value between 0.95 to 1.02 which clearly explained that, the region recorded high rainfall in few months and is markedly seasonal with long drier season, while the southern region of the state has seasonality index value between 0.68-0.75 which means that, the southern region is characterized by seasonal rainfall.

Alluvial soil type are found on the flooded plains of rivers they run along Benue River and other rivers, and do not depend highly on climate and vegetation for their formation but their underlying parent rock is the most important factor in their formation (Iloeje, 2001). Sudan Savanna, Northern Guinea Savanna, Southern Guinea Savanna, Forest derive savanna and mountain forest and grassland are the major vegetation types in the State (Ekaete, 2017). Sudan Savanna covered places around Karim Lamido, Lau, Jalingo, Ardo Kola, Yorro and Zing LGA, while Northern and southern Guinea savanna covers the major part of the State and include LGAs such as Gassol, Ibi, Wukari, Donga, Bali, Takum, Ussa, Kurmi and Gashaka LGA. Mountain forest on the other hand is found in the higher altitude of the state around Gembu.

## Materials and Methods

### Onset, Cessation, and Length of Rainy Season

Onset date of rain according to Adebayo, (2000) is a period at which the soil moisture is sufficient for the establishment of the crop while Cessation is the termination of the effective rainy season. Walter (1967) and modified method of Olaniran's (1988) was used in computing the onset, cessation and LRS of the area. The equations used are presented below;

$$\text{Onset} = \frac{x_n(51-\sum x_r)}{y} \quad - \quad - \quad - \quad - \quad - \quad \text{Equation 1}$$

$$\text{Cessation} = \frac{x_n(51-\sum x_r)}{y} \quad - \quad - \quad - \quad - \quad - \quad \text{Equation 2}$$

Where;

$x_n$ = Number of days in the first month whose rainfall is ≥ 51 (For onset date of rain)
$\sum x_r$ = Rainfall total of the previous month
y = Total rainfall of the first month with rainfall ≥ 51mm.

**Dry-spell**: It is a period in which there is a break in rainfall during the rainy seasons at different time interval. It is a period (day) during the rainy season with precipitation of less than 2mm (Adebayo, 2000).

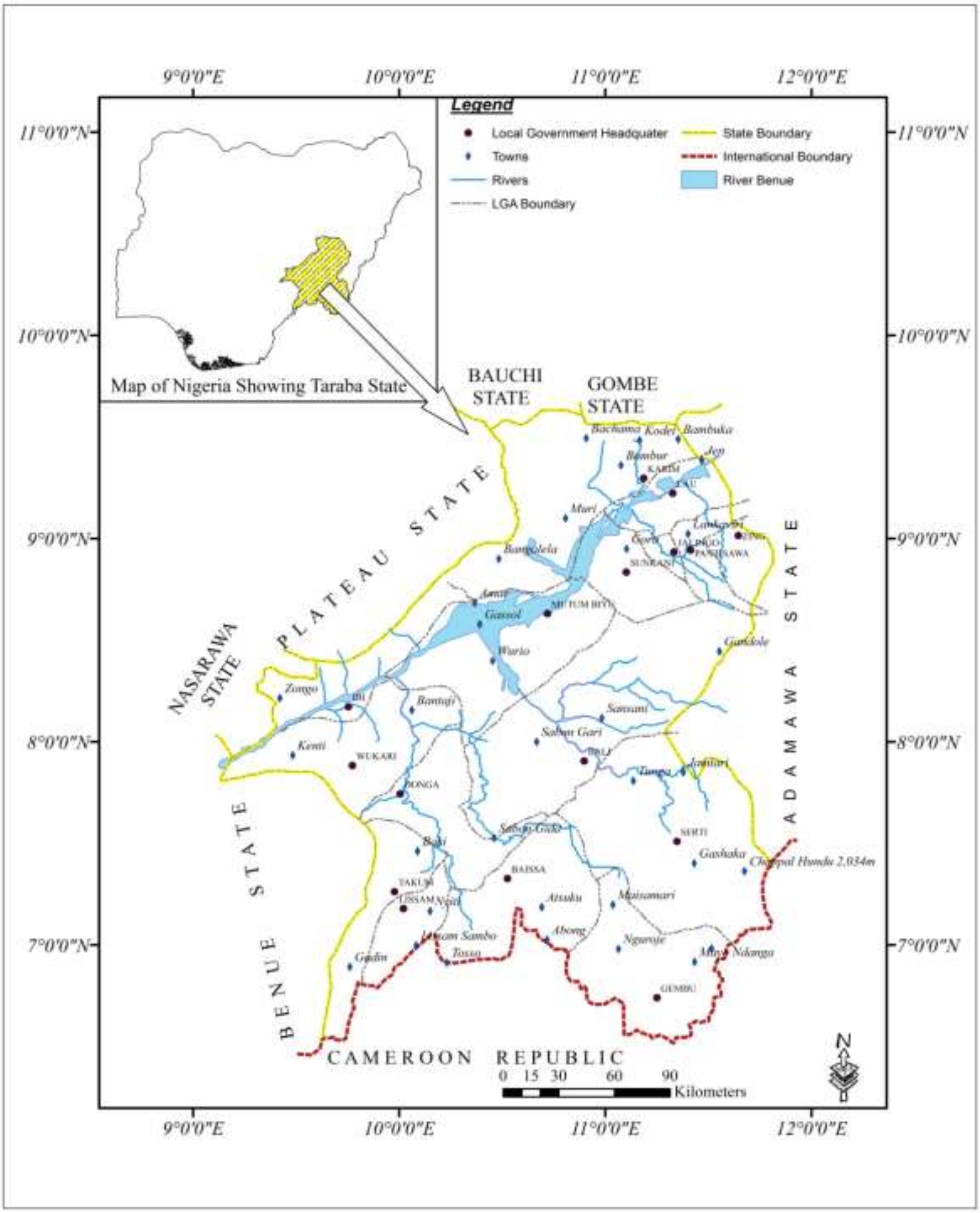


Figure 1: Taraba State

**Seasonality Index**: It is the spread and steadiness of rainfall during the wet season (Adebayo, 2000). In this study, monthly and annual rainfall of all the selected meteorological stations was used for the analysis.

According to the method of Walsh and Lawler (1981), the seasonality Index was computed as follows:

$$SI = 1/R\sum\left|Xn - \frac{R}{12}\right| \qquad \text{- - - - -} \qquad \text{Equation 3}$$

SI = Seasonality Index (Absolute value)
Xn = Mean Rainfall of month n
R = Mean annual Rainfall

Hydrological Ratio: This measures the ratio between mean annual rainfall and potential evaporation of a place. In another word, it determines the level of wetness or dryness of a place. The ratio is measured as:
Hydrological Ratio = precipitation (P)/potential evapotranspiration (PE). - - Equation 4

**Results and Discussions**

Table 1 shows the effect of precipitation effectiveness indices on the yield of yam in the state and the result revealed that June rainfall and hydrological ratio were the variables that are critical to the yield of the crop in the state. The prediction model showed a significant F-value of 34.772 at $p<0.05$ and the coefficient of determination ($r^2$) is 0.959 which implies that the variation in yield of yam is accounted or explained by June rainfall and hydrological ratio to 95.9% leaving the remaining percentage for other factors to explain in the state. It also revealed that the two selected indices are fit for the prediction of yam yield in the study area based on the fact that the F-value is significant at $p<0.05$ probability level. The selected indices also displayed a coefficient value of -0.111 and 10.890 for the two indices respectively which explained that June rainfall in the area contributed negatively to the yield of yam and suggested that a unit increase in onset date of rain will lead to decrease in yield of crop by 0.077. The result also showed that hydrological ratio which determines the moisture nature of an area displayed a positive contribution of 10.890 to the yield of yam in the state and clearly implies that a unit increase in the amount of the indices will lead to an increase in the yield of the variety with 10.890.

Table 1: Stepwise Regression result between Yam and Climatic Variables

| Predictors | Coef | SE Coef | t | $R^2$ (%) | F-Value |
|---|---|---|---|---|---|
| Constant | 24.205 | 1.800 | 13.446** | | |
| June Rainfall | -0.111 | 0.014 | -7.733** | 74.5 | 11.696** |
| Hydrological Ratio | 10.890 | 2.767 | 3.935* | 95.9 | 34.772* |

Source: Calculated from precipitation effectiveness indices and selected crops yield, (2021)

Result on the effects of precipitation indices on yield of Irish potato in Table 2 revealed that August rainfall is the critical indices detected to be significant to the yield of the crop and the prediction model displayed a significant F-value of 15.429 at $p<0.05$ and accounted for 97.4% to the variation in the yield of the crop in the state. The model also showed a positive contribution of August rainfall of 0.013 and a significant t-value of 3.928 at $p<0.05$. This result clearly implies that a unit increase in August rainfall amount will lead to an increase in the yield of Irish potato in the state based on the fact that August rainfall coincide with vegetative stage of crops in the region where water requirement during that stage is high (Ezra *et at.*, 2020a and Ezra *et al.*, 2016).

Table 2: Stepwise Regression result between Irish Potatoes and Climatic Variables

| Predictors | Coef | SE Coef | t | $R^2$ (%) | F-Value |
|---|---|---|---|---|---|
| Constant | 79.783 | 0.734 | | | |
| August Rainfall | 0.013 | 0.003 | 3.928* | 79.4 | 15.429* |

Source: Calculated from precipitation effectiveness indices and selected crops yield, (2021) Rainfall in the month of June is another index identified to be critical in the yield of Cassava as shown in Table 3. The parameter showed a negative contribution of 0.175 Cassava which clearly revealed that a unit increase in June rainfall will lead to a decrease in the yield of Cassava by 0.175 and also explained that rainfall in the month of June is not detriment to the yield of the crop in the state.

Table 3: Stepwise Regression result between Cassava and Climatic Variables

| Predictors | Coef | SE Coef | t | $R^2$ (%) | F-Value |
|---|---|---|---|---|---|
| Constant | 47.445 | 10.046 | 4.723** | | |
| June Rainfall | -0.175 | 0.054 | -3.228* | 72.3 | 10.421* |

Source: Calculated from precipitation effectiveness indices and selected crops yield, (2021)

**Conclusion**

Based on the findings of this study, it was concluded that precipitation effectiveness indices were critical to the variation in yield of crops in the state and was observed that hydrological ratio, rainfall in June, and August were the critical climatic factors affecting the yield of root crops in the state. It was also concluded that hydrological ratio which determined the level of wetness and dryness of an area and rainfall in the month of June were critical to the yield of Yam in the state while August and June rainfall were critical indices detected to be significant to the yieldIrish Potatoes and Cassava respectively.

**Recommendations**

i. There is a need by extension service workers to inform farmers on the critical climatic factors affecting the yield of the selected crops in the study area for agricultural planning.
ii. Farmers should be encouraged by extension workers on the cultivation of the selected root crops where the PEIs are favorable.
iii. There is a need for Government and non Governmental intervention to farmers in terms of farm input in subsidized and affordable rate to improve their crop cultivation.
iv. Farmers should be encouraged by extension workers on good and better adaptation methods which will help in unforeseen event that will affect crop yield. The use of information technology by farmers will greatly facilitate communication among farmers on new adaptation method like early warning system on pest and disease control.

**References**

Adebayo, A. A. & Umar AS. (2020). Hydrology and Water Resources in Adebayo, A. A. & Tukur, A. L. (Eds) Adamawa state in maps. Geography Department, FUT, Yola & Paraclette Publishers, Yola. pp 17-19.

Adebayo, A. A. (2010). Climate: Resource and Resistance to Agriculture. 8th Inaugural Lecture, Federal University of Technology, Yola. ABTI press, Yola. 48pp

Adebayo, A. A. (2000). Agro-Climatic Classification of Adamawa State, for Upland Rice Production, *The Nigerian Geographical Journal, New seris*, Vol. 3 & 4.

Angela I. E and Fidelis H. B (2013). Effects of Climate Change on Rice Farming in Ardo Kola Combination and Ordered Weighted Averaging. *Informatica* 33(4):459-474

Ayoade J. O (2005). *Introduction to Agroclimatology*, Vintage, Publisher, Ibadan, Nigeria. Pp. 87-205

Barron J., Rockslom J., Gichuki, F., and Itatibu N. 2003. Dry spell analysis and maize yield for two semi arid locations in East Africa. *Agri. for Meterol, 117: 23-37.*

Ekaete M (2017).Vegetation zones in Nigeria and their features.(Retrieved 07/04/2017). https://www.legit.ng/1096264-vegetation-zones-nigeria-features.html

Ezra A., Umar A. S and Adebayo A. A (2020a). Effects of Agro-climatic variables on Yield of Selected varieties of rice in Taraba State. *Bayero Journal of Pure and Applied Sciences (BAJOPAS)*.Vol. 13(1). Pp. 32-39.

Ezra, A., Umar A. S and Adebayo A. A (2020b). Analysis of Agro-climatic condition in Taraba State and the Implication for Agricultural Development. Volume 8 Issue 1 of April 2020. Pp 16-27

Ezra, A., Umar, A. S. Joseph, Iand Kefas. A. P. (2016). Effect of Climate on Growth of Rice (*OryzaSativa*) in Greater Yola, Adamawa State. *Global Journal of Human- Social Science*: *B Geography, Geo-Sciences, Environmental Science & Disaster Management. Vol. 16 (5). Pp 1-11*.

Chisomo P. K., Hiroshi Y., Yoshinobu K and Katsuyuki Shimizu (2014). Fluctuation of rainfall time series in Malawi: An analysis of selected areas.Geofizika vol. 31. Pp. 13-28

Haruna S and Tasi'u Y. R (2017). Modelling Relationship between Rainfall Variability andMillet (*pennisetum americanum* l.) and Sorghum (*sorghum bicolor* l. *Moench.*)Yields in the Sudan savanna ecological zone of Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension Vol. 16(1). pp. 5 - 10

Iloeje, N.P. (2001). *A new geography of Nigeria*. New Revised Edition. Longman Nigeria PLC. pp.200.

Kimamo J, George M and Kennedy O (2019). "The analyzing of rainfall variability on agricultural growing season in Narok county, Kenya", *Asian Journal of Science and technology,* 10, (02), 9404-9409.

Moncumill, D.F. (2006). Climate Variability and Corn Yields in Semiarid Ceara; Brazil. *Journal of Applied Meteorology and Climatology,* Vol. 46, 226 -280.

Mostafa M, Mohammad A. N and Mehdi M (2015). Assessing the Impact of Climate Variability on Rice Phenology. *Research Journal of Environmental Sciences, 9: 296-301.*

Olaniran, O. J. (1988). Research in Agroclimatology. *Nigeria Journal of Agric research* 19.15-29.

Sawa, B. and Adebayo, A. (2011).The Impact of Climate on Precipitation Effectiveness Indices in Northern Nigeria. *Journal of Environmental and Earth Sciences*, 481 – 486.

Taraba Youth Progressive Association of Nigeria (TYPA) (2009). Report on small scale environmental studies in Taraba state.

Walsh, P.R.D. and D.M. Lawler, (1981). Rainfall seasonality description, spatial pattern and change through time. Weather, 36(7): 201-208.

Walter, M.W., (1967). Length of the rainy season in Nigeria. *Nigerian Geograph. J.*, 10: 123-128.

Wilhite DA. Glantz MH. (1985). "Understanding the drought phenomenon; the role of definitions". Water International. 10:111-120.

# CONFLUENCE FLOW OF TWO MIXING RIVERS: IMPLICATION ON SEDIMENT TRANSPORT

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***Abstract***
*Confluence flow of two rivers: implication on the sediment transport is considered hydro-dynamically. The governing non-linear partial differential equations are reduced to ordinary differential equations using the similarity transformation approach. The resulting similarity equations are linearized by the method of regular perturbation series expansion, and solved for the velocity characteristics. The effects of magnetic field strength, confluence angle and environmental heat are investigated, and the results presented graphically. The analysis of results shows that the increase in the magnetic field strength and confluence angle reduce the flow velocity; and the increase in the convective current increases the flow velocity. Importantly, the decrease in the flow velocity due to the increase in the magnetic field strength and confluence angle decrease the rate of bed-loads/sediments transport but the increase in the convective current due to the increase in the environmental heat increases the velocity, which in turn increases the rate of sediments transport in the confluence flow towards the mouth of a water body. In fact, the effect of convective current tends to cushion the decreasing effects of magnetic field strength and confluence angle.*

***Keywords:*** *Hydro-dynamic, confluencing flow, river sediments, hydro-dynamic*

## Introduction

A confluence is a place where two flows with the same or different characteristics merge. The flow may be natural or artificial. Specifically, two or more water bodies (rivers, streams, lakes, or canals) may collide, Confluence, or merge to form a new single flowing water body. When two rivers merge, the waters may mix or may not. Examples of confluence -mixing rivers are Rivers Ilz, Danube, and Inn in Passau, Germany; Jialing and Yangtze in Chongqing, China; Thompson and Frazer in Lytton, British Columbia, Canada; Benue and Niger in Nigeria. Similarly, Rivers Ohio and Mississipi at Cairo, Illinois, USA; Rio Negro and Rio Solimoes, near Manaus, Brazil are examples of confluencing but non-mixing rivers; see Wikipedia (n.d.)

Rivers may merge in different forms. Some laterally, as when small rivers or tributaries (the lateral flows) enter a large one (the main flow) to form an open channel flow; in others, the merging of two non-parallel rivers flowing in approximately the same direction. Because rivers rise from different mountains whose gradients, chemical composition of the source rocks, and environmental climatic conditions are different they are bound to have different velocities, chemical compositions, temperature and colours, geological properties, etc.

Merging rivers flow problem have been widely studied. Some studied it ecologically (Blettler et al., 2014), some hydro-dynamically (Best and Reid 1987; Biron et al., 2004; Constantinescu et al., 2012; Mignot et al., 2013; Mark et al., 2015); some sedimentologically (Laurent et al., 2015); some by laboratory experiments (Best and Roy, 1991; Anath, 2018), and others by field survey (Best 1987; Rhoads and Sukhodolov 2001; Biron et al., 2002; Liu et al., 2012). Importantly, on a hydro-dynamic review of reports, Best (1987) studied the flow dynamics of an open confluence flow for several merging angles and discharge ratios, and noticed that the flow has six hydro-dynamic regions: flow deflection, flow stagnation, flow separation, maximum velocity, shear layer, and flow recovery; the flow is characterized by helical flow cell. Anath (2018) gave a review of the flow dynamics and sediment transport at open channel confluences, and showed the link between flow dynamics, sediment transport, and bed morphology.

Not much reports exist on the hydrodynamic study of confluencing rivers. Improving on this, this paper presents an analytic model of the hydrodynamics of the mix-merging flow of two rivers, with the attendant implications on the bed-loads/sediments.

This paper is organized as follows: section 2 is the Methodology; section 3 is the Results and Discussion, and section 4 is the Conclusion.

**Methodology**

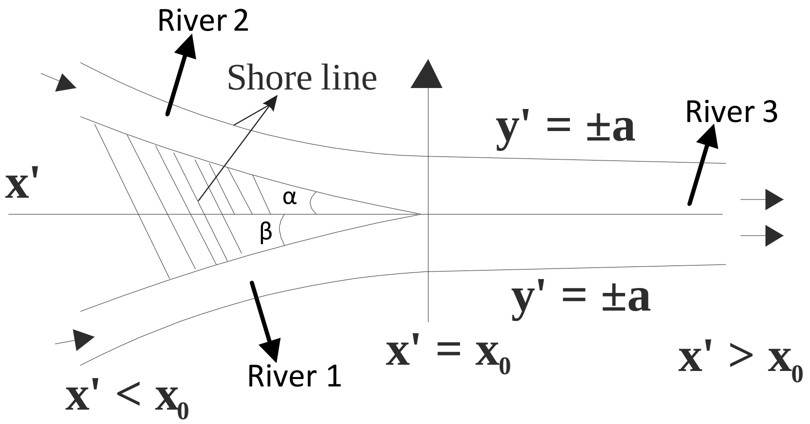


**Fig. 1:** A physical model of symmetrical confluencing rivers (α=β)

Figure 1 is a representation of a merging flow of two rivers whose merging angles range from 0<α<90° and it shows that Rivers 1 and 2 are flowing from different sources/mountains $x' = +\infty$, merge at $x' = x_o$, and continued towards a standing water body $x' = -\infty$. Upon this, the model is divided into two regions: the upstream region $x' < x_o$ and downstream region $x' > x_o$, with $x_o$ as the nodal or merging point.

The modeled problem is formulated based on the premises that: the merging river channels are symmetrical and porous and anisotropic; the river waters are incompressible, Newtonian, and magnetically susceptible (due to the presence of dissolved/decayed materials, alkaline/salts from the source rocks); the waters are at different levels of concentration, and as such a homogeneous chemical reaction of order one exists; the waters are at different velocities, temperature and concentration such that at mixing they have common flow characteristics; the environmental temperature effect caused by the radiation from the sun is present, therefore a thermal differential exists between it and the river waters equilibrium temperatures. Specifically, the environmental/external temperature depends on the radiation from the sun and is usually higher than the ambient temperatures of the rivers.

Rivers are assumed planar in nature. We consider a 2-D case, where the velocity is symmetrical about the $z_i'$-axis. Therefore, if $(u'_i, v_i')$ are the velocities in the mutually orthogonal axes $(x'_i, y_i')$; $C_i'$ and $T_i'$ are the concentration and temperature of the merging rivers, $T_\infty'_i$ and $C_\infty'_i$ are the equilibrium concentration and temperature of the merging rivers, then by the Boussinesq approximations in the non-dimensionalized form treated with similarity transformation, and regular perturbation series expansion solutions of the form

$$n(x,y) = n_o(x,y) + \varepsilon n_1(x,y) + ...$$

where $n$ represents the flow dependent variables, $\varepsilon = \frac{1}{\mathrm{Re}} << 1$ is the perturbation parameter, then the equation of mass balance, momentum, energy, and diffusion guiding the flow are as follows:

For River 1

$$f_{1o}'' = 0 \quad (1)$$

$$f_{1o}''' + f_{1o}'' - M_1^2 f_{1o}' = -Gr\Theta_{1o} - Gc\Phi_{1o} \quad (2)$$

$$\Theta_{1o}'' + \Theta_{1o}' + N^2\Theta_{1o} = 0 \quad (3)$$

$$\Phi_{1o}'' + \Phi_{1o}' + \delta^2{}_1\Phi_{1o} = 0 \quad (4)$$

with the boundary conditions

$$f_{1o} = 0,\ f_{1o}' = 0,\ \Theta_{1o} = 0,\ \Phi_{1o} = 0 \text{ at } \eta = 0 \quad (5)$$

$$f_{1o} = 0,\ f_{1o}' = 0,\ \Theta_{1o} = a_1\Theta_w,\ \Phi_{1o} = a_2\Phi_w,\ a_1 < 1, a_2 < 1 \text{ at } \eta = \alpha x \quad (6)$$

For River 2

$$f_{2o}'' = 0 \quad (7)$$

$$f_{2o}''' + f_{2o}'' - M_1^2 f_{2o}' = -Gr\Theta_{2o} - Gc\Phi_{2o} \quad (8)$$

$$\Theta_{2o}'' + \Theta_{2o}' + N^2\Theta_{2o} = 0 \quad (9)$$

$$\Phi_{2o}'' + \Phi_{2o}' + \delta^2{}_1\Phi_{2o} = 0 \quad (10)$$

with the boundary conditions

$$f_{2o} = 0,\ f_{2o}' = 0,\ \Theta_{2o} = 0,\ \Phi_{2o} = 0 \text{ at } \eta = 0 \quad (11)$$

$$f_{2o} = 0,\ f_{2o}' = 0,\ \Theta_{2o} = a_1\Theta_w,\ \Phi_{2o} = a_2\Phi_w,\ a_1 < 1, a_2 < 1 \text{ at } \eta = \alpha x \quad (12)$$

for the zeroth order in the upstream,

For River 3 (The merger)

$$f_{31}'' = 0 \quad (13)$$

$$f_{31}''' + f_{31}'' - M_1^2 f_{31}' = f_{3o}' f_{3o}'' - f_{3o} f_{3o}'' - Gr\Theta_{31} - Gc\Phi_{31} \quad (14)$$

$$\Theta_{31}'' + \Theta_{31}' + N^2\Theta_{31} = \Pr(f_{3o}'\Theta'_{3o} - f_{3o}\Theta'_{3o}) \quad (15)$$

$$\Phi_{31}'' + \Phi_{31}' + \delta_1^2\Phi_{31} = Sc(f_{3o}'\Phi_{3o}' - f_{3o}\Phi_{3o}') \quad (16)$$

with the boundary conditions

$$f_{31} = 0,\ f_{31}' = 0,\ \Theta_{31} = 0,\ \Phi_{31} = 0 \text{ at } \eta = 0 \quad (17)$$

$f_{31}=0$, $f_{31}'=0$, $\Theta_{31}=0$, $\Phi_{31}=0$ at $\eta=1$ (18)

for the first order in the downstream

Expressing the order zero terms in equations (14) - (16) in terms $f_{3o}=f_{1o}+\lambda f_{2o}$, we get

$$f_{31}'''+f_{31}''-M_1^2 f_{31}'=\left[f_{1o}'f_{1o}''+\lambda f_{1o}'f_{2o}''+\lambda f_{2o}'f_{1o}''+\lambda^2 f_{2o}'f_{2o}''\right]$$
$$-\left[f_{1o}f_{1o}''+\lambda f_{1o}f_{2o}''+\lambda f_{2o}f_{1o}''+\lambda^2 f_{2o}f_{2o}''\right]-Gr\Theta_{31}-Gc\Phi_{31} \quad (19)$$

$$\Theta_{31}''+\Theta_{31}'+N^2\Theta_{31}=\Pr\left[f_{1o}'\Theta'_{1o}+\lambda f_{1o}'\Theta'_{2o}+\lambda f_{2o}'\Theta'_{1o}+\lambda^2 f_{2o}'\Theta'_{2o}\right]$$
$$-\Pr\left[f_{1o}\Theta'_{1o}+\lambda f_{1o}\Theta'_{2o}+\lambda f_{2o}\Theta'_{1o}+\lambda^2 f_{2o}\Theta'_{2o}\right] \quad (20)$$

$$\Phi_{31}''+\Phi_{31}'+\delta_1^2\Phi_{31}=Sc\left[f_{1o}'\Phi_{1o}'+\lambda f_{1o}'\Phi_{2o}'+\lambda f_{2o}'\Phi_{1o}'+\lambda^2 f_{2o}'\Phi_{2o}'\right]$$
$$-Sc\left[f_{1o}\Phi_{1o}'+\lambda f_{1o}\Phi_{2o}'+\lambda f_{2o}\Phi_{1o}'+\lambda^2 f_{2o}\Phi_{2o}'\right] \quad (21)$$

where;

$f_i,\Theta_i,\Phi_i$ are the similarity velocities, dimensionless temperatures and concentrations of the rivers, respectively, $\delta_1^2, M_1^2, \Pr, N^2, Gr, Gc, \lambda$ are the chemical reaction rate, magnetic field strength, Heat exchange parameter, Grashof number due temperature difference, Grashof number due to concentration difference, a positive fraction/constant, respectively.

The order zero equations describe the upstream flow, while the order one equations describe the downstream flow. More so, the presence of the order zero terms in the order one equations indicates the influence of the upstream on the downstream flow.

**Results and Discussion**

We investigated the effects of some hydro-dynamic parameters on the flow velocity structure of the merging two rivers and their attendant implications on sediments transport. The computations were carried out using the Mathematica 11.2 computational software.

For constant values:

$\Theta_w=0.2, \Phi_w=0.2, \mathrm{Re}=100, \chi=0.1, \lambda=0.3,$

$N=0.1, \Pr=0.71, Sc=0.3, \delta=0.1, a_1=0.1, a_2=0.1,$

For varied values:

$M^2=0.04, 0.16, 0.36, 0.64, 1.0;$

$Gr=0.2, 0.4, 0.6, 0.8, 1.0;$

$\alpha=30, 45, 60, 75, 90$

We obtained the graphs shown below.

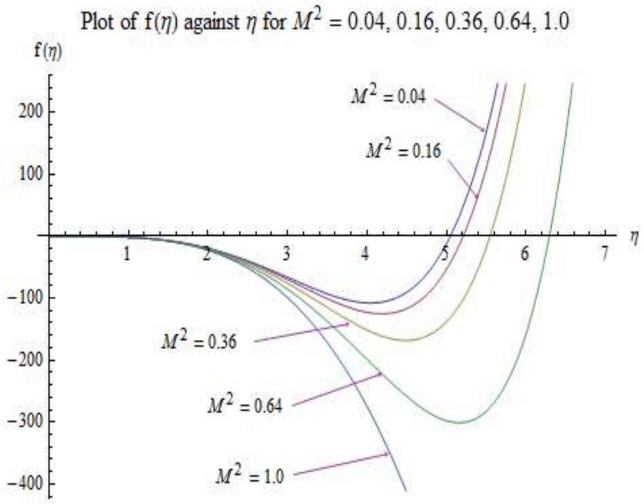


**Fig. 2:** Velocity ( $f(\eta)$ )-Magnetic field ( $M^2$ ) profiles for $0 < \eta \leq 7$)

The effect of the magnetic field on the velocity is seen in Fig. 2. It shows that the flow velocity decreases as the magnetic field strength increases. By the nature of the source rocks, the water of the river is alkaline or slightly acidic, and subsequently magnetically susceptible. Being alkaline, the water particles exist as charges. In the presence of the Earth magnetic field, which is due to the Earth rotation, they produce electric currents. The currents act on the magnetic field to produce a mechanical force, the Lorentz force. This force has the potency for freezing up flow velocities, and this accounts for what is seen in Fig. 2.

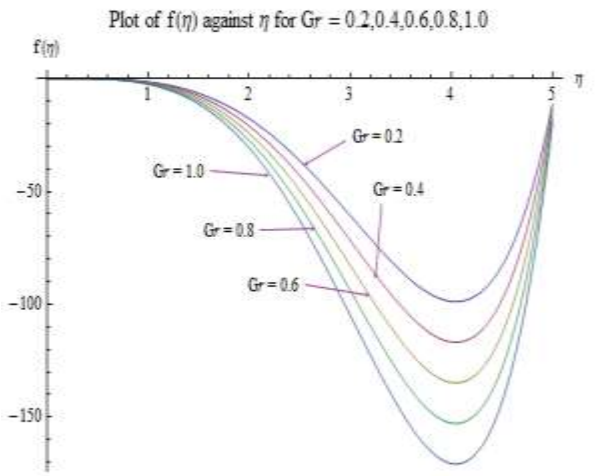


**Fig. 3**: Velocity **(** $f(\eta)$ **)-**Grashof number **(** $Gr$ **)** profiles for $0 < \eta \leq 5$)

The effect of convective currents (Grashof number) on the flow velocity is seen in Fig. 3. The figure depicts that the flow velocity increases as the Grashof number increases. The temperature difference between the environment, which is due to the radiation from the sun, and the ambient temperature of the fluid in the presence of gravity, volumetric expansion coefficient due to temperature, and density effects create convective currents. The convective currents break the fluid particles from the grip of the fluid viscosity, thus making them buoyant and flow with ease. The ease of flow accounts for the increase in the velocity; as seen in Fig. 3.

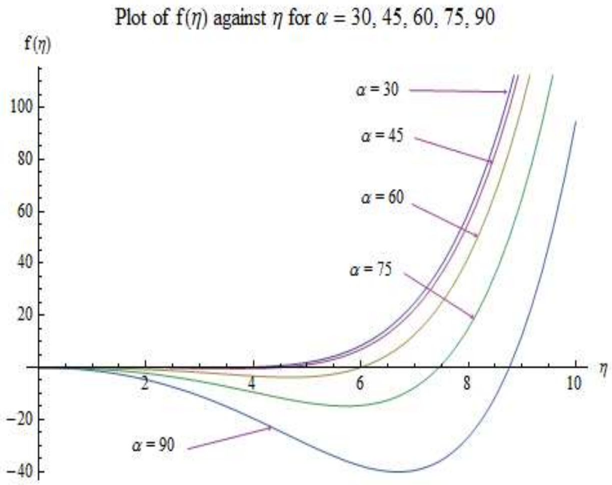


Fig. 4 Velocity ( $f(\eta)$ )-Confluence angle ( $\alpha$ ) profiles for $0 < \eta \leq 10$)

Additionally, the effects of the confluence angle on the flow velocity is seen in Fig. 4. The figure shows that the flow velocity decreases as the confluence angle increases. As the water of rivers 1 and 2 clashes into the merger, rotational and whirling/spinning motions are generated. This creates a sort of turbulence at the merging point. The rotation and spinning tend to reduce the motion in the axial direction, thus accounting for what is seen in Fig. 4. Significantly, the spinning motion creates scours at the merging point.

Apart from the existing gradient/slope between the river and the source mountain, mass volume of the water, depth of the river, gravity, amidst others, hydrodynamic parameters affect river flow, and subsequently affect the transport of the bed-loads/sediments. Usually, as the river flows downwards from the mountains, the particles eroded are carried along with them as bed-loads/sediments. The gradient effect highly enhances their transport in the upper and middle zones of the river, where velocities are high and moderate, respectively. The gradient effects subside or are decayed in the depositional zone. Naturally, the other factors and hydro-dynamic parameters effects take sway completely. Importantly, the decrease in the velocity due to the increase in the magnetic field strength and merging angle retard the transport of the bed-loads/sediments, thus causing early deposition of the materials and shallowing-up of the merger river. On the other hand, the increase in velocity through the increase in the convective currents enhances the transport of the bed-loads/sediments, thus delaying the shallowing-up of the merger river in its course towards a standing water body

**Conclusions**

A hydro-dynamic confluence flow model of two rivers is presented, and the effects of magnetic field strength, convective currents and merging angle on the flow velocity structure are investigated. The analysis of results shows that the increase in:

- magnetic field decreases the velocity;
- Grashof number increases the velocity;
- merging angle decreases the velocity.

The effects of these parameters on the flow have attendant implications on the transport of the merger river bed-load/sediments.

## References


Ananth, W. (2018). Review of flow hydrodynamics and sediment transport at open channel confluences. *Civil Engineering Research, Journal,* 5(3), 1-7. DOI:10.19080/CERJ.2018.05.555664

Best, J., and Reid, I., (1984), Separation zone at open channel junctions. *Journal of Hydraulic Engineering*, 110(11), 1588-1594.

Best, J. L. (1987). Flow dynamics at river channel confluences: implication for sediment transport and bed morphology, in recent developments in fluvial sedimentology. *Special Publication SEPM Society Sedimentological Geology*, 39, 27–35.

Best, J., and Roy, A. (1991). Mixing-layer distortion at the confluence of channels of different depths. *Nature*, 350(6317), 411-413.

Biron, P. M. Richer, A., Kirkbride, A.D., Roy, A. G., and Han, S. (2002). Spatial patterns of water surface topography at a river confluence. *Earth Surface Processes and Landforms*, 27(9), 913-928.

Biron, P. M., ramamurthy, A. S. and Han, s. (2004). Three-Dimensional Numerical Modeling Of Mixing At River Confluences. *Journal of Hydraulic Engineering,* 130, 243-253.

Blettler, M., Amsler, M., Ezcurra de Drago, I., Espinola, L., and Eberle, E. (2014). The Impact of Significant Input of Fine Sediment on Benthic Fauna at Tributary Junctions: A Case Study of the Bermejo-Paraguay River Confluence, Argentina. *Ecohydrology*, 8(2), 340-352.

Constantinescu, G., Miyawaki, S., Rhoads, S., and Sukhodolov, A. (2012). Numerical Analysis of the Effect of Momentum Ratio on the Dynamics and Sediment Entrainment Capacity of Coherent Flow Structures at a Stream Confluence. *Journal of Geophysical Research*, 117, 1-21.

Laurent Schindfessel, Stéphan Creëlle, and Tom De Mulder (2015). Flow Patterns in an Open Channel Confluence With Increasingly Dominant Tributary Inflow. *Water*, 7, 4724-4751. DOI:10.3390/W7094724.

Liu T., Chen L., and Fan, B. (2012). Experimental Study on Flow Pattern and Sediment Transportation at a 90° Open-Channel Confluence. *International Journal Of Sediment Research,* 27(2), 178-187.

Mignot, E., Vinkovic, I., Doppler, D., and Riviere, N. (2013). Mixing Layer in Open-Channel Junction Flows. *Environmental Fluid Mechanics*, 14(5), 1027- 1041.

Mark, T., Andre, M., Marco, O., Marco, I., and Carlo, G. (2015). Sediment transport and Mixing about the Confluence of Negro and Solimões Rivers, Manaus, Brazil, e-Proceedings of the 36th IAHR World Congress. 28 June – 3 July 2015. The Hague.

Rhoads, B. L., and Sukhodolov, A. N. (2001), Field Investigation of Three-Dimensional Flow Structure at Stream Confluences: 1. Thermal mixing and time-averaged velocities. *Water Resources Earch,*res. 37(9), 2393-2410.

Wikipedia (n.d.). When Rivers Collide: 10 Confluences Around The World Retrieved April , 2012 from Http/:Twistedsifter.Com/2012/04/Confluence Around The World.

# ABUNDANCE, DISTRIBUTION AND DIVERSITY OF PHYTOPLANKTON IN RELATION TO HUMAN ACTIVITIES WITHIN THE IDUNDU BRIDGE-END AREA OF THE GREAT KWA RIVER, SOUTHEAST, NIGERIA

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**Abstract**

*Studies on abundance, distribution and diversity of phytoplankton in relation to human activities within the Idundu Bridge-end area of the Great Kwa River, Nigeria, were conducted for 9 months (February-October, 2019) with the objectives of ascertaining the pollution status of the area due to human activities. Phytoplankton samples were collected by filtering20litres of surface water between 007-009 hours, through a 55μm hydro bios bolting net.Filtered samples were concentrated to 100ml capacity, preserved with 4% bufferedformaldehyde solution, stored in plastic boxes and transported to the Biological Oceanography Laboratory, Faculty of Oceanography, University of Calabar, Calabar – Nigeria, for analysis. Each sample was stained with l-2ml of Lugol's iodine solution and well stirred to mix using a glass rod and allowed to stand for 1 minute to enhance the absorption of the stain by the phytoplankton cells, and thereafter observed under an inverted microscope(model: Olympus CH00545 Tokyo, Japan), using xl0 and x40 objectives. Identification of the phytoplankton was carried out to species level based on their morphological features using standard identification guides and atlases. Data were analyzed empirically and ecologically. Statistical analysis of the data was performed using the single factor analysis of variance (ANOVA) at a 0.05 level of significance. Total of 56 phytoplankton species spread into 5 major phytoplankton families were identified. These were Bacillariophyceae (16 species), Chlorophyceae (14 species), Euglenophyceae (11 species), Cyanophyceae (10 species) and Chrysophyceae (5 species). Indicator speciessuch as Melosira variance, Anabaena spimides, Euglena gracilis and Ceratiumhirudinea were identified in the phytoplankton. The absence of Coscinodiscussp in the phytoplankton community provides good ecological support information that the area is under the threat of pollution, although the Bacillariophyceae (diatoms) were the most diverse of the 5 phytoplankton families, with a total of 1794 cells/l00mls constituting 36.34% of the phytoplankton population, followed by Euglenophyceae with 1014 cells/l00mls (20.54%) Cyanophyceae with 1006 cells/l00mls (20.38%), Chlorophyccae with 813 cells/l00mls (16.47%) and Chrysophyceae with 310 cells/l00mls forming 6.27% of the total phytoplankton population. The generally low ranges of the Margalef's index (0.84-3.09) and high ranges of Shannon-Wiener(1.34-2.38), respectively suggest that the environment is under the threat of pollution. Significant difference (p<0.05) was observed in the monthly abundance of the phytoplankton cells within the bridge-end area during the period of study.*

**Keywords:** Abundance, Distribution, Diversity, Phytoplankton, Human Activities, Idundu Bridge-end area, Great Kwa River, Nigeria

## Introduction

Phytoplankton is the base of food web of the aquatic environment and affects the primary production of the system (Castro & Huber, 2005). The quantity and quality of phytoplankton is a good indicator of water quality. Also, the productivity of any aquatic system depends on the amount of plankton present (Davies *et al.*, 2009). Phytoplankton is generally primary producers in any aquatic system (Dimowo, 2013).

Several ecological studies have been conducted on the Nigerian aquatic ecosystem including the Great Kwa River. These, from available literature, include those of Akpan (1997, 2000), Nwankwo (1998), Kadiri (1999), Akpan*et al.* (2002), Kadiri & Omozusi (2002), Ekwu & Sikoki (2005), Ekwu & Sikoki (2006), Emmanuel & Onyema (2007), Eni*et al.*(2012), Onyema*et al.* (2007), Ajuonu*et al.* (2011) and Eyo*et al.*(2013). In the Great Kwa River, in particular, the only known study on phytoplankton is that of Eyo*et al.* (2013), in which the phytoplankton of EsukAtu, Obufa Esuk, Anantigha Beach and Abitu Beach which are some of the locations on the shore of the Great Kwa River, were studied. The phytoplankton of the Idundu Bridge-End of the Great Kwa has not been reported, which the present study is designed with pollution status of the area in the background.

## Materials and Methods

### 2.1 Study area/study location

The study area is described in Eyo*et al.* (2013). The study location is the Idundu bridge-end area of the Great Kwa river in Cross River State, Nigeria ($04^{0}15'$N and $008^{0}18'$E) (Fig. 1). Human activities in the area include among others, fishing, sand-mining, hunting, lumbering, agriculture, boat-building, trading, mat-making using nypa palm leaves and transportation business (land and water).

Fig. Map of the Great Kwa River showing Idundu bridge-end area where samples were collected.

### 2.2 Field and laboratory studies

For this study, plankton samples were collected by filtration method using a - 20 litre bucket and standard plankton net of 55$\mu$m mesh following the method of Nwankwo (1998). The 20 litres of the water was filtered and concentrated to l00mls and preserved in 4% buffered formaldehyde solution following the method of Dimowo (2013).

### 2.3 Data Analysis

#### 2.3.1 Numerical data analysis

The phytoplankton cells (n) in each sample were enumerated to find the total number of all individuals (N) in the family and used for the determination of the relative abundance (%Ra) using the formula: $\%Ra = \frac{n(100)}{N}$(Job *et al.*, 2011).

#### 2.3.2 Ecological data analysis

In this study, the following ecological data were analysed:

i. Margalef's Index (d): Margalef s index (d) is given by the formula: $d = \frac{S-1}{ln.N}$ where S = total number of species. ln = the natural or niperianlongarithm ($log_e$)and N = total number of individuals identified (Margalef, 1978).

ii. Shannon- Wiener Index (H): is given by the formula: $H = \frac{\sum NlogN - \sum filogfi}{N}$, where N = total number of all individuals in the assemblage, group, phyla or class as the case may be. fi= total number of individual species or group of species.

### 2.3.3 Statistical data analysis

The distribution and abundance of the phytoplankton in relation to month of sampling was compared using the single factor analysis of variance (ANOVA) (SAS, 2003).

## 3.0 Results

The result of the phytoplankton analysis is presented in Table 1. Five major phytoplankton families were identified in this study as Bacillariophyceae (Diatoms), Chlorophyceae, Euglenophyceae, Cyanophyceae and Chrysophyceae. The Bacillariophyceae were the most diverse phytoplankton and Chrysophyceae the least diverse. In terms of abundance, Bacillariophyceae topped the list with 1794 cells/100mls, constituting 36.34% of the phytoplankton population, followed by Euglenophyceae with 1014 cells/100mls (20.54%), Cyanophyceae with 1006 cells/100mls (20.38%), Chlorophyceae with 813 cells/100mls (16.47%) and Chrysophyceae with 310 cells/100mls (6.27%) of the phytoplankton.

The distribution pattern of the major phytoplankton families identified within the Idundu bridge area of the Great Kwa River was in the following order:
Bacillariophyceae >Euglenophyceae>Cyanophyceae>Chlorophyceae>Chrysophyceae.

**Table 1:** Numerical and relative abundance of the major phytoplankton families during the period of study (Pooled data)

| Major phytoplankton families | Abundance (numerical/relative) |
|---|---|
| Bacillariophyceae (Diatoms) | 1794 (36.34) |
| Euglenophyceae (Euglenoids) | 1014 (20.54) |
| Cyanophyceae (Blue-Green Algae) | 1006 (20.38) |
| Chlorophyceae (Green Algae) | 813 (16.47) |
| Chrysophyceae (Yellow or brown-green algae) | 310 (6.27) |
| Overall Abundance (N) $20L^{-1}$ | 4937 (100.00) |

*numbers in parenthesis represent relative abundance (%)

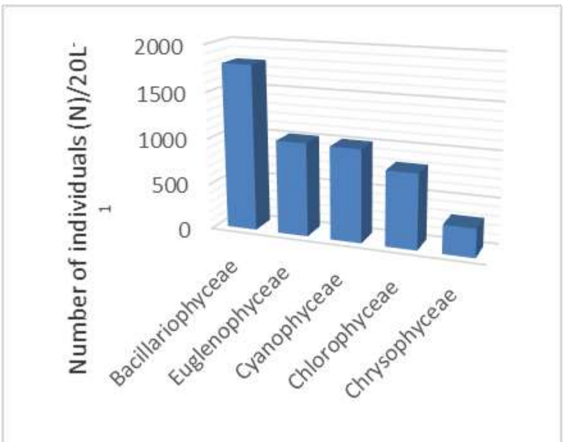


Fig 1a: Numerical abundance of the major phytoplankton families within the Idundu bridge-end area of the Great Kwa River, Nigeria (pooled data)

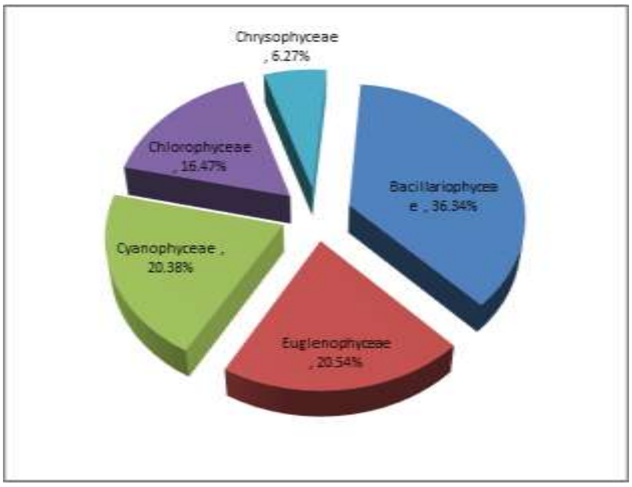


Fig 1b: Relative abundance of the major

**Table 2:** Summary of the monthly numerical abundance of the phytoplankton within the Idundu bridge-end area of the Great Kwa river, Nigeria (Feb. – Oct., 2019)

| Months of sampling | Feb | March | April | May | June | July | Aug. | Sept. | Oct. | Marginal total |
|---|---|---|---|---|---|---|---|---|---|---|
| Numerical abundance (N)/20L$^{-1}$ | 596 (11.99) | 817 (16.85 ) | 611 (12.30 ) | 530 (10.67) | 530 (10.67) | 459 (9.24) | 609 (12.26) | 466 (9.51) | 319 (6.42 ) | 4967 (100) |
| $\bar{d}$ | 0.84 | 1.78 | 1.81 | 2.02 | 1.89 | 1.88 | 1.94 | 3.09 | 1.92 | |
| $\bar{H}$ | 1.92 | 2.38 | 1.94 | 1.84 | 1.81 | 1.89 | 1.34 | 1.84 | 1.89 | |

The monthly abundance of the phytoplankton ranged between 319(6.42%) in October to 837(16.85%) in March while mean Margalef's index ranged between 1.70(February) and 2.03(September), with mean Shannon-Weiner's index ranging between 1.80(August) and 1.92(February) (Table 2) and depicted in Figure 2.

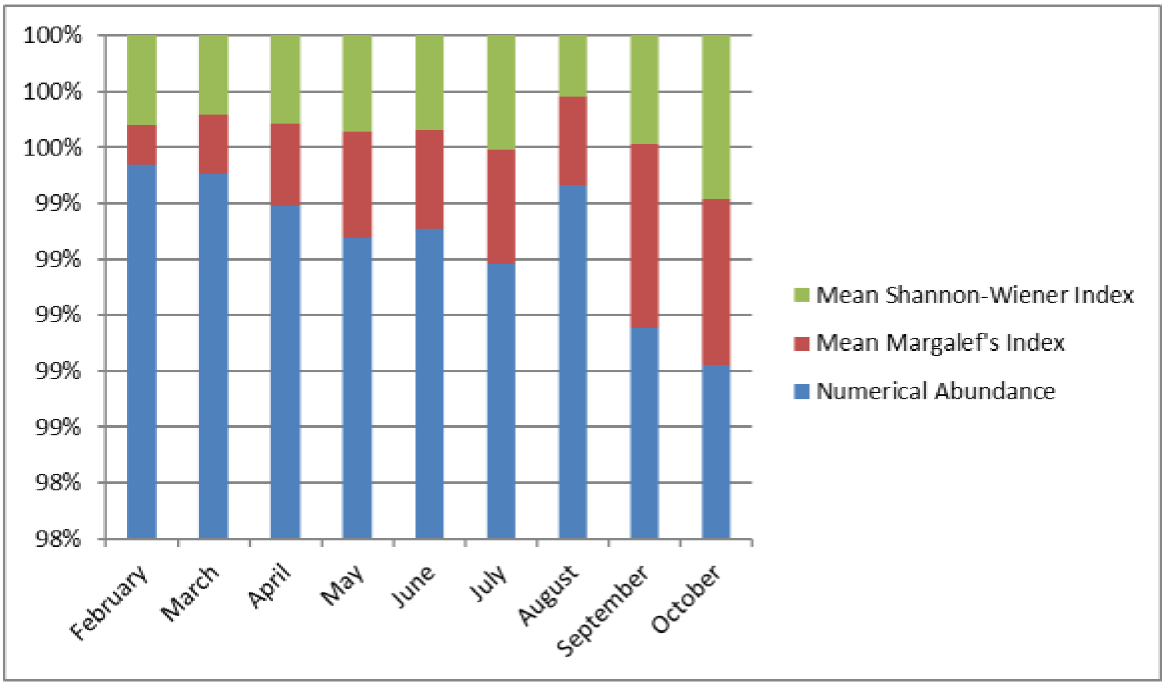


Fig. 2: Trend in the distribution of ecological parameters of the phytoplankton within the Idundu bridge-end area of the Great Kwa River, Nigeria, during the study period.

**4.0 Discussion**

Basically, in a tropical unpolluted lotic aquatic system, the abundant of diatoms indicates clean water (Uttah*et al.*, 2008; Davies *et al.*, 2009; Offem*et al.*, 2011; Dimowo 2013; Imoobe, 2014). Again, the absence or presence of indicator genus or species of phytoplankton in an aquatic ecosystem usually signifies the ecological stability or otherwise of the system (Singh and Singh, 2000; Uttah*et al*, 2008).

In this study, an indicator phytoplankton genus such as *Coscinodiscus*, known to always be the predominant and abundant diatom in an unpolluted water system was completely absent in the samples. This, interplayed with the predominance *of Melosiravarians* (Bacillariophyceae), *Anahaenaspiroides* (Cyanophyceae), *Englenagracilis* (Euglenophycjae) *and Camthnnhindinea* (Chrysophyceae) in the samples, has strong ecological implication and indicates that the Idundu Bridge-end area of the Great Kwa river system, is under pollution threat. Many species of freshwater algae may proliferate quite intensively in eutrophic (i.e. nutrient -rich) waters (Uttah, *et* *al.,* 2008; Takahashi *et al.,* 1982) in the midst of enough solar radiation though they may not form dense surface scums or "blooms" as do some phytoplankton family such as (Cyanobacteria (Uttah *et al.,* 2008, Castro & Huber, 2005).

The Idundu Bridge-end area of the Great Kwa is characterized by commercial sand-mining, one of the major human activities in the area. Such activities in a river system encourage the release of silicate into the water column (Ekwu & Udo, 2013). Silicate, unlike nitrogen is not brought into rivers by rain or freshwater discharge (Akpan, 2006), rather, it results from human activities particularly sand mining (Ekwu & Udo, 2013 and Reynolds, 1998). Even with increased particulate matter which is common in sand-mining areas of river systems, the release of silicate into the water column encourages build-ups of diatom cells, hence the tendency of diatoms to increase in their abundance, distribution and diversity more than other phytoplankton families (Ekwu & Udo, 2013). Again, during the dry season months, when water level was drastically reduced, increased commercial sand-mining activities were observed in the area. With increased sand-mining activities as would be expected, the release of silicate into the water was elevated. Ekwu & Udo (2013) report a general increase in diatom biomass in Ikpa River, Akwa Ibom State, Nigeria, as a result of increased silicate values which was generated from sand dredging activities in the dry season months of the year. Diatoms are known to specialize in high cell build-ups in the presence of silicate (Lind *et al.,* 1992; Wetzel, 2001; Ekwu & Udo, 2013). This ecological scenario might have contributed to the observed high biomass of the Bacillariophyceae in the samples during the period of study, though indicator organisms such as *Melosiravarians* (Bacillariophyceae), *Anabaena spiroides* (Cyanophyceae), *Euglena gracilis* (Euglenophyceae) *and Caratwmhinidined* (Chrysophyceae) predominated the samples. With the absence of phytoplankton of the genus *Coscinodiscus* in the samples it was ecologically clear that the area is under pollution threat.

The low ranges of Margalef’s index provided additional pointer that the area is subjected to the influence of pollution.

As reported by Ali *et al.* (2003), Margalef (1965), Margalef’s index values of between 1-3 indicate moderately polluted water, with values less than 1 indicating heavily polluted environment while values greater than 3 window clean water. The range of the Margalef’s indices obtained for the phytoplankton are clear indications that the system is threatened by pollution, which may be as a result of anthropogenic activities going on within the area. The high values of the Shannon - Wiener indices obtained in all the months for the phytoplankton, may also be linked to unfavorable ecological conditions which may have interplayed with the environmental components of the area. In an unpolluted environment, Shannon-Wiener indices are known to range between 0.0-1.0 (Ogbeibu, 2005; Shannon-Weaver, 1949). Similar observations were made by Dimowo (2013), Offem *et al.,* (2011) and Uttah *et al.,* (2008) on other Nigerian rivers devoid of pollution.

## 5.0 Conclusion and recommendation

The conservation and management of water ecosystem is critical to the interest of the entire mankind, as long as biodiversity constitutes valuable natural resources in economic, cultural, aesthetic scientific and educational terms. The results of the present study are expected therefore, to provide a hinge on which future reference could be drawn for the proper management of this very important area of the Great Kwa River. Proper management of the river systems which include controlled sand mining and other anthropogenic activities within the Bridge-End area of the Great Kwa River is recommended.

The recommendation herein is based on the results of this study which indicate the absence of the phytoplanktongenus such as *Coscinodiscus,*known to always be predominant and abundant diatom in an unpolluted water system, interplayed with the predominance of *Melosiravarians (*Bacillariophycea), *Anabaena spiroides* (Cyanophyceae), *Euglena gracilis* (Euglenophyceae) and *Caratiumhirudinea* (Chrysophyceae) in the sample and the low Margalef’s and high Shannon-Wiener indices which are strong ecological indications that the Idundu Bridge-end area of the Great Kwa river system is under pollution threat.

**References**

Ajuonu, N., Ikaonu, S. U., Oluwajoba, E. O., Mbawuike, B. E. and Myade, E. F. (2011). The abundance and distribution of plankton species in the Bonny estuary, Nigeria. *Agriculture and Biology Journal of North America*, 2(6), 1032-1037.

Akpan, E. R. (1997). Spatial and seasonal distribution of phytoplankton in the Cross River Estuary, Nigeria.*A paper delivered at the 6th Annual Conference of the Nigeria Society for Biological Conservation*, 26th – 28th November, 1997 Calabar, Nigeria.

Akpan, E. R. (2000). Influence of meteorological and hydrographic factors on the water quality of Calabar River, Nigeria. *Tropical Environmental Research* 2(1&2), 107-111.

Akpan, E. R., Offem, J. O. and Nya, A. E. (2002).Baseline ecological studies of the Great Kwa River, Nigeria.Physico-chemical studies. *African Journal of Environmental Pollution and Health*, 1(1), 83-90.

Castro, P. and Huber, M. E. (2005).*Marine Biology* (5th edition). McGrawHill Higher Education, p.452.

Davies, O. A., Abowei, J. F. N. and Otene, B. B. (2009). Seasonal abundance and distribution of plankton of Minichinda stream, Niger Delta, Nigeria. *American Journal of Scientific Research*, 2, 20-30.

Dimowo, B. O. (2013). Monthly spatial occurrence of phytoplankton and zooplankton in River Ogun, Ogun State, Southwest Nigeria. *International Journal of Fisheries and Agriculture*, 5(8), 193-203.

Ekwu, A. O. and Sikoki, F. D. (2005).Phytoplankton diversity in the Cross River Estuary. *Journal of Applied Science and Environmental management*, 10(1), 89-95.

Ekwu, A. O. and Sikoki, F. D. (2006).Species composition and distribution of zooplankton in the lower Cross River Estuary. *African Journal of Applied Zoology and Environmental Biology*, 7, 5-10.

Emmanuel, B. E. and Onyema, I. C. (2007).The plankton and fishes of a tropical creek in southwestern Nigeria. *Turkish Journal of Fisheries and Aquatic Science*, 7, 105-113.

Eni, E. G., Samuel, I. U. and Adem, A. B. (2012).Composition and abundance of phytoplankton of Adiabo River in Calabar River System, Southeast Nigeria. *European Journal of Zoological Research*, 1(4), 93-98.

Eyo, V. O., Andem, A. B. and Ekpo, P. B. (2013).Ecology and diversity of zooplankton in the Great Kwa River, Cross River State, Nigeria. *International Journal of Science and Research*, 2(10), 67-71.

Kadiri, M. O. (1999). Phytoplankton distribution in the coastal area of Nigeria. *Nigerian Journal of Botany*, 12, 51-62.

Kadiri, M. U. and Omozusi, H. I. (2002).A pre-pollution study of the phytoplankton of an oligotrophic river in southern Nigeria. *African Journal of Environmental Pollution and Health*, 1(1), 19-27.

Margalef, D. P. (1965).Ecological correlations and the relationships between primary productivity and community structure. In: 1 Primary Productivity in aquatic environment (ed) C. H. Goldman, University of California Press, Berkaley. *1st Italian Hydrobiological Symposium*, 18 Supplement, 335-365.

Nwankwo, D. I. (1998). Seasonal changes in phytoplankton composition and diversity in the Epe Lagoon, Nigeria. *ActaHydrobiologica*, 40(2), 83-92.

Statistical Analysis System (2003).*User's guide. SAS.Stat-version* (8th edition). SAS Institute Incorporated. Cary, North Carolina, United States of America, 115p.

# BIO-SURVEY OF PLANKTON AS INDICATORS OF WATER QUALITY FOR RECREATIONAL ACTIVITIES IN ESIERE-EBOM STREAM, CALABAR SOUTH, CROSS RIVER STATE, NIGERIA

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***Abstract***

*A bio-survey of Esiere-Ebom stream in Calabar South, Cross River State, Nigeria, was conducted between October - December, 2017 and January - March, 2018, using plankton as indicator organisms in addition to physico-chemical parameters (DO, pH, $BOD_5$, temperature) and nutrients ($NO_3^-$, $SO_4^{2-}$ and $PO_4^{2-}$) to assess the suitability of the stream water for recreational activities. DO, pH, $BOD_5$, and temperature were measured insitu using a multi-parameter water quality monitor (Orion: Model: 1260, USA), while $BOD_5$ was measured by incubation method in the laboratory. Water samples for nutrients measurement in the laboratory were collected in 1L plastic containers. $NO_3$- and $SO_4^{2-}$ were analyzed using the Brucine colorimeter technique, while $PO_4^{2-}$ was measured using turbidimetric technique. All measurements were carried out in duplicates and mean values calculated to enhance the integrity of the results. Plankton samples were collected by filtration method and this involved filtering 20L of the surface water through a-55µm hydro-bios bolting plankton net. Filtered samples were respectively concentrated to 100ml capacity and preserved with 4% buffered formaldehyde solution. Plankton samples were analyzed microscopically in the laboratory. The physico-chemical parameters gave the following readings: Do (6.5 – 8.5mg/l), pH (7.34 – 7.52), $BOD_5$ (0.22 – 1.40mg/l), temperature (22.0 – 24.0$^0$C), $NO_3$-(0.36 – 0.40mg/l), $SO_4^{2-}$ (1.36 – 2.47mg/l) and $PO_4^{2-}$ (0.014 – 0.022mg/l). Results showed that samples were within WHO's permissible limits. The study found that if the stream is properly maintained it would be a good recreational site and a source of domestic water supply for the inhabitants*

**Keywords:** Bio-Survey, Plankton Indicators, Water Quality, Recreational Activities, Esiere-Ebom stream, Calabar South, Nigeria

## Introduction

The term plankton generally refers to the microscopic aquatic organisms which inhabit the open water and remain drifting and suspended in the euphotic zone of the water column. Their drifting ability is at the mercy of wind and water current. Two groups of plankton are known - the phytoplankton and the zooplankton. While phytoplankton are the planktonic plants, zooplankton are the planktonic animals (Castro & Huber, 2005). The quality and quantity of plankton in an aquatic ecosystem determines the ecological status of the system which also influences the primary productivity of the system. These two factors combine to place the water body being considered as either biologically useful or not, especially when concerned with human use of the water for domestic or recreational purposes.

Recreational uses of inland waters and marine are on the increase in many countries including Nigeria. According to Uttah *et al.* (2008) such activities include total-immersion sports, such as swimming, surfing and slalom canoeing and non-contact sports, such as fishing, bird-watching and picnicking. Records have it that in America alone, about 80 million beachgoers spent $74 billion in out-door (non-pool) swimming (Cicin-Sain & Knect, 1999; WHO, 2001). It is basically required that water systems used for recreational activities be clean and healthy. Failure to meet this requirement could affect tourism and recreational use of such water systems (Uttah *et al.*, 2008; Cicin-Sain & Knect, 2001).

Studies on Nigerian water systems in relation to recreational activities using plankton and physico-chemical parameters are sparse. However, Uttah *et al.* (2008) reported on the bio-survey of Calabar river water quality for recreational activities using plankton. No report is so far available on urban streams such as the Esiere-Ebom stream, a major natural water source for the people living within the catchment area of the Calabar River, Nigeria. This paper is therefore designed to assess the quality of planktons inhabiting this very important urban stream which serves a general purpose for the people who use the stream water for bathing, washing and other domestic purposes.

## Materials and Methods

**Study area:** The study area is Calabar South Local Government Area. The study was conducted in Esiere-Ebom stream ($04^0$15'28"N, $008^0$10'45' E) (Plate 1). It is an urban stream in the catchment area of the Calabar River, Nigeria. It is about 155m from the shore of the Calabar River. Water samples for nutrients measurement in the laboratory were collected in 1L plastic containers. Quality control measures were strictly followed prior to samples collection and analysis. $NO_3$- and $SO_4^{2-}$ were analyzed using the Brucine colorimeter technique, while $PO_4^{2-}$ was measured using turbidimetric technique.

**Plate 1:** Typical scene of the use of Esiere-Ebom stream by the inhabitants of the area as observed during the period of study

## Results

### Physico-chemical parameters

DO range between 6.5 and 8.2mg/l, with a range of between 7.34 – 7.52 for pH, 0.22 – 1.40mg/l for BODs, 22.0 – $24.0^0$C for temperature, 0.36 – 0.40mg/l for $N0^-_3$, 1.36 – 2.47mg/l for $S04^{2-}$ and 0.014 – 0.022 mg/l for $P0_4^2$. All the physico-chemical parameters were observed to fall within the permissible limits of WHO, USEPA and FEPA for water systems meant for recreational activities (Table 1a)

Plankton community was observed to consist harmless species, and species group. Phytoplankton was dominated by Bacilllariophyleae (Diatoms) with the absence of harmful species such as *Oscillatoria, Melosira variance, Anabaena sproides, Egulena gracilis, Ceratium hirudinea* and *Phomidium* sp. Baccillariophyceae made up 40.18% being Cyanophyceae with only 0.45% (Table 1b).

Among the Zooplankton, the most abundant were the crustacean copepods with a total population of 57.69% with the least being the Oligochaeta which made up only 8.17% of the plankton population of the stream (Table 1c) in general, phytoplankton were more in abundance than Zooplankton (Table 1d).

**Table 1a:** Summary of the physico-chemical parameters of the surface water of Esiere-Ebom stream Calabar South, Cross River State, Nigeria, during the period of study for recreational activities

| Physico-chemical parameters | 2017 | | | 2018 | | | Permissible limits | | |
|---|---|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | March | WHO 2003 | USEPA | FEPA |
| DO (mg/l) | 8.2 | 7.4 | 6.5 | 6.5 | 6.5 | 6.5 | 5-15 | 5-15 | 5-15 |
| pH | 7.52 | 7.48 | 7.34 | 7.34 | 7.34 | 7.34 | 6.5-8.5 | 6.0-9.0 | 6-9 |
| $BOD_5$ (Mg/l) | 0.22 | 0.85 | 0.85 | 0.85 | 1.40 | 1.40 | 4.0 | 4.0 | 4.0 |
| Temperature (°C) | 22.0 | 23.0 | 24.0 | 24.0 | 24.0 | 24.0 | 25-27 | 25-27 | 25-31 |
| $NO_3$- | 0.40 | 0.38 | 0.36 | 0.38 | 0.38 | 0.38 | 0.2-10 | 0.2-10 | 0.2-10 |
| $SO_4^{2-}$ | 2.47 | 2.02 | 1.36 | 1.36 | 2.02 | 2.02 | 5-100 | 5-100 | 5-100 |
| $PO_4^{3-}$ | 0.022 | 0.022 | 0.018 | 0.018 | 0.014 | 0.014 | 0.005-0.2 | 0.005-0.2 | 0.005-0.2 |

**Table 1b:** Summary of the major phytoplankton in the surface water of Esiere-Ebom stream during the period of study.

| Major phytoplankton families | 2017 | | | 2018 | | | Marginal |
|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | March | |
| Bacillariophyceae | 29 | 33 | 16 | 32 | 28 | 40 | 178 (40.18)* |
| Xanthophyceae | 11 | 13 | 13 | 9 | 21 | - | 67(15.12)* |
| Chlorophyceae | 13 | 15 | 21 | 13 | 13 | 6 | 81(18.28)* |
| Euglenophyceae | 7 | 11 | 8 | 5 | 6 | 9 | 46(10.38)* |
| Cyanophyceae | - | - | 2 | - | - | - | 2(0.45)* |
| Chrysophyceae | 10 | 13 | 13 | 16 | 10 | 7 | (69(15.58)* |
| Total abundance (N) | 70 | 85 | 73 | 75 | 78 | 62 | 443 (~100.0)* |

* Numbers in parenthesis represent relative abundance (%)

**Table 1c:** Summary of the major zooplankton groups in the surface waters of Esiere-Ebom stream, Calabar South, Cross River State, during the period of study.

| Major zooplankton families | 2017 | | | 2018 | | | Marginal |
|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | March | |
| Crustacean copepods | 23 | 22 | 13 | 27 | 16 | 19 | 120(57.69)* |
| Protista | 11 | 4 | - | 9 | 5 | - | 29(13.94)* |
| Rotifera | 8 | - | 5 | 3 | 3 | 5 | 24(11.54)* |
| Oligachaete | 4 | - | 3 | 7 | - | 3 | 17(8.17)* |
| Protozoa | 6 | 8 | - | 2 | - | 2 | 18(8.65)* |
| Total abundance (N) | 52 | 34 | 21 | 48 | 24 | 29 | 208 (~100.0)* |

* Numbers in parenthesis represent relative abundance (%)

**Table 1d:** Summary of the numerical and relative abundance of the plankton community in the surface water of Esiere-Ebom stream, Calabar South, Cross River State, Nigeria, during the period of study.

| Period of study | Phytoplankton | | Zooplankton | |
|---|---|---|---|---|
| 2017 | n | %n | N | %n |
| October | 70 | 32.26 | 52 | 48.60 |
| November | 85 | 39.17 | 34 | 31.78 |
| December | 62 | 28.57 | 21 | 19.62 |
| Total abundance (N) | 217 | 100 | 107 | 100 |
| 2018 | n | %n | N | %n |
| Jan | 75 | 33.19 | 49 | 47.52 |
| Feb. | 78 | 34.51 | 24 | 23.76 |
| March | 73 | 32.30 | 29 | 28.71 |
| Total abundance (N) | 226 | 100 | 101 | 99.99 =100 |

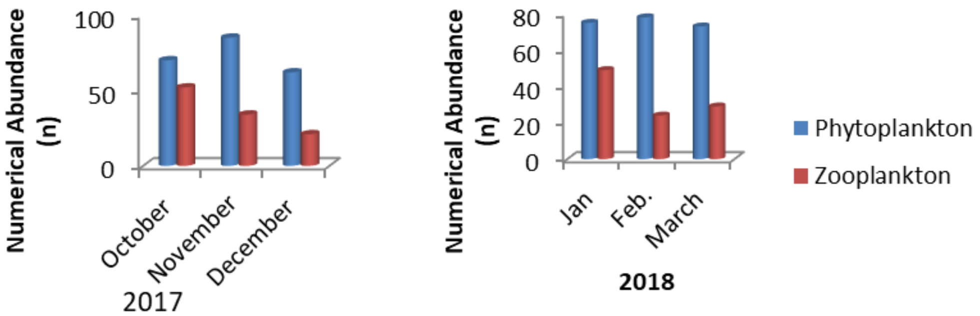


Fig. 1: Distribution of plankton in the surface of Esiere-Ebom stream, Cross River State, Nigeria.

**Discussion**

From the results of the investigation, it is clear that the Esiere-Ebom Stream is safe for recreational and other domestic uses. This is informed by the ranges of the respective physico-chemical parameters which were within the threshold values of WHO (2003), USEPA (1997) and FEPA (1991). The high abundance of the Bacillariophyceae in the surface waters is known to generally depict clean water especially when interplayed with the absence of indicator species such as *Osillatoria, Melosiria variance, Anabaena Spiroides, Egulena gracilis, Ceratium hiradinea* and *Phormidum* sp and the rareness of Protozoans and Oligocheata, among the zooplankton.

Protozoans and Oligochaetes are strong indicator zooplankton groups (Goldman & Horne, 1983: Castro & Huber, 2005), while among the phytoplankton especially those in the Cyanophyceae are known to be strong indicator family (Singh & Singh, 2000). The rare occurrence of members of the Cyanophyceae family among the phytoplankton also strongly indicates that Esiere-Ebom stream is not under the threat of ecological uncertainty of the water being safe for recreational and other domestic uses. Such, scenario has been previously reported in the Calabar river, Nigeria, by Uttah *et al.* (2008) and Singh & Singh (2000) in major water bodies of Imphal district, India.

**Conclusion**

The use of water systems especially those classified as natural for recreational and other domestic activities must meet the recommended standards for such uses. Streams are among the water systems used for recreational and/or other domestic activities and as such, must be devoid of indicator phytoplankters such as *Osillatoria, Melosiria variance, Anabaena Spiroides, Egulena gracilis, Ceratium hiradinea* and zooplankton groups such protozoans and oligochaetes, that are likely to affect the health of users negatively if present in the surface water. Esiere-Ebom stream in Calabar south, Cross River State, Nigeria, from the results of the present investigation is suitable for recreational purposes.

**References**

Cicin –Sain, B. and Kneacht, R. W. (2001). Coastal tourism and recreation: the driver of coastal development. Industry-driver changes and Policy Responses: *a summary of the paper in tourism and recreation prepared for the year of the Ocean 1998*.

FEPA (1991). *Federal Environmental Protection Agency, National Environmental Protection* (Effluent Limitation) Regulations, Cap 131, federal Republic of Nigeria.

Goldman, C. R. and Horne, A. J. (1983). *Limnology*. McGraw-Hill Publishing Company, New York, 464p.

Singh, S. S. and Singh, L. A. (2000). Studies on the physico-chemical characteristics (12 hours variations) of major water bodies of Imphal district, India. *Journal of Environmental Biology*, 21(3): 273 – 274.

USEPA (1997). Drinking water Microbiology Committee on Challenges of Modern Society. Nato/CCM drinking water Pilot Project Series, 238p

Uttah, E.C; Uttah, C.; Akpan, P. A.; Ikpeme, E. M.; Ogbache, J.; Usip, L. and Asor, J. (2008). Bio-Survey of Plankton as indicators of water quality for recreational activities in Calabar River, Nigeria. *Journal of Applied Science and Environmental Management,* 12(2): 35 – 42.

WHO (2001). Bathing water quality and Human Health. Faceal Pollution Outcome of an Expert Consultation, Farham, U.K. April, 2001, ppl 1-58.

WHO (2003). *The World Health Report:* Shaping the future. World Health Organization, 1211, Geneva Switzerland.

# ASSESSMENT OF THE QUALITY OF SOME BRANDS OF SACHET WATER PRODUCED IN ENUGU METROPOLIS, NIGERIA

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***Abstract***

*Safe drinking water is a basic need for good health. This study investigated the quality of some sachet water brands produced in Enugu metropolis for drinking purpose. Five different brands of sachet water were purchased and their physicochemical and bacteriological qualities were determined. The results obtained for physical parameters are as follows: turbidity, 0 NTU; total dissolved solids, 86.19 – 140.12 mg/L; total suspended solid, 0 mg/L; total solid 86.19 - 140.12 mg/L; electrical conductivity, 60.80 – 150.30 $\mu s/cm^3$; total hardness, 0 mg/L; pH, 6.90 – 7.00 and alkalinity 50 mg/L. The odds of the physical parameters conformed to the standards established by World health organization (WHO) and Nigeria standard for drinking water quality (NSDWQ). Again, all the chemical parameters tested conformed to the two standards used. Similarly, the results of bacteriological analysis suggested the absence of biological contamination. The total plate count, 0CFU/mL; total coli form, 0 CFU/mL and E. coli, 0 CFU/ml. The values of each parameter were found within the safe limit stipulated by WHO and NSDWQ. Thus, the examined sachet water brands were considered safe for consumption.*

**Keywords:** Sachet water, Quality, WHO Standard NSDWO, Enugu.

## Introduction

The quality of drinking water to human population is a typical global issue. Thus, the UN General Assembly at its 58th session declared the year 2005-2016 as an international decade for Action "water for life". This is to help reduce by half the population of people without access to sustainable improved drinking water. Water is one of the indispensable resources for continued existence of all living things including man. However, making potable water obtainable to the population is necessary to prevent health threats (Rahmanian *et al*., 2015). It has been revealed by the World Health Organization (2011) that 75% of all the diseases in developing countries are associated with drinking water that is polluted. Reda (2016) reported that, the problems associated with chemical components of water arise primarily from their ability to cause bad health effects after prolonged periods of exposure. Of particular concern are contaminants that have cumulative poisonous properties, such as heavy metals and substances that are carcinogenic. Drinking water contamination by different microorganisms such as coli forms (Kumpel *et al*., 2016), *Staphylococcus aureus and Pseudomonas species* (Igbeneghu and Lamikanra, 2014) have been reported in Nigeria. Also, the presence of metals like iron, calcium, chromium and aluminum have been found in surface water (Titilawo*et al.*, 2018) and sachet-packed water (Emenike *et al.*, 2018). Similarly, cadmium, lead, manganese and nickel can be found in groundwater (Ayedun*et al.*, 2015) above permissible levels for drinking. Other contaminants such as fluoride (Emenike *et al*., 2018) and light polycyclic aromatic hydrocarbons have also been reported to be present in groundwater in levels above permissible limits in some locations in Nigeria (Adekunle *et al*., 2017). One of the major sources of potable water in Enugu city is the use of boreholes, whereby the water is usually carried by commercial tankers and supplied into individual owned overhead tanks within the metropolis. Majority of which are located at Ninth mile, a locality within Enugu metropolis where most natural sources of water are found (United Nations Millennium Development Goal, 2011). Adequate supply of fresh and clean drinking water is a basic need for all human beings (Edema *et al.*, 2011).Drinking water that is fit for human consumption is expected to meet the world health organization and be free from physical and chemical substances and microorganisms in an amount that is not hazardous to health.

Sachet water is any commercially treated water, manufactured, packaged and distributed for sale in sealed food grade containers and is intended for human consumption. The production of sachet water in Nigeria started in the 90s and today the advancement in scientific technology has made sachet water production one of the fastest growing industries in the country. Water consumers are frequently unaware of the potential health risk associated with exposure to water borne contaminants which have often led to disease like diarrhea, cholera, dysentery, typhoid fever, legionnaire's disease and parasitic disease. Continuous increase in the sales and indiscriminate consumption of packaged drinking water in Nigeria is of public health significance, as the prevalence of water related disease in developing countries are determined by the quality of their drinking water (Ezeugwunne *et al.*, 2009).

Enugu is a fast growing and population expanding city in Nigeria whose demands for potable water is becoming critical for water purification industries to meet up with supply. This is one of the reasons why consumption of sachet water in Enugu is on the increase irrespective of whether they have NAFDAC certification or not. High demand for potable water may warrant rapid supply and hence jeopardize the quality of water supplied to the consumers, Nonetheless, several studies on quality of drinking water in different parts of Nigeria revealed high contamination in the various samples of drinking water (Alli *et al.*, 2011). Study by Oyedeji *et al*. (2010 Therefore, the purpose of this study is to investigate the level of physical, chemical and biological contaminations in five selected sachet water manufactured, sold and consumed in Enugu metropolis and nearby environs, because some sachet water in our markets could serve as possible routes of transmission of protozoan parasites (Alli *et al*., 2011).

**Study Area**

Enugu urban lies approximately between latitude 6$^{o}$ 21' N and 6$^{o}$ 30'N and between longitude 7$^{o}$ 26' E and 7$^{o}$ 37'E. The total area coverage is approximately 72.8 square kilometers. Enugu urban comprises of three council areas namely; Enugu North, Enugu East and Enugu South Local Government Areas. It is bounded in the east by Nkanu East LGA, in the West by Udi LGA, in the North by Igbo-Etiti and Isiuzo and in the south by Nkanu West LGA. The predominant soil type is gravely-silt. It is mostly reddish in colour and has a high density bearing capacity for intense building construction. Like those of the rest of southern Nigeria, the soil ranks amongst the poorest Nigerian soils because of its low natural fertility.

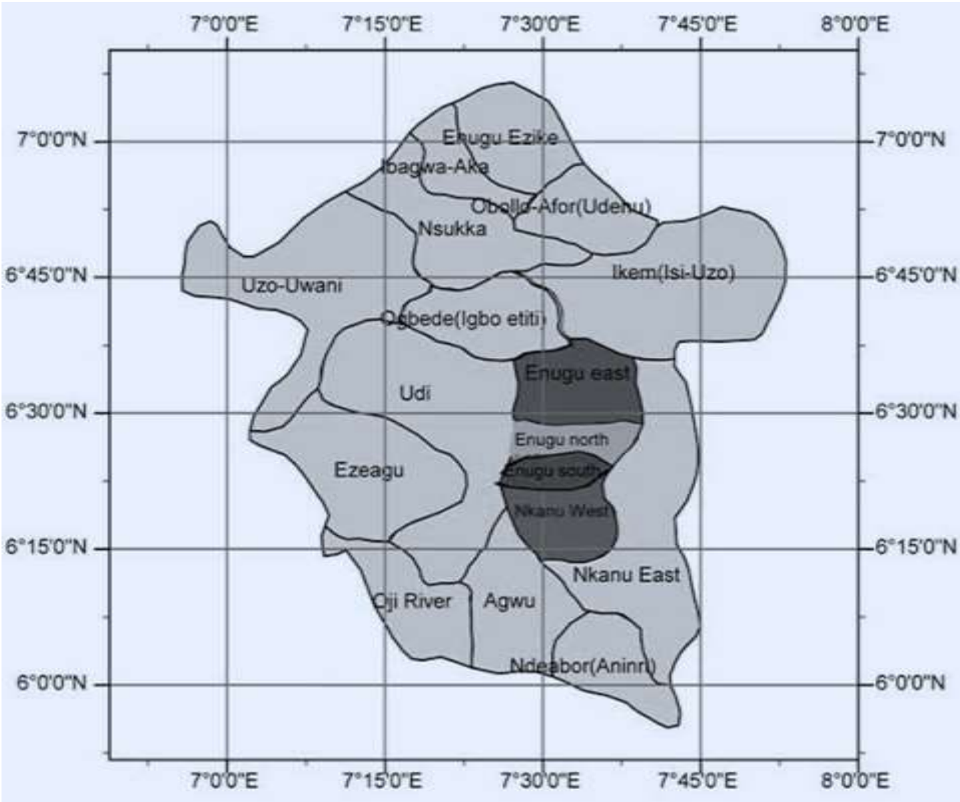


**Fig. 1:** Map of Enugu State *(Source: The National Mirror. 2012)*

## Method of Study

### Materials Used for the Study

Aqua Rapha Sachet water (Sample A) produced by Aqua Rapha Investment Nigeria limited situated opposite Nigeria Brewery Plc. Ngwo, Enugu State with NAFDAC Reg. No. 01-0298L

- Parks Sachet water (Sample B) produced by Parks Ventures at No. 5A Idaw River Avenue, One Day Road, off Agbani Road, Enugu State with NAFDAC Reg No. 01-0298L.
- Baura Sachet water (Sample C) produced by Vaipre Nigeria Ltd at plot no. 866 Premier Layout, OguiNike, Enugu North L.G.A., En ugu State with NAF DAC REG No C1-7375L.
- Andex Sachet water (Sample D) produced by Beejay and Kate Nanny Hollywood Company Nigeria, NAFDAC Reg. NO. 01-1505L at no. 12 Nwamba Street Achara layout Enugu.
- Jinno sachet water (Sample E) produced by Jinno ventures near St. Mary's hospital Abakpa Nike, Enugu.
- Conductivity Mete, Atomic Adsorption Spectrophotometer (AAS),(Ph) meter, Turbidity Meter, Measuring Cylinder, Conical Flask, Volumetric Flask, Burrette, Beaker, Stringe, Filter paper, Funnel, Oven were all used.

### Water Sampling Techniques

### Laboratory Analysis of the water samples

Collected samples were taken to the water quality laboratory Enugu State Water Co-operation, Quality Control Unit 3 at Constitution Road GRA Enugu, Enugu State for analysis of both physic chemical and bacteriological parameters considered included: Temperature, pH (Potential Hydrogen), Electrical Conductivity (EC), Turbidity, Alkalinity, Total Hardness, Copper (Cu), Lead, Chloride, Iron, Sulphate, magnesium and Calcium, phosphorus, Zinc, total dissolved solid (TDS), Suspended Solid and Total Solid were determined.

**Bacteriological analysis**

Plate or colony count, total coli form, E coli were determined.

## Results and Discussion

### Physical characteristics of the sachet water brands studied

Table 1 presents the results obtained for some physical tests conducted on the selected sachet water in Enugu metropolis for the study.

**Table 1:** Result of the physical analysis for the sachet water samples

| Test / Unit | Sample A | Sample B | Sample C | Sample D | Sample E | WHO Std. | NSDWQ Std. | Remark |
|---|---|---|---|---|---|---|---|---|
| Turbidity (NTU) | Nil | Nil | Nil | Nil | Nil | 5.00 | 5.00 | Not turbid |
| Total solid (mg/L) | 86.19 | 109.49 | 115.34 | 133.01 | 140.12 | 1000 | 1000 | Normal |
| T.D.S (mg/L) | 86.19 | 109.49 | 115.34 | 133.01 | 140.12 | 500 | 500 | Normal |
| EC (µs/cm$^{3)}$ | 97.10 | 60.80 | 146.2 | 132.40 | 150.30 | 400 | 400 | Normal |
| Total hardness (mg/L) | Nil | Nil | Nil | Nil | Nil | 100- 200 | 200 | Not hard |
| T.S.S (mg/L) | 00 | 00 | 00 | 00 | 00 | 500 | 500 | Normal |
| pH | 7.00 | 7.00 | 7.00 | 6.90 | 7.00 | 6.5– 8.5 | 6.5– 8.5 | Adequate |
| Alkalinity (mg/L) | 50 | 50 | 50 | 50 | 50 | 100 | 100 | Adequate |
| Temperature (ºC) | 26.70 | 26.80 | 26.70 | 26.90 | 27.00 | 28 | Ambient | Normal |

The results obtained revealed that all the physical parameters were found to be within the acceptable range stipulated by the two standards (WHO, 2008 and NSDWQ, 2007) adopted for the study. The pH of all the tested water samples was found between 6.90 and 7.00; these are within the range (6.5-8.5) stipulated by the two standards used. Turbidity, total suspended solid and total hardness were nil for the water samples investigated; while EC and alkalinity were found within acceptable range stipulated by the standards adopted for the study. Total dissolved solid ranging between 86.19 & 140.12mg/L) water samples. This suggests that the examined water samples were not highly mineralized. Yirdaw and Bamlaku (2016) study, "Drinking water quality assessment and its effect on residents' health in Wondo Genet Campus, Ethiopia'' because the TDS obtained for the samples were found between 86.19 and 140.12 mg/L.

**Table 2:** Results of the chemical analysis of the studied sachet water samples

| Test/ Unit | Sample A | Sample B | Sample C | Sample D | Sample E | WHO Std. | NSDWQ Std. | Remark |
|---|---|---|---|---|---|---|---|---|
| Cu (mg/L) | 0.00 | 0.246 | 0.755 | 0.00 | 0.423 | 1.3 | 1.3 | Normal |
| Fe (mg/L) | 0.017 | 0.026 | 0.034 | 0.043 | 0.024 | 0.3 | 0.3 | Normal |
| Lead (mg/L) | 0.00024 | 0.00015 | 0.00033 | 0.00064 | 0.00052 | 0.01 | 0.01 | Insignificant |
| Chloride (mg/L) | 35.50 | 56.80 | 71.00 | 73.20 | 75.00 | 250 | 250 | Normal |
| Sulphate (mg/L) | 38.51 | 39.80 | 31.41 | 40.50 | 45.00 | 250 | 100 | Adequate |
| Calcium (mg/L) | 12.11 | 12.11 | 12.11 | 19.20 | 20.00 | 75 | 100-200 | Adequate |
| Magnesium (mg/L) | 12.11 | 12.11 | 12.11 | 19.20 | 20.00 | 50 | 100-200 | Adequate |
| Phosphorus (mg/L) | 0.056 | 0.051 | 0.077 | 0.065 | 0.081 | Not >5 | - | Normal |
| Zinc (mg/L) | Nil | Nil | Ni | Nil | Nil | 3 | 3 | Not found |

The result obtained show that the concentration of cu for all brands of sachet water were between 0.00 mg/L and 0.755 mg/L Lead (Pb) concentration was between the ranges of 0.00015 mg/L and 0.00064 mg/L. Parks sachet water has the lowest concentration of Pb while Andex has the highest concentration of Pb of all the five sachet waters used for the study. However, the limits were within the stipulated standards by WHO and NSDWQ as shown in Table 2.Chloride is between 31.41 mg/L and 45.00 mg/L which were found within the safe allowable limit. Ca concentration ranged from 12.11mg/L and 20.00mg/L. Magnesium gave a similar result for the under studied sachet waters. Permissible limit for Mg in drinking water is 50 mg/L and the study's results were within the established standards by the two bodies. Phosphorus contents of the water samples were between 0.051mg/L and 0.081 mg/L. These were within the limits established by WHO (2011) as shown in Table 2. The five sachet waters used for the study showed zero concentration of zinc. Nevertheless, all the chemical parameters tested for the study were found within the safe allowable limit for drinking water purpose.

**Table 3:** The results of the Bacteriological Contaminants

| **Test** | Sample A | Sample B | Sample C | Sample D | Sample E | WHO Std | NSDW Std | Remark |
|---|---|---|---|---|---|---|---|---|
| Total Plate count (CFU/mL) | 00 | 00 | 00 | 00 | 00 | 100.00 | 100.00 | Adequate |
| Total coli form(CFU/mL) | 00 | 00 | 00 | 00 | 00 | 3.00 | 10.00 | Adequate |
| E.coli (CFU/mL) | 00 | 00 | 00 | 00 | 00 | 00 per 100ml | 00 per 100ml | Adequate |

The study revealed that the total plate count for the samples were zero, Total coli form and E. coli were also not found in the water samples used for the study. It therefore indicates that the water samples contained no pathogens.

## Conclusion

On the basis of findings, the study established that all the physico–chemical parameters tested in the selected sachet water brands produced in Enugu metropolis were found consistent within the World Health Organization standard for drinking water (WHO,2007 and 2011) and Nigeria Standard for Drinking Water Quality (NSDWQ, 2007). It is also evident that all the values of lead (Pb), Iron (Fe), phosphorus(P), zinc (Zn), calcium (Ca), magnesium (Mg), chloride (Cl) and sulphate ($SO_4$) fall below the permissible limit. The implication is that there is no risk of toxicity. Besides, or moreso, the water samples of all the brands of water examined did not show extreme variations in the concentrations of cations and anions. Similarly, the results of bacteriological analysis indicating that there were no fecal coli form, E coli and pathogens imply that the different brands of sachet water assessed are considered safe for drinking. Nonetheless, it is important to investigate other sources of contamination like radiological contaminants (Rahmanian *et al.*, 2015) and also examined other brands of sachet water consumed in the city. Indeed, assessment / monitoring of the quality of all the vended pure water in Enugu metropolis from time to time will help in quality control for improved livelihood in the city.

## Reference

Adekunle, A.S., Oyekunle, J.A.O., Ojo, O.S., Maxakato, N.W., Olutona, G.O., and Obisesan, O.R. (2017), Determination of Polycyclic Aromatic Hydrocarbon Levels of Groundwater in Ife North Local Government Area of Osun State, Nigeria. *Toxicology Report*, 4: 39-48.

Alli, J.A., Okonko, I.O., Alabi, O.A., Odu, N.N., Kolade, A.F., Nwanze, J.C., and Onoh, C., M. C. (2011). Parasitological evaluation of some vended sachet water in Southwestern Nigeria. *New York Science journal*, 4(10), 84–92.http://www.sciencepub.net/newyork

Ayedun, H., Gbadebo, A.M., Idowu, O.A., and Arowolo, T.A. (2015), Toxic elements in groundwater of Lagos and Ogun States, Southwest, Nigeria and their human health risk assessment. *Environmental Monitoring and Assessment*, 187: 351-367.

Edema, M.O., Atayese, A.O., and Bankole M.O., (2011). Pure water syndrome: Bacteriological Quality of Sachet Packed Drinking water sold in Nigeria *African Journal of Food, Agriculture, Nutrition and Development.* 11(1): 4595-94609

Emenike, C.P., Tenebe, I.T., and Jarvis, P. (2018), Fluoride contamination in groundwater sources in Southwestern Nigeria: Assessment using multivariate statistical approach and human health risk. *Ecotoxicology and Environmental Safety*, 156: 391–402.

Ezeugwunne, .I.P., Agbakoba, N.R., Nnamah NK, and Anhalu, I.C. (2009). The Prevalence of Bacteria in Packaged Sachet Water Sold in Nnewi South East Nigeria Would J. Diary, Food Sci. 4(10): 19-21. Http//: www.grinningplanet.com/pollution .html.

Igbeneghu, O.A. and Lamikanra, A. 2014, The bacteriological quality of different brands of bottled water available to consumers in IleIfe, south-western Nigeria. BMC Research Notes, 7: 859.

Kumpel, E., Albert, J., Peletz, R., de Waal, D., Hirn, M., Danilenko, A., Uhl, V., Daw, A., and Khush, R. (2016). Urban Water Services in Fragile States: An Analysis of Drinking Water

Sources and Quality in Port Harcourt, Nigeria, and Monrovia, Liberia. *The American Journal of Tropical Medicine and Hygiene,* 95(1): 229–238.

Nigerian Standard for Drinking Water Quality (NSDWQ), (2007). Parameters and Maximum allowable limits, Nigerian Industrial Standards, 15 – 17

Oyedeji, O., Olutiola P.O. and Moninuola MA. (2010), Microbiological quality of packaged drinking water brands marketed in Ibadan metropolis and Ile-Ife city in South Western Nigeria. *African Journal 0f Microbiology Research*, 4(1): 096-102

Rahmanian, N., Ali, S. H. B., Homayoonfard, M., Ali, N. J., Rehan, M., Sadef, Y., and Nizami, A. S. (2015). Analysis of physiochemical parameters to evaluate the drinking water quality in the state of Perak, *Malaysia. Journal of Chemistry*.

Reda, A. H. (2016). Physico-chemical characterization of tannery effluent and its impact on the nearby river. *Journal of Environmental Chemistry and Ecotoxicology*, *8*(6), 44-50.

Standard Organization of Nigeria (SON 2007), Nigeria Standard for Drinking Water Quality.

Titilawo, Y., Adeniji, A., Adeniyi, M., Okoh, A. (2018), Determination of levels of some metal contaminants in the freshwater environments of Osun State, Southwest Nigeria: A risk assessment approach to predict health threat. *Chemosphere*, 211: 834-843.

United Nations Millennium Development Goal (2011), Assessing progress in African towards the Millennium Development Goals Report. New York.

World Health Organization (WHO). (2011), Guidelines for Drinking-water Quality. WHO Press, Geneva, Switzerland' 4th edition.

# ACCESS TO POTABLE WATER SUPPLY IN IKOT EKPENE LOCAL GOVERNMENT AREA, AKWA IBOM STATE, NIGERIA

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**Abstract**

*This research work assessed the distribution of boreholes in Ikot Ekpene, Akwa Ibom State, Nigeria. The study was carried out to map the distribution of government boreholes and examine the relationship between number of government boreholes and population in Ikot Ekpene. Primary data for this study were obtained through the use of geographical positioning system, mainly the coordinates of government boreholes located in the study area. Secondary source of data were obtained from the National population commission, census data of 1991 and projected to 2020. Data were analyzed using the Spearman's ranked-order correlation coefficient analysis. The result revealed that government boreholes were not randomly distributed but clustered. The result revealed that correlation coefficient between location of government boreholes and population was not significant (t-tab = 2.26 > t-cal = 0.308). The researchers concluded that there is no significant relationship between the number of government boreholes and the population in the study area. It was recommended that statutory government organs should interface with stakeholders that are involved in rural water supply programmes to ensure the availability of potable water to the people.*

**Keywords:** Spatial, distribution, population, potable water, and boreholes

## Introduction

Water is essential for all forms of life and access to safe water is imperative for human existence. In spite of its importance, there is a global paucity of safe water (World Health Organization and United Nations International Children Educational Fund, 2004). Nigeria has adequate surface and ground water resources to meet current demands for potable water though the spatial distribution of water has led to scarcity in some locations within the country. Moreover, rapid population growth has not been accompanied by an increase in the delivery of essential urban services such as water supply. Many households in the urban centers, often the poorest, end up purchasing water from private vendors which are much more expensive than from the public supply.

Water supplies must be physically accessible, sufficient in quantity, safe in terms of quality, available when needed, acceptable from the sensory properties' standpoint, and affordable for everyone. This has been implemented in many industrialized countries, but yet to be achieved in many undeveloped worlds especially the rural areas. About one-tenth of world population of 700 million people remain without access to improved drinking water, while 2.5 billion lack basic sanitation with nearly half living in sub-Saharan Africa and one-fifth in Southern Asia (WHO/UNICEF 2015). Access to water of sufficient quantity and acceptable quality remains one of the major problems for many households in most cities of developing countries especially in low income areas (Acey 2008; Sansom & Bos 2008). The Sustainable Development Goal (SDG) target for water by 2030 is to achieve universal and equitable access to safe and affordable drinking water.

However, due to high demand on and perhaps poor-quality service delivery by the public water providers, the private sector is playing a visible complimentary role in the provision of water facilities such as boreholes in Ikot Ekpene as seen from the field survey. While the private sector is driven primarily by economic considerations in their location decisions, the public sector is apparently concerned with maximizing access of the target population to the facilities. Although a lot of money is budget for water service delivery each year in the State, inadequacy of fund and excessive administrative and bureaucratic bottleneck have meant that aggregate demand for water services has always outstripped the supply. But apart from quantitative and qualitative shortage in the provision of water services in study area, the few available facilities are not efficiently distributed within the population it is meant to serve with the effect that some segments of the population are deprived of access to this important public service in the area. The spatial distribution of boreholes in Ikot Ekpene is not documented in literature, hence, it is not clear whether it is efficiently distributed over the population or not.

Current public water supply efforts of government are concentrated in the urban areas (Udom, 2008). Urban population having access to public water service in southeast Nigeria including Ikot Ekpene the study area according to Akpabio and Ekanem (2009) is 1.4 per cent as at 2006. The story for the rural communities is worse as current statistics also show that over 90 per cent of the state rural water projects suffer various degrees of difficulties example abandonment, disuse, not functional, unsuccessful or uncompleted. The very few available ones are mostly and extremely irregular in services. Consequently, there is a very deep gap between water needs and water supplies in the study area be it in terms of quality public investment and other factors. While some works have been reported on the spatial distribution of public amenities especially health facilities using Geographical Information System in the Ikot Ekpene, including Njokwu and Akpan (2013), there is lack of literature however on the spatial distribution of water facilities in the study area. Moreover, access to water facilities in Ikot Ekpene has not been documented yet, long queues are often observed at water facilities in the study area, standing long hours to obtain this resource for their household needs. In view of this, the study examined access to potable water supply in Ikot Ekpene of Akwa Ibom State, Nigeria.

## Research Methodology

### Study Area

Ikot Ekpene is located within latitudes 5° 10` and 5° 30` North of the Equator and longitudes 7° 30` and 7° 45` East of the Greenwich Meridian (FIG. 1). It lies on the north-western flank of Akwa Ibom State. Its position makes it one of the economic gateways to Akwa Ibom State. Ikot Ekpene is historic in local government administration in Nigeria, as it became a premier model local government administration in 1951. It has a boundary with Essien Udim, Obot Akara and Ikono local government areas. Today, Ikot Ekpene is the headquarters of Ikot Ekpene Senatorial District that has 10 Local Government Areas. The climate of the study area is characterized by two seasons, namely, the wet season and the dry season. The effect of excess rainfall over evaporation is the availability of water for groundwater recharge and surface water flow. The dry season begins in mid-November and ends in March. During this brief period, the whole continental tropical air mass and its accompanying north-easterly winds together with their associated dry and dusty harmattan haze engulf the study area (Udo, 1970).

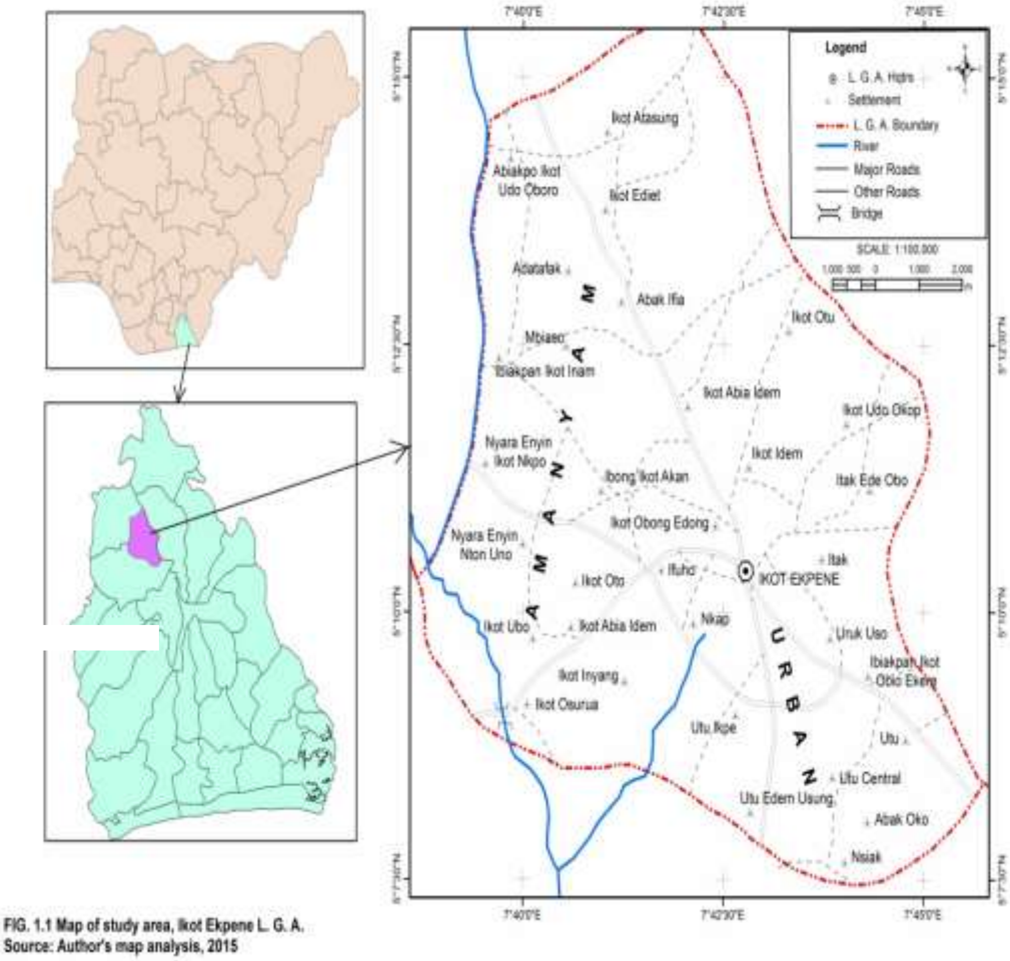


**Fig. 1:** Map of Ikot Ekpene Local Government Area

**Source**: Office of the Surveyor General, Uyo, Akwa Ibom State.

## Procedure for Data Collection

The survey design was adopted for the study, which is the direct field observation. Data used for the study were collected on discrete and cyclic scales. Cyclic data were on the spatial distribution of the boreholes. Discrete type of data was those on the population of the study area. Data were collected from both primary and secondary sources. Primary sources were those on borehole locations. Secondary source of data was the National Population Commission. Data on the locations of boreholes was obtained through the use of geographical positioning system (GPS). On the other hand, population data on population of the area was retrieved from National Population Commission archives, Uyo for 1991 census figure of different wards in Ikot Ekpene and projected to 2020 given a population growth rate of 3.5 percent per annum (National population commission, 1991). Field visitation was conducted with handheld Garmin GPSMAP 76c receiver to pick the coordinates of the existing government borehole locations within the study area. This was guided with the document gotten from Ministry of Rural Development, Akwa Ibom State to locate and identify the ward where government borehole is located and functioning. The study adopted a stratified sampling technique. Hence, the study area was stratified into 11 based on the political wards where the coordinates of the location of government boreholes were obtained, which was also used to produce the map. The spearman's rank correlation formula was used to analysed the data.

## Results and Discussion

### Relationship between number of government boreholes and population in Ikot Ekpene

The mapping of the government borehole's location was carried out in different villages/wards of Ikot Ekpene as shown in FIG. 1. A total of twenty-four (24) government boreholes were identified within the study area with twenty-two (22) boreholes being functional two (2) not functional as seen in Appendix A. The functionality was determined only when is still providing the people's need. The population of one hundred and eighty-three thousand six hundred and fifty (183,650) was gotten from the different wards in the study area projected by the researcher. From the research field work report shown in table 1, it indicates that Ikot Ekpene had twenty-two (22) government boreholes that are functioning in the study area and which some of these government boreholes are located in schools, government estates and is only few is located for the community with the population of 183,650. The few boreholes located for the community were concentrated in a particular area not circulating to the entire area as seen in wards 5 and 8 no government borehole in the two wards but having more in ward 1 with less population. The distribution is not random. Therefore, it could be said that there is a clustered pattern in the distribution of boreholes in Ikot Ekpene Local Government Area. That is, some areas have more boreholes, while other areas are underserved.

The percentages of the population and the number of government boreholes in each ward were used in calculating the Spearman's ranked-order correlation as seen in Table 2.

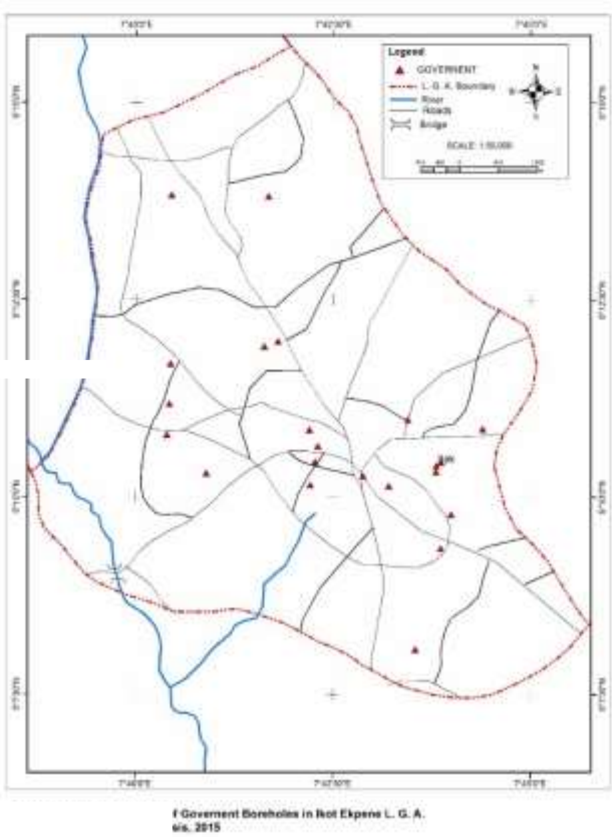


**Fig. 2**: Map of distribution of government boreholes in Ikot Ekpene L.G.A

Source: Authors' map analysis, 2020

**Table 1:** Population and number of government boreholes in Ikot Ekpene

| Ward | Population (2020) | Percentage | No. of boreholes | Percentage |
|---|---|---|---|---|
| 1 | 20,721 | 11.3 | 6 | 27.3 |
| 2 | 57,933 | 31.5 | 1 | 4.5 |
| 3 | 24.179 | 13.2 | 2 | 9.1 |
| 4 | 12,076 | 6.6 | 1 | 4.5 |
| 5 | 19,835 | 10.8 | 0 | 0 |
| 6 | 6,269 | 3.4 | 1 | 4.5 |
| 7 | 12,320 | 6.7 | 3 | 13.6 |
| 8 | 6,641 | 3.6 | 0 | 0 |
| 9 | 6,845 | 3.7 | 3 | 13.6 |
| 10 | 5,898 | 3.2 | 2 | 9.1 |
| 11 | 10,933 | 6.0 | 3 | 13.6 |
| Total | 183,650 | 100 | 22 | 100 |

**Source:** *NPC 1991 and **Authors' fieldwork 2020

**Table 2:** Result of Spearman's ranked-order correlation analysis for government borehole

| Category of boreholes | $r^2$ | t-cal | t –tab | Remarks at 0.05 level |
|---|---|---|---|---|
| Government | 0.102 | 0.308 | 2.26 | Not significant |

Authors' fieldwork 2020

The result of the Spearman's ranked-order correlation analysis for government borehole was slightly lower than the obtained value. With $r^2$ of 0.102, the calculated Students' 't' value is 0.308 while the critical test value at 0.05 is 2.26. Since 2.26 > 0.308, it reveals that there is no relationship between the number of government boreholes and population in the study area. So, the correlation coefficient is not significance, this means that the population of the area does not rely on government boreholes for their needs. In the aspect of distribution of boreholes in Ikot Ekpene, the study has shown that some areas have more boreholes, while other areas are underserved. This was contrary to the findings of Fakayode, Omotesho, Tsoho and Ajayi, (2008) which states that boreholes facilities are not evenly spread over space because certain environmental factors, operation of economic, cultural and political processes often produced areas of concentration and specialization and the spatial disparities in the level of development are the results of uneven distribution of boreholes. From the above findings, the access to potable water supply in Ikot Ekpene in terms of number of boreholes has to involved government in locating borehole where the services are needed, also proper management and maintenance should be taken into consideration. However, Ikpongifonoh (2012) noted that as a result of the sparse distribution in population of most rural environment, the provision of borehole facilities, its operation and maintenance has eluded the hopes and aspirations created in the minds of rural folks as a result of the over concentration of water facilities in the urban areas. Problems of water accessibility is also compounded by the increasing human population in the urban part of the study area who rely on the available commercial boreholes as a result of the fact that the state water agency capacities do not meet the water needs of the people and this is grossly inadequate in terms of funding, manpower and technical capabilities.

## Conclusion

The results revealed that government boreholes were not randomly distributed; there is a clustered pattern in the distribution of boreholes in the study area. It was also observed that there is no significant relationship between the number of government boreholes and the population in the study area. In relation to the observed problems and findings from the study, the following recommendations have been put forward to bring about an efficient water distribution in the study area.There is need for the statutory government organs to interface with stakeholders involved in rural water supply programmes to maintain a robust database. Steps should be taken to reduce the widening gap between water points away from immediate confines. Also, planners must ensure an efficient distribution system that will incorporate a mechanism for monitoring water supply and demand, flexible enough for periodic adjustment in quantity to end users.

## References

Acey, C. (2008). Neighbourhood effects and household responses to water supply problems in Nigerian cities. *J Transdiscipl Res South Afr*, 4(1):123–156.

Akpabio E. M. & Ekanem, E. M. (2009). Water uncertainties in Southeastern Nigeria: Why approach to defining health professional shortage areas: *Areas of Developing Countries: The Nigerian Case. Journal Socio-Economic Planning Science, Health and Place,* 11(2) 131–146.

Fakayode, B. S., Omotesho, O. A., Tsoho, A. B. & Ajayi, P. D. (2008). An economic survey of rural infrastructures and agricultural productivity profile in Nigeria. *European Journal of social science.* 7(2):158-171

Ikpongifonoh, C. O. (2012). An Analysis of the Accessibility of Public Facilities in Nigeria. *Socio-economic Planning Sciences,* p.61 – 69.

National population commission (NPC) (1991), National census data for Nigeria. http://www.qtsnigeria.com/.

Njoku, E. A. & Akpan, P. E. (2013). Locational Efficiency of Healthcare Facilities in Ikot Ekpene Local Government Area, Akwa Ibom State. The role of Geographical Information System (GIS), Journal of Educational and Social Research, Vol 3 p 93-98.

Sansom, K. & Bos, A. (2008). Utility and non-state water service provision for the urban poor. *Int J Water*, 4(3/4):290–303.

Udo, R. K. (1970). Geographical Region of Nigeria. Heinemann Educational Books Ltd. Pp. 66 - 75, ISBN 0 435 95916 6.

Udom, E. (2008). Evaluation of Accessibility to Potable Water in Akwa Ibom State. Preliminary Dissertation Fieldwork Result. Department of Geography & Regional Planning, University of Uyo. Nigeria.

United Nations International Children Educational Fund (2004). Global Assessment of water supply and sanitation Report 2000. Geneva: WHO and UNICEF.

World Health Organization (2004). Cost and benefits of water and sanitation improvements. Online,Available:http://www.who.int/watersanitationhealth/wsh0404summary/en/index.html Accessed June. 2015.

WHO, UNICEF (2015) Progress on sanitation and drinking water 2015 update and MDG assessment. World Health Organisation, Geneva.

## Appendix A

The coordinates of the locations of government boreholes in the study area

| Easting | Northing | Description | Remarks | Wards / Village |
|---|---|---|---|---|
| 358153,91 | 571484,752 | Government | Functional | Ward I Ikot Ekpene |
| 356302,849 | 572802,908 | Government | Not Functional | Ward I Ikot Ekpene |
| 356496,059 | 572418,633 | Government | Functional | Ward I Ikot Ekpene |
| 359263,124 | 571817,268 | Government | Functional | Ward I Ikot Ekpene |
| 359371,34 | 572038,164 | Government | Functional | Ward I Ikot Ekpene |
| 359269,552 | 571952,379 | Government | Functional | Ward I Ikot Ekpene |
| 356430,649 | 572053,313 | Government | Functional | Ward I Ikot Ekpene |
| 356318,692 | 571513,038 | Government | Functional | Ward I Ikot Ekpene |
| 357550,826 | 571713,224 | Government | Functional | Ward I Ikot Ekpene |
| 358938,327 | 567994,508 | Government | Functional | Utu Edem Usung |
| 359612,167 | 570815,423 | Government | Functional | Ibiakpan Ikot Akpan |
| 358628,858 | 576434,279 | Government | Not Functional | Ward III Itak Ikot Okopo |
| 360653,745 | 572760,369 | Government | Functional | Itak Ede Obo |
| 358621,425 | 572749,071 | Government | Functional | Abiakpo Ikot Essien |
| 357734 | 575490,218 | Government | Functional | Ward VI Ikot Idem |
| 355317,859 | 575971,186 | Government | Functional | Ikot Enwang |
| 356136,901 | 574467,754 | Government | Functional | Ikot Abia Idem |
| 356318,063 | 574218,628 | Government | Functional | Ikot Abia Idem |
| 353263,73 | 572870,607 | Government | Functional | Ikot Akpan Abia |
| 352856,738 | 574090,677 | Government | Functional | Nyara Enyin Nton Uno |
| 353839,412 | 574279,029 | Government | Functional | Amanyam |
| 353675,167 | 575252,902 | Government | Functional | Mbiaso |
| 353407,972 | 579976,781 | Government | Functional | Abiakpo Ikot Ntuen |
| 360773,167 | 569302,195 | Government | Functional | Abak Oko |

**POPULATION GROWTH, WATER DEMAND AND SUPPLY AMONG BENUE STATE UNIVERSITY STUDENTS**

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***Abstract***

*The study examines the students' perception on water demand, supply, challenges and the way forward among the students who reside in hostels in Benue State University, Makurdi. The study used 220 copies of questionnaire to obtain information from students in 11 hostel blocks. The respondents were selected through snow ball sampling technique. The study found out that water demand is high irrespective of gender; though higher among the females than male students. The mean water demand per student is 29.67 litres per day while the mean water access per student per day is 23.89 litres. There is a mean water deficit of 5.78 litres per student per day (19.47% of the total water demanded). About 42.7% of the students have access to only 20 litres below per day. The female mean access to water (24.48 litres) is higher than the male (22.86 litres). Students in five (5) hostels have low access to water supply. The study also reveals that pipe-born water, borehole and vendors are the major sources of water on campus. Water from these sources is not adequate. The major challenge in accessing water on campus are failure to pump water to students' bathrooms and toilets, occasional failure to process water for students' use, long distances to sources of water and sometimes, relatively poor water quality. Suggestions for solving water problems include; expanding the capacity of the water work, powering water sources with solar energy, improving the quality of water supply, provide more boreholes on campus and pump water right into the students' bathrooms and toilets in the hostels. This paper recommends that Benue State government and university management should embark on gigantic modern water processing facility or upgrade of the existing one to cater for the water needs of the students. This will impact positively on the students' health and educational pursuit as well as the host community.*

**Keywords**: Population, Water, Demand, Supply, Access, Students

## Introduction

Water is the vehicle of life. It is a basic necessity of life for both plants and animals. Man cannot survive without water (Obeta and Chukwu, 2003 and Aremu et al., 2011). Irrespective of man's socio-economic background, water is necessary for all mankind. Hence the continuous desire for water by men in all societies and across all civilization.

According to Ojo (2011), "access to safe water supply has been one of the recurring issues on the development agenda of many developing countries over the past three to four decades". Despite this, unfortunately water is not equitably distributed and many of the world population lack access to an improved water supply. Consequently, it has hindered productivity in human endeavours (WHO and UNICEF, 2000).

In Benue State and Nigeria, the water supply situation is worrisome because as at 2018, only 72% Benue population have access to basic drinking water services and only 66% of the households in

Nigeria have access to improved sources of drinking water. More so, only 74% of the urban households and 58% of the rural households have access to improved sources of drinking water (NPC and ICF, 2019). Water situation is compounded in most communities in Nigeria because the most secure source of safe drinking water is pipe-borne water from the municipal water treatment plants which do not often deliver or failed to meet water requirement of the serving communities due to corruption, lack of maintenance, poor maintenance, population pressure and logistic problems (Ocheri, 2010 and Orebiyi et al., 2010).

Population is not static. It keeps growing from time to time. As population grows, it increased along with the demand for food and water among other basic needs of mankind. So, it equally becomes important to have adequate water supply and also important for the water to be safe and clean to enhance good human health, growth and development in space. These justify the need for this study among Benue State University students particularly because the university is located at the bank of River Benue with its turbid water and also close to the Benue State Water Works where series of tankers queue for water on daily basis because of its inability to pump water to residential areas for domestic use.

## Materials and Methods

### The Study Area

The study area is Benue State University, Makurdi. It is located between latitude $7^{0}43^{'}$-$7^{0}44^{'}$ north of the equator and longitude $8^{0}32^{'}$-$8^{0}34^{'}$ east of the Greenwich meridian (see fig 1). The university environment is divided into western and eastern campus. The university has a population of 306 students at its inception in 1992/93 academic session and 21,448 students in 2010/11 session. The population later grew to 25352 students in 2016/17 session and 26093 students in 2018/2019 academic session. Currently, 2096 students reside in Benue State University hostel (Benue State University (BSU), 2021).

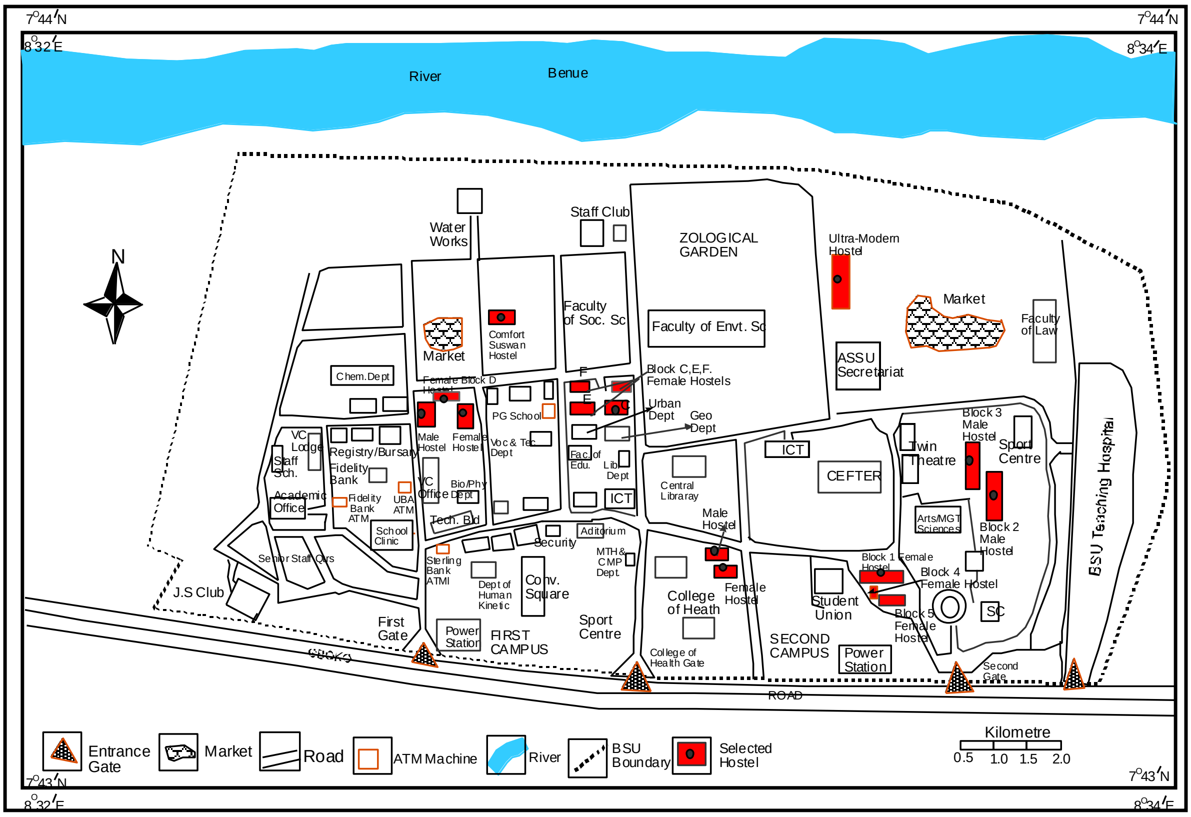

Figure 1: Benue State University, Showing Selected Hostels

Source: Ministry of Lands , Suirvey and Solid Minerals, Makurdi.

**Sample population and Data Collection**

The sample population was determined through Yamane (1967) formula for determining sample size as follows; $n = N/(1 + N(e)^2) = 2096/(1 + 2096(0.06)^2) = 245$. Where n is the required sample size, N is known population (2096 students) and e is the level of precision (0.06). The study therefore administered 245 copies of questionnaire to the students. However, only 220 copies of questionnaire were filled by the students and retrieved for analysis. There was a deficit of 25 questionnaire. This is the challenge encountered in the course of this research. The study therefore used the information retrieved from 220 students who resides in 11 (70%) of the 15 hostel blocks on Campus for the study.

The information used for this study includes data on water demand, access, adequacy, sources, challenges and solutions to the problems associated with water supply in Benue State University, Makurdi. The study obtained the information through research questionnaire administered to only students who live in hostel. Copies of the questionnaire were administered through snow ball sampling technique. The information obtained was analysed and the results were presented via tables in frequency and percentage.

**Results and Discussion**

**Gender and Water Demand among Benue State University Students**

Water is necessary for life. As such both male and female needs water. Table 1 reveals that the total water demanded by the students is 6528 litres. The demand for water is higher among females than the male students as indicated by mean female water demand of 30.02 litres compare to the mean male water demand of 29.05 litres per day. Half of female (54.3%) need between 31 litres and above per day compared to half of male (50.1%). On the whole, water demand is high among the students irrespective of gender as indicated by 116 (52.8%) of the total respondents who needs between 31 litres and above per day. The implication of high water demand on the students is that, it may impact negatively on their studies if the time taken to access water before going for lectures becomes unnecessary long.

**Table 1:** Gender and Water Demand Crosstabulation

| Water Demand | Gender | | Total |
|---|---|---|---|
| in Litres | Male | Female | |
| 15 below | 0 (.0%) | 3 (2.1%) | 3(1.4%) |
| 16-20 | 13 (16.3) | 14 (10.0%) | 27 (12.3%) |
| 21-25 | 5 (6.3%) | 17 (12.1%) | 22 (10.0%) |
| 26-30 | 22 (27.5%) | 30 (21.4%) | 52 (23.6%) |
| 31-35 | 27 (33.8%) | 20 (14.3%) | 47 (21.4%) |
| 36 Litres above | 13 (16.3%) | 56 (40.0%) | 69 (31.4%) |
| Total Respondents | 80 (100%) | 140 (100%) | 220 (100%) |
| Total Water Demand | 2324 | 4204 | 6528 |
| Mean Water Demand | 29.05 | 30.02 | 29.67 |

**Source:** Fieldwork, 2021

## Gender and Water Access among Benue State University Students

The total water accessed by the students is 5257 litres per day (80.53% of the total water demanded) while the mean water accessed is 23.89 litres per day as indicated on table 1 and 2. Mean water accessed (23.89 litres) is lower than mean water demanded per day (29.67 litres). Access to water is very low particularly among those who have high demand for water. Students who accessed 36 litres plus in a day were only 26 (11.8%) compared to 69 (31.4) who demanded for the same quantity of water per day. At high volume, more female (15%) than male (6.3%) have access to 36 litres above. In addition, more females (13.2%) than male (10%) accessed 31-35 litres per day compared to female (14.3%) and male (33.8%) who demanded for the same volume of water per day. Half of the male (50%) accessed 15-20 litres a day compared to 38.6 of the females who accessed the same quantity as indicated on table 2. The students who accessed 20 litres below per day were 42.7% while 57.3% of the student accessed 21 litres and above. The minimum water need of an individual is 20 litres of safe water per day (World Bank, 2002). Low access to water supply does not only have academic implication but water is needed for bathing to keep the body clean, reduce body hotness and also for washing clothes, toilet among others to enhance health living. So, low access is dangerous to health.

**Table 2:** Gender and Water Access Crosstabulation

| Water Access in Litres | Gender | | Total |
|---|---|---|---|
| | Male | Female | |
| 15 below | 12 (15.0%) | 25 (17.9%) | 37 (16.8%) |
| 16-20 | 28 (35.0%) | 29 (20.7%) | 57 (25.9%) |
| 21-25 | 11 (13.8%) | 28 (20.0%) | 39 (17.7%) |
| 26-30 | 16 (20.0%) | 18 (12.9%) | 34 (15.5%) |
| 31-35 | 8 (10.0%) | 19 (13.6%) | 27 (12.3%) |
| 36 Litres above | 5 (6.3%) | 21 (15.0%) | 26 (11.8%) |
| Total Respondents | 80 (100%) | 140 (100%) | 220 (100%) |
| Total Water Accessed | 1829 | 3428 | 5257 |
| Mean Water Accessed | 22.86 | 24.48 | 23.89 |

Source: Fieldwork, 2021

## Hostel and Water Access among Benue State University Students

Table 3 indicates the students and quantity of water accessed in their hostels per day. Only 11.8% of the students have access to 36 litres plus in a day while 12.3% accessed 31-35 litres, whereas 15.5% accessed 26-30 litres. The mean water supply accessed by students in the hostel per day is 23.89 litres compared to 29.67 litres demanded. There is a mean water deficit of 5.78 litres per student per day. This translates to a total of 1271 litres deficit per day in the university. This means that 19.47% of the total water demanded is not met while 80.53% of the water demanded was supply and accessed. Although this finding is better than the general water supply situation in Makurdi town where only 47% of the total water demanded residents was met as portray by Ocheri (2006). More so large number of students (42.7%) accessed only 20 litres below per day. The hostels with the lowest access to water supply includes; main female hostel, block 1 female hostel, block 2 and 3 male hostels which have mean water access of 20 litres below per day while those with moderately good access to water supply includes main male hostel, ultra-modern female hostel and block C technical female hostel which have mean water supply access of 21-25 litres per day whereas those with high access to water supply include Comfort suswam female hostel, school of health sciences male, school of health sciences female and block D technical female hostel which have mean water supply access of 26 litres and above per day. Water access is better in the hostels in the western wing compared to those in the eastern wing. In some of the hostels, there is no functional water closet in the bathroom and toilets. Students have to fetch water from other places in to the hostels as indicated by the students on table 6. This situation needs to be addressed by the university management to avoid stamped in the face of increasing student population.

**Table 3:** Hostel and Water Access Crosstabulation

| Hostel | Water Access in Litres | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | 15 below | 16-20 | 21-25 | 26-30 | 31-35 | 36+ | |
| Main Male Hostel * | 3 (8.1%) | 6(10.5%) | 2(5.1%) | 5(14.7%) | 4(14.8%) | 0 (.0%) | 20 (9.1%) |
| Block 2 Male Hostel ** | 5 (13.5%) | 8 (14.0%) | 4 (10.3%) | 3 (8.8%) | 0 (.0%) | 0 (.0%) | 20 (9.1%) |
| Main Female Hostel * | 10 (27.0%) | 0 (.0%) | 10 (25.6%) | 0 (.0%) | 0 (.0%) | 0 (.0%) | 20 (9.1%) |
| Block 1 Female Hostel ** | 11 (29.7%) | 4 (7.0%) | 0 (.0%) | 3 (8.8%) | 2 (7.4%) | 0 (.0%) | 20 (9.1%) |
| Comfort Suswam Hostel * | 0 (.0%) | 0 (.0%) | 3 (7.7%) | 7 (20.6%) | 1 (3.7%) | 9 (34.6%) | 20 (9.1%) |
| Ultra-Modern Hostel ** | 0 (.0%) | 8 (14.0%) | 12 (30.8%) | 0 (.0%) | 0 (.0%) | 0 (.0%) | 20 (9.1%) |
| Technical BlockC Female* | 2 (5.4%) | 11 (19.3%) | 1 (2.6%) | 0 (.0%) | 4 (14.8%) | 2 (7.7%) | 20 (9.1%) |
| Male Hostel School of Health Sciences * | 0 (.0%) | 5 (8.8%) | 2 (5.1%) | 4 (11.8%) | 4 (14.8%) | 5 (19.2%) | 20 (9.1%) |
| Female Hostel School of Health Sciences * | 2 (5.4%) | 6 (10.5%) | 1 (2.6%) | 1 (2.9%) | 4 (14.8%) | 6 (23.1%) | 20 (9.1%) |
| Technical BlockD Female* | 0 (.0%) | 0 (.0%) | 1 (2.6%) | 7 (20.6%) | 8 (29.6%) | 4 (15.4%) | 20 (9.1%) |
| Block 3 Male Hostel ** | 4 (10.8%) | 9 (15.8%) | 3 (7.7%) | 4 (11.8%) | 0 (.0%) | 0 (.0%) | 20 (9.1%) |
| Total | 37 (16.8%) | 57 (25.9%) | 39(17.7%) | 34(15.3) | 27(12.3) | 26(11.8) | 220(100%) |

Source: Fieldwork, 2021
(Hostel in Western Wing*, Hostel in Eastern Wing **)

**Water Adequacy among Benue State University Students**

Water supply is not adequate as indicated by 116 (52.7%) of the students compared to 84 (38.2%) who opined that water supply is adequate in their hostel. 20 (9.1%) students were not sure of the water adequacy status as shown on table 4. This agrees with table 3 which indicates low access to water supply in hostels. Water adequacy is high in the western wing compare to the eastern wing as indicated by 52.9% of the respondents. Inadequacy may have negative effect on students' academic activities, environmental cleanliness and health. Therefore, efforts should be made to address water shortage in the University.

**Table 4:** Campus and Water Adequacy Crosstabulation

| Water Adequacy | Camp | | Total |
|---|---|---|---|
| | Western Wing | Eastern Wing | |
| Yes | 74 (52.9%) | 10 (12.5%) | 84 (38.2%) |
| No | 63 (45%) | 53 (66%) | 116 (52.7) |
| I am not sure | 3 (2.1%) | 17 (21.3%) | 20 (9.1%) |
| Total | 140 (100%) | 80 (100) | 220 (100%) |

Source: Fieldwork, 2021

**Sources of Water among Benue State University Students**

Table 5 indicate that 71.4% of the respondents obtain water from the pipe supplied by the university water works while 61.4% obtain water from borehole whereas 43.2% buy water from vendors. The least source of water is well and rainfall as reveal by 4.5% of the students respectively. More students in the western wing source water from pipe (92.8%) and vendors (47.1%) compared to those in the eastern wing as portray by 33.7% and 36.2% of the students respectively. Borehole is the major source of water in the eastern wing as indicated by 91.2% of the students.

**Table 5:** Campus and Water Sources Crosstabulation

| Campus | Sources of Water | | | | | Total |
|---|---|---|---|---|---|---|
| | Pipe | Borehole | Well | Rain | Vendors | |
| Western Wing | 130 (92.8%) | 62 (44.2) | 0 (0.0 %) | 9 (6.4%) | 66 (47.1%) | 140 |
| Eastern Wing | 27 (33.7) | 73 (91.2) | 10 (12.5%) | 1 (1.25%) | 29 (36.2%) | 80 |
| Total | 157 (71.4%) | 135 (61.4%) | 10 (4.5%) | 10 (4.5%) | 95 (43.2%) | 220 |

Source: Fieldwork, 2021

**Challenges associated with Water Accessibility and Quality**

In an attempt to fetch and use water, there are several challenges confronting the students as reveal by the study on table 6. Some of the challenges include; failure of the university water works to pump water into the bathroom/toilets in the hostels as accounted by 85.9% of the students while occasional failure to processed water is the second major problem (32.7%). Other problems include poor water taste sometimes (26.8%), long distances to source of water (16.8%) and lastly, the quality of water (taste=26.8% and physical quality=10%). Water problem is higher in the western wing than the eastern wing as shown on table 6. Failure to processed and supply quality water on time and to the desired location needs to be addressed urgently.

**Table 6:** Campus and Water Challenge Crosstabulation

| Campus Water Challenges | Campus | | Total |
|---|---|---|---|
| | Western Wing | Eastern Wing | |
| Long distances to Sources of water | 21 (15.0%) | 16 (20.0%) | 37 (16.8%) |
| Sometimes, the quality of water seems poor physically | 21 (15.0%) | 1 (1.3%) | 22 (10%) |
| Sometimes, the water have poor taste | 33 (23.6%) | 26 (32.5%) | 59 (26.8%) |
| Occasional failure of the water work to processed water | 56 (40.0%) | 15 (18.8%) | 71 (32.3%) |
| Failure to pump water to bathrooms/toilets in hostels | 123 (87.9%) | 66 (82.5%) | 189 (85.9%) |
| Others (broken water pipes) | 6 (4.3%) | 0 (0.0%) | 6 (2.7%) |
| Total | 140 (63.6% | 80 (36.4%) | 220 (1005) |

**Source:** Fieldwork, 2021

**Solution to the Problems of Water Supply on Campus**

The major solution suggested by the students for solving water problem as indicated on table 7 include; water sources should be powered by solar energy (82.3%), improved the quality of water (43.2%), expand the capacity of water work (38.6%), provide more borehole on campus (16.8%) and pump water to the students' bathroom and toilets. If these solutions are adhered to, challenges associated with water supply on Campus will be reduced if not eradicated.

**Table 7:** Solution to Campus Water Problems

| Solution to Campus Water Problems | Campus | | Total |
|---|---|---|---|
| | Western Wing | Eastern Wing | |
| Expand the capacity of the water work | 37 (26.4%) | 48 (60.0%) | 85 (38.6%) |
| Provide more boreholes on campus | 20 (14.3%) | 17 (21.3%) | 37 (16.8%) |
| Improved the quality of water on campus | 52 (37.1%) | 43 (53.8%) | 95 (43.2%) |
| Water sources should be powered by solar energy | 108 (77.1%) | 73 (91.3%) | 181 (82.3%) |
| Others (pump water to bathroom and toilet) | 51 (36.4%) | 1 (1.3%) | 52 (23.6%) |
| Total | 140 (63.6%) | 80 (36.4%) | 220 (100%) |

**Source:** Fieldwork, 2021

**Conclusion and Recommendation**

The study concludes that water supply and access is not adequate in Benue State University. The demands for water slightly outweigh its supply. The study therefore recommend that Benue State government and university management should embark on gigantic modern water processing facility or upgrade of the existing one to cater for the students' water need/enhance students' access to quality water right in their hostels.

**References**

Aremu, M. O., Atolaiye, B. O., Gav, B. L., Opaluwa, O. D., Sangari, D. U and Madu, P. C (2011). Metal Concentrations in Sediments and Water from River Doma, Farinruwa and Mada in Nassarawa State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology, 3(9):244-251.*

BSU (2021). *Student Statistics. Academic* Unit, Benue State University, Makurdi.

NPC and ICF International (2019). *Nigeria Demographic and Health Survey 2018.*Abuja, Nigeria and Rockville, Maryland, USA: National Population Commission and ICF International.

Obeta, M. C and Chukwu, K. I (2013). "*Water Supply and Demand in Nigeria" Or Water Reource Development and Management in Nigeria''.* Ed. Anyadike, R. N. C and Oberta, M. C. Merit International Publication (Nig), pp 18-26

Ocheri, M. I (2006). Analysis of Water Consumption Pattern in Makurdi Metropolis. *Journal of Geography and Development, 1(1):71-83.*

Ocheri, M. I (2010). Distribution of Iron in Rural Ground Water of Benue State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment, 2(2):74-89.*

Ojo, O (2011). A Study of Rural Water Supply Demand Situation in South West Nigeria. *WIT Transaction on Ecology and Environment, 145: 51-61*

Orebiyi, E. O., Awomeso, J. A., Oguntoke, E. O., and Taiwo, A. M (2010). Assessment of Pollution Hazards of Shallow Well Water in Abeokuta and Environs, South West Nigeria. *American Journal of Environmental Sciences, 6(1):50-56.*

WHO and Unicef (2000). *Global Water Supply and Sanitation Assessment Report*. Geneva and New-York

World Bank Group (2002). *"Report: Access to Safe Supply,"* Retrieved 29/04/2021 from http://www.worldbank.org/depweb/english/moules/environment/water/htm

Yamane, T. (1967*). Statistics; An Introductory Analysis*. 2nd Ed., Harber and Row New York.

# EFFECTS OF SEPTIC TANK EFFLUENT ON WELL WATER QUALITY IN CALABAR METROPOLIS

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**Abstract**
*Human activities especially septic tank effluent results in changes in the composition and quality of well water with high spatial and temporal variability. These modifications are reflected sensitively in potential impacts on endusers. Examination of water quality of some wells located at septic tank distance of 5-25m were carried in the study area. Twelve (12) locations were selected for the study. Water samples were collected and taken to the University of Calabar Laboratory for analysis of physico-chemical and bacteriological parameters. The results revealed that groundwater is acidic, the colour matrix of water indicates contamination with dissolved substances. All water samples were within the WHO and NSDWQ limits except for same 2, 7, 9 and 10. Elevated levels of nitrates were reported in sample 1, 2, 7 and 9. Calcium, magnesium, zinc, copper, lead, phosphates, sulphates and fluoride were all below the WHO and NSDWQ permissible limits for drinking water except for sample 7 due to presence of municipal waste landfill. Bacteriological parameters examination revealed that all the locations have traces of total and faecal coliform counts greater than zero. Distances from septic tanks were in close proximity to drinking water source, thus making the water unsafe and predisposes the public to health implication.*

**Keywords**: Septic tank effluent, well water, contaminants, water quality

## Introduction

Water is the hub of life, no meaningful use of these resources can take place sustainably without a vivid understanding of the physical, chemical and biological properties of water. Human activities and complementary demands for water for various purposes has led to the exploitation, development and pollution of ground water sources. These scenario in largely governed by natural processes and human activities which can either be point or non-point sources (Nweke, 2013, Butu, 2013; Peyman, 2009 and Ezenwaji, 2010, Etim *et al.*, 2013). Unsafe water is a public health threat and has accounted for increasing water related illments, chemical intoxication and decreasing portability of fresh water sources (Hughes & Koplan, 2005, Okonko *et al.*, 2008, Chandaluri *et al.*, 2010). Onsite wastewater via septic tank/soakway are point sources of pollution that exert impact on groundwater sources in the immediate neighborhood. This has attracted overwhelming attention by public health experts and researchers on the consequences of over dependence on untreated groundwater abstracted through hand dug well and boreholes in urban areas of Nigeria (Eni *et al.*, 2011, Ocheri, 2010; Chukwu, 2008, Adelena *et al.*, 2008).

Wells and borehole located with few metres from soakaways are more susceptible to contamination generated by human wastes through processes of hydrolysis and solubilisation caused by series of complex biochemical reactions during degradation of human waste. The resulting liquid containing fulvic acids and other microbes migrate downward and contaminate the groundwater. This downward flow of leachate yields water of poor and dangerous quality in immediate and adjoining wells/boreholes posing a major risk factor to public health and usability of water. The presence and concentration of their contaminants varies with time, location and distance of well/boreholes from septic tank/soakaway. The present investigation was carryout to determine the effect of septic tank effluent on well water/ boreholes discharge in Calabar metropolis by determining the concentration levels of contaminants in the groundwater and show how improver sitting of well water/boreholes can lead to contamination of water intended for domestic uses.

**Statement of the Problem**

Groundwater quality in most urban areas in Nigeria especially handdug wells/boreholes located some distances from septic tanks/soakaway facilities has been a source of concern to public and researchers due to its varying physico-chemical and biological properties that had been attributed to the number of emerging urban health challenges of fatal fecal-oral transmission of diseases such as cholera and typhoid, methemoglobinemia (blue baby syndrome) in children, dental and skeletal fluorosin and other risk factors.

**Aim and Objectives**

The aim of the study is to investigate the effects of septic tank effluent on well water/borehole discharge in Calabar metropolis. The specific objectives are to;

(i) Identify areas or locations where the groundwater sources are vulnerable to contamination.

(ii) Examine the effect of distances from septic tanks/soakaway on the level of groundwater contamination.

(iii) Identify the major contaminants present in the groundwater in each of the selected locations.

(iv) Compare the water quality with WHO and NSDWQ water quality standards.

**Methodology**

**The study area**

The study area is Calabar, capital of Cross River State. For administration it is divided into two local governments: Calabar Municipality with 10 wards and Calabar South with 12 wards (Figure 1).

Calabar is located between longitude $8^{0}$15'00"E and $8^{0}$21'00"E and latitude $4^{0}$45'0"N and $5^{0}$30'0"N respectively. It has an area of about 164 $km^2$ and is bounded in the North by Odukpani L.G.A, in the East by the great Kwa River, in the West by the Calabar River and the South by the estuary. The city lies on a peninsular formed by the Calabar River, the Kwa River, the Cross River Estuary and the Atlantic Ocean.

The rapid growth and urbanization of the city of Calabar has been fueled by influx of people from the surrounding hinterland to the city for job opportunities. Calabar is a fast-growing city in terms of volume of socio-economic activities. The city is characterized by various land uses such as residential (the 8 miles, federal Housing, State housing, Ekorinim and others), commercial land use as seen in the volume of activities in the city center of Calabar Road and Marian, institutional land uses (Banks, school and office complex, Industrial land uses such as the Export Processing Zone (EPZ) and Niger Mills and recreational land uses which are a major revenue earner for the state. Recreational land uses include the Tinapa Business and Leisure Resort, the Marina resort and numerous hotels and bars. The socio-economic activities in the city ranges from primary activities such as farming and fishing in the hinterland, secondary activities such as manufacturing and industry to tertiary activities of services such as banking, hoteling and tourism.

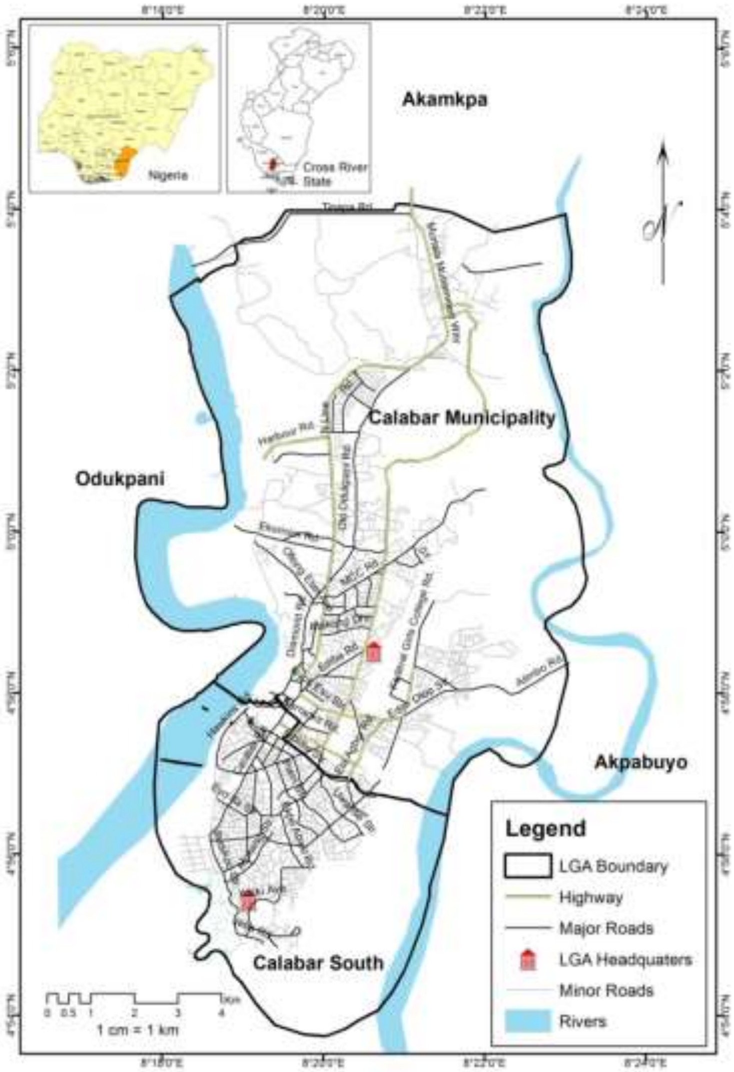


Figure 1: Map of Calabar Metropolis (Source: CRGIA, 2015)

**Sampling technique**

The stratified random sampling technique and the simple random sampling technique were both employed in this study. The stratified random sampling technique was used to delineate them into 4 blocks and from each block 3 samples each were randomly selected bringing the total sample to 12.

**Sampling procedure**

A total of 12 sampling was drawn from the study area. Sampling was done on fortnight basis on well water/borehole discharge located in and within residential houses, distances of the water sources from septic tanks/soakaway were measured using the metric tape. Water samples for physics-chemical test were collected in sterilized bottles, adequately corked and air tight. The samples used for dissolved oxygen test were collected with sterilized 250ml reagent bottles. Temperature, pH, DO, colour were measured on-site by a thermometer, pH and Do meter. BOD was determined by Winkler Azide method, turbidity by the nephetometric method using 2100AN turbidity meter. Other parameters were measured using the approved standard techniques.

Bacteriological analysis was carried out using the membrane filtration method. All the glass, wares and the media used were sterilized in an autoclave at $120^0$c for 15mins. The media used (Edo agar and MF-c agar base), were prepared following the existing laid down procedures (APHA, 1998).

**Table 1: Mean values of the physicbemical and biological parameters of well water in Calabar Municipality**

| | Sampled locations | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Anatigha 1 | Okoro-Agbo 2 | Parliamentary town 3 | Ekorinium 4 | State housing 5 | Atekong 6 | Lemina 7 | Asari Eso 8 | Ikot Ishie 9 | Ikot Ansa 10 | Ikot Nkebre 11 | Technical 12 | NSDWQ | WHO |
| Appearance (colour) | Clear | Cloudy | Clear | Clear | Clear | Clear | Cloudy | Clear | Cloudy | Cloudy | Clear | Clear | Clear | Clear |
| Odour | Objectable | Objectable | Unobjectable | Unobjectable | Ditto | - | Objectable | - | Objectable | Objectable | Unobjectable | Unobjectable | Unobjectable | Objectable |
| Temperature (°C) | 26.5 | 27.0 | 25.7 | 28.4 | 24.58 | 25.2 | 26.4 | 23.6 | 26.5 | 26.8 | 24.6 | 23.4 | Ambient | 25.0 |
| pH | 5.5 | 5.7 | 4.8 | 5.4 | 5.2 | 4.8 | 3.8 | 4.6 | 3.6 | 3.9 | 5.1 | 4.9 | 6.5-8.5 | 6.5-8.5 |
| Turbidity (NTU) | 1.59 | 6.81 | 1.32 | 1.46 | 1.34 | 1.22 | 6.98 | 1.08 | 5.01 | 5.12 | 1.20 | 1.26 | 5.0 | 5.0 |
| Conductivity (NS/cm) | 70.9 | 60.7 | 40.0 | 29.0 | 70.0 | 65.0 | 240.0 | 55.8 | 220.0 | 270.0 | 94.0 | 99.6 | 1000 | 1000 |
| TDS (mg/1) | 60.7 | 80.2 | 95.4 | 94.6 | 102.8 | 124.6 | 148.4 | 116.4 | 147.4 | 139.0 | 55.8 | 62.0 | 500 | 500 |
| TSS (mg/1) | 10.4 | 8.6 | 0.00 | 0.00 | 0.00 | 0.00 | 12.4 | 0.00 | 6.0 | 8.2 | 0.00 | 0.00 | 0.1 | |
| DO (mg/1) | 8.00 | 5.8 | 8.60 | 7.8 | 4.5 | 6.4 | 14.00 | 4.0 | 13.60 | 13.10 | 10.2 | 10.6 | 0.1 | 4.0 |
| Zinc (mg/1) | 0.19 | 0.22 | 0.30 | 0.24 | 0.18 | 0.35 | 2.40 | 0.17 | 3.20 | 2.84 | 0.22 | 0.38 | 5.0 | |
| Iron (mg/1) | 0.42 | 0.31 | 0.24 | 0.15 | 0.10 | 0.20 | 0.84 | 0.10 | 0.42 | 0.28 | 0.2 | 0.26 | 0.30 | 1.14 |
| Copper (mg/1) | 0.15 | 0.17 | 0.11 | 0.17 | 0.09 | 0.16 | 0.72 | 0.17 | 0.64 | 0.36 | 0.17 | 0.24 | 1.0 | 1.0 |
| Nitrite (mg/1) NO2 | 0.09 | 0.07 | 0.06 | 0.04 | 0.05 | 0.07 | 10.70 | 0.06 | 0.09 | 0.08 | 0.05 | 0.07 | 0.1 | 0.1 |
| Nitrate (mg/1) NO3 | 28.42 | 49.48 | 38.20 | 37.92 | 46.00 | 48.40 | 79.28 | 46.80 | 98.46 | 79.30 | 37.40 | 47.20 | 10 | 50 |
| Alkalinity (mg/1) | 6.01 | 6.42 | 6.10 | 6.12 | 6.42 | 6.55 | 6.51 | 6.44 | 6.82 | 6.02 | 6.11 | 6.40 | 200 | 200 |
| Calcium (mg/1) | 5.60 | 8.20 | 9.40 | 9.20 | 8.40 | 8.10 | 55.90 | 5.60 | 6.00 | 4.20 | 5.00 | 8.05 | 75 | 100 |
| Magnesium (mg/1) | 6.00 | 4.84 | 6.40 | 8.52 | 7.30 | 9.20 | 72.8 | 4.92 | 13.6 | 10.8 | 7.30 | 7.26 | 15.0 | 0.2 |
| Total hardness (mg/1) | 10.4 | 55.2 | 8.50 | 10.5 | 10.4 | 11.35 | 65.0 | 12.4 | 48.8 | 42.0 | 14.80 | 14.10 | 5.00 | 150 |
| Chromium (mg/1) | 0.000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 |
| Lead (mg/l) | 0.001 | 0.001 | 0.00 | 0.00 | 0.00 | 0.00 | 0.005 | 0.001 | 0.001 | 0.00 | 0.00 | 0.00 | 0.001 | 0.001 |
| Phosphate (mg/l) | 6.40 | 5.84 | 7.40 | 6.80 | 6.20 | 2.15 | 8.42 | 4.84 | 7.26 | 6.30 | 5.24 | 4.82 | 100 | 100 |
| Sulphate (mg/l) | 4.02 | 4.82 | 3.24 | 2.80 | 3.14 | 4.24 | 74.05 | 2.65 | 4.94 | 5.02 | 4.22 | 3.55 | 100 | 100 |
| Fluoride | 0.84 | 0.68 | 0.52 | 0.58 | 0.46 | 0.54 | 0.92 | 0.66 | 1.38 | 1.42 | 0.60 | 0.87 | 1.5 | 1.5 |

**Table 2:** Mean values of bacteriological quality of well water/borehole

| | Anatigha 1 | Okoro-Agbo 2 | Parliamentary town 3 | Ekorinium 4 | State housing 5 | Atekong 6 | Lemina 7 | Asari Eso 8 | Ikot Ishie 9 | Ikot Ansa 10 | Ikot Nkebre 11 | Technical 12 | NSDWQ | WHO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total coliform count (cfu/100 ml) | 0.18 | 0.20 | 0.37 | 0.45 | 0.38 | 0.25 | 0.68 | 0.37 | 0.54 | 0.51 | 0.22 | 0.18 | 0 | 0 |
| Fecal coliform count (cfu/100 ml) | 0.23 | 0.21 | 0.21 | 0.20 | 0.16 | 0.18 | 0.29 | 0.22 | 0.35 | 0.42 | 0.15 | 0.10 | 0 | 0 |

**Table 3:** Pollution index of sample point

| Parameter | Sample Points | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Anatigha 1 | Okoro-Agbo 2 | Parliamentary town 3 | Ekorinium 4 | State housing 5 | Atekong 6 | Lemina 7 | Asari Eso 8 | Ikot Ishie 9 | Ikot Ansa 10 | Ikot Nkebre 11 | Technical 12 |
| pH | 0.85 | 0.87 | 0.73 | 0.83 | 0.8 | 0.73 | 0.58 | 0.70 | 0.55 | 0.6 | 0.78 | 0.75 |
| Turbidity (NTU) | 0.31 | 1.36 | 0.26 | 0.292 | 0.26 | 0.24 | 1.39 | 0.21 | 1.00 | 1.02 | 0.24 | 0.25 |
| Conductivity (NS/cm) | 0.07 | 0.06 | 0.04 | 0.02 | 0.07 | 0.06 | 0.24 | 0.05 | 0.22 | 0.27 | 0.09 | 0.09 |
| TDS (mg/1) | 0.12 | 0.16 | 0.19 | 0.18 | 0.20 | 0.24 | 0.29 | 0.23 | 0.29 | 0.27 | 0.11 | 0.12 |
| TSS (mg/1) | 10.4 | 86 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24 | 0.00 | 6.0 | 82 | 0.00 | 0.00 |
| DO (mg/1) | 2 | 1.45 | 2.15 | 1.95 | 1.12 | 1.6 | 3.5 | 4.01 | 3.4 | 3.27 | 2.55 | 2.65 |
| Zinc (mg/1) | 0.03 | 0.04 | 0.06 | 0.04 | 0.03 | 0.07 | 107 | 0.6 | 0.9 | 0.8 | 0.5 | 0.7 |
| Iron (mg/1) | 0.36 | 0.27 | 0.21 | 0.13 | 0.08 | 0.17 | 0.73 | 0.08 | 0.36 | 0.24 | 0.17 | 0.22 |
| Copper (mg/1) | 0.15 | 0.17 | 0.11 | 0.17 | 0.09 | 0.16 | 0.72 | 0.17 | 0.64 | 0.36 | 0.17 | 0.24 |
| Nitrite (mg/1) NO2 | 0.9 | 0.7 | 0.6 | 0.4 | 0.5 | 0.7 | 107 | 0.6 | 0.9 | 0.8 | 0.5 | 0.7 |
| Nitrate (mg/1) NO3 | 0.56 | 0.98 | 0.76 | 0.75 | 0.92 | 0.96 | 1.58 | 0.93 | 1.96 | 1.58 | 0.74 | 0.94 |
| Alkalinity (mg/1) | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Calcium (mg/1) | 0.05 | 0.08 | 0.09 | 0.09 | 0.08 | 0.08 | 0.55 | 0.05 | 0.06 | 0.04 | 0.05 | 0.08 |
| Magnesium (mg/1) | 6.00 | 24.2 | 32 | 42.6 | 36.5 | 46 | 36.4 | 24.6 | 68 | 54 | 36.5 | 36.3 |
| Total hardness (mg/1) | 0.06 | 0.36 | 0.05 | 0.07 | 0.06 | 0.07 | 0.43 | 0.08 | 0.32 | 0.28 | 0.09 | 0.09 |
| Chromium (mg/1) | 0.000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Lead (mg/l) | 0.001 | 0.001 | 0.00 | 0.00 | 0.00 | 0.00 | 0.005 | 0.001 | 0.001 | 0.00 | 0.00 | 0.00 |
| Phosphate (mg/l) | 0.06 | 0.05 | 0.074 | 0.06 | 0.06 | 0.02 | 0.08 | 0.04 | 0.07 | 0.06 | 0.05 | 0.04 |
| Sulphate (mg/l) | 0.04 | 0.04 | 0.03 | 0.02 | 0.03 | 0.04 | 0.74 | 0.02 | 0.04 | 0.05 | 0.04 | 0.03 |
| Fluoride | 0.56 | 0.68 | 0.45 | 0.38 | 0.30 | 0.36 | 0.61 | 0.44 | 0.92 | 0.94 | 0.4 | 0.58 |

**Results and Discussion**

Table 1 shows the values of the physico-chemical parameters, the pH of the waters ranges from 3.6-5.7. This is a clear indication that the groundwater is acidic. The colour matrix ranges from 3.0-5.0. The results shows that the colour of the samples were within the permissible limits of WHO and NSDWQ. Although the physical appearance of some samples suggests (Cloudy) connoting contamination with dissolved substances/and parent materials. All the water samples are within the limits for both the WHO and NSDWQ except for sample 2, 7, 9 and 10. The turbidity was above the permissible level this indicate the presence of large number of tiny colloidal particles which can provide a living place for pathogenic organism. All the samples fall below the permissible limit for dedrical conductivity but the presence of electrical conductivity in all the samples though in acceptable limits indicates the presence of salts in the wells/borehole water conferning on the water some level of unfavorable taste.

All the water sample were within the acceptable limits stated by WHO and NSDWQ for total dissolved solids and hardness except for sample 2, 7, 9 and 10 where the water sparingly lather with soap. Also elevated levels of nitrates were resulted in sample 1, 2, 7 and 10 above the WHO and NSDWQ limits which implies that there is contamination in the groundwater sources. Elevated levels of iron were recorded in sample 1, 2, 7 and 9 while the rest of the samples were within the WHO and NSDDWQ limits. Calcium, Magnesium, Zinc Copper, Chromium, lead, Phosphates, Salphate and fluoride were all below the WHO and NSDWQ permissible limits for drinking water except for sample 7 because of the presence of municipal waste landfill which is poorly engineered and managed.

Bacteriological parameters: Results extracted from table II shows that all the water samples collected from all the locations are contaminated, having traces of total and faecal coliform counts greater than zero as against the WHO (2003, 2008) AND NSDWQ (2006) standards for drinking water quality.

**Table 4:** mean values range of well/borehole distance measured from existing septic tank/ soakaway

| Location | Distances (m) |
|---|---|
| Anantigha | 9.0 |
| Okoro-Agbo | 8.0m |
| Parliamentary Town | 16.0m |
| Ekorinum | 20.5m |
| State Housing Estate | 10.0m |
| Atekong | 8.5m |
| Lemina | 7.0m |
| Asari Eso | 8.0m |
| Ikot Ishie | 6.5m |
| Ikot Nkebre | 7.2m |
| Ikot Nkebre | 10.5m |
| Technical | 15.0m |

Results from table 3 shows that only wells/borehole in sample 3, 4, and 12 (parliamentary town, Ekorinum and technical) have met atleast half of the minimum effective distance of 30.0m limit of WHO (2006) for constructing septic tank/soakaway from drinking/domestic water source. These areas are places where development control is a bit effective depending on the calibre of occupants inhabiting the location and also the plot sizes and building arrangement are very important determinants of safe distances of well/borehole from soakaway. From the results it can be deduced that there is a correlation between distances from the contaminant source and well borehole water sources. The greater the distances from the source of contaminant, the safer the drinking water.

## Conclusion

Results from physico-chemical and bacteriological parameters revealed that drilling boreholes/wells within and around compounds utilizing septic tanks/soakaway system for waste water disposal in close proximity to drinking water source is very unreliable, unsafe and predisposes the public to many health implications. Developers should adhere to the 30metre minimum distance from an existing septic tank/soakaway as specified by WHO (2006). It was observed that some of the evaluated parameters because of the increasing levels of anthropogenic inputs from residents, and the continuous usage of the septic tank over time, there is the tendency for its pollution potential to increase towards or above WHO and NSDWQ standards for drinking water especially in the high density area of the metropolis.

## Recommendations

From the results of analysis, the following recommendations were made;

1. There is need for chemical treatment of water collected from some of these wells/borehole sources before consumption
2. Most of the wells/boreholes located at minimum distances less than 30m from existing septic tank/soakaway should be relocated to reduce the seepage of effluents from septic tanks via the wells/boreholes.
3. Government should improve the general public water supply to these areas to reduce the over dependence on well/borehole sources.

## References


Adelana, S. M. A., Bale, R. B. & Wu, M. (2003). Quality of assessment of pollution vulnerability of groundwater in Lagos Metropolis, SW Nigeria in: Proceedings of the aquifer vulnerability risk conference AUROs Salamenia Mexico, 2, 1-17.

Ajujieze, C. N. (2006). Remedies of soil and groundwater pollution: An overview. *Africa Sci.*, 7(2), 61-68.

Asuquo, J. E. & Etim, E. E. (2012a). Water quality index for assessment of borehole water quality in Uyo Metropolis, Akwa Ibom State, Nigeria. *International Journal of Modern Chemistry,* 1(3), 102-108.

Asuquo, J. E. & Etim, E. E. (2012b). Physico-chemical and bacteriological analysis of borehole water in selected areas in Uyo Metropolis. *Journal of Modern Chemistry,* 2(1), 7-14.

Chandaluri, S. R., Sreeniva, R. A., Hariharann, V. L. N. & Manjula, R. (2010). Determination of water quality index of some areas in Guntur district Andhra Pradesh. IJABPT. 1: 79-86.

Chukwu, G. U. (2008). Water quality assessment of boreholes in Umuahia South Local Government Area of Abia State, Nigeria. *The Pacific Journal of Science and Technology,* 9(2).

Edet, E. J., Etim, E. E. & Titus, O. M. (2012). Bacteriological and physico-chemical analyses of stream water in Nduetong Oku community, Uyo, Akwa Ibom State, Nigeria. *International Journal of Modern Chemistry,* 3(1), 65-75.

Eni, D. V., Obiefuna, J., Oko, C. & Ekwok, I. (2011). Impact of urbanization on sub-surface water quality in Calabar Municipality, Nigeria. *international Journal of Humanities and Social Sciences,* 1(10), 167-172.

Etim, E. E., Odoli, R., Itodo, A. U., Umoh, S. D. & Lawal, H. (2013). Water quality index for the assessment of water quality from different sources in the Niger Delta Region of Nigeria. *Scientific and Academic Publishing.*

Hughes, J. M. & Koplan, J. P. (2005). Saving lives through global safe water. *Journal of Emerging Infectious Diseases,* 11(10), 1636-1637.

Nweke, P. (2013). Effects of urbanization on Rivers Nworie and Ofamiri in Owerri, Nigeria. Unpublished B.Sc. project Nnamdi Azikiwe University, Akwa.

Ocheri, M. I. & Mile, I. I. (2010). Spatial and temporal variation in groundwater quality of Makurdi sedimentary formation. *Journal of Geography, Environment and Planning,* 6(1), 141-146.

Okonko, I. O., Ogunjobi, A. A., Adejoye, A. D., Ogunusi, T. A. & Olasogba, M. C. (2008). Comparative studies and microbial risk assessment of different water supplies used for processing frozen sea food in Ijorn-Olopa, Lagos state, Nigeria. *African Journal of Biotechnology,* 7(16), 2902-2907.

Okoye, G. E., Aiyegbusi, M. S., Mbachu, M. A., Aghomishie, C. C. & Akujieze, C. N. (2010). Physico-chemical quality of water resources in Calabar and its environs, South-South Nigeria. Proceeding annual conference of Nigeria Association of hydro geologists on water resources development and climate change, 6.

Wetzel, G. W. (2001). *Limnology: lake and river ecosystems.* New York: Academic press, 152.

World Health Organization (2006). *Core questions on drinking – water, sanitation and hygiene for household surveys*: Geneva and New York.

# ALTERATION OF SURFACE WATER QUALITY BY GAS FLARING IN IBENO, AKWA IBOM STATE, NIGERIA

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**Abstract**

*The threat to human health and the biophysical components of the ecosystem within the oil producing communities and environs have long been a major concern. The study examined the alteration of surface water quality by gas flaring in Ibeno, Akwa Ibom State, Nigeria. The gas flaring site is located at Mkpanak (Gas Flare site). Surface water were sampled in four (4) locations. location 1 (Mkpanak river), location 2 (Iwuochang river), location 3 (Usung Ikim Ekeme river) and location 4 (Ikot Akpan Abia river). The control point is at Ikot Akpan Abia, located 10km away from the flare site. Samples were randomly collected from the upstream, midstream and downstream respectively, and were taken to the laboratory for analysis. The laboratory analysis results indicated that phenol compounds was 0.05 mg/l, 0.02 mg/l, 0.02 mg/l and 0 mg/l at location 1, 2, 3 and 4. Sulphate concentration was 529.75 mg/l, 243.75 mg/l, 239.5 mg/l and 21.25 mg/l at location 1, 2, 3 and 4. Lead was 0.36 mg/l, 0.26 mg/l, 0.24 mg/l and 0.18 mg/l for location 1, 2, 3 and 4. Selenium was 0.09 mg/l, 0.06 mg/l, 0.05 mg/l and 0.06 mg/l for location 1, 2, 3 and 4. Nickel was 0.14 mg/l, 0.62 mg/l, 0.41 mg/l and 0.14 mg/l for location 1, 2, 3 and 4. Bicarbonate ($HCO_3^-$) was 4.79 mg/l, 5.47 mg/l, 6.37 mg/l and 0.97 mg/l at location 1, 2, 3 and 4 respectively. The pollution indexing results revealed that phenol compounds was 23.75, 8.75, 8.75 and 0 at location 1, 2, 3 and 4. Sulphate was 1.325, 0.609, 0.599 and 0.054 at location 1, 2, 3 and 4 respectively. Lead was 36, 26, 24 and 18 for location 1, 2, 3 and 4. Selenium was 9, 6, 5 and 6 for location 1, 2, 3 and 4. Nickel was 2.8, 12.4, 8.2 and 2.8 for location 1, 2, 3 and 4 respectively. The pollution index indicated that the physico-chemical and heavy metals contents level of surface water at Mkpanak Flare river, Iwuochang river and Usung Ikim Ekeme river are very heavily polluted as a result of high concentration of phenol, sulphate, lead, selenium and nickel. The study therefore recommended constant monitory of the physicochemical and heavy metals elements level of surface water at Mkpanak river, Iwuochang river and Usung Ikim Ekeme river at Ibeno, Akwa Ibom State, Nigeria.*

**Keywords:** Gas flare, Surface water, PhysicochemicalParameters, Heavy metals.

## Introduction

Throughout the entire earth, surface water is undoubtedly one of the most important basic commodities for man survival. Surface water is use for various purposes such as drinking, household needs, agriculture, irrigation, transport navigation, recreation and industrial needs. Surface water include rivers, streams, oceans, natural lakes, artificial lakes and wetlands. Environmentally unfriendly activity may adversely affect surface water quality, making it unfit for human use. Surface water may be susceptible to pollution as a result of gas flaring. In the process of hydrocarbon exploitation effluent discharge and gas flare may be release into the surrounding.

Gas flaring is the burning of natural gas accompanying crude oil, releasing contaminants such as sulphur and nitrates into the atmosphere (Obioh, 1999; Kindzieski, 2000). When these contaminants combine with moisture, it results in acid rain, which in-turn render streams, rivers and lakes unfit for human uses and the survival of aquatic life (Nwankwo & Ogagame, 2011). Sulphur and nitrates in the presence of moisture give rise to sulphuric acid and nitric acid, and this in turn give rise to acid rain, a non-point source contaminants which can fall to the surface of the earth several hundred kilometres downwind of their source through precipitation. Acid rain can travel long distances depending on wind direction and speed, destroying environment remote from their point of origin (Ekpoh, 2002).

Hydrocarbon exploitation resulting to gas flaring is a global concern. Globally, almost 8 billion cubic meters of gas are burned yearly. In Libya about 21 percent of natural gas is burned, Saudi Arabia 20 percent, Canada 8 percent and Algeria 5 percent. In Nigeria, about 76 percent of natural gas burned in 2002. In 2004 Nigeria yearly gas flare value was between $500million and $2.5 billion (Global Gas Flaring Reduction, 2002). Between 2015 and 2016, Nigeria lost $523 billion to gas flaring.

Ibeno Local Government Area is a typical Niger Delta Coastal area with unrestricted gas flaring activity at the Qua Iboe Terminal flow station since 1970 (Esara, 1997; Akharume, 2001). Mobile Producing Nigeria Unlimited (MPN) is the principal operator in Ibeno area. In all of the company’s oil field locations at the Qua Iboe Basin of Akwa Ibom State, the towering flame flaring gas at Qua Iboe Terminal flow station in Ibeno may adversely affects surrounding surface water. Most of the inhabitants of Ibeno and its environs depends on river, streams and rain water as the main source of water needs. Some literatures on gas flaring activities in Nigeria, include (Egwurugwu, Nwafor, Chinko, Olurunfemi, Iwuji & Nwamkpa, 2013; Nwankwo and Ogagarue, 2011; Emumejaye, 2012; Amadi, 2014; Seiyaboh & Izah, 2017). Unfortunately, there is constant need to empirically test gas flaring on surface water quality in Nigeria. The study therefore seeks to assess the alteration of surface water quality by gas flaring in Ibeno, Akwa Ibom State, Nigeria.

**Study location**

**Study Area**

Ibeno Local Government Area of Akwa Ibom State comprises twenty-four (24) communities with Upenekang as the headquarter. It is located in the oil rich region of Niger Delta of Nigeria, and spreads between longitudes $7^0$ $48^1$ and $8^0 18^1$ East of the Greenwich Meridian, and latitudes $4^0 30^1$ and $4^0 36^1$ North of the equator. It covers over 1200 square kilometres bounded to the North by Eket Local Govermentr Area and to the South Atlantic Ocean. Toward the North East is Esit Eket Local Government Area; Onna Local Government Area is by the North West and toward the South East is Mbo Local Government Area as well as Eastern Obolo Local Government Area in the South West (Fig.1).


**Figure 1:** Akwa Ibom State showing the study area

**Source:** Ministry of Lands and Survey, Akwa Ibom State, 2018.

**Plate 1:** Mobil QIT flare site at Mkpanak, Ibeno Local Government Area

**Source:** Author's photograph, 2015.

## Materials and methods

### Selection of Sample Sites and Sampling Technique

The study examined the alteration of surface water quality by gas flaring in Ibeno, Akwa Ibom State, Nigeria. The gas flaring site is located at Mkpanak Gas Flare site. Surface water were sampled from four (4) rivers. The rivers stretched from location 1 (Mkpanak river), location 2 (Iwuochang river), location 3 (Usung Ikim Ekeme, river) respectively between 2km-5km from the flare point. Location 4 (Ikot Akpan Abia, river) is located 10km away from the flare site as the control point. Samples were collected from the upstream, midstream and downstream respectively. Four samples were collected from each river. A total of sixteen (16) water samples were collected for the analyses of 23 physicochemical parameters. The samples were collected in July, 2018. Water samples collected were preserved at $4^0$C.

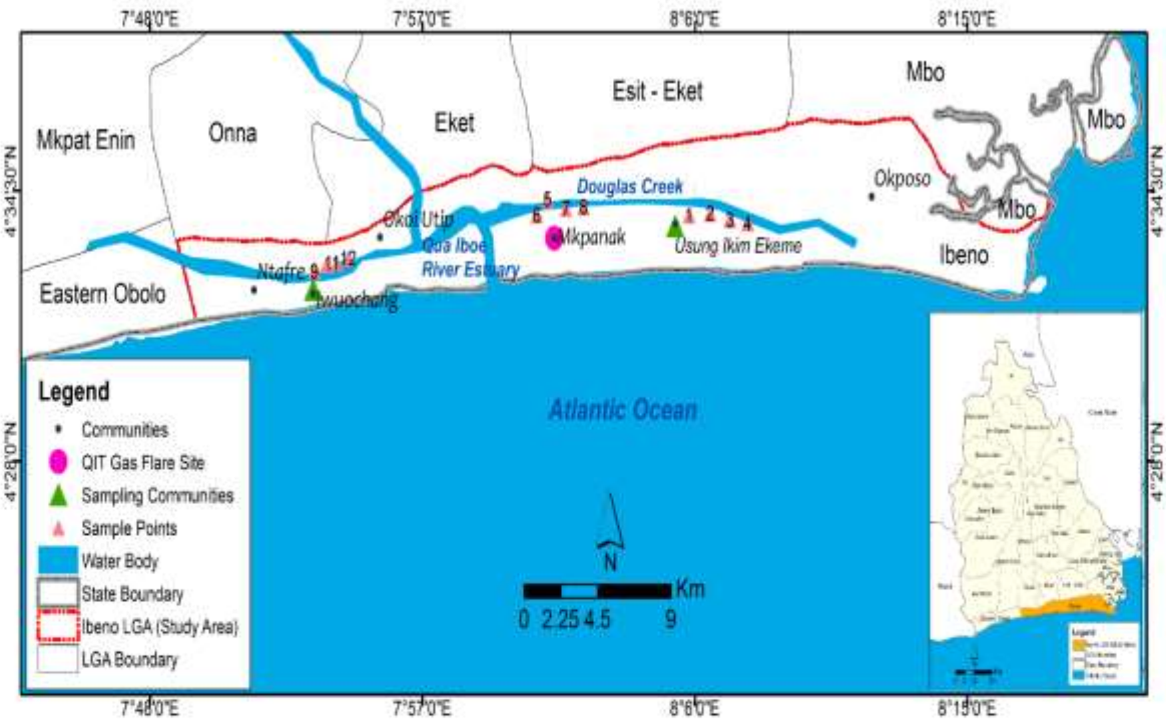


Figure 2: The study area: Sampled locations

Source: Ministry of Agriculture and Water Resources, Akwa Ibom State, 2018

## Laboratory Procedure

The study examined the alteration of surface water quality by gas flaring in Ibeno, Akwa Ibom State, Nigeria. The gas flaring site is located at Mkpanak Gas Flare site. The water samples collected from location 1 (Mkpanak river), location 2 (Iwuochang river), location 3 (Usung Ikim Ekeme river) and location 4 (Ikot Akpan Abia river) respectively were analysed in the laboratory for 23 parameters. The parameters include Temperature ($^0$C), pH, Total Dissolved Solid (TDS), Dissolved Oxygen (DO) Biochemical Oxygen Demand (BOD), Turbidity(NTU), Total Hardness (TH),Bicarbonate ($HCO_3^-$), Phenol ($C_6H_5OH$), Sulphate ($S0_4^2$), Nitrates ($NO_3$), Phosphates (PO4), Electrical Conductivity (EC), Copper (Cu), Lead (Pb), Cadmium (Cd), Selenium (Se), Mercury (Hg), Nickle (Ni), Manganese (Mn), Chromium (Cr) and Arsenic (As). Temperature was measured at the sampling sites immediately after collection using standard celsius thermometer. pH and electrical conductivity were measured using probe and electrode meter. Total dissolve solid was determined using photometric method. Dissolved oxygen was measured using dissolved oxygen meter, while biochemical oxygen demand was measured using incubation method in the laboratory. Turbidity was measures using spectrophotometer -450nm wave length. Heavy metals were determined using Atomic Absorption Spectrometry (AAS) (Model Analyst 300, Perkins-Elmer, USA). TDS was determined gravimetrically. Total hardness was analyzed using acid based titration method. Bicarbonate was determined using titration method. Nitrate, sulphate and phenol were analyzed using modular ion Chromatography (Metrohm, Switzerland, Metrohm IC-709 programmable pump, Metrohm IC-733 separation center).

## Statistical Analysis

The physico-chemical and heavy metals parameters of Mkpanak, Iwuochang, Ikim Ekeme and Ikot Akpan Abia in Ibeno, Akwa Ibom State Nigeria were analyzed using Pearson’s product correlation in SPSS version 22, and Pollution Index. The National Environmental Surface and Ground Water

Quality Control Regulation, 2011 and World Health Organization standard were used with pollution index. Pollution index is a method of rating that shows the compound influence of individual parameters on the general quality of water (World Health Organization, 1993; Caerio et,al., 2005; Amadi et,al., 2012; Abua & Ajake, 2014). Pollution index is given as:

$$\mathrm{WPI} = \sum_{i=1}^{n} \frac{Ci}{SFQSi} \times \frac{1}{n}$$

WPI = Pollution index
Ci = Mean concentration
Si = World Health Organization Standard for Water Quality (WHO 2001)
n = Number of parameters analysed

**Table 1:** Classification of Pollution Index

| Class | Characteristics | Pollution index |
|---|---|---|
| I | Very pure | ≤0.3 |
| II | Pure | 0.3-1.0 |
| III | Moderately polluted | 1.0-2.0 |
| IV | Polluted | 2.0-4.0 |
| V | Impure | 4.0-6.0 |
| VI | Heavily Impure | ≥6 |

## Results and Discussion

Table 2 shows the mean values of physico-chemical parameters contents of surface water sampled from Location 1, Mkpanak river; Location 2, Iwuochang river; Location 3, Usung Ikim Ekeme river; Location 4, Ikot Akpan Abia river respectively. The temperature level for location 1, 2,3 and 4 was 27.2 $^0$C, 26.93 $^0$C, 27 $^0$C and 27.35 $^0$C respectively. The pH value for location 1, 2, 3 & 4 was 4.61, 5, 4.75 and 4.44. Total dissolved solid was2.63mg/l, 74.64 mg/l, 16.75 mg/l and 8.58 mg/l for location 1, 2, 3 and 4 respectively. Dissolved oxygen was 9.42 mg/l, 10.52 mg/l, 12 mg/l and 6.84 mg/l for location 1, 2, 3 and 4. Biological oxygen demand at the various locations was 5.7 mg/l, 5.71 mg/l, 5.61 mg/l and 95.67 mg/l for location 1, 2, 3 and 4. Turbidity of the surface water sampled was 6.97 NTU, 9.28 NTU, 6.24 NTU and 1.47 NTU for location 1, 2, 3 and 4 respectively. Total hardness was 23.42 mg/l, 13.68 mg/l, 13.68 mg/l and 13.68 mg/l for location 1, 2, 3 and 4 respectively. Nitrates content in the surface water samples was 0.04 mg/l, 0.03 mg/l, 0.02 mg/l and 0.04 mg/l at location 1, 2, 3 and 4. Phosphate content was respectively 0.39 mg/l, 0.54 mg/l, 0.06 mg/l and 0.16 mg/l at location 1, 2, 3 and 4 respectively. Electrical conductivity levels were 4.36 us/cm, 121.1 us/cm, 28.02 us/cm and 14.4 us/cm for location 1, 2, 3 and 4 respectively. Total suspended solid in the surface water sampled was 0.09 mg/l, 2.05 mg/l, 0.12 mg/l and 0 mg/l at location 1, 2, 3 and 4 respectively. Phenol compound was 0.05 mg/l, 0.02 mg/l, 0.02 mg/l and 0 mg/l at location 1, 2, 3 and 4. Sulphate concentration in the surface water sampled was 529.75 mg/l, 243.75 mg/l, 239.5 mg/l and 21.25 mg/l at location 1, 2, 3 and 4 respectively.

Bicarbonate ($HCO_3^-$) concentration in the surface water sampled was 4.79 mg/l, 5.47 mg/l, 6.37 mg/l and 0.97 mg/l at location 1, 2, 3 and 4 respectivel

**Table 2:** Calculation of Physicochemical Parameters Using Water Pollution Index

| S/N | Parameters | Mean values | | | | WHO Permissible limit | Water pollution index (WPI) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Loc. 1 | Loc. 2 | Loc. 3 | Loc. 4 | | Loc. 1 | Loc. 2 | Loc. 3 | Loc. 4 |
| 1 | Temp ($^0$C) | 27.2 | 26.93 | 27 | 27.35 | 35 | 0.77 | 0.77 | 0.77 | 0.77 |
| 2 | Ph | 4.61 | 5 | 4.75 | 4.44 | 6.5-8.5 | 0.55 | 0.58 | 0.055 | 0.053 |
| 3 | TDS (mg/L) | 2.63 | 74.64 | 16.75 | 8.58 | 1000 | 0.002 | 0.07 | 0.016 | 0.008 |
| 4 | DO (mg/L) | 9.42 | 10.52 | 12 | 6.84 | 8-10 | 0.095 | 1.052 | 1.2 | 0.68 |
| 5 | BOD (mg/L) | 5.7 | 5.71 | 5.61 | 5.67 | 10 | 0.57 | 0.57 | 0.56 | 0.56 |
| 6 | Turbidity NTU | 6.97 | 9.28 | 6.24 | 1.47 | 25 | 0.027 | 0.037 | 0.024 | 0.058 |
| 7 | Total hardness (mg/L) | 23.42 | 13.68 | 13.68 | 13.68 | 500 | 0.046 | 0.027 | 0.027 | 0.027 |
| 8 | Nitrates (mg/L) | 0.04 | 0.03 | 0.02 | 0.04 | 10 | 0.004 | 0.003 | 0.002 | 0.004 |
| 9 | Phosphates (mg/L) | 0.39 | 0.54 | 0.06 | 0.16 | 250 | 0.001 | 0.002 | 0.00024 | 0.00016 |
| 10 | EC (us/cm) | 4.36 | 21.1 | 28.02 | 14.4 | 200 | 0.021 | 0.105 | 0.140 | 0.072 |
| 11 | TSS (mg/L) | 0.09 | 2.05 | 0.12 | 0 | 20 | 0.004 | 0.102 | 0.006 | 0 |
| 12 | Phenol (mg/L) | 0.0475 | 0.0175 | 0.0175 | 0 | 0.002 | 23.75 | 8.75 | 8.75 | 0 |
| 13 | $S0_4^2$(mg/L) | 529.75 | 243.75 | 239.5 | 21.25 | 400 | 1.325 | 0.609 | 0.599 | 0.054 |
| 14 | Bicarbonate ($HCO_3^-$) | 4.79 | 5.47 | 6.34 | 0.97 | 0 | 4.79 | 5.47 | 6.34 | 0.97 |
| | | | | | | Total | 31.955 | 18.147 | 18.48924 | 3.25616 |

*Note: Loc. = Location
Location 1, Mkpanak river; Location 2, Iwuochang river; Location 3, Usung Ikim Ekeme river; Location 4, Ikot Akpan Abia river.

Table 2 shows the mean value of physicochemical parameters and pollution index of surface water sampled from the four locations in the study area. The pollution index of temperature level for location 1, 2,3 and 4 was respectively 0.071, 0.07, 0.07 and 0.071. The pH index for location 1, 2, 3 & 4 was 0.056, 0.061, 0.058 and 0.054 respectively. Total dissolved solid was 0, 0.007, 0.002 and 0.001 for location 1, 2, 3 and 4. Dissolved oxygen was 0.095, 0.106, 0.121 and 0.067 for location 1, 2, 3 and 4. Biological oxygen demand pollution index at the various locations was 0.052, 0.052, 0.051 and 0.052 for location 1, 2, 3 and 4. Turbidity was 0.025, 0.034, 0.023 and 0.005 for location 1, 2, 3 and 4. Total hardness was 0.004, 0.002, 0.002 and 0.002 for location 1, 2, 3 and 4. Nitrates and phosphates pollution indexing was 0 for location 1, 2, 3 and 4 respectively. Electrical conductivity was 0.002, 0.0055, 0.013 and 0.007 for location 1, 2, 3 and 4. Total suspended solid was 0, 0.009, 0.001 and 0 at location 1, 2, 3 and 4. Phenol compounds was 23.75, 8.75, 8.75 and 0 at location 1, 2, 3 and 4. Sulphate was 1.325, 0.609, 0.599 and 0.054 at location 1, 2, 3 and 4 respectively. The physico-chemical level of pollution indexing indicated that the surface water at Mkpanak river, Iwuochang river and Usung Ikim Ekeme river was very heavily polluted as a result of high concentration of phenol and sulphates. There was also significant difference in the pollution index of physicochemical elements between location 1 (Mkpanak river) 31.955, location 2 (Iwuochang river) 18.147, location 3 (Usung Ikim Ekeme river) 18.48924 and the control point, location 4 (Ikot Akpan Abia river) 3.25616. The concentration of nitrate and phosphate was above the WHO permissible limit. This implies that exploitation of hydrocarbon adversely affects surface water in the study area.

**Table 3:** Calculation of Heavy Metals Using Water Pollution Index

| S/N | Parameters | Mean values | | | | WHO Permissible limit | Metal Pollution Index (MPI) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Loc. 1 | Loc. 2 | Loc. 3 | Loc. 4 | | Loc. 1 | Loc. 2 | Loc. 3 | Loc. 4 |
| 1 | CU (mg/L) | 0.21 | 0.31 | 0.31 | 0.17 | 2 | 0.105 | 0.155 | 0.155 | 0.085 |
| 2 | Pb (mg/L) | 0.36 | 0.26 | 0.24 | 0.18 | 0.01 | 36 | 26 | 24 | 18 |
| 3 | Cd (mg/L) | 0.02 | 0.14 | 0.02 | 0.01 | 0.05 | 0.4 | 2.8 | 0.4 | 0.2 |
| 4 | Se (mg/L) | 0.09 | 0.06 | 0.05 | 0.06 | 0.01 | 9 | 6 | 5 | 6 |
| 5 | Ni (mg/L) | 0.14 | 0.62 | 0.41 | 0.14 | 0.05 | 2.8 | 12.4 | 8.2 | 2.8 |
| 6 | Mn(mg/L) | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 | 0.2 | 0.2 | 0.2 | 0.2 |
| 7 | Cr(mg/L) | 0.02 | 0.02 | 0.01 | 0.01 | 0.05 | 0.4 | 0.4 | 0.2 | 0.2 |
| 8 | Mg(mg/L) | BDL | BDL | BDL | BDL | | | | | |
| 9 | As(mg/L) | ND | ND | ND | ND | | | | | |
| | | | | | | Total | 48.91 | 47.96 | 38.16 | 27.49 |

*Note: Loc. = Location
Location 1, Mkpanak river; Location 2, Iwuochang; Location 3, Usung Ikim Ekeme; Location 4, Ikot Akpan Abia. BDL:Below Detection Limit, ND: Note Detectred.

Table 3 shows the mean value of heavy metals contents of surface water sampled from location 1 (Mkpanak river), location 2 (Iwuochang river), location 3 (Usung Ikim Ekeme river) and location 4 (Ikot Akpan Abia river) respectively. The concentration of copper contents in surface water was 0.21 mg/l, 0.31 mg/l, 0.31 mg/l and 0.17 mg/l for location 1, 2, 3 and 4. Lead was 0.36 mg/l, 0.26 mg/l, 0.24 mg/l and 0.18 mg/l for location 1, 2, 3 and 4. Cadmium was 0.02mg/l, 0.14 mg/l, 0.02

mg/l and 0.01 mg/l for location 1, 2, 3 and 4. Selenium was respectively 0.09 mg/l, 0.06 mg/l, 0.05 mg/l and 0.06 mg/l for location 1, 2, 3 and 4. Nickle was 0.14 mg/l, 0.62 mg/l, 0.41 mg/l and 0.14 mg/l for location 1, 2, 3 and 4. Manganese for location 1, 2, 3 and 4 was 0.01 mg/l for each location. Chromium was 0.02 mg/l, 0.02 mg/l, 0.01 mg/l and 0.01 mg/l for location 1, 2, 3 and 4 respectively. Mercury and arsenic was not detected in the surface water sampled.

Table 3 shows the pollution index mean value of heavy metals on surface water sampled from the four locations in the study area. The pollution index for copper was 0.105, 0.155, 0.155 and 0.085 for location 1, 2, 3 and 4 respectively. Lead was 36, 26, 24 and 18 for location 1, 2, 3 and 4. Cadmium was 0.4, 2.8, 0.4 and 0.2 for location 1, 2, 3 and 4. Selenium was 9, 6, 5 and 6 respectively for location 1, 2, 3 and 4. Nickle was 2.8, 12.4, 8.2 and 2.8 for location 1, 2, 3 and 4. Manganese pollution indexing for location 1, 2, 3 and 4 was 0.2 for each location. Chromium 0.4, 0.4, 0.2 and 0.2 for location 1, 2, 3 and 4 respectively. Mercury was below detection limit and arsenic was not detected in the surface water sampled. The heavy metals contents level of pollution indexing indicated that the surface water at Mkpanak river, Iwuochang river and Usung Ikim Ekeme river was very heavily polluted as a result of high concentration of bicarbonate, lead, selenium and nickel. The was also significant difference in the pollution index of heavy metal between location 1 (Mkpanak river) 48.91, location 2 (Iwuochang river) 47.96, location 3 (Usung Ikim Ekeme river) 38.16 and the control point location 4 (Ikot Akpan Abia river) 27.49. Every chemical element has a spectrum of possible effects on water. This spectrum can be altered when the set limit of an element is exceeded. General studies of gas flaring on surface water revealed high concentration of nickel and lead in surface water (Ahuchaogu, Ime & Ofose, 2019; Emumejaye, 2012). Gas flaring also alters water ions (especially sulphate, bicarbonate, nitrate), heavy metals (such as lead and iron), pH and conductivity concentration (Enetimi & Sylvester, 2017). This indicates that gas flaring can alter the spectrum of chemical element in surface water.

**Conclusion**

The study has shown that distance from the gas flare site or point of discharge of the gas flaring activities has substantial influence on physicochemical and heavy metals parameters in surface water. Surface water quality that are contiguous to the flare site were observed to have increased concentration of physicochemical and heavy metals concentrations. The pollution index indicated that the physicochemical and heavy metals contents level of surface water at Mkpanak river, Iwuochang river and Usung Ikim Ekeme river were very heavily polluted as a result of high concentration of bicarbonate, phenol, sulphate, lead, selenium and nickel.The was also significant difference in the pollution index of heavy metal between location 1 (Mkpanak river) 48.91, location 2 (Iwuochang river) 47.96, location 3 (Usung Ikim Ekeme river) 38.16 and the control point location 4 (Ikot Akpan Abia river) 27.49. There was also significant difference in the pollution index of physicochemical elements between location 1 (Mkpanak river) 31.955, location 2 (Iwuochang river) 18.147, location 3 (Usung Ikim Ekeme river) 18.48924 and the control point location 4 (Ikot Akpan Abia river) 3.25616. The spectrum of chemical element in surface water at Mkpanak river, Iwuochang river, Usung Ikim Ekeme river and Ikot Akpan Abia river was different. Gas faring in the study area has a significant negative effects on the surface water. The study therefore recommended constant monitory of the physicochemical and heavy metals contents level of surface water at Mkpanak river, Iwuochang river and Usung Ikim Ekeme river in Ibeno, Akwa Ibom State, Nigeria.

## References


Abua, M. A. & Ajake, O. A. (2014). Water quality status around animal dung in Adiabo River Catchments of Odukpani Local Government Area of Cross River State, Nigeria. *International Journal of Bioscience,* 4(4), 28-43.

Amadi, A. N. (2012). Quality assessment of Aba river using heavy metal pollution index, *American Journal of Basic and Applied Science,* 5(11), 763-770.

Amadi, A. N. (2014). Impact of gas flaring on the quality of rain water, groundwater and surface water in parts of eastern Niger Delta, Nigeria. *Journal of Geosciences and Geomatics,* 2 (3): 114-119.

Ahuchaogu. I. Israe, Ime Etim and Ofose. V. Etim (2019). Effects of gas flaring on surface water in Mkpanak community of Akwa Ibom State, Nigeria. *International Journal of Engineering Research & Technology.* Vol 8(9).

Akharume, P. (2001). The impact of gas flaring on building metrials. A paper presented at continuing professional development workshop organized by Akwa Ibom State Branch of Nigeria Institution of Estate Surveyors and Valuers, Uyo.

Caerio, S., Coasta, M. H., Rumos, T. B., Fernandes, F., Silverira, N., Coimbra, A. & Painho, M. (2005). Assessing heavy metals contamination in Sado estuary sediment: An index analysis of approach. *Ecological Indicators,* 5, 155-169.

Cohen, L. (1992). Power Primer. Psychological Bulletin, 112(1) 155-159.

Egwurugwu, J. N., Nwafor, A., Chinko, B. C., Olurunfemi, O. J., Iwuji, S. C & Nwankpa, P. (2013). Pro-long gas flaring on quality in Abiakpu Egbema, Imo State, Nigeria.

Ekpoh, I. J. (2002). Environmental Change and Management. Calabar. St. Pual's publishing Company.

Emumejaye, I. (2012). Effect of gas flaring on surface water and groundwater in Irvi town and environs. Niger Delta, Nigeria. IOSR *Journal of Environmental Science, Toxicology and Food Technology* (1) 5: 29-33.

Enetimi Idah Seiyaboh, Sylvester Chibueze Izah, (2017). A Review of Impacts of Gas Flaring on Vegetation and Water Resources in the Niger Delta Region of Nigeria, *International Journal of Economy, Energy and Environment*. Vol. 2(4), pp. 48-55. doi: 10.11648/j.ijeee.20170204.11.

Iwara, A. I., Njar, G. N., Deekor, T. N. & Ita, A. E. (2012). Effect of Adiabor abattoir on the water quality status of Calabar River in Odukpani, Cross River State, Nigeria. *Continental J. Environmental Sciences,* 6(2): 36-43.

National Environmental Surface and Ground Water Quality Control Regulation (2011). The National Environmental Surface and Ground Water Quality Control Regulation. *Federal Republic of Nigeria Official Gazette*. No. 49. Vol. 98.: pp, 693-727.

Nwankwo, C. N. & Ogagarue, D. O. (2011). Effect of gas flaring on surface and ground water in Delta State. *Journal of Geology and Mining Research* 3(5): 131-136.

Obioh, I. B. (1999). Environmental Impact Assessment of emission from major Facilities at QIT: Atmospheric Emission and Dispersion Modelling. Report submitted to Faithlink Consults Nigeria Ltd; Port-Harcourt, Rivers State, Nigeria.

Seiyaboh, E. I. & Izah, S. C. (2017). A review of impacts of gas flaring on vegetation and water resources in Niger Delta Region of Nigeria. *International Journal of Economy, Energy and Environment,* 2 (4): 48-55.

World Health Organization (WHO) (2001). WHO guidelines for drinking water quality, 4th ed. World Health Organization, Switzerland, ISBN 9789241548151.

World Health Organization (WHO) (2011). WHO guidelines for drinking water quality, 4th ed. World Health Organization, Geneva, pp 219-229.

Appendix 1

| PhysiceChemical Parameters of Water Samples from the Study Area | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Parameters | Location 1 Mkpanak | | | | Location2 Iwuochang | | | | Loaction 3 Usung Ikim Ekeme | | | | Location 4 Ikkot Akpan Abia (Control sample) | | | |
| | | Sample 1 | sample 2 | Sample 3 | sample 4 | sample 1 | sample 2 | sample 3 | sample 4 | sample 1 | sample 2 | sample 3 | Sample 4 | sample 1 | sample 2 | sample 3 | sample 4 |
| 1 | Temperature ($^0$C) | 27.2 | 27.3 | 27.1 | 27.2 | 26.9 | 26.9 | 26.9 | 27 | 26.9 | 27.1 | 26.9 | 27.1 | 27 | 27.6 | 27.3 | 27.5 |
| 2 | Ph | 5.9 | 5.88 | 5.5 | 5.76 | 6.74 | 5.73 | 6.2 | 6.35 | 5.46 | 5.86 | 6.44 | 5.99 | 5.65 | 5.5 | 5.46 | 5.58 |
| 3 | TDS (mg/L) | 3.366 | 3.084 | 3.336 | 3.355 | 103.38 | 109.3 | 72.42 | 88.09 | 19.56 | 20.22 | 21.84 | 22.12 | 10.374 | 10.59 | 10.968 | 10.99 |
| 4 | DO (mg/L) | 12.6 | 10.8 | 11.3 | 12.4 | 10.9 | 15.8 | 12.4 | 13.5 | 16.1 | 16.5 | 13.1 | 14.3 | 8.2 | 8 | 9.2 | 8.8 |
| 5 | BOD (mg/L) | 7.11 | 7.15 | 7.03 | 7.19 | 7.16 | 7.07 | 7.19 | 7.14 | 7.09 | 7.02 | 6.79 | 7.14 | 7.06 | 7.12 | 7.1 | 7.09 |
| 6 | Turbidity NTU | 7.12 | 13.6 | 4.65 | 9.47 | 10.9 | 12.2 | 11.5 | 11.8 | 7.17 | 7.87 | 8.04 | 8.12 | 1.97 | 1.89 | 1.86 | 1.64 |
| 7 | Total hardness (mg/L) | 34.2 | 17.1 | 34.2 | 31.6 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 |
| 8 | Nitrates (mg/L) | 0.04 | 0.06 | 0.03 | 0.05 | 0.02 | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.05 | 0.07 | 0.03 | 0.04 |
| 9 | Phosphates (mg/L) | 0.87 | 0.4 | 0.39 | 0.3 | 0.7 | 0.67 | 0.68 | 0.66 | 0.75 | 0.81 | 0.71 | 0.73 | 0.18 | 0.22 | 0.18 | 0.21 |
| 10 | EC (us/cm) | 5.61 | 5.14 | 5.56 | 5.49 | 172.3 | 182.2 | 120.7 | 130.3 | 32.6 | 33.7 | 36.4 | 37.4 | 17.29 | 17.65 | 18.28 | 18.76 |
| 11 | TSS (mg/L) | 0.1 | 0.12 | 0.1 | 0.11 | 10.012 | 0.01 | 0.1 | 0.12 | 0.7 | 0.1 | 0.1 | 0.2 | 0.008 | ND | ND | ND |
| 12 | Phenol ($C_6H_5OH$) (mg/L) | 0.05 | 0.04 | 0.05 | 0.05 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | ND | ND | ND | ND |
| 13 | Sulphate ($SO_4$) (mg/L) | 502 | 560 | 507 | 550 | 240 | 240 | 243 | 248 | 237 | 236 | 245 | 240 | 21 | 24 | 20 | 20 |
| 14 | Bicarbonate ($HCO_3^-$) | 4.56 | 4.57 | 4.67 | 4.56 | 5.45 | 5.49 | 5.48 | 5.45 | 6.34 | 6.34 | 6.34 | 6.34 | 0.97 | 0.97 | 0.97 | 0.97 |
| | **Heavy Metals Concentrations of Water Samples from the Study Area in (mg/L)** | | | | | | | | | | | | | | | | |
| 15 | Copper CU (mg/L) | 0.22 | 0.19 | 0.2 | 0.21 | 0.31 | 0.33 | 0.29 | 0.3 | 0.31 | 0.29 | 0.3 | 0.32 | 0.11 | 0.14 | 0.2 | 0.22 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | Lead Pb (mg/L) | 0.28 | 0.36 | 0.25 | 0.29 | 0.2 | 0.21 | 0.3 | 0.32 | 0.2 | 0.18 | 0.29 | 0.27 | 0.16 | 0.19 | 0.19 | 0.18 |
| 17 | Cadmium Cd (mg/L) | 0.021 | 0.016 | 0.019 | 0.018 | 0.12 | 0.15 | 0.14 | 0.13 | 0.011 | 0.03 | 0.01 | 0.02 | 0.017 | 0.013 | 0.011 | 0.014 |
| 18 | Selenium Se (mg/L) | 0.1 | 0.1 | 0.08 | 0.09 | 0.06 | 0.05 | 0.05 | 0.06 | 0.03 | 0.05 | 0.06 | 0.06 | ND | 0.06 | 0.1 | 0.09 |
| 19 | Mercury (Hg) | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL |
| 20 | Nickle Ni (mg/L) | 0.059 | 0.36 | 0.068 | 0.074 | 0.38 | 0.73 | 0.69 | 0.66 | 0.56 | 0.066 | 0.51 | 0.49 | 0.059 | 0.36 | 0.068 | 0.061 |
| 21 | Arsenic (As) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 22 | Manganese Mn (mg/L) | 0.1 | <0.1 | <0.1 | 0.1 | 0.1 | <0.1 | 0.1 | <0.1 | 0.1 | 0.1 | 0.1 | 0.1 | <0.1 | 0.1 | <0.1 | 0.1 |
| 23 | Chromium (mg/L) | 0.019 | 0.021 | 0.016 | 0.017 | 0.013 | 0.017 | 0.014 | 0.016 | 0.013 | 0.016 | 0.011 | 0.012 | 0.01 | 0.012 | 0.011 | 0.012 |

**Note**: ND = Not detected, BDL= Below detection level

# CHARCOAL ENERGY CONSUMPTION PATTERN IN URBAN HOUSEHOLDS OF FCT ABUJA, NIGERIA

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***Abstract***

*This paper considers those factors contributing to charcoal consumption in the urban households in capital city of Nigeria using in-house questionnaire data collection from ninety households. Thirty households each from three study areas namely; Maintama, Garki and Kubwa, mapped out in three categories based on building designs; duplex houses, Terrence/flat apartment and bungalows, and demographic information like (marital statues, income, education and employment). The results shows that duplex and bungalows house designs consumes more of charcoal 39% and 51% respectively than 10% of terrence/flat apartment, same with married and high and low income earners which shows that charcoal consumption rates were higher for the households with more family members, high/low income and cooking frequency. This study shows the relevancy of charcoal in the urban area, also that income is an important variable and this study also suggest need for other variables like food choice, cost of living, household size and preference, same time recommend policies and means to address this charcoal consumption that poses great threats to our forest reserves which serves as carbon storage, water, air purification and also reduces the intensity of flooding events.*

**Keywords:** Charcoal, House designs, Consumption rate.

## 1. Introduction

Charcoal remains a dominant energy source in the developing world in both rural and urban areas and over 2 billion people in developing countries are still mainly dependent on charcoal for cooking and heating (FOA, 2010). In Africa around 90% of the population use charcoal for cooking, in the equivalent amount of roughly 1.5 tons of oil per family per year (Anderson and Dennis, 1984). Charcoal accounts for more than 75 percent of the energy used in countries such as Nepal, Bangladesh, Ethiopia, Burkina Faso, and even oil-rich Nigeria.Consumption of charcoal energy by households is ten times the total consumption of commercial energy for all purposes like; transport and electricity generation in low income countries and in Nigeria alone it is double of the total with annual rate of consumption estimated to have exceed the annual rate of additions to supply through the growth of trees. In Senegal urban areas account for roughly 30% and a rising share of consumption and in Nigeria about 40% of the urban population use charcoal, but yet lower income countries the percentage is much greater. (Fishwick et al, 1983)

## Drivers of Charcoal Energy Consumption

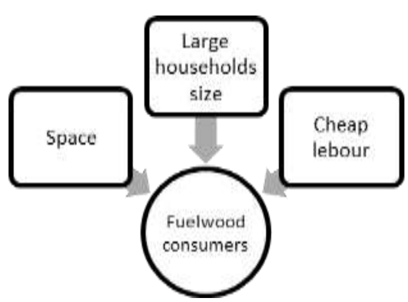
The primary drivers to total energy consumption in the household sector are population size and levels of household income. The agro-ecological situation also influences the total energy consumption same with socio-cultural factors and also determine why energy consumption differs from place to place like households in temperate regions use more wood for cooking and space heating (FAO, 2007). Data from Pakistan World Bank/ESMAP and UNDP (1993) showed that around 60 % of fuelwood used in the country are gathered while data from the Philippines World Bank/ESMAP, (1991) gave an estimate of about 78% for that country. It must be noted that in both countries, there are households which both gather and buy the wood they use.

The most preferred way to explain fuel choice of households is with energy ladder theory which stated that increase/improvement of socio-economic conditions like household incomes and cleanliness of the energy source increases according to the energy ladder and process incorporates a three stage energy transition (Leach 1992).Total dependence on biomass is the first stage, followed by dependence on fuelwood, coal and kerosene and finally dependence on LPG (liquefied petroleum gas), natural gas and electricity(Leach 1992). The Energy Ladder also shows a typical increase in cleanliness, convenience, efficiency and cost as the household income increases (van Ruijven et al. 2008). Analysis of energy with this model gives some practical idea on how a national energy policy can be designed using the economic framework of households (Dewees 1989).

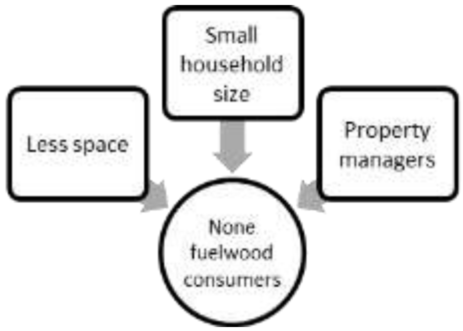
## Relationship Between House Designs on Charcoal Consumption.

According City of San Diego General Plan (2008), urban design describes the physical features that define the character or image of a street, neighborhood, community, or the City as a whole, the visual and sensory relationship between people, the built and natural environment, includes buildings and streets, and the natural environment. In Myanmar the per capita firewood consumption rates were higher for the households with less family members, more income and more cooking frequency (Zar Chi Win et al., 2018). According to property Proinsider (2020), there are three major house designs in Nigeria and each determines the household size and recommended energy consumption namely; duplex houses, Terrence/flat apartment and bungalows.

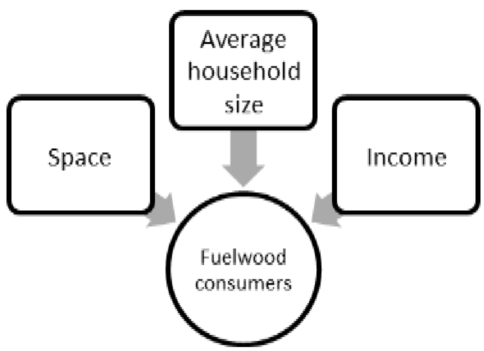
***Duplex houses:*** These are stacked apartments on two different floors which often look either two houses put together or a large single houses sharing a wall between halves and some with three or four housing units or floors are called triplex or fourplex and mostly owned by the occupants. This designs mostly found in highbrow areas within the study areas and it supports fuelwood energy cooking driving by some circumstances like space within the compound, large household size; which comprises relatives and love once in the African cultural settings and lastly the cheap labour (cost employing maids with cheap salaries), and all these combined are the main drivers that makes residence of these house designs to engage charcoal cooking energy.



**Terraced/Flat Apartment:** These are line houses which are identical and placed directly onto each other built with shared walls between them with uniform frontage, while flat apartment are those self contained housing unit all in same large building with several units which can come with 1 to 4 bedroom space but predominantly 1 to 3 bedrooms and mostly on rent by the occupants. This particular design does not support charcoal energy usage due to some circumstances like less space, small household size and property managers that won’t allow the usage of charcoal.




**Bungalows:** These are a single storey houses without basement that comes in detached or semi detached; detached ones stands alone and shares no wall with any other structures, while semi detached are linked together by a common walls. This design also support charcoal energy cooking due to some circumstances like space, average household size and income; for most occupants are average or low income earners.




A research on Consumption Rates and Use Patterns of Firewood and Charcoal in Urban and Rural Communities in Yedashe Township, Myanmar which considered the the annual household income ranged from US$720 to $24,000; the average annual income was $4338 ± $460 and household size. The main livelihood activities were government work, agricultural work, self-employment, physical labor, and others; those categories accounted for 19.7%, 3.0%, 56.1%, 16.7%, and 4.5%, respectively, of households, support the claim that households size determines the amount of charcoal consumption (Zar Chi Win et al., 2018)

**Impacts of Charcoal Consumption on Forest reserves and Environment**

When evaluating the impact of charcoal consumption on forests with choice size of wood (>10 cm in diameter) and species of trees used it shows that 61.2% of the fuelwood consumed are forest derived green and much higher than rural area with 16.1% (Zar Chi Win et al., 2018). Based on estimate 69.1% of total charcoal consumed in the urban area were bought from charcoal producers who tend to cut living trees in forests. When compare the amount of charcoal consumption, it shows that the impact of the household use of firewood on forests was greater in the urban than in the rural area (Zar Chi Win et al., 2018)

Charcoal production alone contributes highly to forest degradation, biodiversity loss and environmental degradation (Emeodilichi, 2018). In Tanzania, charcoal production is said to be responsible for the loss of 150433 *ha* of forest annually that contributes to the lose of about 2.8 million hectares of forest in providing charcoal to the city of Dar es Salaam alone between 2010 and 2030 (Msuya *et al.*, 2011). Rembold *et al.* (2013) observed that for the period between 2006 and 2012, 7.2 % of tree cover in Somalia was harvested for charcoal production, and Bolognesi *et al.* (2015) also observed a 2.7 % loss in tree cover in Somalia for the period between 2011 and 2013. This most likely will continue unless the perceived illegality associated with charcoal are addressed by institutions mandated to manage and that is why World Bank (2011) proclaimed that it is the attitude of the people that must change and observed that many poor countries have rich natural capital in the form of forests, but continuous poverty scourge contributed to the failure of utilizing these resources and the enhancement are not mutually exclusive.

Charcoal involves felling down of trees and subsequent removal of vegetation cover that leads to loss of biodiversity, these tree removal results in alteration of plant community structures, distribution of different species and plant density (Kgathi *et al*., 1997). Disruption of essential ecological processes is associated with accelerated and irreplaceable depletion of genes, populations, species and ecosystems (Jacobs, 1988).Forestry or trees are endowed with important ecological benefits including soil erosion control, catchment protection and wildlife conservation (O‟keefe, 1979).

According to Bailis (2005) charcoal production activities alone can lead to:

- Reduced biodiversity as a result of deforestation and forest degradation. When forest cover is removed, wildlife is deprived of habitat and becomes more vulnerable to hunting.
- Deforestation causes 15% of global greenhouse gas emissions. Carbon dioxide emissions represent up to one-third of total carbon dioxide emissions released because of human causes.
- Disrupted water cycles as a result of deforestation, trees no longer evaporate groundwater, which can cause the local climate to be much drier.
- Increased soil erosion as deforestation accelerates the rate of soil erosion, by increasing runoff and reducing the protection of the soil from tree litter.
- Disruption of livelihoods as millions of people relies directly on forests, through small scale agriculture, hunting and gathering, and by harvesting forest products such as rubber.
- Deforestation continues to pose severe social problems, sometimes leading to violent conflict.

The global wood production in 2000 reached approximately 3.9 billion $m^3$ whereby 2.3 billion $m^3$ was used as charcoal implying that approximately 60% of world’s total wood removals from forest and trees are used for energy purpose (FAO, 2008). The global projection of consumption of charcoal by 2010 ranged from 1.5 billion $m^3$ to 4.25 billion $m^3$ (Brooks, 1996). In Africa over 90% of the wood taken from forest is charcoal. The majority is of wood is consumed as charcoal, however, a varying but significant amount is transformed into charcoal. More than 80% of the charcoal is consumed in urban areas making charcoal the most important source of household energy in many Africa cities (Siedel, 2008). There will be a greater demand for charcoal by the year 2030 in Africa and shortage in its supply (Ekpo & Mba, 2020)

## 2. Material and Methodology

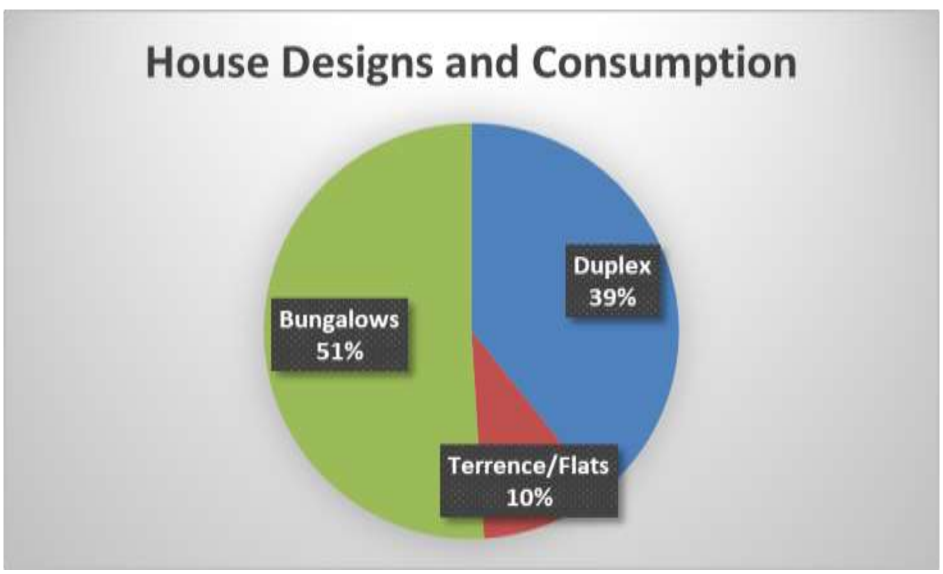
This study was conducted in Abuja, located in the center of Nigeria and has a land area of 8,000 square Kilometers. It is bounded on the north by Kaduna state, on the west by Niger state, on the east and south-east by Nasarawa state and on the south-west by Kogi state. It falls within latitude 7 45' and 7 39'. This three type of waste-water management described above are been practiced in different parts of the city but this paper tried to determine which is more sustainable to the environment and vegetation. Three locations was selected based on house designs and quantitative and qualitative mode of inquiries was used to explore this urban charcoal consumption patterns in the selected areas namely; Maintaima, Gark and Kubwa.

Primary and secondary source through in-house survey and interviews with selected 30 households each from the three locations. Households selected are family residence in highbrow, middle class and densely populated lower class area and other information's was accessed through review of relevant texts, journals, newspapers, official publications, magazines and internet which served as tangible source of insight into waste-water management.

In - house survey questionnaire method was employed in the study areas to determine which of the households that makes use of charcoal, how often they cooks with charcoal, reason why they cook with charcoal and family size. The respondents home was visited in two intervals rainy and dry (July to December), for more insight records from the respondents.

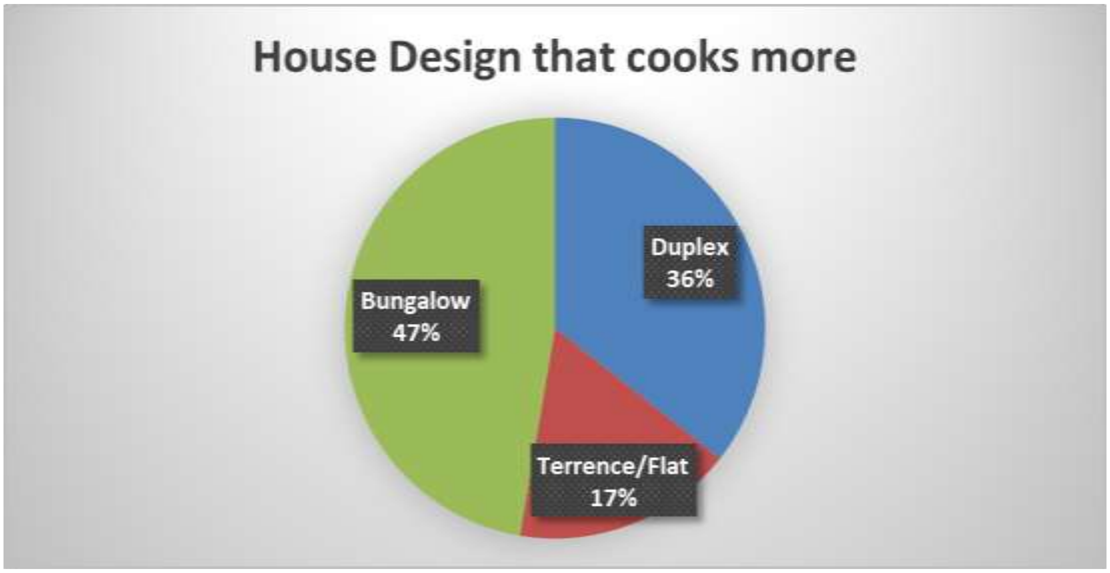
**3. Results and Discussion.**

House design that consumes more charcoal according house designs areas.



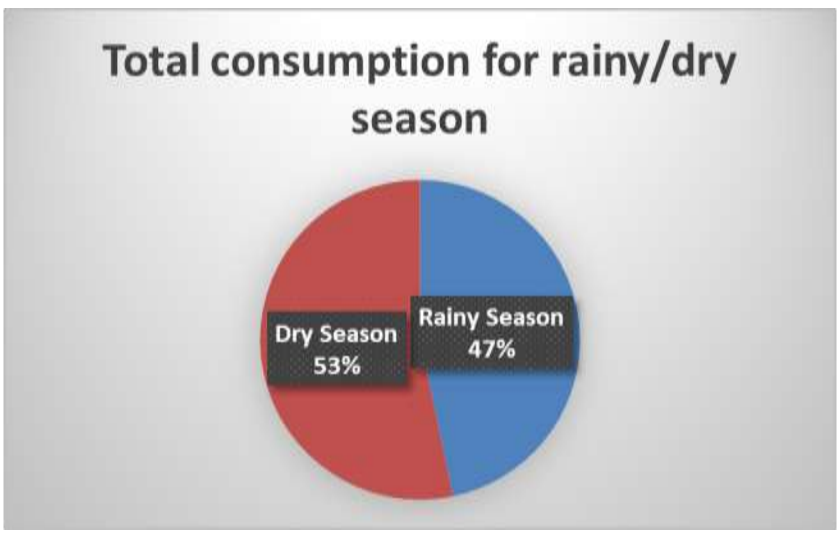

From the diagram above, bungalow and duplex households consumes more with 51% and 39% respectively compare to 10% of terrence/flats households and there are factors contributing to this like; Low income, high cost of LPG, family size, dish choice.

Households that cooks more often among the 3 house designs.




From the diagram above, bungalow and duplex households cooks more often 47% and 36% respectively more than the terrence/flat household, factors contributed it like low income, family size.

Consumption during rainy and dry season




The diagram above shows that households tends to make use of charcoal more during dry season more than rainy season reason because of space, for most charcoal users cooks outside the house in an open space and once it rains it will not be possible to make the charcoal fire and that is why LPG sells more during raining season more than dry season.

**4. Recommendation and Conclusion**

Solutions to urban charcoal energy consumption challenges in Nigeria cities are through awareness, subsidizing of LPG, careful choice of priorities, prudent forest management and getting involve the private sectors, combined with proactive actions and policies.

Public should focus more in creating enabling environment by engaging on tree planting not only in the forest but within our environs while government should be to facilitate, support and make those basic amenities easy to access also leverage the strength of the stakeholders to create policies with significant outreach at maximum efficient with less burden on the public resources. Contribution of the public sector, NGO, global partnerships, research and academics communities discovering the best means of cooking with less consumption of this charcoal that have a direct impact to our forest.

**Reference**

FAO (2010c) What Woodfuels can do to Mitigate Climate Change? FAO Forestry Paper 162. FAO, Rome.

Anderson and Dennis, 1984 Fuelwood consumption and deforestation in African countries.

Fishwick, R. and F. Weber (1983). "Shelterbelt Establishment in the Drylands of West Africa." In Environmental Change in the West African Sahel, National Academy Press.

FAO (2007). Definitional issues related to reducing emissions from deforestation in developing countries. Forests and Climate Change Working Paper 5, Food and Agriculture Organization of the United Nations, Rome, 2007.

Clean Cooking Initiatives Supported by the World Bank and the Energy Sector Management Assistance Program (ESMAP) World Bank/ESMAP and UNDP (2013)

GeraldLeach )1992). The energy transition.

Bas J van Ruijven, Frauke Urban, Rene Benders, Detlef P. van Vuuren (2008) Modeling Energy and Development: An Evaluation of Models and Concepts World Development 36(12):2801-2821DOI: 10.1016/j.worlddev.2008.01.011

Dewees (1989). The woodfuel crisis reconsidered: Observations on the dynamics of abundance and scarcity

City of San Diego General Plan (2008), urban design

Consumption Rates and Use Patterns of Firewood and Charcoal in Urban and Rural Communities in Yedashe Township, Myanmar Zar Chi Win 1,2, Nobuya Mizoue 3,* ID , Tetsuji Ota 4 , Tsuyoshi Kajisa 5 and Shigejiro Yoshida, 2018

Property Proinsider (2020)

Emeodilichi H. Mba, (2018) Assessment of charcoal production process and the environmental impact in Kaduna, Nigeria.

Neema Msuya, Enock Masanja, Abraham Temu., (2011). Environmental Burden of Charcoal Production and Use in Dar es Salaam, Tanzania

M.Bolognesiab, A.Vrielingb, F.Remboldc, H.Gadaina (2015). Rapid mapping and impact estimation of illegal charcoal production in southern Somalia based on WorldView-1 imagery

Kgathi, D. L. ; Mlotshwa, C. V. (1997). Fuelwood procurement, consumption and substitution in selected areas of Botswana.

O‟keefe, P.P and Bernow, S. (1984). Energy Environment and Development in Africa: Energy Development in kenya: Opportunities and Constraints. Stockholm. Beijer institute press.

Bailis, R., Ezzati, M. and Kammen, D. M. (2005). Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa. Science, 308: 98 – 103.

FAO (2008). Industrial Charcoal Production. Domac J. & Trossero M. (eds.). TCP/CRO/3101 (A) Development of a sustainable charcoal industry. Zagreb, Croatia.

(Emily, 2001).

Seidel A. (2008). Charcoal in Africa, Importance, Problems and Possible Strategies. GTZ.

A.S. Ekpo & E. H. Mba., (2020). Assessment of commercial charcola production effect on woodland of Nasarawa state, Nigeria.

# CONSEQUENCES OF REFUSE DISPOSAL ON DRAINAGE SYSTEMS IN CALABAR SOUTH LOCAL GOVERNMENT AREA, CROSS RIVER STATE

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**Abstract**

*This study examined the consequences of refuse disposal in Calabar South Local Government Area of Cross River State, Nigeria. This study targeted staff of the Cross Rivers Urban Development Agency (CUDA) and heads of households within Calabar South for sampling. Seven major streets were selected for sampling based on population density and the large amounts of waste generated. The streets comprised Palm Street, Main Avenue, Goldie Street, Afokang Street, Edibe Street, New Airport Street and Hawkins road. The research used a table of random numbers to conveniently select 30 households from each street, which amounted to 210 households. Heads of households irrespective of gender constituted the respondents for this study. Data collection was by means of reconnaissance survey of the study area, taking of photographs using digital camera, key informant interviews on CUDA officials and questionnaire administration on heads of households. The research employed a survey approach, and a simple percentage that was used to analyzed the questionnaire with photographs that provided a qualitative analysis. The study revealed that, dumping of refuse on drainage pathways has effect on the environment and man. however, the research recommend that waste management agencies should always embark on awareness programs, provision of bigger waste bins should be made available and located close to residents, more funds should be allocated to waste management agencies*.

**Keywords:** Domestic waste management, refuse disposal, drainage system, Calabar South Nigeria, household hazardous wastes (HHW)

## Introduction

Waste generation and management in most cities of the world, especially in developing countries have become one of the stubborn environmental issues.Population growth due to urbanization, industrialization and rising living standards has been identified as the main cause of the rise in waste generation (Barteling, 2003; Ndum, 2013). Feasibly, the most noteworthy characteristic of solid waste is their variety. Household solid waste could be seen as; food scraps, old newspapers, cans, wood, old appliances, tires, worn out furniture, clothes, broken toys, plastics and a host of other items two numerous to mention, (Marchettini, Ridolfi, & Rustici, 2007).Thus, Dar (2017) pointed to studies that show how waste generation is proportional to population that a population of 100,000 has a per capita waste generation capacity of 0.21kg per day, a population of 200,000 has 0.42kg per day and a population of more than 5 million generates 0.5kg per day per capita (or over 20,000 tons per annum). This makes waste management an issue globally despite the giant strides in terms of new technologies in waste management achieved by developed countries of the world. In developed parts of the world such as the United States, France and Germany for instance, waste management has reached an advance stage of what is called “integrated waste management”, which according to Environmental Protection Agency (EPA) in 2002 “is a comprehensive waste prevention, recycling, composting and disposal program". The waste management hierarchy designed by EPA in 2017 is shown in Figure 1.

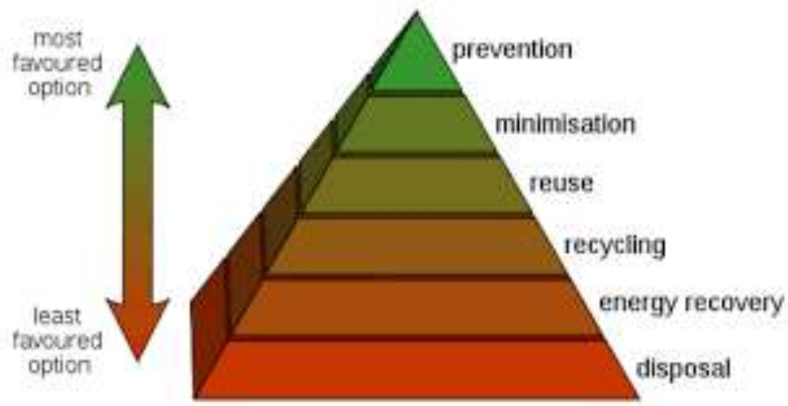


**Fig. 1:** Waste Management Hierarchy

For the developing parts of the world comprising South America, Asia and Africa, waste generation is a problem that can be attributed to the little or low level of technology involved in addressing generation of waste (Wilson, 2007). Artisans, roadside mechanics, mason, tailors, carpenters, welders etc. engage in the practice of dumping and abandoning of wastes in gutters or by roadside, thereby constituting a threat to the quality of the environment, and this practice is usually said to be responsible to urban waste generation.

In Nigeria, the challenge of urban waste managements is over whelming that they have almost defied realistic monetary and social costing (Lucas, 2006). The deterioration of Nigerian urban environment in terms of irresponsibly dumped and accumulated solid wastes in and around drainage systems is most apparent in our growing cities today(Anana, 2006). Most studies on waste management in Nigeria (Imam, 2008; Taiwo, 2009; Oyeniyi, 2011; Gakungu et al, 2012; Ogundele et al, 2019; Jahknwa et al, 2019) have shown that issues of poor funding, poor regulatory framework, absence of synergy between the formal and informal actors in waste management and the capital intensiveness of the adoption and integration of technology driven waste management practices has undermined progress in waste management.

Today's modern life in which foods and drinks are packaged in cans and plastics has reflected itself in our daily pattern of consumption and on how we discard these wastes. Refuse dumps are commonly seen on roadsides, on drainage pathways, mostly litters on open spaces, and market places. Residential locations are not exception where you commonly see auto scrap dumped anywhere within the city, and according to Uchegbu, (2002)and Ezekiel, (2001) all these practices accounts for the present aesthetic disaster in some parts of the city. Statutorily, waste management is the responsibility of the Local Government Authority as established in the 1979 constitution. However, in Calabar South, solid waste presents many faceted problems. Disposal of trash in and around drainage systems within the area creates litter, accumulations of cans on streets attracts rodents, roaches, flies and mosquitoes that portends public health risks. Continuous open defecation on the drainage pathways within the city has resulted in bad odor. All these uncontrolled and uncultured refuse disposal practices is capable of stimulating bacterial growth and collection numerous consequences.

Although, the Government at the localandstate levels has establishedthe Calabar Urban Development Authority (CUDA), an agency saddled with the responsibility of general urban planning and waste management for a friendly and clean environment, yet waste management remains a problem that poses an aesthetic disaster threat to the environment. This even made researchers to observed that; "In recent times, the quality of life in Calabar South Local Government Area has become diminished by uncontrolled and poorly managed solid waste, culminating into a serious environmental pollution, in the area, (Asuquo, 1997; Bisong&Ajake, 2001). Calabar South is one of the cities in Nigeria that has solid waste management problem as indicated by inappropriate dumping of refuse in different locations of the Calabar South axis (Olaniran, Akpan, Ikpeme,& Udofia; 1995).

Observation reveals that in Calabar south, many households dispose of their refuse anywhere and anyhow throughout the urban centers without considering the effects. These blocks gutters and drainage systems in the area, thereby obstructing the free flow of water after rain fall. Thus, despite the existence of a waste management regulatory framework which gave birth to a waste management agency in Cross Rivers State, yet waste management problem has continued to linger. Consequently, this research objectively examined waste management issues in terms of the level of indiscriminate dumping of refuse in drainage pathways and its impact on the environment. It further investigated the level of involvement of communities in policy formulation, implementation and evaluation, and the capacity of the waste management agency and how private sector participation affects waste management in the study area.

## Materials and Methods

This study **was** conducted in January of 2021. Calabar South is located at the Southern part of Cross River State, within latitudes 4°37'N and 4°40'N and longitudes 8°90'E and 8°12'E of the Greenwich Meridian. It is bounded by Calabar municipality in the North and the coastal fringes of the Atlantic Ocean in the South (Figure 1).The national population commission of Nigeria reported a population figure of 191,630, in 2006.

Accordingly, this study targeted staff of the Cross Rivers Urban Development Agency (CUDA) and heads of households within Calabar South for sampling (Figure 1). Seven major streets were selected for sampling based on population density and the large amounts of waste generated. The streets comprised Palm Street, Main Avenue, Goldie Street, Afokang Street, Edibe Street, New Airport Street and Howkins road (Figure 2). The research used a table of random numbers to conveniently select 30 households from each street, which amounted to 210 households. Heads of households irrespective of gender constituted the responds for this study. Given the cosmopolitan nature of the study area with its proximity to the University of Calabar campus, houses offering accommodation to students were not left out in the sampling exercise. The instrument of data collection was a questionnaire developed to get respondents opinion on waste management in the study area. Data collection was guided by the checklist method in Tong et al (2007). All the authors of this study comprised members of the survey team for this study. Data collection was by means of reconnaissance survey of the study area, taking of photographs using digital camera, key informant interviews on CUDA officials and questionnaire administration on heads of households.

The research employed a survey approach, and a simple percentage that was used to analyzed the questionnaire while photographs provide the qualitative analysis.


**Fig. 1:** Calabar South Municipality


**Fig. 2:** Road Networks of Calabar South Municipality

**Result from Key Informants**

The key informant interviews were based on ten (10) questions aimed at gauging the capacity of the government at both the local government level through the Cross Rivers Urban Development Agency in the adequate management of wastes generated in Calabar South municipal. This is representative of a scale where a score range of 1-3 indicates poor/dismal capacity; 4-6 indicates average/satisfactory capacity and 7-10 indicates a good/adequate capacity.

Two key informants were identified and interviewed in the Cross Rivers Urban Development Agency. The interviews reveal the following:

On the question of the existence of an environmental monitoring and sanitation unit, all respondents answered in the affirmative. It further reveals that the unit is saddled with the responsibility of monitoring all sanitation units within the municipal. Their capacity is however undermined by the poor logistics and manpower.

On the question of the existence of a waste disposal and facilities management unit, all respondents also answered in the affirmative. They further reveal that the unit has the responsibility of ensuring wastes are evacuated from units in each street to the landfill and also manage the maintenance of waste disposal facilities. The existence of operational machinery for the evacuation of bins from community sites to a provisional landfill will definitely require a department for the maintenance of such. This presents the indispensable need for such a department.

On the question of the existence of a waste logistic unit saddled with ensuring the provision of all logistics to departments in the agency, respondents answered in the affirmative. They however, lamented on the lack of adequate funds that would ensure the adequate provision of requisite logistics to departments in the agency, which undermines goals attainment.

On the question of a commodity trading responsible for ensuring “waste to wealth” practices in the waste management value chain, the respondents answered in the negative. This indicates that CUDA does not have the capacity of processing waste for wealth generation at the moment. It also means that the immediate communities have not been enlightened of how they can reduce waste generation by processing some types of wastes for other purposes.

On the question of the existence of a solid waste treatment unit responsible for the treatment of the two main types of wastes, the respondents answered in the negative. This indicates that the Agency has of yet no capacity for solid waste treatment.

Similarly, on the question of the existence of a liquid waste treatment unit responsible for the treatment of the two main types of wastes, the respondents answered in the negative. This indicates that the Agency has of yet no capacity for liquid waste treatment.

In terms of the existence for resource recovery from wastes generated in the municipal via either recycling and/or metal recovery, the respondents also answered in the negative. This suggest that there is no provision for resource recovery in Calabar, and if and where there is, then it is carried out illegally, as there is no regulatory provision yet for it.

With respect to the question of the existence of a department for technical services especially in terms of waste classification per weight per capita and research and development, the respondents answered in the affirmative. This suggests that despite the creation of such a department for future research and policy making decisions, yet it is non-functional for lack of political will.

On the question of the existence of a department for on-site services in terms of waste minimization, the respondents answered in the negative. This suggests that the Agency has not envisioned the need for waste minimization in the study area.

On the question of the existence of a department for legal compliance with respect to local laws and regulations for waste management especially in terms of reporting, the respondents answered in the positive. This indicates that there is a reporting feedback for persons engaging in unwholesome practices with respect to waste management.

Furthermore, the interview also revealed that CUDA as a waste management agency though has a landfill for waste management where open air burning activities take place with known possible negative consequences on the ozone layer, it is deficient in the provision of the following:

i. A recycling program for waste;
ii. A waste to energy program;
iii. A waste treatment program in terms of composting, anaerobic digestion, bioreactor landfills, controlled dumps, sanitary landfills, incineration, gasification and pyrolysis;
iv. Gas collection system;
v. Leachate collection system;
vi. Engineered linear system;
vii. Online presence for information on waste management.

There is however, the following:

i. A payment system for garbage collection;
ii. The involvement of private individuals and companies in the waste management system;
iii. There is synergy at the most basic level between CUDA as a regulatory agency and private waste management actors;
iv. There is a provision for a database for the types and quantities of wastes generated.

Thus, going by the scale, result show that Calabar has a score of 5. This suggests that the Agency is rated to have an average/satisfactory capacity in waste management disposal despite the absence of provisions for recycling and recovery. With the requisite basic framework in place, all that is required for the optimal activation and delivery of waste management services is adequate funding and capacity building for a technology oriented but capital intensive services.

**Result from Household Survey**

**Prevailing Waste Management Practices**

The result on prevailing waste management practices carried out by respondents is presented in Table 1-3. Table 1 is on household perception of waste disposal practices, Table 2 on prevailing points of indiscriminate waste disposal methods and Table 3 is on Perception of the implication of indiscriminate waste disposal practices.

Table 1: Households waste disposal practices

| S/n | Question | Percentage |
|---|---|---|
| 1 | Do you dump refuse in drainage systems | 91.2 |
| 2 | Rise in the level of refuse in drainage | 92.1 |
| 3 | Transport to point of disposal | |
| | By adults | 36.0 |
| | By children | 60.1 |
| | By hired helps | 9.6 |
| | Others | 0.9 |
| 4 | Causes of improper waste disposal | |
| | Far dumpsite | 22.8 |
| | No dumpsite | 39.5 |
| | Dumpsites are too dirty | 9.2 |
| | Not aware of public dumpsites | 28.5 |
| | Total | 100% |

Source: Fieldwork (2021)

Table 1 shows that almost all households sampled engage in the dumping of wastes (solid or liquid) in the most proximate drainage system or open space readily available. This is without a doubt a sure means of spread of germs and thus presents a public health risk. The table also reveals that households are well aware of the rising levels of refuse in drainages, which undermines free flow of sewage and flood water and could be a major cause of seasonal flood. Of particular concern in Table 1 is the fact that of the adults, children and hired helps who engage in transporting wastes from households to the nearest government designated dumps, it is children who are used the most (60%) in the disposal process; which suggests that anything (such as indiscriminate disposal) can happen from the source to the designated points. On the causes of improper waste disposal, Table 1 further shows that the absence of dumpsites in most neighborhoods (39.5%) and/or the far distance to points of disposal from homes in some neighborhoods (22.8%) is the major cause of improper disposal. This in addition to use of children and lack of adequate awareness on the use of dumpsites is attributed by respondents as the case of improper waste disposal especially for solid waste in Calabar South.

**Table 2:** Indiscriminate methods of refuse disposal

| S/n | Option | Frequency | Percentage |
|---|---|---|---|
| 1 | Nearby bushes | 13 | 5.7 |
| 2 | Along the road | 12 | 5.3 |
| 3 | Drainage systems | 18 | 7.9 |
| 4 | Burning | 91 | 39.9 |
| 5 | Public dumpsters | 94 | 41.2 |
| | Total | 228 | 100 |

**Source:** Fieldwork (2021)

Table 2 shows that respondents dispose of their refuse mostly by burning (39.9%) and the use of designated public dumps (41.2%). Other disposal methods as shown in the table include dumping into any available drainage system (7.9%) with the belief that rain water will wash the waste away; any nearby earth road (5.3%) and bushes (5.75). The result in Table 2 suggests that households in Calabar South really practice poor waste disposal methods with dire implications on both public health and the environment.

**Table 3:** Implications of improper refuse disposal

| S/n | Option | Frequency | Percentage |
|---|---|---|---|
| 1 | Air pollution | 14 | 6.1 |
| 2 | Flooding | 15 | 6.6 |
| 3 | Distortion of environmental beauty | 9 | 4.0 |
| 4 | Home to rodents and insects | 105 | 46.1 |
| 5 | Disease outbreak | 85 | 37.2 |
| | Total | 228 | 100 |

**Source:** Fieldwork (2021)

Table 3 shows respondents general perception of improper waste disposal. The responses in Table shows that indiscriminate waste disposal is a likely cause of air pollution, flooding, distortion of environmental beauty, breeding grounds for rodents and disease causing parasites, and disease outbreaks with over 83% of respondents claiming it to be the cause of disease outbreaks by providing enabling environment for breeding of rodents and insects. This suggests that respondents are well aware of the implications of improper waste disposal.

**Result from reconnaissance survey photographs**

Results are presented as picture evidences of solid waste disposal practices in each of the selected streets in the study area (Figure 1-9).

**Figure 3: Dumpsites at Palm Street[L] and Goldie Street[R]**

**Fig. 4:** Dumpsites at Howkins Road [L] and Main Avenue[R]

**Fig. 5:** Dumpsites at Afokang Street [L] and Edibe Street[R]

**Fig. 6:** Calabar Landfill

Figure 3 shows the waste dumpsite at Palm Street and at Goldie Street; Figure 4 shows pictures of dumpsites at Howkins and Main Avenue; Figure 5 shows dumpsites at Afokang and Edibe; and Figure 6 shows pictures of the Calabar landfill. All the picture indicate that there is no frequent evacuation of the wastes from dumpsites and perhaps the reason behind the overflow which distorts the beauty of the environment and serves as breeding grounds for disease causing organisms, reptiles and rodents. Figure 3L shows how indiscriminate dumping of waste leads to accumulation of waste on the road with the possibility of affecting vehicular movements. Figure 4L of the dumpsite at Howkins indicates how dumps by riversides have the sure potential of polluting the river water that could lead to epidemics such as cholera. Figure 5LR at Afokang and Edibe how dumpsites have become hills because of non-evacuation for a considerable length of time. Figure 6 of the Calabar landfill shows no activity of sorting for recycling, or of incineration, which suggest that Calabar waste management does not follow the integrated waste management procedure.

## Conclusion

Waste generation and management in most cities of the developing countries have become one of the intractable environmental problems because of the rapid increase in population coupled with the unavailability of social infrastructures such as waste bins to match the available generated waste, this results in widespread occurrence of waste in the environment. From the information collected and analyzed for this study, it is obvious that improper refuse disposal especially in drainage system is prevalence in Calabar South Local Government Area of Cross River State, Nigeria. The study noted that indiscriminate refuse disposal especially in drainage systems has resulted in several environmental consequences such as distortion of environmental beauty, pollution (both land, water and air), outbreak of diseases as well as general environmental deterioration which affects the quality of life and environment of people living around the locality.

Based on the research findings, the research recommends that both individuals and waste management agencies should always embark on environmental sensitization and awareness on the dangers of indiscriminate dumping of refuse on the environment as well as their health, they should be provision of bigger waste bins and regular evacuation of the disposed waste to prevent adverse effect, and that waste bin should be located close to the residents or households to encourage the use of waste bins.

## References

Adedipe, N. O. (1995). International Workshop on Governance and Urban Waste Management in Africa. Ibadan University Press.

Anana, I. M. (2006). The Applicability of oil and gas laws in Nigeria: a case study of Mobil Ibeno. A research project submitted to the Department of Geography and Regional Planning University of Calabar.

Asuquo, F. E. (1997). Domestic Waste Composition and Pollution Status of Calabar City, Calabar. Institute of Oceanography, University of Calabar.

Aziegbe, F. (2007). "Seasonality and Environmental Impact Status of Polyethylene (cellphane)" Generation and Disposal in Benin City, Nigeria". Journal of Human Ecology 22(2): 141 – 147.

Bisong, F. E. &Ajake, A. O. (2001). Solid waste management for development in natural resource use and conservation systems for sustainable development. Francis Bisong Ed, 186 – 198.

Cunningham, W. P., &Saigo, B. W. (1997). Environmental Science: Aglobalconcern.McGraw-hill USA.

Ezekiel, E. (2001). The environmental pollution. The Punch Newspapers No. 20892 vol. 17 p 20. Lagos, Nigeria.

Fox, A. (1998). Incineration of solid waste, New York.

Gakungu NK, Gitau AN, Njoroge BNK, Kimani MW (2012) Solid waste management in kenya: A case study of public technical training institutions. ICASTOR J Eng 5: 127-38

Imam A, Mohammed B, Wilson DC, Cheesman CR (2008) Solid Waste Management in Abuja, Nigeria. Waste Management 28: 468-72.

Jahknwa JC, Buhari MK, Sindigawo Z (2019) Challenges and Prospects of Sustainable Waste Management in Jimeta Metropolis, Adamawa State, Nigeria. J Waste Manag Disposal 2: 204

Lucas, O, A, & Gilles, H, M. (2006). A Short Textbook of Public Health Medicine for the Tropics: New York Edward Arnold.

Marchettini, N., Ridolfi, R., & Rustici, M. (2007). An environmental analysis for comparing waste management options and strategies. Waste Management, 27(4), 562-571.

Miller, G. (2007). Living in the Environment. 5th Edition, International Student Edition, USA.

Ngoka, I. H. (2001). Environmental Pollution and Industry: a case study of Nnewi Town, Unpublished B.sc Thesis, Department of Geography, University of Nigeria Nsukka.

Obot, J. U., Animashaun, A. I., & Fayose, E. A. (2002). Environment and development in Nigeria. Port-Harcourt: Double Diamond Publications.

Ogundele OM, Rapheal OM, Abiodun AM (2019) Effects of Municipal Waste Disposal Methods on Community Health in Ibadan-Nigeria. Polytechnica 1: 61.

Olaniran, Akpan, Ikpeme& Udofia (1995). Environmental Health Macmillan Nigeria Publisher's Ltd.

Oyeniyi BA (2011) Waste Management in Contemporary Nigeria: The Abuja Example. Int J Politics Good Governance 2: 1-18.

Sule, R. O. (2001). Fundamental of Urban Planning: Theory and Practice in Nigeria BAAJ International Company, Calabar Lagos.

Taiwo AA (2009) Waste management towards sustainable development in Nigeria: A case study of Lagos state. International NGO Journal. Waste management towards sustainable development in Nigeria: A case study of Lagos state 4: 173-9

Tong A, Sainsbury P, Craig J (2007) Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. Int J Qual Health Care 19: 349-57.

Uchegbu, S. (2002). Environmental management and protection precision printers and publishers.

Wilson, D. C. (2007). Development drivers for waste management. Waste Management & Research the Journal of the International Solid Wastes & Public Cleansing Association Iswa, 25(3), 198-207.

# SUB-THEME 2:

# WATER, SANITATION, HYGIENE AND COVID-19 PANDEMIC

# KNOWLEDGE, ATTITUDE, AND PRACTICE OF WATER, SANITATION AND HYGIENE BY HOUSEHOLDS IN BALANGA NORTH, GOMBE, NIGERIA

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**Abstract**

*Increasing disease burden and diminishing environmental health conditions among the urban and rural poor in Sub Saharan African countries has been attributed to poor sanitation and hygiene practices. This study sought to assess the knowledge, attitude and practice of households regarding water, sanitation and hygiene (WASH). Data was gathered through conducting a questionnaire survey and stratified random sampling techniques was adopted to select 150 household units among the stratified settlement clusters at a response rate of 100%. Results of the study revealed that majority of the households (48.7%)had water sourced from wells and boreholes. The results indicated that (37.7%) and (32% )of households reported their water sources to be safe and potable respectively while 31.3% reported unsafe water use. The result also indicated recorded cases of unsafe water use to include cholera, diarrhea, typhoid and dysentery with incidences of 12.7%, 40.7%, 39.3% and 7.3% respectively. Majority of the households represented by 56% were not satisfied with the water situation as a result of irregular supply. The result also revealed that all the households were aware of the benefits of hand washing and use of toilet facilities compare to practice of open defecation and most of them practiced hand washing before meal. The results also indicated that households that uses pit latrines and water closet to septic tanks for their sanitary needs is represented by 66.7% and 2% respectively while 31.3% lacked sanitation facility and practice open defecation. Only 9.3% of households practiced safe sanitation of refuse disposal at designated dumpsites, while 44%, 14.6% and 32% disposed off their refuse around the home, on the road sides and indiscriminate dumping respectively. In conclusion, this study showed the absence or near absence of public water supply and also revealed good sanitation knowledge of households, however waste handling and hygiene practices of hand washing is poor and several households still engaged in the practice of open defecation. Recommendations made based on the findings is government at all levels should make provision for community tap points that will ensure safe water use to reduce the incidences of water borne diseases, public education on waste handling as well as the critical times of hand washing is encouraged and the provision of public conveniences at strategic locations to discourage open defecation.*

**Keywords**: Attitude, Household, Hygiene, Knowledge, Sanitation, Water

## Introduction

Safe sanitation is one of the foundations of a healthy, comfortable and dignified life as well as a human right and everyone is entitled to sanitation services that not only provide privacy, ensure dignity and safety but also physically accessible and affordable. But the reality for billions of people is one of polluted environments, in which one or many of the links in the chain that makes up safe sanitation such as provision of potable water, toilet facilities, waste treatment and efficient disposal and management is missing or probably out of reach (UNICEF/WHO, 2020).

The practice of water, sanitation and hygiene (WASH) still poses a great challenge to many countries across the globe. It was estimated that 68% of Nigeria's total population in 2018 had access to basic water supply, and progress towards achievement of universal and equitable access to basic water supply has been slow. Only 19% of the total population use safely managed sanitation services, 24% are still practicing open defecation (OD) with 30% of this practice obtainable in the rural areas. Unless this problem is effectively addressed, the current number of people still practicing OD is predicted to increase with population growth trends (FGN/UNICEF, 2020).

The COVID-19 pandemic had not only exacerbated sanitation challenges in most rural and urban informal settlements, but also re-awakened the consciousness to the central role that water, sanitation and hygiene (WASH) plays in protecting people from diseases (UNICEF/WHO, 2020). While the impact of poor sanitation and hygiene on human health has been widely acknowledged (Bartram, Lewis, Lenton and Wright, 2005; Montgomery and Elimelech, 2007; Mara, Lane, Scott, and Trouba, 2010; Ezeh, Agho, Dibley and Hall, 2014; W.H.O, 2016), some studies have shown that the knowledge, attitude and practice of safe water, sanitation and hygiene particularly in the rural areas are not encouraging (Shittu et al, 2014; Orimoloye et al, 2015; Wada et al,2021).If Target 6.2 of the Sustainable Development Goals and the commitment of the Federal Government to make Nigeria open defecation free by 2025 is anything to go by, there must be efforts geared towards the periodic assessment of the knowledge, attitude and practice of water, sanitation and hygiene (WASH) at the household level particularly in the rural areas where basic and improved sanitation coverage is inadequate. The objective of this study is to assess the knowledge, attitude and practice of households regarding water, sanitation and hygiene (WASH) in Balanga north, Gombe.

## Materials and Methods

### Description of the study area

Balanga north is located between latitudes $9^0 50' 00''$N and $10^0\ 5'00''$N and longitudes $11^0 35'00''$E and $11^0 50'00''$E. The major towns that make up Balanga North include Balanga, Talasse, Gelengu, Putoki, Swa and Bangu as shown on Figure 1.

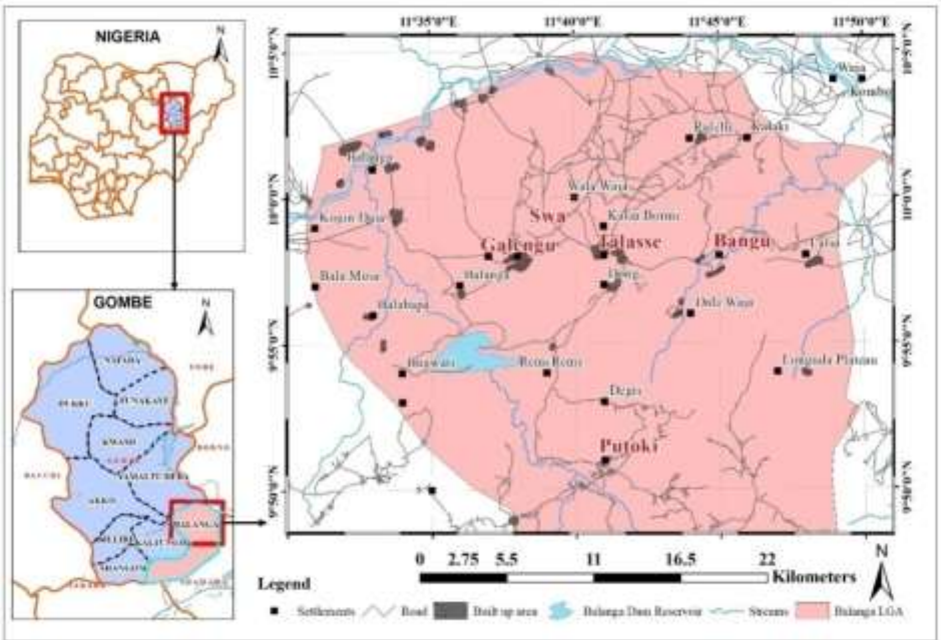


**Fig 1:** The Study Area

**Source:** Modified from Ministry of Land and Survey, Gombe State

**Data Collection and Analysis**

Based on settlement hierarchy and composition of household dwellings, a stratified random sampling technique was adopted to select household units among the settlement clusters of Gelengu, Swa, Talasse, Bangu and Putoki for the study. A total of 150 households were selected for the administration of questionnaire. The data generated from the questionnaire were summarized using descriptive statistics and cross-tabulations.

**Results and Discussion**

**Water, sanitation and hygiene knowledge of household**

Table 1 shows data on water, sanitation and hygiene knowledge of household. It reveals the available sources of water for households include water sourced from streams or rivers, groundwater of wells and boreholes,tap water and water fromprivate water vendor supply.

**Table 1:** Water, sanitation and hygiene knowledge of household

| Characteristics | Talasse (n=50) F | % | Gelengu (n=30) F | % | Putoki (n=30) F | % | Bangu (n=20) F | % | Swa (n=20) F | % | TOTAL F | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water sources** | | | | | | | | | | | | |
| Stream/River | 4 | 8% | 7 | 23.3% | 21 | 70% | 3 | 15% | 6 | 30% | 41 | 27.3% |
| Well/Borehole | 24 | 48% | 16 | 53. 3% | 9 | 30% | 15 | 75% | 9 | 45% | 73 | 48.7% |
| Tap water | 15 | 30% | 5 | 16. 7% | 0 | 0% | 2 | 10% | 5 | 25% | 27 | 18% |
| Private water Supply 6% | 7 | 14% | 2 | 6.7% | 0 | 0% | 0 | 0% | 0 | 0% | 9 | |
| **Quality of water sources** | | | | | | | | | | | | |
| Safe | 25 | 50% | 7 | 23.3% | 3 | 10% | 11 | 55% | 9 | 45% | 55 | 36.7% |
| Unsafe | 5 | 10% | 7 | 23.3% | 25 | 83.3% | 4 | 20% | 6 | 30% | 47 | 31.3% |
| Potable | 20 | 40% | 16 | 53.3% | 2 | 6.7% | 5 | 25% | 5 | 25% | 48 | 32% |
| **Effect of unsafe drinking water** | | | | | | | | | | | | |
| Cholera | 8 | 16% | 4 | 13.3% | 2 | 6.7% | 3 | 15% | 2 | 10% | 19 | 12.7% |
| Diarrhea | 17 | 34% | 11 | 36.7% | 16 | 53.3% | 10 | 50% | 7 | 35% | 61 | 40.7% |
| Typhoid | 18 | 36% | 13 | 3.3% | 11 | 36.7% | 6 | 30% | 11 | 55% | 59 | 39.3% |
| Dysentery | 7 | 14% | 2 | 6.7% | 1 | 3.3% | 1 | 5% | 0 | 0% | 11 | 7.3% |
| **Levels of satisfaction with water supply situation** | | | | | | | | | | | | |
| Satisfactory | 10 | 20% | 6 | 20% | 7 | 23.3% | 4 | 20% | 2 | 10% | 29 | 19.3% |
| Very Poor | 27 | 54% | 14 | 46.7% | 17 | 56.7% | 8 | 40% | 18 | 90% | 84 | 56% |
| Inadequate | 7 | 14% | 7 | 23.3% | 5 | 16.7% | 5 | 25% | 0 | 0% | 24 | 16% |
| Undecided | 6 | 12% | 3 | 10% | 1 | 3.3% | 3 | 15 % | 0 | 0% | 13 | 8.7% |

**Source:** Fieldwork, 2020

The result shows that well and borehole is the dominant source of water supply representing 48.7% on the average. Sources from stream and rivers were placed second with a record of 27.3%. Households with tap piped water connection were 15%. Vendor water through private water supply is the least source in the study area with a percentage of 6%. The observed dominance of well and borehole utilization either through individual, communal and commercial hand dug well and borehole clearly shows the absence or near absence of public water supply in the area. This has implications on the quantity of water consumption available to households and may consequently jeopardize sanitation and hygiene practices of the rural households. The tendency is that water rationing among various uses becomes prioritized thereby compromising hygienic practices that encourages bathing at least twice daily, thorough washing of cooking utensils and hand washing among others.

The result of the relative satisfaction of the interviewed households in relation to domestic water quality shows a record of 36.7%, 31.3% and 32% respectively for safe, unsafe and potable water quality. One of the reasons for poor water quality could be attributable to poor sanitary condition around the water sources as some of the wells are open well without cover lids. Also the dipping of containers to draw water from these open hand dug wells could have been significantly contaminated. Table 1 shows that the interviewed households agreed that unsafe drinking water have resultant effects and they have recorded incidence cholera, diarrhea, typhoid and dysentery respectively. The average incidence of water borne infections of cholera, diarrhea, typhoid and dysentery across the study settlements is 12.7%%, 40.7%, 39.3% and 7.3% respectively. The awareness of the effects of unsafe drinking water on health is high among households and further consumption of unsafe drinking water may lead to one or more infectious diseases.

Regarding the level of satisfaction with water supply situation as presented in Table 1 the result shows varying degree of responses with majority dissatisfied with the situation while very few were satisfied with some indifferent to the situation. On the average, majority of the households were not satisfied with the water supply situation with responses of very poor and inadequate recording 56% and 16% respectively. While those satisfied and undecided recorded 19.3% and 8.7% respectively. Water supply situation is worrisome in most rural communities particularly during the dry season when people had to trek many kilometers in searching of water thereby dissipating much energy. The finding of this study is in line with earlier studies that reported households with improved drinking water source were more likely to use improved sanitation facilities than those with unimproved water sources (Abubakar, 2017; Olukanni and Okorie, 2015).

**Attitude of Household to Sanitation and Hygiene Practice**

Analysis of the attitude of household to sanitation and hygiene practice is presented in table 2.

**Table 2:** Attitude of household to sanitation and hygiene practice

| Characteristics | Talasse (n=50) | | Gelengu (n=30) | | Putoki (n=30) | | Bangu (n=20) | | Swa (n=20) | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | % | F | % | F | % | F | % | F | % | F | % |
| **Benefits of toilet facilities compare to open defecation** | | | | | | | | | | | | |
| Avoid bad small | 29 | 58% | 13 | 43.3% | 9 | 30% | 9 | 45% | 5 | 25% | 65 | 43.3% |
| Limit spread of Infection | 15 | 30% | 12 | 40% | 19 | 63.3% | 7 | 35% | 9 | 45% | 62 | 41.3% |
| Enhance privacy | 2 | 4 % | 5 | 16.7% | 2 | 6.7% | 3 | 15% | 4 | 20% | 16 | 10.7% |
| Avoid harassment | 4 | 8% | 0 | 0% | 0 | 0% | 1 | 5% | 2 | 10% | 7 | 4.7% |
| **Critical time for household hand washing practices** | | | | | | | | | | | | |
| Before eating | 36 | 72% | 21 | 70% | 16 | 53.3% | 7 | 35% | 9 | 45% | 89 | 59.3% |
| After eating | 4 | 8% | 1 | 3.3% | 3 | 10% | 2 | 10% | 3 | 15% | 13 | 8.6% |
| After use of toilet/ Defecation | 4 | 8% | 7 | 23.3% | 8 | 26.7% | 11 | 55% | 8 | 40% | 38 | 25.3% |
| After house cleaning | 6 | 12% | 1 | 3.3% | 3 | 10% | 0 | 0% | 0 | 0% | 10 | 6.7% |

**Source:** Fieldwork, 2020

The assessment of the benefits of toilet facilities over open defecation in the promotion of sanitation and hygiene presented on table 2 reveals a good level of sanitary education of the sampled households. The identified benefits include avoid bad smell, limit spread of infection, enhance privacy and avoid harassment. On the average 43.3% of the household believed that toilet help to avoid bad smell compare to open defecation, limit spread of infection 41.3%, enhance privacy 10.7% and avoid harassment 4.7%.Open defecation and disposal of night soil into the environment is partly responsible for the health risks and also accountable for some of disease burden in the developing countries. While increased use of appropriate toilet facilities has helped to promote sanitation and hygiene thereby reducing poor sanitation related fatalities. The critical time that the sampled household performs hand washing routine within the context of water, sanitation and hygiene (WASH) practices presented on table 2 reveals WASH practices were carried out before eating, after eating, after use of toilet or defecation and finally after house cleaning. The analysis on the average shows the following pattern of WASH practice, before eating 59.3%, after eating 8.6%, after use of toilet or defecation 25.3% and after house cleaning 6.7%. The importance of water, sanitation and hygiene in reducing community transmission of diseases and promoting healthy living is well established. In this study the, the respondents' awareness to WASH is very low particularly with practices of hand washing after eating and after use of toilet or defecation.

**Sanitation and Hygiene Practice of Household**

The respondents' household sanitation and hygiene practice is presented in table 3

**Table 3:** Sanitation and hygiene practice of household

| Characteristics | Talasse (n=50) | | Gelengu (n=30) | | Putoki (n=30) | | Bangu (n=20) | | Swa (n=20) | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | % | F | % | F | % | F | % | F | % | F | % |
| **Toilet facilities/ Practices Employed by households** | | | | | | | | | | | | |
| Open defecation | 11 | 22% | 14 | 46.7% | 11 | 36.7% | 8 | 40% | 3 | 15% | 47 | 31.3% |
| Open pit latrine | 38 | 76% | 15 | 50% | 18 | 60% | 12 | 60% | 17 | 85% | 100 | 66.7% |
| Water closet | 1 | 2% | 1 | 3.3% | 1 | 3.3% | 0 | 0% | 0 | 0% | 3 | 2% |
| **Methods of household refuse disposal** | | | | | | | | | | | | |
| Dump around the Home | 21 | 2% | 13 | 3.3% | 15 | 50% | 8 | 40% | 9 | 45% | 66 | 44% |
| Dump on road side | 9 | 18% | 6 | 20% | 2 | 6.7% | 4 | 20% | 1 | 5% | 22 | 14.6% |
| Indiscriminate Dumping | 18 | 36% | 7 | 23.3% | 8 | 26.6% | 6 | 30% | 9 | 45% | 48 | 32% |
| Designated dumpsite | 2 | 4% | 4 | 13.3% | 5 | 16.7% | 2 | 10% | 1 | 5% | 14 | 9.3% |
| **Frequency of hand washing after using toilet** | | | | | | | | | | | | |
| Regularly with soap and water | 15 | 30% | 3 | 10% | 3 | 10% | 3 | 15% | 1 | 5% | 25 | 16.7% |
| Irregularly with soap and water | 17 | 34% | 4 | 13.3% | 14 | 46.7% | 4 | 20% | 3 | 15% | 42 | 28% |
| Use only water | 6 | 12% | 4 | 13.3% | 5 | 16.6% | 5 | 25% | 4 | 20% | 24 | 16% |
| Do not wash at all | 12 | 24% | 19 | 63.3% | 8 | 26.7% | 8 | 40% | 12 | 60% | 59 | 39.3% |
| **Benefits of hand washing** | | | | | | | | | | | | |
| Improve hygiene | 7 | 14% | 7 | 23.3% | 4 | 13.3% | 3 | 15% | 5 | 25% | 26 | 17.3% |
| Kill germ | 10 | 20% | 9 | 30% | 4 | 13.3% | 5 | 25% | 2 | 10% | 30 | 20% |
| Prevent odour | 3 | 6% | 3 | 10% | 2 | 6.7% | 1 | 5% | 0 | 0% | 9 | 6% |
| Prevention of disease | 30 | 60% | 11 | 36.7% | 20 | 66.7% | 11 | 55% | 13 | 65% | 85 | 56.7% |

**Source:** Fieldwork, 2020

Assessment of sampled household in table 3 with regards to toilet facilities used to ensure safe sanitation reveals that most household employed open defecation, open pit latrine and a few used water closets. On the average across settlements and households, open defecation accounts 31.3%, open pit latrine account for 66.7% and water closet account only 2%. It is evident that open pit latrine is most common among the households. Open defecation is also a common practice owing to the fact that some of the households are without provision for toilet facilities thereby using the nearest bushes, open spaces and dilapidated buildings as free toilets for all. Observation around the pit latrines shows that they are not insulated with brick structure and leachate from it is capable of polluting groundwater while open defecation is a potential environmental contaminant.

The result of this study is in agreement with the findings of Abubakar, (2017); Kaoje et al, (2019) and Inah et al, (2020) who reported that more urban households used modern sanitation facilities (toilets that flush to sewer systems or septic) than rural households whose preference is either tailored to the use of ventilated improved pit (VIP) latrines or open pit latrines with close to one-third of the households having no access to any sanitation facility practicing defecation in the open. With relation to solid waste management, the assessment of sampled household in table 3 reveals that most household disposed off their refuse around the home, some on the road side while others either dispose them indiscriminately or dispose it at designated dumpsite. It is disturbing that safe sanitation issue relating to solid waste management is very poor with majority of the households on the average practicing dumping around the home 44%, dumping on roadside 14.6%, indiscriminate dumping 32% and designated dumpsite 7.3%.

The attitude of sampled households toward hand washing practice after using toilet facilities as presented on table 3 shows that respondents that regularly wash their hands with soap and water comprised 16.7%, irregularly with soap and water make up 28%, those that use only water make up 16% while the remaining 39.3% do not wash their hands at all after use of toilet. The opinions of sampled households on awareness of the benefits of hand washing are presented on table 3. The awareness of the benefits of hand washing varies from improve hygiene, kill germs, prevent odour and prevention of diseases. Averagely all the sampled household has a good knowledge of the benefits of hand washing with the majority representing 56.7% having awareness of prevention of diseases. Findings from the studies of Sadiq et al, (2018); Kaojeet al, (2019) and Inah, et al, (2020) also reported some negative environmental practices like dumping of refuse indiscriminately and hand washing mostly done after meal with water alone.

## Conclusion and Recommendations

This study underscores the importance of regular assessment of the knowledge, attitude and practice of water, sanitation and hygiene (WASH) at the household level. In conclusion, this study showed the absence or near absence of public water supply and also revealed good sanitation knowledge of households, however waste handling and hygiene practices of hand washing is poor and several households still engaged in the practice of open defecation. Recommendations made based on the findings is government at all levels should make provision for community tap points that will ensure safe water use to reduce the incidences of water borne diseases, public education on waste handling as well as the critical times of hand washing is encouraged and the provision of public conveniences at strategic locations to discourage open defecation.

## References

Abubakar, I.R. (2017). Access to Sanitation Facilities among Nigerian Households: Determinants and Sustainability Implications. *Sustainability, 9, (547), 1-17*.

Bartram, J., Lewis, K., Lenton, R. and Wright, A. (2005). Focusing on Improved Water and Sanitation for Health. *Lancet*, *365, 810–812*.

Ezeh, O. K., Agho, K. E. Dibley, M. J. Hall, J. and Page, A. N. (2014). The impact of Water and Sanitation on Childhood Mortality in Nigeria: Evidence from Demographic and Health Surveys, 2003–2013. *International Journal of Environmental Research and Public Health*, 11, 9256–9272.

FGN/UNICEF (2020). Evaluation of Nigeria's Government and UNICEF Water, Sanitation and Hygiene (WASH) Programme (2014-2017), Final report.

Inah, S. A., Eko, J. E., John, E. A., Ochei, K. C., Obot, N., Iniam, D. E. and Elemi, L. A. (2020). Assessment of Water Supply, Sanitation and Hygiene Practices among Households in Southern Nigeria. *International Journal of Environment and Pollution Research*,8, (2), *42-53*.

Kaoje, A. U., Yahaya, M., Raji, M. O., Hadiza, S. M., Sylvanus, A., and Musa,T. M. (2019). Drinking Water Quality, Sanitation and Hygiene Practices in a Rural Community of Sokoto State, Nigeria. *International Journal of Medical Science and Public Health*, *8(1),78-85*.

Mara, D., Lane, J., Scott, B. and Trouba, D. (2010). Sanitation and Health. *PLoS Med*., 7

Montgomery, M. A. and Elimelech, M. (2007). Water and Sanitation in Developing Countries: Including Health in the Equation. *Environmental Science and Technology, 41, 17–24*.

Olukanni, D. O. and Okorie, U. E. (2015). Empirical Assessment of Water, Sanitation and Hygiene Practices in a Semi-Urban Setting: A Socio-Economic and Cultural Mirror. *Journal of Scientific Research and Reports,* 8 (7), *1-11*.

Orimoloye, E. O., Amadi, C. O. A., Amadi, A. N., Azuamah, Y. C., Nwoke, E. A., Zacchaeus, U. and Dozie, I. N. S. (2015). Assessment of Water Sanitation and Hygiene Practices in Ibadan, Nigeria. *International Journal of Research*, 2, (2), *94-100*.

Sadiq, Q. O., Ezeamaka C. K., Daful, M. G., Anjide, T. W., Sani, H. and Ogbole, M. (2018). Environmental sanitation practices in Kuchigworo and Garamajiji along airport road, Abuja. *Journal of Geography and Regional Planning, 11(11), 172-182*.

Shittu, O. B., Akpan, I., Mafiana, C. F., Ogunshola, E. O. and Sodipe, O. (2014). Assessment of Sanitation and Water HandlingPractices in Rural Communities of Ogun State,Southwestern Nigeria. *International Journal of Public Health Research, 2(5) 44-53*.

State of the World's Sanitation (2020). *An urgent call to transform sanitation for better health, environments, economies and societies*. New York: United Nations Children's Fund (UNICEF) and the World Health Organization.

Wada, O. Z., Olawade, D. B.,Asogbon, O., Makinde, F. T. and Adebayo, I.( 2021). Evaluation of Household Water, Sanitation, and Hygiene Management in a Nigerian Rural Community. *International Journal of Tropical Disease and Health*. *42(5), 21-33*.

World Health Organization (WHO) (2016). *Sanitation: Fact Sheet*; World Health Organization Media Center.Available online: http://www.who.int/mediacentre/factsheets/fs392/en/ (accessed on 11 October 2020)

# WATER AND SANITATION HYGIENE KNOWLEDGE, ATTITUDE, AND PRACTICES AMONG RURAL HOUSEHOLDS IN A NIGERIAN COASTAL SETTLEMENT OF ORON

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**Abstract**

*Poor hygiene practices and inadequate sanitary conditions play major roles in the increased burden of communicable diseases within developing countries. Household knowledge, attitude and practices towards water, hygiene and sanitation services represent significant evolving element in relation to the quality, efficiency and performance of those services. Through a random sampling technique, 400 households were selected from eight communities in the coastal settlement of Oron, Akwa Ibom State with a view to understanding their knowledge and practices towards water, hygiene and sanitation services using structured questionnaire complemented by oral interview and focus group discussion as data collection instrument. The study revealed the problem of poor access to water and basic sanitation services by a greater percentage of the coastal household as majority (58.75%) of the households still depend on rivers/streams as their major water source and the use of unhygienic pit toilets. Majority of the households perceived the quality of water as being unsafe while 73.5% did not follow any methods of water treatment. The study identified availability and access to major water source rather than quality as significant factor influencing the households' attitudes and preferences for the use of water supply services while the cost and convenience of having sanitation services rather than hygiene/safety are major factors that determine their preference for the choice of sanitation services. The study recommends regular monitoring of key epidemiological and other public health indicators related to water and faecal contamination in the study area as the risk of exposure to faecal and water borne pathogens in the coastal settlement is seriously feared.*

**Keywords:** Water, Sanitation, Hygiene knowledge, Attitude and Coastal households.

## 1.1 Introduction

The Millennium Development Goals (MDG) campaign was launched in 2002 and ran until 2015. Its overall objective was to halt extreme poverty (United Nations 2017). The campaign, adopted by 189 UN member states, set eight development goals (WHO 2017a). Target 7c aimed to halve the number of people without sustainable access to safe water and basic sanitation, including hygiene. The target was repeatedly modified until it was adopted in 2006. Drinking water and sanitation access is apropos to disease prevention. It is estimated that 58% of diarrhoeal diseases can be attributed to unsafe water supply, sanitation and hygiene (WHO 2017b). The MDGs were succeeded by the Sustainable Development Goals (SDGs) for the 2016–2030 period, including a self-standing goal—SDG 6—regarding access to water and sanitation. MDG 7c and SDG 6 guide water and sanitation data that are collected worldwide which determines our knowledge about access to water and sanitation. The goals influence national policies, donor funding strategies (Cotton and Bartram 2008; Bain et al. 2012) and service delivery to a large part of the world population.

Progress towards MDG 7c was measured by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) through the Joint Monitoring Program for Water Supply and Sanitation (JMP). JMP measures access to 'improved and unimproved' water sources and 'improved and unimproved' sanitation facilities as indicators for safe water and basic sanitation access. According to JMP statistics, the targets set for access to safe drinking water were met in 2010, 5 years before the deadline (United Nations MDG Monitor 2017). It is further said that between 1990 and 2015, 2.6 billion people gained access to 'improved' drinking water sources, and 2.1 billion people gained access to 'improved' sanitation. The number of people practicing open defecation has gone down by nearly 50% since 1990 (Bain, Gundry, Wright, Yang, Pedley and Bartram, 2012; Cotton and Bartram 2008). Given this brilliant statistics, the question arises of what probably could be the main problem of lack of adequate access to safe drinking water and basic sanitation services as revealed through field observation in the coastal settlement of Oron.

The coastal settlement of Oron has historically faced severe water quality challenges. In the settlement, many Water and Sanitation, Hygiene (WASH) implemented projects have failed for two main reasons. First, the rural households do not take ownership of the implemented projects by NGOs, which results in a lack of maintenance and the ultimate failure of the water points. Second, the quality of underground water sources is poor due to bacterial contamination making the settlement prone to waterborne diseases because of a lack of access to safe drinking water.

Field observation showed that access to safe water supply and sanitation facilities by the households remain pitiable. The coastal settlement is dotted by increasingly growth of squatter settlements, overcrowding dwellings, breakdown of waste disposal arrangements, air and water pollution and inadequate water and sanitation services (Esin, 2017). Connected to the foregoing are several problems of mortality, morbidity and poverty which have been reported in the literature as consequences of a lack of safe drinking water supplies and sanitation coverage (Esin, Ikurekong and Hula, 2011; Esin, 2017). Thus, for effective reduction of effects from poor water and sanitation practices, there is a need for understanding the households' attitudes and practices towards water and sanitation hygiene services and the effect of currently existing interventions in the coastal settings as it would help improve our understanding of the extent of sustainability of rural water provision, hygiene and sanitation systems. This study is designed to achieve this objective, as understanding these aspects of rural water supply systems and generating useful knowledge base can give an insight into evolving policies which can potentially address large scale non-sustainability of rural water and sanitation practices in the coastal settlement.

## Material and Methods

### The Study Area

The study was carried out in Oron Local Government Area, in Akwa Ibom State, Nigeria. The Local Government Area is basically a coastal settlement located approximately between Latitudes $40^0 46^1$ – $40^0 52^1$ north and Longitudes $80^0 12^1$East with a total land mass of about 309.27km$^2$. Oron LGA is located at the right bank estuary of the Cross River close to the Atlantic Ocean. It is a river port and ferry or packet station, linking Calabar and other rivers and coastal ports in the region and the Cameroon and Equatorial Guinea outside Nigeria. The LGA is situated in a gentle rolling coastal plain sands typified by sedimentary basin formation of largely unconsolidated deposits. Rainfall is heavy and last about 10 months in the year.

**Methods of Data Collection**

i) Socio-demographic characteristics: Information was gathered about age (years), gender, educational status (no formal education, primary, secondary, graduate or equivalent and postgraduate), marital status (single/married/divorce or separated/widow), annual household income, type of family (joint, nuclear, broken, extended), number of family members, and occupation status (farming, fishing, trading, civil service, and artisan).

ii) Water facility and related issues: Information was gathered on the various sources of drinking water, individuals that were responsible for fetching water in household, periods of water shortage, distance of water source from household, water supply timings and water storage practices.

iii) Water treatment and storage practices: Information was gathered on household's attitudes toward water treatment practices, water safety, effects of unsafe drinking water on health, and the practices that were adopted to make water safe.

**Sanitation and related health issues**

Information was gathered about toilet facilities, hand washing, waste disposal facilities and quantity of water being used in the house for various purposes (drinking, cooking, washing clothes, house cleaning and miscellaneous). Additional information was sought regarding any health related episode in the household in the past 3 months.

The data were complemented by means of informal and qualitative methods, principally through focus group discussions, participatory rural appraisal, in-depth interviews with key informants and direct observation approaches. Focus group discussion (FGD) was employed to bring together various households drawn from eight (8) out of the 17 communities. Effort was made to ensure that the focus group discussion cut across the village heads, youth groups, women leaders, community members, political leaders in each of the community. The study subscribes to interviewing only heads of households. But where relevant information cannot be obtained by the head of households, their spouse or other household members were asked to provide such information. The data generated was analyzed using descriptive statistical technique.

**2.0 Results and Discussion**

The respondents were mostly in their active age as 87% of the sample is greater than 35years old (Table 1). Majority of them were males (81%) while 75% of them were married. The sampled respondents are educated as only 17% had no formal education while 83% had a form of education. The results also indicated that majority (70%) of the respondents were engaged in primary activities as their means of livelihood. Majority of the respondents (70%) have large household size. The size of a household determines among others the adequacy and sustainability of water hygiene and sanitation facility. What the household size suggests is that there would be more demand on water and sanitation facilities by households in the coastal settlement. Income level of head of household is important because it determines affordability and sustainability of water hygiene and sanitation facility owned by respondents. The respondents are basically low income earners as the monthly income of majority (80%) of the households is less than #30,000.00. This has obvious implication in accessing sustainable water and basic sanitation services (Table 1).

**Table 1**: Socio Demographic Information of respondents

| Variables | | Response | % |
|---|---|---|---|
| 1. | **Gender** | | |
| | Male | 324 | 81 |
| | Female | 76 | 19 |
| | **Total** | **400** | **100** |
| 2 | **Age of household head** | | |
| | 15-25 | 6 | 1.5 |
| | 25-35 | 26 | 6.5 |
| | 35-45 | 94 | 23.5 |
| | Above 45 | 274 | 63.5 |
| | **Total** | **400** | **100** |
| 3 | **Marital status** | | |
| | Single | 18 | 4.5 |
| | Married | 306 | 76.5 |
| | Widow | 40 | 10 |
| | Divorced | 4 | 1 |
| | Separated | 32 | 8 |
| | **Total** | **400** | **100** |
| 4 | **Occupation** | | |
| | Farming | 150 | 37.5 |
| | Fishing | 130 | 32.5 |
| | Trading | 62 | 15.5 |
| | Civil service | 54 | 13.5 |
| | Student | 2 | 0.5 |
| | Artisan | 2 | 0.5 |
| | **Total** | **400** | **100** |
| 5 | **Educational attainment** | | |
| | No formal education | 68 | 17 |
| | FSCL | 102 | 25.5 |
| | WASSCE | 180 | 45 |
| | Post-secondary | 50 | 12.5 |
| | **Total** | **400** | **100** |
| 6 | **Income of household head** | | |
| | Less than 18,000 | 18 | 4.5 |
| | 18,000-30,000 | 306 | 76.5 |
| | 31,000-43,000 | 40 | 10 |
| | 44,000-56,000 | 4 | 1 |
| | Above 56,000 | 32 | 8 |
| | **Total** | **400** | **100** |
| 7 | **Household Size** | | |
| | Less than 2 | 54 | 13.5 |
| | 3-6 | 150 | 37.5 |
| | 6-10 | 130 | 32.5 |
| | 11-15 | 62 | 15.5 |
| | Above 15 | 4 | 1 |
| | **Total** | **400** | **100** |

**Source –** Field Work (2019)

## 2.2 Water facilities and Associated Issues in the Coastal Settlement of Oron

It is evident in Table 2 that the major sources of water consumed by households in the coastal settlement were River/streams/ponds (41%) and private borehole (17.5%). Sixteen percent of the participants were dependent on private water supply. 49.25% of the water consume by the households' is obtained from private individual while 28.25% obtained theirs from the government supply. Majority (47%) of the respondents' fetched water within 5mins trekking distance. The walking distance in accessing water services by majority of the households' is 1 km. Majority (83.5%) of the respondents who are engaged in fetching water were women in the age group of 15-60 years. Table 2 further revealed that Majority of the respondents' (67.5%) reported meeting the daily need of water quantity. 29.75% of the respondents' reported water shortage twice in a year with average shortage period of 2-3 days (25%). 92% of the respondents' indicated January-March as water shortage months while 3.75% suggested that they do not experience water scarcity.

**Table 2: Water facilities and associated issues in Oron**

| Variables | Response | % |
|---|---|---|
| **Sources of drinking water** | | |
| Private borehole | 70 | 17.5 |
| Public tap | 6 | 1.5 |
| Open public well | - | - |
| Open well in dwelling | 4 | 1 |
| Protected public well | - | - |
| River/streams/ponds | - | - |
| Rainwater | 164 | 41 |
| Commercial borehole | 128 | 32 |
| **Sources of water supply** | | |
| Government/public | 113 | 28.25 |
| Private | 197 | 49.25 |
| None | 90 | 22.5 |
| **Time consumed in bringing water from source** | | |
| 5min | 190 | 47.5 |
| ≤30mins | 175 | 43.75 |
| ≥ 30mins | 25 | 6.25 |
| **Distance of water source** | | |
| 0 - 0.5km | 190 | 47.5 |
| 0.5 – 1km | 110 | 27.5 |
| 1km – 1.5km | 75 | 18.75 |
| 1.5km – 2km | 25 | 6.25 |
| **Family member responsible for fetching water** | | |
| Girls ≤ 15yrs | 40 | 10 |
| Women 15-60yrs | 274 | 68.5 |
| Women ≥ 60yrs | 60 | 15 |
| Men 15-60yrs | 26 | 6.5 |
| **Level of satisfaction with quantity of water fetched** | | |
| Not satisfied | 72 | 18.0 |

| | | |
|---|---|---|
| Satisfied | 271 | 67.75 |
| Do not know | 57 | 14.25 |
| **Number of time scarcity of water is faced** | | |
| Once | 72 | 18.0 |
| Twice | 271 | 67.75 |
| Thrice | 57 | 14.25 |
| No shortage | 14 | 3.5 |
| **Average time period of water shortage** | | |
| ≤ 1 day | 28 | 7.0 |
| 1 day | 181 | 45.25 |
| 2-3 days | 34 | 8.5 |
| Not applicable | 118 | 29.5 |
| More than a week | - | - |
| Do not know | 39 | 9.75 |
| **Period of the year maximum water shortage is faced** | | |
| January – March | 368 | 92 |
| April – June | 4 | 1 |
| July – September | 13 | 3.25 |
| None | 15 | 3.75 |
| Always | - | - |

**Source:** Field Work (2019)

### 2.3 Water and Sanitation Hygiene Attitudes and Practices

Majority of the sampled respondents (50.75%) perceived that the quality of water being used was unsafe, 83.25% of the respondents agreed that quality of water can affect health status, 37.5% of the households stored drinking water in kegs closed container and most of them cleaned the water container daily (Table 3). 73.5% of the respondents were not following any methods of water treatment and among them 21% felt that treated water does not taste good and as such does not require any additional treatment. Majority of the respondents (52.75%) agreed that unsafe drinking water can cause gastro-intestinal tract. Cases of common cold, diarrhea vomiting and gastro-enteritis were reported during oral interview by the coastal households respectively as potential consequence of drinking unsafe water. Water supply timing was the biggest challenge faced by the majority. Most (58.75%) of the respondents use pit toilets which were generally accessed outside the households with only 5% having access to septic tank type of toilets (Table 3). This is so because good sanitation systems are in the realm of the wealthy landlords who attract in-house sewage systems to their homes. In such circumstances, the greatest majority of the coastal households hardly afford such residences, making the basic services the exclusive preserve of the rich. Pit toilets as a means of waste disposal is characterized by odour, flies breeding, water and soil as well as food contamination, which also greatly diminish the aesthetic quality of the environment. Field observations reveal that most of the pit latrines are often poorly constructed with shallow structure and depth that allows easy penetration of light rays and are in most cases unhygienic with no fitted cover plates. However, where cover plates are provided, they are not always replaced immediately after use, which often attract swarms of flies to the pit in large numbers, especially once the plates are removed. Consequently, offensive odour and flies are common phenomenon in these areas, which always constitute both nuisance and threat to human health. As observed by Harrison (1991), as many as 50,000 flies a year can breed and emerge in a single pit latrine. Such flies are carriers of diseases and are a great nuisance in the homestead (Esin, Ikurekong and Hula, 2011). The majority (73%) of the respondents agreed that hand should be washed before and after meals, while only 5.75% felt that hand should be washed after defecation. 51% of the respondents reported that they discharge their waste by indiscriminate dumping while 30% burn their waste in open space (Table 3).

**Table 3:** Water and Sanitation Hygiene Attitudes and Practices

| Variables | Response | % |
|---|---|---|
| **Is the quality of water you use safe?** | | |
| It is safe | 197 | 49.25 |
| It is not safe | 203 | 50.75 |
| **Does the quality of water affect your health?** | | |
| It does | 333 | 83.25 |
| It does not | 67 | 16.75 |
| **What method do you use in storing your water?** | | |
| Drum | 100 | 25.0 |
| Kegs | 150 | 37.5 |
| Bowl | 75 | 18.75 |
| Bucket | 25 | 6.25 |
| Local pot | 35 | 8.75 |
| Surface tanks | 15 | 3.75 |
| **What is the most common effect of using unsafe water?** | | |
| Gastro-intestinal tract disturbance | 211 | 52.75 |
| Fever | 155 | 38.75 |
| Others | 34 | 8.5 |
| **What method do you use in making your water safe?** | | |
| Nothing | 294 | 73.5 |
| Filter | 76 | 19.0 |
| Boiling | 30 | 7.5 |
| **Reasons for not treating water** | | |
| Water is already clean/safe | 81 | 20.25 |
| Do not know how to do it | 102 | 25.5 |
| It is too expensive | 71 | 17.75 |
| Treated water does not taste good | 84 | 21.0 |
| Our culture forbids treating water | 62 | 15.5 |
| **Sanitation facility** | | |
| Pit toilet | 235 | 58.75 |
| Ventilated improved latrine | 20 | 5.0 |
| Open defecation (farmlands, bush etc) | 55 | 13.75 |
| Flush toilet | 90 | 22.5 |
| **Attitudes towards hand washing** | | |
| Before handling food | 69 | 17.25 |
| After eating food | 128 | 32.0 |
| After defecation | 23 | 5.75 |

| | | |
|---|---|---|
| After weaning/changing the baby | 14 | 3.5 |
| When entering home from outdoors | 2 | 0.5 |
| Before eating | 164 | 41.0 |
| **Reasons for hand washing** | | |
| Hygiene: feel clean | 231 | 57.75 |
| Appearance: appears good | 48 | 12.0 |
| Health: prevent infection | 23 | 5.75 |
| Bandwagon: because everyone does | 98 | 24.5 |
| **What is the most common effect of using unsafe water?** | | |
| Gastro-intestinal tract disturbance | 41 | 10.25 |
| Fever | 290 | 72.5 |
| Others | 69 | 17.25 |
| **Solid waste disposal** | | |
| Burn in open space | 120 | 30.0 |
| Buried | 76 | 19.0 |
| Dump anywhere | 204 | 51.0 |
| Others | | |

**Source:** Field Work (2019)

## Conclusions

The study revealed that the existing policy to supply water through boreholes especially in situations where there is no regular electricity supply to power the machines, as currently obtained in the coastal settlement is counter-productive. Given the fact that women and children are the ones mostly involved in fetching water, there is need to devise technologies for water supply which are women and children friendly. Rain water is a major source of water in settlement, but the technology for storing and preserving the water is still very poor. There is the need to design appropriate water storage devices for use in the rural areas in order to make water available for the people throughout the year. Considering the fact that most of these rural communities are small, centrally placed storage devices that the whole community can use ensure easy accessibility to everyone in the community. Added to this is the need to provide the settlement with cost effective sanitation facilities such as the ventilated improved latrines which are more hygienic than the uncovered pit toilets.

## References

Bain, R. E. S., Gundry, S. W., Wright, J. A., Yang, H., Pedley, S., & Bartram, J. K. (2012). Accounting for water quality in monitoring access to safe drinking-water as part of the Millennium Development Goals: Lessons from five countries. Bulletin of the World Health Organization, 90(3), 228–235.

Cotton, A., & Bartram, J. (2008). Sanitation: On- or off-track? Issues of monitoring sanitation and the role of the joint monitoring programme. Waterlines, 27(1), 12–29.

Esin, J.O and Uwajuonye, V.E (2017). Public attitude towards water supply and sanitation services in a Nigerian coastal settlement of Oron. Proceedings of the 8th international conference on hydrology and water resources development in Nigeria. Ayuba, H.K, Iwugo, K.O, Dami, A. and Idris, N.M (editors).

Esin, J.O, Ikurekong, E.E and Hula, M.A (2011). The health implications of surface and sub- surface water pollution from faecal disposal in Oron coastal settlement, Nigeria. Journal of Geography and Development. Vol.3 (1&2).

United Nations MDG Monitor. (2017). MDG 7: Ensure environmental sustainability. 6 June 2017, from http://www.mdgmonitor .org/mdg-7-ensur -environmental-sustainability/. UNDP & Institute for National Planning (INP). (2004). Egypt human development report 2004: Choosing decentralization for good governance.

United Nations. (2017). UN Millennium Campaign. July 2017, from http://www.un.org/millennium goals / bkgd.shtml

WHO. (2017a). Millenium development goals. 11 December 2017, from http://www.who.int/topic s/millennium _development goals /en/.

WHO. (2017b). Diseases and risks. 4 January 2017, from http://www.who.int/water _sanitation health/diseases-risks /en/. WHO. (2017c). Annex 2: Safely managed sanitation services. November 2017, from http://www.who.int/ water _sanitation _health/monit oring /cover age/explanatory note -sdg-621-safel managed sanitations Services161 027.pdf.

WHO. (2017d). Safely managed drinking water—Thematic report on drinking water. November 2017, from http://data.unice f.org/resources/safely-managed-drinking-water /.

WHO/UNICEF Joint Monitoring Programme. Improved and unimproved water and sanitation facilities. 7 June 2016, from http://www.wssin fo.org/definition s-methods/watsan-categ ories /.

# ASSESSMENT OF MICROBIAL AND PHYSICOCHEMICAL CONTAMINATIONS OF WATER FOR DOMESTIC USE IN CALABAR METROPOLIS, NIGERIA

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**Abstract**

*An assessment of domestic water quality using microbial and physicochemical parameters was conducted on both domestic water supply sources and storage containers viz: borehole, upper and lower overhead tanks and stream water in calabar metropolis. Water samples meant for physico-chemical and microbial studies were collected in 1.5L plastic containers and stored in safe condition prior to laboratory analysis of their Physicochemical and microbial parameters in line with APHA recommended standard and WHO permissible limits to ascertain if the mean values of the water parameters were or not within the acceptable limits for human consumption. The results of the descriptive statical analysis of the physicochemical and microbial components of the different domestic water sources revealed mean pH of 6,4±0.6 for the stream water, 6.33±0.57 for the borehole, 5.9±0.9 for the upper overhead tank and 5.79±0.59 for the lower overhead tank. Mean DO concentration of the stream was 7.25±0.25mg/l, with 8.66±0.54mg/l for the borehole, 6.8±0.2mg/l for the upper overhead tank and 1.79±0.39mg/l for the lower overhead tank (Table 1). Mean water temperature recorded for the stream was 27.5±0.5$^0$C, with 27.40±0.6$^0$C for the borehole, 27.45±0.55$^0$C for the upper overhead tank and 27.71±0.31$^0$C for the lower overhead tank. Fe had mean concentration of 1.035±0.001mg/l in the stream water, with 0.040±0.560mg/l in the borehole, 0.664±0.014mg/l in upper overhead tank. Hg mean concentration was <0.001±0.00mg in all the water samples. Bicarbonate had mean concentration of 30.75±0.25mg/l in the stream water, with 36.85±0.256mg/l in the borehole, 24.69±0.31mg/l in the upper overhead tank and 30.75±0.25mg/l in the lower overhead tank. Mean total coliform components were 84.75±0.5 cfu/100ml in the stream water, with 127±2.5 cfu/100ml in the borehole water, 44±2.0 cfu/100ml in the upper overhead tank and 34.5±0.5 cfu/100ml in the lower overhead tank. Total plate count (TPC) had mean values of 127±1,0 cfu/100ml in the stream water, with 164.5±1.5 cfu/100ml in the borehole, 42±8.0 cfu/100ml in the lower overhead tank. Yeast/mould had mean concentration of 0.005±0.005 cfu/100ml in the stream water, with 1.5±0.5 cfu/100ml in the borehole water, 3.5±0.5 cfu/100ml in the upper overhead tank and 2.4±0.4 cfu/100ml in the lower overhead tank. To reduce the risk of human infection that may arise from the continuous use of the water sources and the tank-stored water, it is strongly recommended that tanks be washed at regular intervals and the treatment of water with recommended doses of chemicals meant for such purposes.*

**Keywords**: water sources, water quality, storage containers microbial and physico-chemical contamination.

## 1.0 Introduction

Water is connected to every form of life on earth to the extent that without it the earth will be incompatible and uninhabitable by human and to any life form. At a basic level, everyone needs access to safe water in adequate quantities for drinking, cooking, personal hygiene and sanitation facilities that do not compromise the dignity of drinking water (Chia *et al.,* 2013). Therefore, access to safe and dependable water is a fundamental human right (United Nations Report, 2006). The United Nations and other countries declared that access to clean and safe drinking water is not only a basic human right, but constitute a very important step toward improving living standards worldwide.

Unsafe drinking water is a leading cause of preventable diseases particularly in developing countries (Momba&Kaleni, 2002). Waterborne pathogens, including a variety of viral, bacterial, algal and protozoan account for much of the deaths each year worldwide (Kosek *et al.,* 2003; Clasen *et al.,* 2006 & UN, 2006). Wright *et al.,* (2004) and Chia *et al.,* (2013) attributed the prevalence of water related diseases to storage site and facility couple with management practices.

In tropical developing countries, the predominance of unsafe water sources for drinking and other purposes is alarming the situation is complicated by attempts by different households to source for veritable means of constant water supply in order to avert associated problem of infrequent availability (Brick *et al.,* 2004, Chia *et al.,* 2013). Unfortunately, many do it in an unsafe manner thus, creating an ambiance for bacterial and other microscopic organisms to thrive. Olanrewaju and Ogunyemi (2014) attributed the presence of bacteriological and physicochemical indicators in domestic water supply to storage containers and source of supply. Majesty *et al*.,(2013) also corroborated and said that these indicators in water including their storage containers have profound influence on domestic water supply. The type of conainer and time was also examined (Adebeli and Nwaiwu, 2018). In Nigeria, Calabar in particular the situation is not different as most households depend on wells, boreholes, streams and pipe borne waters as veritable sources of domestic water supply. However, consequent upon the intermittent and unreliable supply frequencies of the later it has become inevitable to store water for drinking and other domestic purposes using available storage facilities such as tanks, plastic containers, basins, wells and others (Ziadat, 2005) to guard against inconsistencies associated with timely supplies (Ukata*et al*., 2011). From literatures it could be said that a lot has been done in respect of water contamination due to physicochemical and bacteriological effects on borehole water but more is yet to be accomplished on other water sources example, surrounding streams). This work focuses on the assessment of microbial and physicochemical contamination of water supply sources and the storage containers in Calabar Metropolis.

## 2.0 Materials and methods

This study area is Calabar Metropolis located between Longitude $08^0$ $14^1$ $40^{11}$ and $08^0$ $17^1$ $30^{11}$ of the Greenwich Meridian and Latitude $05^0$ $08^1$ $30^{11}$ and $04^0$ $56^1$ $20^{11}$N of the Equator. After a well articulated survey, it was necessary to create four study locations purposively, they included; ikoteneobong, Ekorinim, Satellite town and Anatigha all in Calabar Metropolis, information were elicited through personal observation and interviews on their experiences in the use of plastic storage facility and water usage. Four months duration was used for this study (April – July 2020) each site was allotted different month beginning from Anatigha to Ikot eneobong during raining season when the water table was supposedly high and the environmental condition tend to favour the prevalence of physicochemical indicators and the fecundity of bacterial organism which drain into the soil usually found their way into adjacent water body (Egbai*et al.,* 20017). Streams and borehole water constitute major water sources that are used to feed storage facilities in the study area

Effort was made to purposively select residential household base on certain characteristics. Consequently, two bed room residential building with a family size of 2–4 household members with water storage capacity of two (2) plastic containers measuring 3000Litres each were considered appropriate for the study. The reason is that it takes a longer time to exhaust 6000litres of water by a family of 2-4 persons. Two plastic containers mounted on a 6m platform made of galvanized poles were strategically positioned (upper and lower overhead tanks). While the water in upper plastic container can be exhausted between 4-7 days the lower plastic container takes a longer time depending on household size and water usage. Water samples were collected from the lower overhead tank within the first three (1-3) days after pumping water into the over head tank while samples were collected within 4-7 days from the upper overhead tank by this time water in the lower overhead tank is supposedly used up leaving the one in upper overhead tank.

Water samples meant for physicochemical and microbial studies were collected in 1.5Litres plastic container. Prior to samples collection, samples containers were washed with neutral liquid and rinsed with distilled and deionized water according to APHA (1985) recommended standard.

## 2.1 Physico chemical analysis

Fast changing parameters such as DO, pH and temperature were taken *insitu* according to the APHA (1985, 2012) method. $HCO^{-}_{3}$ was measured in the laboratory using HACH 2000 spectrophometer following APHA (1985, 2012) recommendation. All physicochemical parameters were measured in duplicates for authenticity of result. Mean values were compared with WHO permissible limits (Table 1).

## 2.2 Microbial analysis

Quantitative, qualitative and biochemical tests were conducted on the water samples following APHA (1985, 2012) recommended method.

## 3.0 Result and Discussion

**Table 1:** Physico-chemical and microbial parameters of the different water sources (range and mean)

| Parameters | Stream | Borehole | Upper tank | Lower tank | WHO |
|---|---|---|---|---|---|
| | Anat Sat Ekori Ikot | Anat Sat Ekori Ikot | Anat SatEkori Ikot | Anat SatEkori Ikot | |
| PH | 5.80 5.90 6.1 7.00 | 5.76 5.80 6.9 6.20 | 5.88 6.80 5.1 5.0 | 5.74 5.64 5.20 6.38 | |
| | Range: 5.8 – 7.0 | Range: 5.76 – 6.90 | Range: 5.0 – 6.80 | Range: 5.20 – 6.38 | 6.5 – 8.5 |
| | Mean 6.4 ± 0.6 | Mean = 6.33 ± 0.57 | Mean = 5.9 ± 0.9 | Mean = 5.79 ± 0.59 | |
| Do mgl | 8.4 8.12 9.2 8.3 | 7.1 7.1 7.3 7.0 | 1.4 1.5 1.7 2.18 | 6.8 6.6 6.9 7.10 | |
| | Range: 8.12 - 9.2 | Range: 7.0 – 7.5 | Range: 1.4 – 2.18 =1.79 | Range: 6.6 – 7.0 = 6.8 | 6.5 – 8. 0 |
| | Mean: 8.66_+ 0.54 | Mean = 7.25 ± 0.25 | Mean: 1.7 ± 0.39 | Mean = 6.8 ± 0.2 | |
| Temp. | 27.5 26.9 28.0 27.0 | 26.8 27.20 28.00 27.00 | 28.0 27.20 26.90 27 | 27.4 28.0 28.02 27.67 | |
| | Range: 27 – 28.0 = 27.5 | Range: 28 – 26.8 = 26.8 | Range: 26.90 – 28.0 | Range: 27.40 – 28.02 | 25.0 – 27.0 |
| | Mean = 27.50 ± 0.5 | Mean = 26.8 – 28 =27.4 27.40 ± 0.6 | Mean = 27.45 ± 0.55 | Mean = 27. 71 ± 6.31 | |
| Fe | 1.025 1.045 1.027 1.062 | 0.562 0.571 0.6 0.52 | 0.673 0.650 0.670 0.679 | 0.366 0.370 0.325 0.335 | |
| | Range: 1.025 – 1,045 | Range: 0.520 – 0.600 | Range: 0.650 – 0.679 | Range: 0.325 – 0.366 | 0.3 |
| | Mean = 1.035 ± 0.01 | Mean = 26.8 – 28 = 27.4 27.40 ± 0.6 | Mean = 0.664 ± 0.014 | Mean = 0.345 ± 0.020 | |
| Hg | <0.001 0.001 0.001 1.062 | <0.001 0.001 0.001 0.001 | <0.001 0.0001 0.002 0.001 | <0.000 0.001 0.000 0.001 | |
| | Range: 0.001 – 0.001 | Range: 0.001 – 0.001 | Range: 0.001- 0.002 | Range: 0.000 – 0.001 | <0.001 |
| | Mean = 0.001 ± 0.000 | Mean = 0.001 ± 0.000 | Mean = 0.0115 ± 0.0005 | Mean = 0.005 ± 0.0005 | |
| Bicarbonate | 30.50 30.67 31.00 31.00 | 36.60 36.79 37.00 37.10 | 24.40 24.38 24.60 25 | 30.50 30.60 31.00 30.70 | |
| | Range: 30.50 – 31.00 | Range: 36.60 – 37.10 | Range: 25.00 – 24.38 | Range: 30.50 – 31.00 | 200 |
| | Mean = 30.75 ± 0.25 | Mean = 36.85 ± 0.25 | Mean 24.66 ± 0.31 | Mean = 30.75 ± 0.25 | |
| Plate count | 42 44 46 50 | 34 40 45 50 | 163 165 166 164 | 126 127 128 127 | |
| | Range: 42 – 50 | Range 34 – 50 | Range: 163 – 166 | Range: 126—128 | 0 |
| | Mean = 46 ± 4.0 | Mean = 42 ± 8.0 | Mean = 164.5 ± 1.5 | Mean:127-' 1.0 | |
| Yeast | 0.0 0.1 0.0 0.0 | 1.0 2.0 2.0 1.0 | 3.0 3.0 4.0 3.0 | 2.0 2.7 2.8 2.2 | |
| | Range: 0.0 – 0.1 | Range: 1.0 – 2.0 | Range: 3.0-.4.0 | Range: 2.0 – 2.8 | 0 |
| | Mean = 0.005 ± 0.005 | Mean = 1.5 ± 0.5 | Mean:=3.5++0.5 | Mean = 2.4 ± 0.4 | |
| Coli form | 84.01 85.00 85.50 84 | 125 127 130 125 | 42 46 43 43.4 | 34 35 35 34 | |
| | Range: 84.0 – 85.5 | Range: 125 – 130 | Range: 42 – 46 | Range: 34 – 35 | 10 |
| | Mean = 84.75 ± 0.5 | Mean = 127.5 ± 2.5 | Mean = 44 ± 2.0 | Mean = 34.5 ± 0.5 | |

### 3.1 Results

**Physicochemical and microbial components**

The results of the analysis of the physicochemical and microbial components of the different domestic water sources revealed mean pH of 6,4±0.6 for the stream water, 6.33±0.57 for the borehole, 5.9±0.9 for the upper overhead tank and 5.79±0.59 for the lower overhead tank. Mean DO concentration of the stream was 7.25±0.25mg/l, with 8.66±0.54mg/l for the borehole, 6.8±0.2mg/l for the upper overhead tank and 1.79±0.39mg/l for the lower overhead tank (Table 1). Mean water temperature recorded for the stream was 27.5±0.5$^0$C, with 27.40±0.6$^0$C for the borehole, 27.45±0.55$^0$C for the upper overhead tank and 27.71±0.31$^0$C for the lower overhead tank.

Fe had mean concentration of 1.035±0.001mg/l in the stream water, with 0.040±0.560mg/l in the borehole, 0.664±0.014mg/l in upper overhead tank. Hg mean concentration was <0.001±0.00mg in all the water samples. Bicarbonate had mean concentration of 30.75±0.25mg/l in the stream water, with 36.85±0.256mg/l in the borehole, 24.69±0.31mg/l in the upper overhead tank and 30.75±0.25mg/l in the lower overhead tank. Mean total coliform components were 84.75±0.5 cfu/100ml in the stream water, with 127±2.5 cfu/100ml in the borehole water, 44±2.0 cfu/100ml in the upper overhead tank and 34.5±0.5 cfu/100ml in the lower overhead tank. Total plate count (TPC) had mean values of 127±1,0 cfu/100ml in the stream water, with 164.5±1.5 cfu/100ml in the borehole, 42±8.0 cfu/100ml in the lower overhead tank. Yeast/mould had mean concentration of 0.005±0.005 cfu/100ml in the stream water, with 1.5±0.5

cfu/100ml in the borehole water, 3.5±0.5 cfu/100ml in the upper overhead tank and 2.4±0.4 cfu/100ml in the lower overhead tank. As shown in Table 1, apart from bicarbonate and Hg, every other physicochemical component exceeded the WHO permissible limits for drinking water. Similar observation was recorded in the mean concentrations of the microbial components (Total plate counts, Total coliform and Yeast/mouldcfu/100ml).

### 3.2 Discussion

Water quality for domestic use is better assessed by determining the levels of physicochemical and microbial components and comparing the observed data with acceptable and recommended limits (Asuquo & Asuquo, 1999; WHO, 2012). The results of the present study indicate that the mean levels of the physico-chemical and microbial load of the water sources and stored water were above the WHO permissible limits for drinking water,. The pH ranges of 5.74±0.59 – 6.4±0.6 indicate high acidity of the water from the various sources and those in the storage containers. Demineralization of buried organic matter in the soils releases $CO_2$ as a by-product, therefore, underground and stream waters draining through such substrates leach the trapped $CO_2$, thereby contributing to increased acidity of the aquifers (Asuquo & Asuquo, 1999; Wright *et al.*, 2004).

Free $CO_2$ may also be present as a result of erosion of $CaCO_3$ deposits by underground water. The low pH in all the water sources may not be unconnected with the presence of humic acids. The consumption of acidic (low pH waters) is potentially dangerous, bearing in mind that this can cause an increase in acidic content of the stomach leading to peptic ulcer in some cases (Asuquo & Asuquo; Eja, 1999; Agbogu*et al.*, 2006; Chica *et al.*, 2013).

DO levels above 5.0mg/l are known to be an indication of an oxidized state (Asuquo, 1998; Asuquo & Asuquo, 1999; Clasen & Bastable, 2003; Chigor*et al.*, 2012). The lowest mean value of 1.79mg/l recorded in the upper overhead tank showed that the water might have stayed relatively longer in the tank than expected. Such can support the growth of anaerobic microbes, which are detrimental to human health.

Fe level exceeding the permissible limit of 0.3mg/l for drinking water is dangerous to biological systems and could lead to iron intoxication and suffocation especially when it is found in the reduced form ($Fe^{2+}$) (WHO, 1984; Asuquo & Asuquo, 1999; WHO, 2012). Patients who receive iron treatment gain weight. Iron therapy increases serum ferritin levels accompanying with body weight. Consumption of iron laden water can lead to associated danger of weight gain

The microbial numerical estimates of the isolate showed that the microbial components (Total plate count, Total coliform, Yeast/mouldcfu/100ml) each exceeded the international drinking water standard set by WHO (WHO, 2012). Potable water should not contain more than 10 total coliform per 100ml. The high numbers of total coliform (34.5±0.5 – 127.5±2.5 cfu/100ml) and total plate count (42±8.0 cfu/100ml – 164.5±1.5 cfu/100ml) are strong indications of the microbial contamination of the water sources and those in the storage containers. Water from diverse sources such as discharge and seepage of domestic sewage into underground water addition of non-flushing and washing of reservoir water tanks for several months (Asuquo & Asuquo, 1999; Chia *et al.*, 2013). The absence of yeast/mould in the stream water may not be unconnected with constant flow of the stream water and the high mean iron concentration in the stream water, a result which collaborates with those of Asuquo & Asuquo, 1999) Chigor*et al.,* (2013) during their respective studies on assessment of domestic water quality in Calabar and Zaria, Nigeria.

## 4.0 Conclusion and Recommendations

From the results it is evident that, both the water in the storage containers and from stream and borehole sources used for the domestic purposes are contaminated and potentially unsafe for human consumption.

The stream water was however not contaminated with yeast/mould, possibly due to the high mean iron concentration and its constant flow.

To reduce the risk of human infection that may arise from the continuous use of the water sources and the tank-stored water, it is strongly recommended that tanks be washed at regular intervals and the treatment of water with recommended and appropriate doses of chemicals meant for such purposes. Water engineers are to be strictly involved in borehole and domestic water management from point of release to point of use by consumers. The results of the physicochemical and microbial data of the different water sources and storage containers (mean ± SD) were compared with WHO permissible limits for ascertaining the usability of the domestic water sources.

**References**

Adibeli, J. O.&Nwaiwu, N. E. (2018). Effect of storage conditions on physicochemical parameters of Borehole Water. American Journal of Engineering Research (AJER)8(1); pp 87-98

APHA (1985). *Standard methods for the examination of water and waste.* 16th Edition Washington D.C.

APHA (2012). *Standard methods for the examination of water and waste water*. 22nd edition. Washington DC.

Asuquo, E. F. & Asuquo, E. F. (1999). Quality of drinking water sources and associated health problems in Calabar, Nigeria*Journal of Applied Science and Environmenta*l *Management*, 3, 29-35.

Chia, M. A., Onyie, S. J &Swanta, A. A. (2013). Domestic water quality assessment: microalgal and Cynanobacterialcontamination of stored water in plastic tanks in Zaria, Nigeria. *European Journal of Scientific Research* 110,4,501-510.

Chigor, V. N., Umoh, V. J., Okuofu, C. A., Ameh, J. B., Igbinosa, E. O. & Okoh, I. A. (2012). Water quality assessment: surface water sources used for drinking and irrigation in Zaria, Nigeria, are a public health hazard. *Environmental Monitoring and Assessment,* 184, 3389-3400.

Clasen, T. & Bastable, A. (2003). Faecal contamination of drinking water during collection and household storage: the need to external protection to the point of use. *Journal of water Health,* 1(3), 109-115.

Egbai, O. O. (2016).Effect of crop cover on soil susceptibility to erosion in southeastern Nigeria. Journal of physical science and environmental studies 2(4), 50-57

Eja, M.E. (1999). Seasonal occurrence of enteric bacteria pathogens in Calabar Municipal water supplies. *Global Journal of pure and Applied Science,* 5,37-40.

Goldman, C. R. & Horne, A. J. (1983). *Limnology*. MCGraw-Hill publishing Company, New York, 464p.

Kosek, M., Bern, C. & Guerrant, R. L. (2003). The global burden of diarrhoea disease as estimated from studies published between 1992 and 2000. *WHO Bulletin,*81,197-204.

Majesty, D,. Chioma, A., Benjamin, A., Chijoke, N., & Nze, H. (2013). Effect of different storage vessels on water quality. Global research journal of science, 2(2); 9-13

Nowbam, N. B. &Kaleni, P. (2002). Regrowth and survival of indicator microorganisms on the surfaces of household containers used for storage of drinking water in rural communities of south Africa.*WaterResearch*, 36, 3023-3028.

Olanrewaju, O. & Oluwatoyin, O. (2014). Effect of storage containers on water quality of house drinking water in Ibadan, Nigeria, International journal of public Health Science (IJPHS) 3(4); pp 253-258

Ukata, S., Egbai, O. O., Ndik, E. j., Ewa, E. E., Uquetan, U. I. (2011). Domestic water supply issue in Calabar Metropolis CRS, Nigeria. *Journal of Human Ecology* 36(3), 199-203

United Nations (2006). *Human Development Report,* 2006. United Nations Development Programme, New York 214p.

WHO (2003).*Chloride in drinking water. Background document for preparation of WHO Guidelines for drinking water quality*. Geneva. World Health Organization (WHO/SDE/WSH/03.04/3).

Wright, J., Gundry, S. & Conroy, R. (2004). Household drinking water in developing countries. A systematic review of microbiological contamination between source and point of use. *Tropical Medicine and Intensive Health.* 9(1), 106-107.

Ziadat, A. (2005). Impact of storage tanks on drinking water quality. Journal of Applied Science 5, (4) 634-638

# SPATIAL ASSESSMENT OF THE EFFECT OF GRAVEYARDS ON BOREHOLE WATER QUALITY IN CALABAR METROPOLIS

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**Abstract**

*Graveyards are sources of contaminants to borehole water especially when located at proximity to residential areas. Factors such as infiltration rate, depth, geological formation, depth to water table, climate condition of the area and the soil types affect the rate which graveyard contaminants affect ground water supply . The study sourced water samples from ten (10) boreholes located around cemeteries in 8miles, Calabar Harbour Axis, Ikot Ansa, Esuk Ediba, Big Qua, Etta Agbo, Goldie, Hawkins, Eta Agbor and Mbukpa. These samples made up the test samples. The water samples were subjected to laboratory test to assess its constituents. Furthermore, the hypothesis formulated in the study was subjected to statistical test using simple t-test and nearest neighbor analysis. The result of the water analysis conducted availed the physico-chemical constituents of the water sample which showed average temperature to be 26.09$^{o}$c, TDS was 20.66, average nitrate constituent was 100.3, average chloride constituent of water sample was 103.2, average total coliforms of the water sample was 21.2 and average feacal coliforms of the water sample was 19.5. It was thus observed that these values were above the stipulated WHO recommendation standard. The result of the t-test further buttresses the significant difference between physico-chemical characteristics of the water sample and the WHO standard. In addition, the nearest neighbor analysis showed that the spatial distribution of graveyards exhibited a clustered pattern. The researchers recommended that graveyards should be sited at least 250 m away from the residential boreholes and slabs or tiles should be used in walling graves before coffins are buried.*

**Keywords: Graveyards; Contaminants, Boreholes, Pollution and Water parameters.**

## Introduction

Water demand, supply and rate of pollution is a serious challenge facing Calabar Metropolis. While most studies focused on agriculture, industries and landfills as major sources of ground water pollution, there have been few studies that have focused on water contaminant from graveyards. Rodrigues and Pacheco (2003) opine that human corpse is a complex matrix that contains 50% water 15% bones and 30% organic substance. This complex substance is also made up on 17% protein, 17%, fat and 6% , carbohydrate coupled with some inorganic and trace elements such as calcium, phosphorus, nitrogen and sodium, which are subjected to continuous autolysis, purification and decay.

Graveyards have effect on the immediate environment and the underlying groundwater. During the decomposition of dead bodies, both organic contaminants from dead bodies and inorganic contaminants like heavy metals from coffins are leached into the soil (Spongberg & Becks, 2000). The rate of leaching is determined by nature and infiltration rate of soil, burial types and rainfall impact.

Research has shown that there exists a relationship between ground water pollution and graveyard location (Killgrove& Montgomery 2016). Eni, Obiefuna, Oko, and Ekwok (2011) opined that the detrimental effect of graveyards on ground water pollution is very visible in the high concentrations of bicarbonates, sulphates, electrical conductivity and chlorides which further increases the spread of infection diseases and epidermic. A study undertaken by Hart and Casper (2019) revealed that there were higher concentrations of microbial contaminants such as total and faecal coliform, faecalstretoptococcus, heterotrphic bacteria , clostridia and protcolytic bacteria in ground water samples around grave yards.

As result of the potential impact of grave yards on ground water, many researchers are of the view that drinking water supply scheme such as boreholes, wells and springs should be located away from graveyards. For instance, to eliminate the possibility of ground water contamination from grave yard leachates, Miller & Wiens, (2017) stressed that graveyards must have setback distances. There are regulations or by-laws that stipulate how far from water sources, drainage, ditches and graveyards must be situated. Several government regulations of different country emphasize the need for graveyards to be located at specific distances from the central business districts. For instance, the United Kingdom Environmental Agency (2019) specified some restrictions for where a graveyard can be located. According to the agency, new burial site, or an extension to an existing graveyard, cannot be located less than 250m from any well, borehole or spring used to supply water for human consumption or food production and not less than 30m from any spring or watercourse.

Likewise, the British Columbia Public Health Act, Health Hazards regulation 216/2011, contains information that specifies that water wells must be 120 m from possible sources of contamination, including graveyards (Government of British Columbia, 2011). This provision dates back to 1917 and was more likely a “rule of thumb” approach, rather than having any scientific basis. Furthermore, a study in South Africa concludes that graveyard should be between 50 m and 500 m distance from potential water wells. Also, a study by Zume (2011) concludes that hand-dug wells within 25 m of traditional burial sites in Nigeria are liable to contamination from graveyards. In Calabar Metropolis, graveyards are cited without consideration of the potential impact it would cause to the immediate environment, particularly on ground water. Hence, this study sought to assess the impact of graveyards emissions on ground water in Calabar Metropolis.

Calabar Metropolis is spatially located in the southern part of Cross River State and it constitute of Calabar Municipality and the Calabar South Local Government Areas. It lies geographically between longitudes $8^0$18 East to $8^0$24 East of the Greenwich Meridian and latitudes $4^0$54 North to $5^0$10 North of the equator. Calabar is characterized by a humid tropical climate with a double maxima rainfall pattern of approximately 3063mm. Calabar is Characterized with rapid urbanization regime owing to the massive urban-rural migration.

**Methods and Materials**

The continuous types of data were adopted in both laboratory and geo-spatial assessment of the ground water. Both primary and secondary sources of data were adopted in the study. The primary sources of data adopted in this study were the geographic coordinates from the field and water samples parameters. While the secondary sources of data which include: reports of water quality standard from World Health Organization (WHO), downloaded from WHO publication website. Water samples were collected from wells around grave yards using a water receptacle and labelled before being conveyed to the lab for further analysis. Furthermore, geographic coordinates of graveyards in Calabar Metropolis were obtained from field survey using the GPS and a note pad. The descriptive statistics technique such as mean and standard deviation was adopted in presenting the result of the laboratory test.

## Result and Discussion

The result of the water sample parameter test as presented in table 1 showed that the mean pH value of the water samples was 6.98 while the recommended standard was 6.5 to 8.5, hence, the water samples are within the acceptable limit as postulated by who standard. Also, the mean Electric Conductivity (EC)of water sample was 5.44 EC while the recommended value was 2500 EC. This showed that the mean electric conductivity of boreholes was lower than WHO standard and this can be correlated to the fact that purification process of deceased bodies does not affect the EC of water. More so, in terms of water hardness, the mean water hardness was 66.25PPM while the recommended hardness from WHO was 250PPM, the mean Total Dissolved Solid (TDS) from the water sample was 20.66PPM while the standard limit for TDS was 500PPM. Also, the assessment of water turbidity availed that the mean water sample was 0.481NTU while the who standard was 1.5NTU. Again, the lower level of parameters proved that the presence of graveyards does not affect the hardness, TDS and turbidity of ground water.

However, it was observed that some parameters were higher than the recommended limits of WHO. for instance, the mean temperature of the water samples availed a result of 26.69 $^{o}$c while the standard limit was 25$^{o}$c as recommended by WHO. This implies that the temperature condition of reservoir from the boreholes within the graveyard region is higher than the stipulated limit of WHO and this can be correlated to the presence of the graveyards within the region of the borehole. Furthermore, the result of the mean Sulphate ion deposit was 6.02mg/l, while the recommended limit was 0.1mg/l. Again, this is due to the proximity of the borehole to the graveyards. More so, the mean Phosphate of water sample displayed a result of 1.6 while the recommended level was 0.1, the mean nitrate deposit of water sample was 100.3, while the recommended nitrate deposit was 50, the mean manganese deposit of the water sample was 0.12 while 0.05 was the recommended limit by WHO. Lastly, it was observed that both the mean value of the total coliform was 21.1. In summary it was observed that the location of the borehole close to the graveyards affect some water parameters such as temperature, sulphate, phosphate, nitrate, manganese, iron, calcium and total coliform.

**Table 1:** Height to water table in the different borehole sites

| Borehole Location | Height |
|---|---|
| 8miles | 40m |
| Harbour | 39m |
| Ikot Ansa | 35m |
| Big Qua | 30m |
| Esuk Ediba | 28m |
| Etta Abgo | 25m |
| Hawkin | 30m |

Source: Researcher’s field work 2021

**Table 2:** Water Quality Parameters, Mean, Standard Deviation and WHO Standards

| ` | Parameters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean | S.D | WHO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | PH | 7.2 | 6.8 | 6.4 | 6.9 | 8.6 | 6.3 | 6.5 | 6.8 | 7.9 | 6.4 | 6.98 | 2.275822581 | 6.2-8.5 |
| 2 | Temperature () | 25.6 | 26.5 | 27.8 | 24.8 | 26.5 | 28.5 | 29.5 | 25.6 | 25.6 | 26.5 | 26.69 | 10.1748542 | 25 |
| 3 | Electrical Conductivity | 6.43 | 5.44 | 4.55 | 4.8 | 4.5 | 5.4 | 6.4 | 8.6 | 3.8 | 4.5 | 5.442 | 10.98943004 | 2500 |
| 4 | Total Hardness | 37.5 | 40.5 | 58.9 | 26.5 | 64.5 | 84.6 | 95.6 | 76.5 | 82.3 | 95.6 | 66.25 | 35.58134985 | 250 |
| 5 | Total dissolved solid | 28.5 | 30.6 | 45.3 | 19.4 | 10.5 | 16.5 | 10.3 | 11.6 | 14.5 | 19.4 | 20.66 | 29.96463661 | 500 |
| 6 | Turbidity | 0.07 | 0.08 | 0.15 | 0.01 | 1 | 0.6 | 0.9 | 0.7 | 0.7 | 0.6 | 0.481 | 12.88747759 | 1.5 |
| 7 | Sulphate ion | 4.5 | 6.3 | 7.8 | 2 | 9 | 9.6 | 4.6 | 7.8 | 5.4 | 3.2 | 6.02 | 3.33694546 | 0.1 |
| 8 | Phosphate | 0.06 | 0.08 | 0.2 | 0.01 | 0.1 | 10 | 1.5 | 2.6 | 0.6 | 0.9 | 1.605 | 3.545768234 | 0.1 |
| 9 | Nitrate | 1.08 | 1.02 | 1.4 | 0.02 | 140 | 150 | 160 | 200 | 170 | 180 | 100.352 | 78.51860593 | 50 |
| 10 | Manganese | 0.05 | 0.06 | 0.02 | 0.01 | 0.04 | 0.05 | 0.06 | 0.1 | 0.25 | 0.6 | 0.124 | 78.98283662 | 0.05 |
| 11 | Iron | 1.5 | 2.4 | 3.05 | 0.06 | 0.2 | 0.6 | 0.3 | 0.4 | 0.5 | 0.7 | 0.971 | 0.832174545 | 0.2 |
| 12 | Calcium | 0.08 | 0.09 | 0.04 | 0.02 | 0.07 | 0.9 | 0.8 | 0.1 | 0.6 | 0.4 | 0.31 | 0.811194538 | 0.05 |
| 13 | Chloride | 1.8 | 2.1 | 3.15 | 0.05 | 215 | 150 | 160 | 180 | 110 | 210 | 103.21 | 82.51399384 | 250 |
| 14 | Total Coliform | 10 | 30 | 20 | 16 | 10 | 15 | 20 | 46 | 25 | 20 | 21.2 | 76.45959872 | 0 |

**Source:** Researcher's field work and WHO report, 2016

## 4.0. Conclusion and Recommendation

Safety should paramount in the distribution of water resources. The study thus concludes that proximity of graveyards to public utility borehole can prove fatal to the residents sharing the water sources. Graveyards have the potential to release organic and inorganic constituents that can leach into the water table and contaminate the water sources. Water parameters such as temperature, sulphate, phosphate, nitrate, manganese, iron, total coliforms and faecal coliforms amongst other tends to be affected the most, which could prove fatal to both man, plant and animals depend on the contaminated source. Lastly it was thus concluded that boreholes closer to graveyards tend to be affected more than boreholes farther from the graveyards. Hence, it is thus recommended that;

i. Grave yards should be sited far away from potential useful boreholes within the community; at least 250m away from the residential boreholes

ii. Slabs and tiles should be used in walling graves before the coffins can be buried; this will ensure that there is no seepage of organic and inorganic constituents when the bodies starts decaying

iii. Coffins should be designed to seal organic constituents properly

iv. Ground water should be treated properly by the government distribution and by residents before consumption

## Reference

Government of British Columbia (2011). Public Health Act Health Hazards Regulation 216/2011. Available from: http://www.bclaws. ca/civix/document/id/complete/statreg/216_2011

Miller, A., & Wiens, M. (2017). Graveyard setback distances to prevent surface water contamination. National Collaborating Centre for Environmental Health at the British Columbia Centre for Disease Control.

UK. Environment Agency, 2019. Graveyards and burials: prevent groundwater pollution, Environment Agency. Available at: https://www.gov.uk/guidance/graveyards-and-burials-preventgroundwater-pollution

World Health Organization (WHO, 1998). The impact of graveyards on the environment and public health: an introductory briefing. Copenhagen, Denmark: World Health Organization, Regional Office for Europe; 1998. Available from: http://apps.who.int/iris/bitstream/10665/108132/1/EUR_ICP_EHNA_01_04_01(A).pdf

Zume, J.T. (2011). Assessing the potential risks of burial practices on groundwater quality in rural north-central Nigeria. J Water Health. Pp:609-16.

Zychowski, J. & Bryndal, T. (2015). Impact of graveyards on groundwater contamination by bacteria and viruses – a review. Journal of Water and Health. Vol 13 (2); Pp: 285-302

Eni, D.I., Obiefuna, J.N., Oko, C., Ekwok, I. (2011). Impact of urbanization on sub-surface water quality in Calabar municipality, Nigeria'. International Journal of Humanities and Social Science, 1, 167-172.

Killgrove, K., & Montgomery, J. (2016). All roads lead to Rome: exploring human migration to the eternal city through biochemistry of skeletons from two imperial-era graveyards (1st-3rd c AD). PLoS One, 11(2), 1-30

Hart, Alwyn & Casper, Susan. (2004). Potential groundwater pollutants from graveyards. Retrieved from: http://10.13140/RG.2.1.3830.2489.

Miller. A., & Wiens, M.(2017). Graveyard setback distances to prevent surface water contamination. Retrieved from https://ncceh.ca /sites/default/files/Ce metery_setback_distan ces_surface_water_contamination-Oct_2017.pdf

Rodrigues, L. & Pacheco, A.(2003) Groundwater contamination from graveyards cases of study In: International Symposium: Environment 2010: Situation and Perspectives for the European Union, Abstract Book CD-ROM Full Paper C01University of Porto pp. 1–6

Spongberg, Alison & Becks, Paul. (2000). Inorganic Soil Contamination from Graveyard Leachate. Water Air and Soil Pollution. 117. 313-327.

Zume, Joseph. (2011). Assessing the potential risks of burial practices on groundwater quality in rural north-central Nigeria. Journal of water and health. 9.

Żychowski J, Bryndal T. Impact of graveyards on groundwater contamination by bacteria and viruses - a review. J Water Health. 2015 Jun;13(2):285-301. doi: 10.2166/wh.2014.119. PMID: 26042963.

# EVALUATION OF WATER QUALITY VARIATION FOR DRINKING IN SOME SELECTED EX-MINING PONDS IN RIRUWAI RING COMPLEX AREA, KANO STATE, NIGERIA

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**Abstract**

*Surface water quality evaluation for drinking in some old mining ponds of Riruwai was undertaken. Ex-mining ponds serves as major sources of drinking water in the study area and the water might be unsafe for drinking since it is not treated. Three ex-mining ponds were purposively selected. From each of the ponds three water samples were collected at three points in both wet and dry seasons. Water samples were analysed in the laboratory using standard techniques. The data was analysed using descriptive statistics and ANOVA. Results show that conductivity recorded highest mean values as 60.57us/cm, 92.77us/cm and 288.67us/cm in green-water, Rafin-kwalwa and dam ponds respectively. Nitrite recorded the lowest mean value of 0.02mg/l, 0.02mg/l and 0.04mg/l in Green-water, Rifin-kwalwa and Dam respectively. Result of the ANOVA analysis in Green-water among the three points based on seasons indicated that only turbidity and TDS are significant with P-value 0.002 and 0.019 respectively. In Rafin-kwalwa pond 13 parameters are significant with exception of Hardness, Nitrire, and Cl with P-values 0.650, 0.223 and 0.095 respectively. It was indicated that 11 parameters are significant in Dam-pond with exception of temperature, pH, Cl and BOD with P-values 0.926, 0.415, 0.184 and 0.117 respectively. Among the three water bodies 13 parameters are significant except colour and temperature with P-values 0.639 and 0.103 respectively. In comparison with standards in Green-water pond 9 parameters are within the acceptable limit except for turbidity, mg, $SO_4$, Cl and BOD. In Rafin-kwalwa 8 parameters are within the acceptable limit except for temperature, turbidity, mg, Fe, $SO_4$, Cl and BOD. For dam-pond 7 parameters are within the permissible limit except for temperature, turbidity, Mg, Fe, $SO_4$, Cl and BOD. It is concluded that Green-water pond is less turbid and more potable than the rest of the ponds. Reference to the findings it is recommended that, all the three ex-mining ponds need to be treated for safe potable drinking water supply in the area.*

**Keywords**: Ex-mining ponds, Water Quality, Variation, Ring Complex area, Kano

## Introduction

Water is an essential part of life which without people would remain in distrait condition. Surface water is more open to contamination than groundwater. Availability of portable drinking water is an issue of global concern. Surface water is one of the major sources of drinking water that is why treatment plants are mostly attached to rivers, reservoirs and other surface water bodies. Rural dwellers particularly in areas of younger granites depend mostly on surface water sources than groundwater sources. In some areas surface water is taken directly without treatment which may lead to spread of water borne diseases.

For that it is necessary to pay more attention to surface water level of contamination. Water pollution is a major global problem requires evaluation and revision of water policy at all levels (Imo, Nwakuba, Asoegwu, and Okereke, 2017).

Old mining ponds are used as sources of drinking water in different parts of the globe and are most likely sources of contaminants. Globally, estimates by the United States of America's Bureau of Mines indicate that over 19,000 km of rivers and streams and 73,000 hectares of lakes, ponds and reservoirs are negatively impacted by mine water from abandoned coal and metal mines and others (Ashraf,Maah, and Yusoff, 2012). In Nigeria despite public and international agencies concern on water quality condition in old mining ponds it seems no much attention is paid to the issue (Adamu, Nganje and Ede, 2015). That is why water quality status of such mines and old mining ponds of which people used to take its water need to be investigated for effective environmental and health protection.

Studies conducted on old mining ponds water quality include that of Ashraf,*et al* (2012) that determined the Morphology, Geology and Water Quality of Former Tin Mining Catchment in Malaysia and find that all the parameterspH, temperature, electric conductivity, dissolved oxygen DO, total dissolved solids TDS, chlorides, ammonium, nitrates were above the limit and the ponds are polluted. Kah, *et al* (2016) evaluated lakes, rivers, and ex-mining ponds in Malaysia and revealed that Principal component analysis indicated that TSS, COD, BOD, Pb, and arsenic are highly associated with ex-mining ponds and are above the acceptable limits.Also, Adamu, *et al* (2015) determined water quality of abandoned mine in Cross River state and find out that the average concentrations of Fe, Hg and Pb were above the required standard which indicates anthropogenic inputs from barite mining activities in to the water in the old barite mining ponds. Most of these studies were conducted not in the study area and are associated with lakes, old mining ponds and the mineral mined in the area in the fast are different from those of this study area.

In Riruwai people depend on surface water source as a major source of water for drinking which is called green water. Groundwater in the area is scares due to the geology there. One of the remarkable hydrological features in Riruwai is the presence of surface water reservoir known as green water (Alhaji, Adamu and Buba, 2017). Water from green water is stored in tanks and distributed to the house holds directly without treatment (Plate 1 Appendix I). This is due to the fact that people in the area believed that water from the rock is being added to this old mining pond which is clean. Previous studies in Riruwai centered more on geomorphology and human geography of the area without evaluating water quality status of these old mining ponds that are used as water sources. That is why the aim of the study was to determine and compare the level of water quality in the existing old mining ponds in the area for effective portable water supply.

## Materials and Methods

### The study Area

Riruwai, a town in Doguwa local government area southern part of Kano State is surrounded by ring complex. It is located between latitude 10°48′00″N and 10°49′20″N and between longitude 8°44′00″E and 8°45′10″E (Figure 1). The geology of Riruwai composed of both older and younger granites. In terms of relief it is the highest point in Kano state. The geology of the area composed of younger and older granites of 165ma in Jurassic period (Olofin, 2006). The highest elevation in Riruwai is 1230m around Shatu hill. The average elevation in Riruwai is 1100metres (Alhaji, *et al*, 2017). In terms of climate; it falls under Aw characterised by wet and dry seasons, average temperature 23°C, and rainfall 1100mm (Alhaji, *et al*, 2017). The vegetation of the area is characterized by Guinea Savannah. The hydrology of the area is made up of rivers like Sansantsa, Magajiya, Tandama and Mace da Ciki among others. The area serves as watershed to most of the rivers flowing towards Kano and Bauchi. The major surface water reservoir in the area is green water old mining pond among others. In terms of groundwater the area falls under low groundwater potential zone (Rilwanu, 2014).

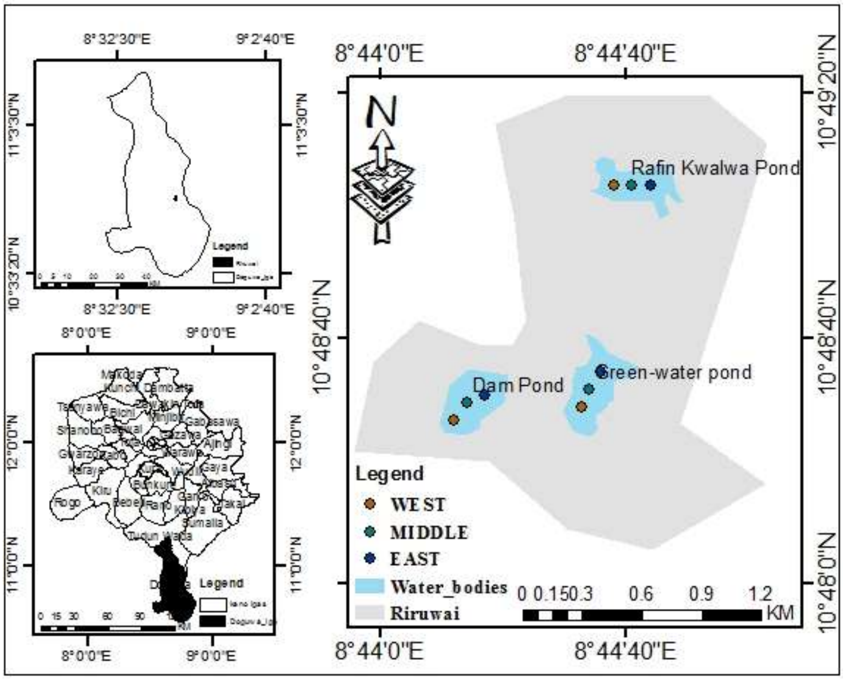


**Fig. 1.** Riruwai showing the study sites

### Sampling Procedures

Three ex-mining ponds were purposively selected because people are drinking water from them. From each of the three old mining ponds three sampling points were selected at east, west and middle and samples water samples were collected in wet and dry seasons as adopted from Rilwanu (2019).

### Methods of Data collection

Water samples were collected in sterilized bottles, refrigerated and analysed in the laboratory using standard methods for determining water quality parameters that include Colour, Turbidity, Hardness, Conductivity, TDS, Ca, Nitrite, Fe, Sulphate, Cl, BOD and pH with spectro-photo metre. But temperature was determined at the point of samples collection.

### Methods of Data Analysis

The data was analysed using descriptive statistics (mean) and inferential statistics (ANOVA of differences) as adopted from Rilwanu (2019).

### Results and Discussion

Result shows that conductivity is higher than all the parameters with 60.57 us/cm, 65.45 us/cm and 142.88 us/cm in green-water, Rafin-kwalwa and dam ponds respectively while Nitrite recorded the least values of 0.02mg/l, 0.02mg/l and 0.04mg/l in green-water, Rafin-kwalwa and dam ponds respectively

(Table 1). This indicates presence of high dissolved solid in Rafin-kwalwa and dam ponds. Conductivity is good indicator of the approximate concentration of dissolved solids in surface water (National Standard of Drinking Water Quality, 2007). Result of ANOVA of differences for green-water shows that only two parameters re significant at 0.05 level which are Turbidity and TDS with P-values 0.002 and 0.0019 respectively while all the rest are not significant (Table 2). This finding is supported by that of Kah, *et al* (2016) that most of the parameter are associated. The result of ANOVA of differences in Rafin-kwalwa pond indicated that most of the parameter are significant, only three are associated as Hardness, Nitrite and BOD with P-values 0.650, 0.223 and 0.095 respectively (Table 3). This finding is contrary to that of Kah, *et al* (2016) in which most of the parameters are not significantly different. The result for the ANOVA at dam pond indicated that all the parameters are significant except for temperature, pH, Cl and BOD with P-values 0.926, 0.415, 0.184 and 0.117 respectively (Table 4). For the test of differences among the three ex-mining ponds result shows that all the parameters are significant except only two colour and temperature with P-values 0.639 and 0.103 respectively (Table 5).

In comparing with standard result shows that in green-water pond all the parameters are within the acceptable limit except for turbidity, mg, SO4 that are above the limits of WHO, NSDWQ and NESREA while Cl, and BOD above the limit of WHO and NSDWQ. At Rafin-kwalwa Pond the parameters are within the acceptable limits of WHO, NSDWQ and NESREA except temperature and Cl are above the limits of WHO, Fe is above the limit of NSDWQ and NESREA while turbidity, mg and SO4 are above the standards of WHO, NSDWQ and NESREA. At green-water pond all the parameters are within the acceptable limit except for turbidity, mg, SO4 that Cl, and BOD above the limit of WHO, NSDWQ and NESREA. At Rafin-kwalwa and dam-ponds 8 parameters were found to be within the limit with exception of temperature, Cl, Fe, turbidity, mg, and BOD are above the standards of WHO, NSDWQ and NESREA (Table 6). This is supported by the work of Ashraf,*et al* (2012).

Table 1 Mean concentration of the Parameters

| Parameters | Green-water Pond | Rafin-kwalwa Pond | Dam Pond |
|---|---|---|---|
| Colour | 5.83 | 6.73 | 7 |
| Temperature | 32.35 | 31.25 | 32.58 |
| Turbidity | 6.67 | 21.15 | 21.78 |
| Hardness | 37.57 | 44.89 | 92.79 |
| Conductivity | 60.57 | 92.77 | 288.67 |
| TDS | 29.1 | 65.45 | 142.88 |
| SS | 4.3 | 25.93 | 22.33 |
| pH | 7.67 | 6.5 | 6.93 |
| Ca | 10.2 | 15.04 | 20.49 |
| Mg | 2.92 | 1.91 | 10.25 |
| Nitrite | 0.02 | 0.02 | 0.04 |
| Fe | 0.24 | 1.23 | 2.12 |
| Sulphate | 8 | 4.78 | 6.35 |
| Cl | 16.08 | 25.05 | 30.17 |
| BOD | 7.96 | 60.3 | 52.05 |

Table 2: ANOVA for of Green-water old mining Pond

| Parameters | F | P | Remark |
|---|---|---|---|
| Colour | 1 | 0.465 | Not Significant |
| Temperature | 2.75 | 0.21 | Not Significant |
| Turbidity | 109 | 0.002 | Significant |
| Hardness | 2.488 | 0.231 | Not Significant |
| Conductivity | 3.348 | 0.172 | Not Significant |
| TDS | 0.117 | 0.019 | Significant |
| SS | 6.759 | 0.894 | Not Significant |
| pH | 1.359 | 0.07 | Not Significant |
| Ca | 0.5 | 0.38 | Not Significant |
| Mg | 0.84 | 0.65 | Not Significant |
| Nitrite | 0.551 | 0.513 | Not Significant |
| Fe | 0.551 | 0.626 | Not Significant |
| Sulphate | 1.5 | 0.354 | Not Significant |
| Cl | 2.432 | 0.236 | Not Significant |
| BOD | 0.577 | 0.614 | NotSignificant |

**Table 3:** ANOVE for Kwalwa old mining Pond

| Parameters | F | P | Remark |
|---|---|---|---|
| Colour | 32.019 | 0.009 | Significant |
| Temperature | 36.48 | 0.008 | Significant |
| Turbidity | 254.411 | 0 | Significant |
| Hardness | 0.5 | 0.65 | Not Significant |
| Conductivity | 37.253 | 0.008 | Significant |
| TDS | 45.88 | 0.006 | Significant |
| SS | 516.008 | 0 | Significant |
| pH | 26.817 | 0.012 | Significant |
| Ca | 2696.59 | 0 | Significant |
| Mg | 19.244 | 0.019 | Significant |
| Nitrite | 2.584 | 0.223 | Not Significant |
| Fe | 157.952 | 0.001 | Significant |
| Sulphate | 57.233 | 0.004 | Significant |
| Cl | 7930.86 | 0 | Significant |
| BOD | 5.723 | 0.095 | Not Significant |

**Table 4** ANOVA for the Dam old mining Pond

| Parameters | F | P | Remark |
|---|---|---|---|
| Colour | 40.5 | 0.007 | Significant |
| Temperature | .079 | 0.926 | Not Signific |
| Turbidity | 252.203 | 0 | Significant |
| Hardness | 14401 | 0 | Significant |
| Conductivity | 10.257 | 0.046 | Significant |
| TDS | 35.459 | 0.008 | Significant |
| SS | 102.071 | 0.002 | Significant |
| pH | 1.197 | 0.415 | Not Signific |
| Ca | 589.344 | 0 | Significant |
| Mg | 1140.49 | 0 | Significant |
| Nitrite | 154.5 | 0.001 | Significant |
| Fe | 125.073 | 0.001 | Significant |
| Sulphate | 24.503 | 0.014 | Significant |
| Cl | 3.144 | 0.184 | Not Signific |
| BOD | 4.778 | 0.117 | Not Significa |

Table 5 ANOVA for the three old mining Ponds

| Parameters | F | P | Remark |
|---|---|---|---|
| Colour | 0.461 | 0.639 | Not Significant |
| Temperature | 2.656 | 0.103 | Not Significant |
| Turbidity | 9.143 | 0.003 | Significant |
| Hardness | 276.671 | 0 | Significant |
| Conductivity | 182.352 | 0 | Significant |
| TDS | 553.554 | 0 | Significant |
| SS | 16.703 | 0 | Significant |
| pH | 6.301 | 0.01 | Significant |
| Ca | 37.202 | 0 | Significant |
| Mg | 208.198 | 0 | Significant |

Table 6 Comparing water Quality parameters with Standards

| Parameters | Green-water pond | Rafin-kwalwa Pond | Dam Pond | WHO/NSD WQ Standard |
|---|---|---|---|---|
| Colour | 5.83 | 6.73 | 7 | NIL |
| Temperature | 32.35 | 31.25 | 32.58 | 35 |
| Turbidity | 6.67 | 21.15 | 21.78 | 5 |
| Hardness | 37.57 | 44.89 | 92.79 | 100 |
| Conductivity (us/cm) | 60.57 | 92.77 | 288.67 | 250 |
| TDS | 29.1 | 65.45 | 142.88 | 250 |
| SS | 4.3 | 25.93 | 22.33 | 30 |
| pH | 7.67 | 6.5 | 6.93 | 6.5-8.5 |
| Ca | 10.2 | 15.04 | 20.49 | 30 |
| Mg | 2.92 | 1.91 | 10.25 | 0.4 |

| | | | |
|---|---|---|---|
| Nitrite | 4.8 | 0.024 | Significant |
| Fe | 33.674 | 0 | Significant |
| Sulphate | 8.337 | 0.004 | Significant |
| Cl | 12.622 | 0.001 | Significant |
| BOD | 20.279 | 0 | Significant |

| | | | | |
|---|---|---|---|---|
| NO3 | 0.02 | 0.02 | 0.04 | 5 |
| Fe | 0.24 | 1.23 | 2.12 | 2 |
| Sulphate | 8 | 4.78 | 6.35 | 0.05 |
| Cl | 16.08 | 25.05 | 30.17 | 5 |
| BOD | 7.96 | 60.3 | 52.05 | 10 |

Author’s Data, NSDWQ (2007) and WHO (2018)

**Conclusion and Recommendations**

It is concluded that Green-water old mining pond is less polluted as compared to Rafin-kwalwa and dam ponds. The Dam and Rafin-kwalwa ponds are more turbid with high level of conductivity. All parameters are significant among the three ex-mining ponds except for colour and temperature because of similarities in sediments types and climate. In almost all the three ponds Cl, Fe, Turbidity, Mg and BOD among others were found to be above acceptable limit. With reference to the findings, is recommended, among others issues that, water in the three ex-mining ponds should be treated before distribution into the town for effective portable drinking water supply in the area.

**References**

Adamu, C.I., Nganje, T.N. and Ede, A.(2015) Heavy metal contamination and health risk assessment associatedwith abandoned barite mines in Cross River State, southeasternNigeria, *Environmental Nanotechnology, Monitoring & Management*, 3(2015):10-21.

Alhaji, M., Adamu, S. and Buba, L.F. (2017) Assessment of Summer Heat Stress Condition for Tourism Development in Riruwai Ring-Complex, Doguwa Local Government, Kano State, *Dutse Journal of Pure and Applied Sciences*, 2(3): 288-299.

Ashraf, M.A., Maah, M.J. and Yusoff, I. (2012) Morphology, Geology and Water Quality Assessment of Former Tin Mining Catchment, *The Scientific World Journal*, 2012:1-15, Article ID 369206, 15 pages doi:10.1100/2012/369206.

Imo, C.I., Nwakuba, N.R., Asoegwu, S.N. and Okereke, N.A.A. (2017) Impact of Brewery Effluents on Surface Water Quality in Nigeria: A Review, *Chemistry Research Journal*, 2(6):101-113.

Kah, H.L., Isa, Hafizan J., Azman A., Shima, B., Rabia, I., Hamisu, A.M. and Sharifuddin M. Z. (2016)Evaluation of water quality variation in lakes, rivers, and ex-mining ponds in Malaysia (review).*Desalination and Water Treatment* 57(5): 28215-28239.

National Standard of Drinking Water Quality (2007) Nigerian Standard for Drinking Water Quality. *Nigerian Industrial Standard NIS 554*, Standard Organization of Nigeria, p30.

Olofin (2006) Wudil within Kano region. A Geographical synthesis. Edited by E.A Olofin, A.B Nabegu, and A.M. Dambazau.

Rilwanu, T.Y.(2014) *An Assessment of Groundwater potential for rural water supply in parts of Kano State*, *Northern Nigeria*, An un Published Ph.D Thesis ABU, Zaria.

Rilwanu, T.Y. (2019) Comparative Assessment of Fluvial Sediments Concentration in Guzu-Guzu and Magaga Reservoirs, Kano West, Nigeria. *Proceedings of the 10th International Conference of the Nigeria Association of Hydrological Sciences (NAHS) held from 21st – 24th October, 2019 at The Department of Geography UsmanuDanfodiyo University, Sokoto titled Water Security, Society and Patnership for Sustainable Development*. Edited by Iliya, M.A., Adamu, I.A., Abubakar, S.D., Dankani, I.M. and Bello, N. PP. 70-76

World Health Organization (2018) *A global overview of national regulations and standards for drinking-water quality*,Water, Sanitation, Hygiene and Health, World Health Organization, 20, Avenue Appia, 1211 Geneva 27,Switzerland.

**Appendix I**

Plate 1 Green-water as a major source of pipe borne water in Riruwai

# AN EVALUATION OF THE AVAILABILITY OF RUNNING WATER FOR HANDWASHING AT THE UNIVERSITY OF CALABAR, NIGERIA

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**Abstract**
*The study determined the availability of water for handwashing at the University of Calabar, Nigeria. The survey method was adopted for data gathering and the data collected was analysed using Statistical Package for Social Sciences software version 22. Results presented as cumulative percentages indicated that 59% of participants provided the water for themselves while the remaining 41% that used available running water in the University also expressed inconsistency in its supply with only 30% indicating a constant water supply at handwash stands and toilets. The findings implies that the University of Calabar's poor availability of water facility for handwashing needs of staff and students leaves the members of the community at risk of spreading and contracting diseases such as Covid-19. The study recommended immediate installation and rehabilitation of existing water supply facilities at the university.*

**Keywords**: Water; Hygiene; Handwashing; Covid-19; University; Nigeria

## Introduction

The criticality of access to running water for handwashing with soap for the prevention and spread of diseases has been reinforced with the onset of the global COVID-19 pandemic. However, while significant progress has been made in provision of clean water for drinking, billions of people in Sub-Sahara Africa still lack access to water for their sanitation and hygiene needs. This situation is especially dire in the urban areas of Nigeria like Calabar, Cross River State, where the water pipelines have remained dried for several years. The benefits of having access to clean water for drinking can only be fully realized when there is adequate access to clean water for sanitation and hygiene for all people.

Hygiene is especially important for human wellbeing but finding clean running water is often difficult. According to WHO/UNICEF (2021),1 in 3 people that is 2.3 billion people around the world lack basic handwashing facilities at home and 547 million people gained access to basic hygiene between 2015 and 2020, at a rate of 300 thousand people per day. Over half (55percent) of people in rural areas and nearly three quarters of the population of Least Developed Countries lack handwashing facilities with soap and water at home (WHO/UNICEF 2019). Almost half of the schools in the world do not have handwashing facilities with soap and water available to students (WHO/UNICEF 2020). Hygiene promotion is the most cost-effective health intervention (World Bank 2016). Universal access to safe drinking water and adequate sanitation and hygiene would reduce the global disease burden by 10% (WHO 2012).

Access to water and sanitation are human rights, as recognized in 2010 by the United Nations General Assembly.That is why the Sustainable Development Goal (SDG) 6 includes a target to ensure all persons have access to 'adequate and equitable' hygiene by 2030. One of the measures of the success of that target is the proportion of population having access to sanitation services, like handwashing facility with soap and water. Universities in Nigeria are densely populated with majority of the population spending on average 7 hours daily on the campuses. These long hours on campus involved a mobile habit (moving from halls of residence, to lecture room, library, offices, restroom, cafeteria etc.) plus some form of socialization. These activities presuppose that members of the university communitypractice good hygiene such as frequent handwashing with clean running water and soap, hence the paper sought to answer the following research questions; do members of the University of Calabar community practice good handwashing hygiene, and are members of the university community adequately accessing running water for their handwashing hygiene needs?

## Objective of the Paper

The paper sought to evaluate the availability of clean running water facility for hand washing at the University of Calabar. The paper specifically:

i. Ascertained the availability of water facility for handwashing needs of staff and students at the University of Calabar, Nigeria.
ii. Determined the utilization of available handwashing facility by staff and students at the University of Calabar, Nigeria.

## Materials and Methods

**Study Area:** University of Calabar, Nigeria. One hundred and fifty-one copies of questionnaire were administered across 8 Faculties and the Directorate of External linkages. One copy of questionnaire was found to be inconsistent with the objective of the study thus, 150 copies of the retrieved questionnaire were retained for the study. Data was collected in a multi-stage stratified random sampling method as follows:

Stage 1: Selection of Faculties (10 out of the existing 13 were selected that is 76.92 percent of the faculties).

Stage 2: Selection of departments (50 out of 63 departments /79.36 percent of the departments) and the directorate of external linkages which was purposively included in the studies because of its specific duties.

Stage 3: Simple random was adopted for administration of questionnaire.

The questionnaire was administered to students, and academic and administrative staff. On-site verification of the existence and functionality of running water facilities at each department was also carried out by the researcher. Data was analysed using descriptive statistics (frequency counts and percentages). The SPSS version 22 was used for the data analysis and results presented cumulative percentages in tables.

## Results and Discussion

**Demography**: The gender ratio of the sampled population is presented on Table 1. The result on Table 1 demonstrated that 55.3 percent of the population of study were males and 44.7 percent were females. Out of this 70 percent were students, 27.4 were staff (16.7 admin staff and 10.7 academic staff), and business vendors made up the remaining 2 percent. This result showed that all the critical stakeholders of the university community were proportionately captured in the study.

**Table 1:** Gender of sample

| Gender | Frequency | Percent |
|---|---|---|
| Male | 83 | 55.3 |
| Female | 67 | 44.7 |
| Total | 150 | 100.0 |

**Table 2**: Status/designation of study population

| Status/designation | Frequency | Percent |
|---|---|---|
| Staff Admin | 25 | 16.7 |
| Staff Academic | 16 | 10.7 |
| Student | 106 | 70.7 |
| Business Vendor | 3 | 2.0 |
| Total | 150 | 100.0 |

**Handwashing Hygiene practice**: Handwashing hygiene habit of the study population is depicted on Table 3. The responses collated on frequency of handwashing while at the campus of the university of Calabar presented on Table 3 indicated that 43.3 percent of the sampled population do not wash their hands throughout the duration of their daily 6-8 hours (usually between 8:00am-4: 00pm). Twenty-eight percent of the population wash their hands 1-2 times daily while on the campus of the university, 14.7 percent 3-4 times. The result on Table 3 implies that only about 28 percent of the population had good handwashing hygiene habit. This result may also indicate that there are limited handwashing facilities on the campus.

**Access to water for handwashing:** Results on Table 4 demonstrates that more than half of the population (58.7 percent) access water for handwashing needs through their personnel efforts (42 percent buy from vendors and 16.7 percent bring water from their homes). This finding is overly critical as availability to water for handwashing is achieved when majority of the population have adequate access to clean water for their handwashing hygiene needs.

**Table 3:** Frequency of handwashing with running water while at the university of Calabar

| Handwashing | Frequency | Percent |
|---|---|---|
| 0 | 65 | 43.3 |
| 1-2 | 43 | 28.7 |
| 3-4 | 22 | 14.7 |
| 5-6 | 20 | 13.3 |
| Total | 150 | 100.0 |

**Table 4: Access to/source of the water for Handwashing**

| Access to water | Frequency | Percent |
|---|---|---|
| Buy | 63 | 4 |
| Come from home | 25 | 1 |
| Handwash Stand | 46 | 3 |
| restroom/toilet | 16 | 1 |
| Total | 150 | 10 |

**Availability of water for handwashing:** The study also sought to determine the availability of water for handwashing by assessing the consistency of water supply at the handwash stand and rest room. Results on Table 5 and Fig 1 depicted that of the 30.7 and 10.7 percent of the population that access water for their handwashing needs from designated hand washstand, and restroom as shown Table 4 have the challenge of inconsistency in the supply of running water for their handwashing needs at the wash hand stands. The scenario is the same for those that accessed water for handwashing at the restroom as depicted on Table 6-7.

**Table 5:** Access to running water at the handwash stand

| Access to water | Frequency | Percent |
|---|---|---|
| Yes | 46 | 30.7 |
| No | 104 | 69.3 |
| Total | 150 | 100.0 |

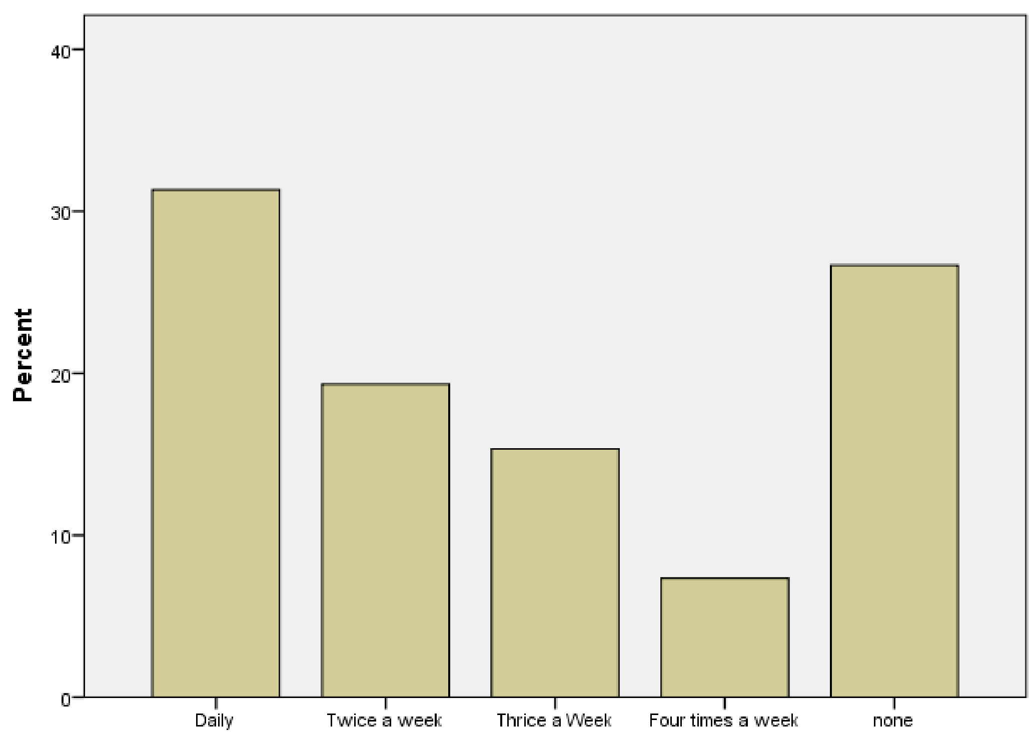


**Fig. 1**: Frequency of running water at the handwash stand.

**Table 6:** Availability of running water at restroom/toilet/urinary

| Responses | Frequency | Percent |
|---|---|---|
| Yes | 80 | 53.3 |
| No | 70 | 46.7 |
| Total | 150 | 100.0 |

**Table 7:** Frequency of running water at restroom/toilet/urinary in a week

| Responses | Frequency | Percent |
|---|---|---|
| 0 | 52 | 34.7 |
| 1-2 | 20 | 13.3 |
| 3-4 | 26 | 17.3 |
| 5 & above | 52 | 34.7 |
| Total | 150 | 100.0 |

## Discussion of findings

Access to running water for handwashing with soap is essential in reducing the global disease burden especially in developing countries. In highly populated environments such as Nigerian universities lack of access to running water for handwashing with soap creates a petri dish for disease transmission. The study investigated the availability of water facility for handwashing needs of staff and students at the University of Calabar, Nigeria. Fifty-nine percent of participants provided the water for themselves while the remaining 41% that used available running water in the University also expressed inconsistency in its supply with only 30% indicating a constant water supply at handwash stands and toilets. This finding is in tandem with WHO/UNICEF 2020 position that half of the schools in the world do not have handwashing facilities with soap and water available to students. The study also found only 28% of people had adequate hand washing hygiene, this result could stem from a variety of reasons including the inconsistency in available running water supply in the University. The lack and inconsistency in running water at hand washstands is also experienced at the restroom/toilet/urinary as demonstrated by the results on Table 6 and 7. Restroom are meant to have constant clean, running water, with sinks and soap that will help users in their hygiene need especially so for female staff and students to be able to manage menstruation safely and with dignity but this is not the scenario at the study university.

## Conclusion

Good hygiene is paramount in combating the spread of infectious diseases, from this study it becomes clear that the University of Calabar's poor availability of water facility for handwashing needs of staff and students leaves the members of the community at risk of spreading and contracting diseases such as Covid-19. The study recommends provision of adequate running water facilities at all the Departments of the University of Calabar. This can be achieved by the immediate rehabilitation of faulty water supply facilities and the provision of new water facility in departments where none previously existed.

**References**

WHO/UNICEF (2019). Progress on household drinking water, sanitation and hygiene 2000-2017: Special focus on inequalities**.**

The Un-Water SDG 6 Data Portal – Indicator 6.2.1b on hygiene

WHO (2012): Global Health Observatory: Mortality and burden of disease from water and sanitation

World Bank Group (2016): Disease Control Priorities: Reproductive, maternal, newborn, and child health

WHO/UNICEF (2019): Baseline report on WASH in Health Care Facilities. Fact sheet on water, sanitation and hygiene in healthcare facilities

WHO/UNICEF (2020): JMP 2020, COVID-19 Global Hygiene Snapshot

WHO/UNICEF (2021): JMP Progress on household drinking water, sanitation and hygiene 2000 – 2020

**A REVIEW OF INTEGRATED EMERGENCY NUTRITION, WATER, SANITATION, HYGIENE AND LIVELIHOODS INTERVENTIONS AS PANACEA FOR COVID-19 IMPACT**

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**Abstract**
*The pandemic caused by SARS-CoV-2, the virus that causes COVID-19 has generated not only a health crisis but is significantly affecting societies and economies in varying degrees. Water, Sanitation, and Hygiene (WASH) services was prioritized as a non-clinical medical response to the pandemic. This study assesses the use of WASH in a different dimension – as a solution or panacea for novel events such as COVID-19 by drawing an analogy with the well-established application of WASH intervention in emergencies and population displacement. To buttress this point, this paper has examined documented approaches employed by Nigeria, Uganda and other countries to respond to and recover from crisis in conflict areas where persons have suddenly lost means of livelihoods, with special emphasis on nutrition, water, sanitation, hygiene and livelihoods. A review of literature and published data on WASH and management of Internally displaced persons provided relevant information for conclusions to be drawn. The problems and challenges of displaced persons mirror the consequences of the impact of COVID -19 on the populace. The measures applied to remedy the situation of displaced persons apply very well to the general population, particularly in the context of the economic catastrophe, insecurity, hunger and lack of basic necessities for the minimum quality of life. WASH programmes have been used as interventional tool to end hunger and human suffering. It can also be applied as an integrated program with livelihoods support as a panacea for extreme events such as COVID-19.*

**Keywords**: Emergency, interventions, panacea, livelihoods, hygiene and sanitation.

## Introduction

In 2017, the Worldbank in their report titled: A wake up call: Nigeria Water Supply, Sanitation, and Hygiene Poverty Diagnostic stated that More than 71 million people in Nigeria continue to live without access to improved water and that about twice this number (130 million people) failed to meet the Millennium Development goals for water and sanitation (Worldbank, 2017). Evidence from literature also suggests that limited or no access to water supply, sanitation, and hygiene (WASH) services adversely affects individuals' health, hinders their access to educational and economic opportunities, and affects their work efficiency and labor productivity, the consequence of which include poverty, insecurity and civil unrest.

Perhaps it is for this reason that in 2018, Nigeria's Federal Government announced a state of emergency for WASH and launched a National WASH Action Plan (FMWR). Unfortunately, despite the huge expenditure on WASH by successive governments, much of it has failed to produce the intended outcomes. According to the World Bank, Nigeria's sanitation sector is in critical condition: Only 29 percent of Nigerians have access to improved sanitation, only 31 percent have access to improved water on premises and access to piped water on premises in urban areas declined from 32 percent in 1990 to 7 percent in 2015(Worldbank, 2017).

Household contributions to WASH services, especially through tariffs and self-supply provide the major source of financing for WASH in Nigeria. It is estimated that at least 64% of all water facilities are self-supplied. The WASH National Outcome Routine Mapping (NORM II) reported a substantially high amount of sector spending by households, at $9 billion in 2018. Thus the burden of out-of-pocket expenses on the poor is usually greater, since it typically accounts for a larger share of their total expenditures (WASH NORM Report, 2019). This paper contends that there is a nexus between poor WASH services and household expenditure and that poverty is related to high out of pocket expenditure on WASH.  It has also been argued by others that poverty leads to conflict, defined as any violent activity that is capable of disrupting peace, development and stability in any nation or system (Ihejiaku, 2012).

The impacts of covid-19 on businesses and homes are similar to impacts of civil unrest and insecurity in several respects: the fear factor, the uncertainties and the erosion of livelihoods,  particularly for the low and middle income earners resulting in persons abandoning homes or business areas in search of greener pastures or for survival thus losing their sense of identity and basic necessities of life. Thus the pandemic has produced a critical mass of displaced people not accounted for by the traditional definition of internal displacement.

Over the years Integrated WASH programmes have been used as interventional tool for malnutrition. Current indicators show that the North East region of Nigeria, which also is the epicenter of banditry and terrorist activities has the lowest WASH access at 2% and the South West having the highest at 31% (WASH NORM Report 2019).

While the importance of water, sanitation and hygiene as a determinant of under nutrition is well understood, translating this into integrated approaches as a tool or panacea for novel events and disease outbreaks has not been achieved. This study is an attempt to draw analogy between the use of WASH as a critical tool in crises situations leading to displaced population and the current emphasis as non-medical management of the COVID-19 pandemic.

Using specific case studies of the management strategies for displaced persons by Nigeria, Uganda, Yemen and the United Nations, the research seeks answers to the questions: To what extent has international approach to the management of internally displaced persons paralleled Nigeria's approach used in addressing the challenges posed by COVID 19? What are the main concerns addressed, and what lessons can we draw from these approaches in solving Nigeria's complex and multidimensional challenges of internal displacement compounded by the pandemic?

## Materials and Methods

This study carried out an analysis of WASH interventions and related strategies and policies for population displacement in crises or war torn areas of Nigeria, Uganda and Yemen as a basis for drawing analogies between the approach to these emergencies and the COVID-19 pandemic**.**  These selected countries are important cases to study because they have in common active armed conflict, a plausible increase in poverty over the last decade, and the weakest performance on WASH-related indicators in their region. They also share to variable extents the experience of COVID -19 pandemic.

Data sources include WASH data from the Nigeria national bureau of statistics (UNICEF the 2019 NigeriaWater, Sanitation, Hygiene National Outcome Routine Mapping), Jobs and livelihoods refugee policy document from the Ugandan Government (jobs and livelihoods integrated response plan for refugees and host communities in Uganda and The ACF Yemen Integrated emergency nutrition, water, sanitation, hygiene and livelihoods interventions for vulnerable populations. To facilitate the review, a documentary framework to enable greater scrutiny of the issues consisting of a set of six key issues was used (Table 1). These questions are designed to explore the administrative and regulatory framework for WASH intervention in displaced populations, the main concerns addressed by the intervention, type of evidence used as basis for implementation of the strategy, Impact on national development and the engagement of stakeholders.

## Results and Discussions

Nigeria, with a population of 182.2 million people, tops the list of countries in Africa with the highest population of displaced persons. Nigeria also has one of the poorest WASH implementation rating in the West African region. This paper will argue that the WASH gap represents a relative inequality and imposes a disproportionate economic burden on the poor. According to Ihejiaku (2012), the Frustration-aggression theory and relative deprivation theory suggest that individuals turn aggressive when there are perceived/latent or real impediments to their route to success in life, *including WASH deprivation*. The Relative deprivation theory offers a plausible explanation to the association between the abysmal WASH performance and conflict in the North East Nigeria. With unequal accesses to water, sanitation, some segments of the population are likely to have better opportunities relatively to others which in turn leads to persistence and deepening poverty among certain group(s) and potentially creating frustration, aggression scenario (Darman, 2003).

**Table 1:** Documentary framework for the assessment of key issues addressed through WASH and IDP interventions

| **Key parameters** | **Nigeria WASH programme implementation** | **Nigeria's programme for internally displaced** | **Uganda's Program for Internally Displaced Persons** | **Yemen intervention for displaced persons** | **Nigeria's COVID-19 Response** |
|---|---|---|---|---|---|
| Administrative and regulatory framework | Federal Ministry of Water Resources | Existing policy, weak institutional framework and poor implementation, mainly undertaken by agencies on ad hoc basis. | National policy for internally displaced persons that is actively implemented | Intervention provided and sustained mainly by foreign Aid | Comprehensive program of response includes clinical and non-clinical packages |
| Main concerns addressed | Water supply by boosting the productivity and efficiency of state water boards, Hygiene improvements through | Managed mainly as an emergency response to humanitarian crises | Resettlement, WASH and livelihoods support | Water and sanitation services, Livelihoods support and housing | 3-pronged approach: Clinical measures (treat the sick, provide hospital supplies); Preventive measures (Enforce had washing, social distancing, use of face mask) and Economic (food subsidies, livelihoods support) |
| What Type of evidence was used as basis for implementation | Payment of counterpart funds by States, | Conflicts, displacement of people and squalor | Conflicts, displacement of people and squalor | Conflicts, displacement of people and squalor | Number of people with infection and number of deaths |
| Integration of Intervention with national development | National WASH Action Plan, boosting the productivity and efficiency of state water boards, SDGs | No national integration due to weak institutional and administrative framework | Strong national integration into Government planning and sustainability program | Donor driven with poor /no national integration | Some national integration |
| Involvement of stakeholders(To what extent has the Programme influenced a change/increase in community voice and accountability)? | Stakeholders at the grass roots and end users are hardly involved and often have no voice in the implementation of WASH programmes | No administrative framework to involve critical stakeholders. Community participation is absent. | Robust framework for community participation | Community participation and livelihoods restoration at the core of the proram | Strong stakeholder involvement at the centre, Weak community participation at grassroots |

In several ways the needs of displaced people mirror those of the majority of Nigerians deprived of their livelihoods or economically impacted by COVID 19. Food security is a critical aspect of national security and development. Nigeria has one of the highest rates of severe acute malnutrition (SAM) in the World which currently stands at around 2 million children each year. Thus about one in ten of all severely malnourished children worldwide live in Nigeria. According to UNICEF, about two out of every three SAM cases in Nigeria do not have access to treatment (UNICEF: SAM Management in Nigeria). In addition, of the 7.6 million deaths annually among children who are under 5 years of age in developing nations, approximately 50% are due to nutrition-related factors and 4.4% of these deaths have been shown to be specifically attributable to severe wasting.

Nigeria is already today struggling to cope with chronic water shortages and inadequate water infrastructure. National water security must thus feature prominently on the national agenda. The World Economic Forum identified water crises as the global systemic risk of third highest concern. Policies, institutions and infrastructure to improve drinking water sanitation, hygiene and wastewater management must be put in place today. Such actions will also build resilience to cope with the COVID-19 pandemic and even the impacts of climate change.

The WHO estimates the total global economic loss per annum resulting from poor water supply and sanitation at 260 billion US Dollars. According to World Bank studies, countries in sub-Saharan Africa, as well as Bangladesh and India, on average lose more than 4% and 6% of their Gross Domestic Product (GDP), respectively, due to inadequate sanitation. The evidence is clear: poor sanitation and inadequate water supply play a role in keeping countries poor and poor countries are likely to suffer greater consequences of COVID-19 (World Bank, 2021).

**Current Status of Wash Services in Nigeria**

According to recent data from the Nigeria bureau of statistics and UNICEF, the overall status of the WASH sector in Nigeria is very low. Only 9% of Nigerians have access to basic water, sanitation and hygiene services (FMWR, NB and UNICEF, 2020). The 2019 NORM report has also shown that less people have access to basic WASH in 2019 compared to 2019, a decline of about three million people (2%).

From the late 1970s, the World Bank has invested over US$ 700 million in urban water supply projects in Nigeria with largely unsatisfactory results (World Bank, 2018, p56). Previously financed World Bank programmes in Nigeria's WASH sector produced mixed results, in most cases, projects outcomes were rated unsatisfactory by the World Bank Independent Evaluation Group. Before the 2nd National Urban Water Sector Reform Programme (NUWSRP2), eight predecessor projects financed by the World Bank, seven were rated unsatisfactory or moderately unsatisfactory. Several factors may be responsible for this abysmal performance of the WASH sector. Although Nigeria declared emergency in this sector in 2018 (FMWR, 2019) and has a federal ministry with responsibility for the sector, no specific or consistent framework has been produced with regards to the decisions regarding the implementation of WASH programs due largely to political and other considerations.

Currently Nigeria has obtained a facility from the World bank to revitalize WASH, a program known as SURWASH (Sustainable Urban and Rural Water Supply, Sanitation and Hygiene program), which is a five year programme designed to support the implementation of the National Action Plan (NAP) for the Revitalization of Nigeria's WASH sector in seven states- Delta, Ekiti, Gombe, Imo, Kaduna, Katsina, Plateau; and the Federal level. It is financed by a $700m World Bank loan and $175m co-financing from the seven benefitting states. However the major consideration has been the willingness of states to participate based largely on ability and willingness to provide counterpart funding and the necessary structures to support implementation rather than on a needs basis.

The gap in WASH services requires extraordinary efforts from the Nigerian government to reach more than 171 million people with safely managed water supply services if the country is to achieving the SDG goal 6.1 by 2030. Progress in access to basic sanitation services post-MDGs also lacks momentum. Data analysis on trends in ending open defecation has shown negligible changes in the number of people practicing open defecation since 2015. In addition, the NBS estimate that over 157 million Nigerians are off the SDG sanitation targets (only 1 in 5 Nigerians use safely managed sanitation services). Access to basic hygiene services was observed to reduce markedly in one year moving from 21% in 2018 to 16% in 2019. It can thus be generally inferred that a downward trend is being exhibited for access to basic hygiene in Nigeria (FMWR, NBS and UNICEF, 2019).

According to WaterAid, the annual cost for Nigeria to achieve universal access to water and sanitation by 2030 may be as high as $20 billion in capital, operations, and maintenance. (https://www.devex.com/news/q-a-nigeria-is-finally-getting-serious-about-wash-96344). With the current status of the Nigerian economy and the instability in the oil price, it can be extrapolated that this is indeed a tall order. UnfortunatelyCOVID-19 has significantly changed the project and funding landscape for water, sanitation, and hygiene, and will continue to do so due to the global effect of the pandemic on world economies.

**Nigeria's approach to Managing COVID-19**

Nigeria's North-East region is "one of the most pronounced, multi-faceted and complex humanitarian and development crises known to the international community today". It is within this humanitarian and development context that the threat of the COVID-19 pandemic looms largest, particularly for its 1.8 million internally displaced persons (IDPs) in the three states. The other states are Lagos and Kano in the south west and North west respectively.

Many of the prescribed global preventative measures will be difficult to implement given the conditions of where Nigeria's most vulnerable populations reside. Assessments of the IDP camps by DMS/CCM, Shelter and NFIS indicate that one in four of the camps – where 430,000 IDPs reside - in the BAY states are highly congested with per capita space of less than 15m2. In terms of the impact of the pandemic on livelihoods, it is estimated that 41 million micro-businesses and 73,000 small and medium businesses employ about 86.3% of the total workforce (SMEDAN/NBS Survey (2017). This is the size of the people whose livelihoods were threatened by the sudden appearance of COVID-19. These businesses include those selling food products, pharmaceuticals, and home goods or offering tailoring or other personal care services that not only provide employment for many young men and women, but also provide crucial goods and services to their communities. With the the COVID-19 restrictions of movement, social and religious gathering of people, and call for social distancing and isolation measures, the livelihoods of millions of Nigerians are threatened.

Various monetary and fiscal policies have been launched by the government of Nigeria via the Central Bank of Nigeria (CBN) to stop further damages from the pandemic, stimulate recovery of the economy and guarantee growth. It is not clear if these monetary policies will be mainstreamed into national development, especially towards the attainment of the SDGs. Another critical issue is that of stakeholder involvement and participation. As laudable as these programs are, there is no clear framework or pathway to guarantee that communities and people at the grassroots have a voice to hold the system accountable.

The most critical cause of the less effectiveness of the multi-sector policies is the lack of an existing data base of Nigerians. The national identity project had failed and so who is a Nigerian to benefit from the policy is still a mirage. The Core Welfare Indicator Questionnaire has loosely identified the number of poor people in Nigeria and per state but who is that poor Nigerian is still vague. There is no data bank of peasant farmers who constitute about 80% of the farmer population in Nigeria and so who collects the stimulus meant for the peasant farmer remains fuzzy. The issue of corruption is another major huddle in the success of implementation. Nigeria scored 26 points out of 100 on the 2019 Corruption Perceptions Index and was rated as one of the most corrupt countries on planet earth. The country placed 146 out of 180 countries evaluated (Transparency International, 2019). It is no wonder therefore that despite the billions injected into the economy, there is increased scarcity of foodstuff and skyrocketing inflation (Kyarem, 2020).

## Conclusion

The COVID-19 pandemic has impacted humanity in unimaginable ways leaving behind a trail of social and economic destruction. In Nigeria this is compounded by insecurity, hunger and a large proportion of displaced persons. The problems and challenges of displaced persons mirror the consequences of the impact of COVID -19 on the populace. The measures applied to remedy the situation of displaced persons apply very well to the general population, particularly in the context of the economic catastrophe, insecurity, hunger and lack of basic necessities for the minimum quality of life. Integrated nutrition, water, sanitation and hygiene must be given greater priority as Nigeria becomes part of the third wave of the pandemic. WASH programmes have been used as interventional tool to end hunger and human suffering. It can also be applied as an integrated program with livelihoods support as a panacea for extreme events such as COVID-19.

## References

Dolan, C. & Hovil, L. (2006) Humanitarian Protection In Uganda. A Trojan Horse? Humanitarian Policy Group, Overseas Development Institute, Background Paper, 6.

Federal Ministry of Health. (2016). National Guidelines for in-patient management of severe acute malnutrition in infants and young children in Nigeria. Federal Ministry of Health, Nigeria Family Health Division, February, 2016.

Federal Ministry of Water Resources (FMWR), Government of Nigeria, National Bureau of Statistics (NBS) and UNICEF. 2020. Water, Sanitation and Hygiene: National Outcome Routine Mapping (WASH NORM) 2019: A Report of Findings. FCT Abuja. Nigeria

FMWR.National Action Plan for Revitalization of the Nigeria's WASH Sector. 2018. Available at https://www.wateraid.org/ng/sites/g/files/jkxoof381/files/nigerias-national-action-plan-for-the-revitalization-of-the-wash-sector.

Ihejiaku B.V. Poverty-Conflict Nexus: The Contentious Issue Revisited. European Journal of Sustainable Development (2012), 1, 2, 127-150

Kyarem, R. (2020). Managing the COVID-19 Nigerian Economy: Policy Retrospection. DOI: 10.48028/iiprds/ijasbsm.v8.i1.02

National Commission for Refugees. NATIONAL POLICY ON INTERNALLY DISPLACED PERSONS (IDPs) IN NIGERIA, Abuja. 2013

National policy on internally displaced persons in Nigeria, 2013. Available at https://www.refworld.org/pdfid/5a7ae2324.

SMEDAN/NBS Survey (2017)

Toby, B.G., Ajie C. &Nwanyanwu, M. E.(2021).Legal Protection of Internally Displaced Persons (IDPs) in Nigeria amidst Coronavirus (Covid-19) Pandemic. PEOPLE: InternationalJournal of Social Sciences, 6(3),269-283

World Bank (2021) Monitoring COVID-19 Impact on Nigerian Households

World Bank. 2017. Dire Straits : The Crisis Surrounding Poverty, Conflict, and Water in the Republic of Yemen. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/27531 License: CC BY 3.0 IGO."

World Bank. 2017. A Wake Up Call: Nigeria Water Supply, Sanitation, and Hygiene Poverty Diagnostic. WASH Poverty Diagnostic. World Bank, Washington, DC.

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# WATER, SANITATION AND HYGENE (WASH) IN THE MIDST OF COVID-19: A CASE OF YAKURR LOCAL GOVERNMENT AREA CROSS RIVER STATE, NIGERIA

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**Abstract**
*Water, sanitation, and hygiene (WASH) are often the first line of defence against infectious disease outbreaks, such as the ongoing COVID-19 pandemic. WASH practices like handwashing with soap, use of alcohol-based sanitisers, keeping of clean environment and use of facemask are preventive measures which have evidently reduced the spread of COVID-19 by contributing 83% to COVID-19 prevention. Nigerian Centre for Disease Control (NCDC) in line with the World Health Organization sensitised the nation on COVID-19 prevention. This research work had both primary and secondary data. The primary data was obtained through administration of questionnaires to a sample population of 205 from a selected population of 440 households using Krejcie and Morgan (1970) sample table. There were 200 respondents. The questionnaire was to attest for the awareness of the respondents about COVID-19 and to determine their response to COVID-19 prevention. The result shows that there is a positive compliance to WASH practices as a COVID-19 preventive measure. Whereas the secondary data was obtained from NCDC database, showing the number of cases Cross River recorded between July, 2020 to April, 2021 that places Cross River State to be 2nd least affected. NCDC published result shows that Cross River recorded 394 cases with 18 deaths. This also implies that, there was a serious adherence to the COVID-19 preventive rules by the people of Cross River from the time of its first plague in Nigeria, that is February, 2020 to the time Cross River recorded her first case in July, 2020.*

**Keywords:** WASH, Sanitation, Hygiene, Yakurr, Cross River.

## Introduction

WASH is the collective term for water, sanitation and hygiene. Due to their interdependent nature, these three core issues are grouped together to represent a growing sector. While each remaining a separate field of work, each is dependent on the presence of the other. For example, without toilets, water sources basic hygiene practices are not possible. Water, sanitation, and hygiene (WASH) are often the first line of defence against infectious disease outbreaks, such as the ongoing COVID-19 pandemic. Adequate sanitation, good hygiene and safe water are essential to good health. On the contrary, poor sanitation, lack of clean water and hygiene cause diseases. Prüss, Kay, Fewtrell and Bartram, (2002) estimated that inadequate sanitation was responsible for 4.0 percent of deaths and 5.7 percent of disease burden worldwide.

Water is very important in WASH practices for handwashing. Handwashing with soap is a hygiene practice that protects health and saves lives, it prevents many common and life-threatening infections. Many illnesses start when hands become contaminated with disease-causing bacteria and viruses. This can happen after using the toilet, contact with excreta, coughing, sneezing, touching other people's hands, and touching other contaminated surfaces. For example, a single gram of human feces can contain 10 million viruses and one million bacteria, and infant feces are particularly pathogenic (Majorin, Freeman, Barnard, Routray, Boisson and Clasen, 2014). Washing of hands with soap helps to remove bacteria and viruses before they enter the body or spread to other people. Cleaning hands with soap, particularly before eating or preparing food, and after contact with fecal material from using the toilet or cleaning a child's bottom, is one of the most effective ways to prevent disease (GHP, 2017). According to the World Health Organisation (WHO), frequent and proper hand washing is one of the most important measures that can be used to control the spread of COVID-19 (WHO and UNICEF, 2020).

Sanitation is a public and environmental health conditions that deals with the provision of facilities and services for the safe disposal of human urine and faeces. Whereas, hygiene is a series of practices performed to preserve health. WHO defines hygiene "as conditions and practices that help to maintain health and prevent the spread of diseases". The provision of safe water, sanitation and hygienic conditions is essential for protecting human health during all infectious disease outbreaks, like COVID-19. Ensuring evidence-based and consistently applying WASH practices in communities, homes, schools, marketplaces, and health care facilities will help prevent human-to-human transmission of the virus that causes COVID-19.

Coronavirus disease (COVID-19) is a disease caused by Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Covid-19 has been plaguing the world since December 2019, with its first outbreak identified in Wuhan, a commercial city in China, following reports of serious pneumonia. (Qun, Xuhua, Peng, Wang, Zhou, Tong,Ren, Kathy, Leung, Lau, Wong, Xing, Xiang, Wu, Li, Chen, Dan, Tian, Jing, Liu and Wenxiao, 2020). COVID-19 is a deadly viral disease transmitted widely through respiratory droplets by direct contact with infected people and indirect contact with surfaces in the immediate environment or with objects used by the infected persons (WHO, 2020). Recent research shows that several climate and environmental pollution factors affect the diffusion of COVID-19 (Haque and Rahman, 2020). Researchers also believe that air pollution is one of the determining indicators affecting the spread of COVID-19 (Coccia, 2020). In March 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a pandemic. Public health groups, including the U.S. Centers for Disease Control and Prevention (CDC) and WHO, are monitoring the pandemic and posting updates on their websites. These groups have also issued recommendations for preventing and treating the illness (Mayo Clinic, 2021). It is imperative to note that almost all the preventive measures highlighted by WHO (such as physical distancing, wearing a mask, keeping rooms well ventilated, avoiding crowds, cleaning your hands, and coughing into a bent elbow or tissue among others) (WHO, 2021) are sanitary and hygiene based.

In Nigeria, the first official case of COVID-19 was announced on February 27, 2020. The patient was an Italian citizen, who arrived in Lagos from Europe and who, a few days later, tested positive for the disease. Another patient who was discovered to have been in contact with the first patient was identified in Ogun state, a neighboring state to Lagos. Since then, the situation has developed with more cases occurring, regardless of measures initiated by the state and federal government to combat the virus and return to normalcy (Bernard, 2020). Despite the awareness created by the Nigerian Center for Disease Control (NCDC) on the preventive measures in line with the WHO guidelines, between February 27, 2020 and May 6, 2021 about 165215 cases were confirmed, 155371 cases were discharged and 2063 deaths were recorded in 36 states and the Federal Capital Territory, with Cross River State recording 394 cases (NCDC, 2021).

Cross River State, like other states, enforced the interstate lockdown on her boundaries, as commanded by the federal government, though people still had their ways into the state. While the lockdown was on, the state Ministry of Health in conjunction with other health agencies, COVID-19 taskforce set up by the state government made a very serious campaign and sensitisation on the prevention of COVID-19 as directed by NCDC. These preventive measures were embraced and fully practised by most people in the state, especially people resident in Calabar, the state capital during the first five months Nigeria started recording some cases. But gradually, rather than getting used to these preventive measures, they tend to abuse them, even though it has changed their social lives (Edinyang, Ogbaji and Iwara, 2020). Cross River State recorded her first 5 COVID-19 cases as confirmed by NCDC on 7th July, 2020 five months after the first case in Nigeria was confirmed at Lagos on 27th February, 2020 placing them second to the least in the table and the last State to record a case (NCDC, 7 July, 2020). See table1.

This research work aims at identifying the impact of WASH in preventing COVID-19 in Cross River State.

**Study Area**

This research work was carried out in Yakurr Local Government Area of Cross River State, Nigeria. Yakurr is found in central Cross River, with ten (10) communities. It lies between latitude 5°40'and 6°N and longititude 7°55' and 8°33'E, with a population of 192,271 people as at 2006 cencus. It has boundaries with Abi, Biase, Akamkpa and Obubrua. Yakurr was selected for this work because it is made up of both rural and urban areas, which made it easier to compare the response of people in both rural and urban areas to covid-19 prevention. It was also reported that the first suspected case in Cross River was from Yakurr.

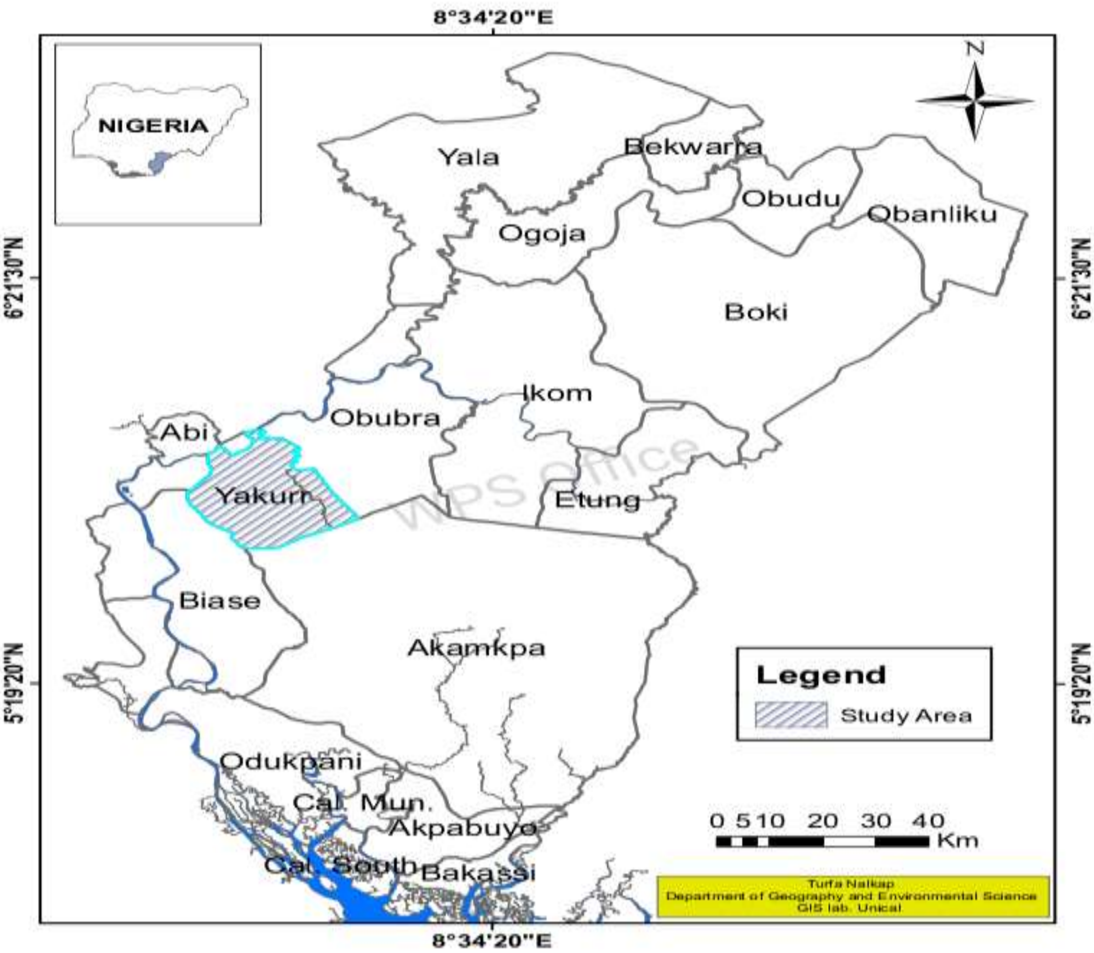


Figure 1: Cross River showing Yakurr LGA.

**Methods**

The researcher collected primary and secondary data. A sample size of 205 was selected using Krejcie and Morgan (1970) sample table, from a population of 440 selected households.Two hundred and five (205) copies of questionnaire were administered and 200 were returned.

Information obtained were; to attest for their awareness of COVID-19 pandemic, know if they believe in the existence of the pandemic and the number of people that have received the COVID-19 vaccine; also, were to determine how often people wash their hands with soap, use nose mask, observe social distancing and practice open defecation before and during COVID-19. Data collected from this survey were presented in tables and analysed using percentages. See tables 3 to 7. While secondary data were collected from the NCDC database showing monthly reports of all the COVID-19 cases in Nigeria. Cumulative frequency was used to determine the number of occurrence of cases in Cross River State per month beginning from the first month of occurrence to the month of research (July, 2020 to April, 2021). See Tables 1 and 2.

**Table 1:** Number of Covid-19 Cases in Cross River State

| S/N | Month/year | Confirmed cases | Discharged cases | Death | Total active cases |
|---|---|---|---|---|---|
| 1 | July, 2020 | 45 | 9 | 3 | 33 |
| 2 | August, 2020 | 37 | 64 | 5 | -32 |
| 3 | September, 2020 | 5 | 1 | 1 | 3 |
| 4 | October, 2020 | 0 | 0 | 0 | 0 |
| 5 | November, 2020 | 3 | 4 | 0 | -1 |
| 6 | December, 2020 | 79 | 79 | 3 | -3 |
| 7 | January, 2021 | 53 | 43 | 0 | 10 |
| 8 | February, 2021 | 112 | 74 | 5 | 33 |
| 9 | March, 2021 | 43 | 74 | 1 | -32 |
| 10 | April, 2021 | 17 | 28 | 0 | -11 |

Source: https://ncdc.gov.ng/diseases/sitreps/?cat=14&name=An%20update%20of%20COVID-19%20outbreak%20in%20Nigeria

**Table 2:** Cumulative Frequency of Covid-19 Cases in Cross River

| S/N | Month/year | Confirmed cases | Discharged cases | Death | Total active cases |
|---|---|---|---|---|---|
| 1 | July, 2020 | 45 | 9 | 3 | 33 |
| 2 | August, 2020 | 82 | 73 | 8 | 1 |
| 3 | September, 2020 | 87 | 74 | 9 | 4 |
| 4 | October, 2020 | 87 | 74 | 9 | 4 |
| 5 | November, 2020 | 90 | 78 | 9 | 3 |
| 6 | December, 2020 | 169 | 157 | 12 | 0 |
| 7 | January, 2021 | 222 | 200 | 12 | 10 |
| 8 | February, 2021 | 334 | 274 | 17 | 43 |
| 9 | March, 2021 | 377 | 348 | 18 | 11 |
| 10 | April, 2021 | 394 | 376 | 18 | 0 |

Source: https://ncdc.gov.ng/diseases/sitreps/?cat=14&name=An%20update%20of%20COVID-19%20outbreak%20in%20Nigeria

**Table 3:** Covid-19 Awareness

| | No. of Respondence | Percentage (%) |
|---|---|---|
| Heard of Covid-19 | 192 | 96 |
| Not Heard | 4 | 2 |
| No Information | 4 | 2 |
| Believe in Covid-19 | 168 | 84 |
| Do Not Believe | 24 | 12 |
| No Information | 8 | 4 |
| Taken Vaccine | 20 | 10 |
| Not Taken | 168 | 84 |
| No Information | 12 | 6 |

**Table 4:** Hand Washing With Soap

| | Regularly | | Not regularly | | Not at all | |
|---|---|---|---|---|---|---|
| | NR | (%) | NR | (%) | NR | (%) |
| BC | 72 | 36 | 112 | 56 | 16 | 8 |
| DC | 132 | 66 | 48 | 24 | 20 | 10 |

**Table 5:** Use of Nose Nose Mask

| | Regularly | | Not Regularly | | Not At All | |
|---|---|---|---|---|---|---|
| | NR | (%) | NR | (%) | NR | (%) |
| BC | 28 | 14 | 92 | 46 | 80 | 40 |
| DC | 116 | 58 | 60 | 30 | 24 | 12 |

**Table 6:** Social Distancing

| | Regularly | | Not Regularly | | Not At All | |
|---|---|---|---|---|---|---|
| | NR | (%) | NR | (%) | NR | (%) |
| BC | 28 | 14 | 40 | 20 | 132 | 66 |
| DC | 72 | 36 | 56 | 28 | 72 | 36 |

**Table 7:** Open Defecation

| | Regularly | | Not Regularly | | Not At All | |
|---|---|---|---|---|---|---|
| | NR | (%) | NR | (%) | NR | (%) |
| BC | 48 | 24 | 28 | 14 | 124 | 62 |
| DC | 56 | 28 | 40 | 20 | 104 | 52 |

BC: Before Covid-19
DC: During Covid-19
NR: Number of Respondence

**Result and Discussion**

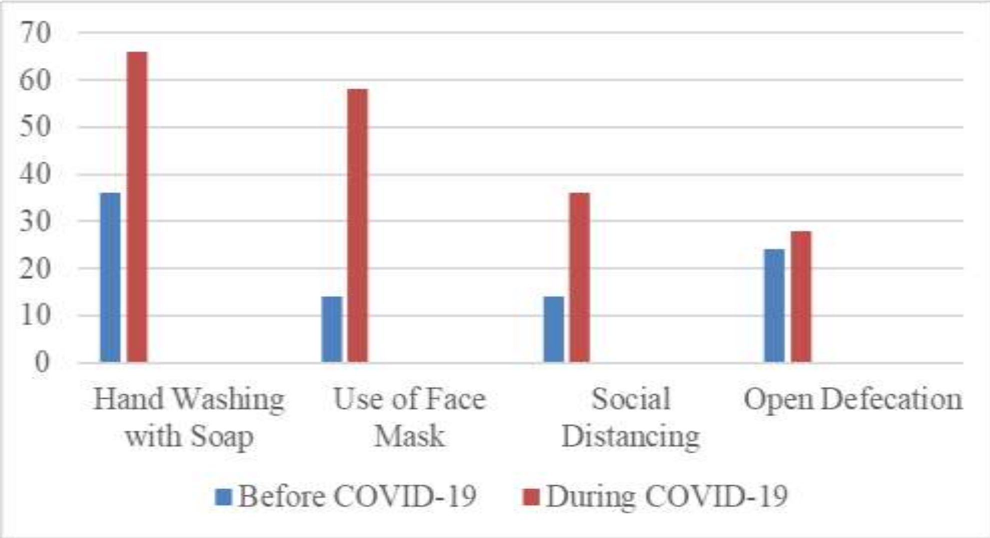


Figure 2: Chart showing COVID-19 preventive measures before and during COVID-19.

The result shows that there is 96% sensitization of COVID-19 in Cross River, but only about 84%of people believed in the existence of the dreaded disease. There is a significant difference in the behaviour of people to WASH practices before and during COVID-19 pandemic. 36% of people were found to be practicing proper hand washing with soap before COVID-19 and 66% during COVID-19. 14% were using nosemask before COVID-19, whereas during COVID-19, 58% were using nosemask. This is in tandem with Edinyang, Ogbaji and Iwara(2020) who reported that COVID-19 has caused people to experience a social change in their interactions, culture and behaviour. There is also a good compliance to COVID-19 preventive measures except in the aspect of social distancing where only about 36% of people were found practicing social distancing during COVID-19, with 72% not practicing at all. This can be a reason for the low number of cases Cross River recorded. Although proper use of nosemask can prevent the spread of the virus even where social distancing is not observed. The result also shows that there is a smaller number of people that practice open defecation before and during COVID-19 as seen in table 7. This is in line with Haque and Rahman, (2020) findings that several climate and environmental pollution factors affect the diffusion of COVID-19. Coccia, (2020) also believed that air pollution is one the determining indicators affecting the spread of COVID-19. This could be the reason Cross River recorded a very low number of cases.

The result as seen in figure 2 also shows that there is good adherence to WASH practices in the disease prevention, as the percentage of people practicing handwashing and use of facemask increased relatively from 36% to 66% and 14% to 58% respectively. Whereas there is a decrease in the practise of open defecation. This is a prove that WASH is the first line of action in diseaes prevention.

**Conclusion**

There was a good response in Cross River to WASH practises as the principal measures of COVID-19 prevention, hence the reason for the low number of cases recorded. Nevertheless, of the six (6) preventive measures of COVID-19, only social distancing is not a WASH practice. WASH therefore contributes 83% to COVID-19 prevention. WASH practices should therefore be encouraged through thorough sensitization to help combact present and future diseases.

**References**

Bernard, Kalu (2020). COVID-19 in Nigeria: a disease of hunger. *The Lancet Respiratory Medicine*. DOI:https://doi.org/10.1016/S2213-2600(20)30220-4

Coccia, M. (2020). Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID. The Science of the Total *Environment.* 729

Coronavirus disease (COVID-19) outbreak. World HealthOrganization.

https://www.who.int/emergencies/diseases/novel-coronavirus-2019. Accessed May 6, 2021.

Edinyang, S. D., Ogbaji, I. D. and Iwara H. B. (2020). Covid-19, socialization, and social change in Calabar Metropolis of Cross River State, Nigeria. *World Journal of Innovative Research*. Vol.9, Issue-1, Pages 76-80.

Global Handwashing Partnership (2017). "How to" Series: Tips on Communicating for Hand Hygiene during COVID-19. https://globalhandwashing.org/wp-content/uploads/2020/05/GHP-Communications-Brief-FINAL.pdf

Haque, S. E. and Rahman, M. (2020). Association between temperature, humidity, and COVID-19 outbreaksin Bangladesh. *Environmental Science and Policy*.https://doi.org/10.1016/j.envsci.2020.08.012

https://www.cdc.gov/healthywater/hygiene/etiquette/index.html. Retrieved, May, 25 2021.

https://ncdc.gov.ng/diseases/sitreps/?cat=14&name=An%20update%20of%20COVID-19%20outbreak%20in%20Nigeria

Majorin, F., Freeman, M. C., Barnard, S., Routray, P., Boisson, S. and Clasen, Thomas (2014). Child feces disposal practices in rural Orissa: A Cross Sectional Study. *Public Library of Science*
ONE 9(2): e89551. doi:10.1371.

Nigerian Centre for Disease Control (2021) www.covid19.ncdc.gov.ng

Qun Li, Xuhua Guan, Peng Wu, Xiaoye Wang, Lei Zhou, Yeqing Tong, Ruiqi Ren, Kathy S.M. Leung, Eric H.Y. Lau, Jessica Y. Wong, Xuesen Xing, Nijuan Xiang, Yang Wu, Chao Li, Qi Chen, Dan Li, Tian Liu, Jing Zhao, Man Liu and Wenxiao Tu (2020). Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *New England Journal of Medicine.* 10.1056.

Pruss, A., Kay, D., Fewtrell, L., and Bartram, J. (2002). Estimating the burden of disease from water, sanitation, and hygiene at a global level. *Environmental Health Perspective;* 110, 537-542.

WHO and UNICEF (2020). COVID-19 advice for thepublic.https//www.who.int.emergency/diseases

# THE ROLE OF WATER AND HYGIENE IN CURBING THE SPREAD OF COVID-19 IN THE UNIVERSITY OF CALABAR, NIGERIA

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**Abstract**

*The paper examines the role of water and hygiene in curbing the spread of COVID-19 in the University of Calabar, Nigeria. The objective was to assess the availability and circulation of water in strategic locations within the University of Calabar. Data were gathered using questionnaire and on-spot assessment of spatial distribution of boreholes, using GPS-Garmin Version. Pearson product moment correlation was deployed to examine the relationship between water availability and control of covid-19. The result of the test revealed no significant relationship between water availability and Covid-19. The result further revealed that probability value sig = 0.372 is greater that (p value = 0.05). We therefore accept the null hypothesis and conclude that there is a no significant relationship between water availability in curbing the spread of Covid-19. The study concluded that access to water in various strategic locations on campus is challenging which has made frequent hand washing almost impossible in the University of Calabar*.

**Keywords:** Water and Hygiene; covid-19; University of Calabar; Hand-washing

## Introduction

Water, sanitation, and hygiene (WASH) are often the first line of defense against infectious disease outbreaks, such as the ongoing COVID-19 pandemic. According to the World Health Organization (WHO), "Frequent and proper hand hygiene is one of the most important measures that can be used to control the spread of COVID-19." And this can be achieved through adequate and effective circulation of water for public consumption,

Globally, 2.5 billion people lack access to improved sanitation, 748 million people lack access to an improved drinking water, and 1 billion people engage inn open defecation. Also, half the countries did not report an access to adequate sanitation in schools or healthcare centers, and 34% of primary schools are bereft of improved sanitation facilities (Glass, 2012). Similarly, 2.2 million children below the age of five die every year because of unsafe water, inadequate sanitation and lack of hygiene. Reportedly, Diarrhea kills 1.5 million children below the age of five every year. It kills more than AIDS in relation to younger ones (Hazel, 2011).

For many developing countries, however, inadequacies in the WASH sector put millions of lives at greater risk to COVID-19. In a developing country like Kenya, only half of the population has access to safe water, while less than a third are connected to proper sanitation. In the Democratic Republic of Congo, less than half of health facilities have reliable supplies of soap that could allow basic protection for staff on the frontline battle against the dreaded disease occasioned by the spread of COVID-19. These challenges are particularly important for dense urban areas and higher institutions of learning, especially in developing countries like Nigeria. Without active investment to improve the WASH sector in developing cities, the world is much more likely to see prolonged and repeated pandemics, either through reinfection or new and more deadly diseases. As is currently reported in Vanguard of Thursday 15th July, 2021, the University of Lagos has directed its students to vacate the various halls of residence. The move is to further check the spread of the coronavirus pandemic which was dictated among students on campus.

Currently, 2 billion people lack access to safety managed drinking water services and 3.6 billion people lack safely managed sanitation services. Unsafe hygiene practices are widespread, compounding the effects on people's health. The impact on child mortality rates is devastating with more than 297 000 children under five who die annually from diarrheal diseases due to poor sanitation, poor hygiene, or unsafe drinking water. For children who are in school, the situation may be no better than at home: worldwide, around a third of schools have no safe water supply or adequate sanitation, leaving children dehydrated and less able to concentrate, and forcing pupils to use inadequate latrines or go to the toilet outside in the school grounds.

Aside from regular washing of hands as one of the protocols, lockdowns and social distancing have largely focused on controlling COVID-19 by limiting contact between individuals, especially in higher institutions like the University of Calabar where the large students' population and the lack or inadequate infrastructures posed a worrisome issue to the implementation of the COVID-19 protocol. As these policies are much more difficult to implement in low-income contexts, and might even pose elevated health or economic risks on the University population, comprising of staff, students and visitors. More so, majority of students in developing countries like Nigeria function more in a formal set up of a learning environment that is inadequate and lacks the basic hygiene facilities such as conveniences and accessibility to water and soap. And on the contrary, cannot even learn from home, due to inadequate or lack of basic electronically learning and teaching devices, thus exposing them to the high risk of learning in such crowded and volatile environment, in addition to the fact that they have few safety nets to support the large crowd of students through a lengthy crisis of the COVID-19 pandemic. These factors not only make it economically challenging to support sustained shutdowns, but they make the rapid transmission of COVID-19 all the more likely.

Much is still unknown about the appropriate policies for different countries. Yet it is evident that COVID-19 measures must be context-driven and responsive both to health and economic consequences. As lockdowns are relaxed, and resumption of academic activities, travel, and social activities resumed on campuses, it is also clear that there will be an increasing need for safe interaction between individuals from different states and households. One of the best ways that policymakers and administrators of institutions of learning can prepare for and respond to pandemics is to invest in core public health infrastructure such as adequate provision of water within and around the campus before, during, and after a crisis.

A survey of the sources of water supply in the University of Calabar revealed that 23 functional boreholes were situated in different Faculty buildings and departments as shown in the table below;

**Table 1:** Spatial location boreholes on campus

| Subject/Description | DD | MM | SS | DD | MM | SS | ELEV | DE | Remark |
|---|---|---|---|---|---|---|---|---|---|
| Abraham Odia stadium | O4$^0$ | 56$^i$ | 37.6$^{ii}$ | 008$^0$ | 20$^1$ | 35.7$^{ii}$ | 35m | 3M | Functional |
| Unical Staff school | O4$^0$ | 56$^i$ | 36.5$^{ii}$ | 008$^0$ | 20$^1$ | 37.5$^{ii}$ | 33m | 3M | Not functional |
| Malabor (students Hostel) | O4$^0$ | 56$^i$ | 48.8$^{ii}$ | 008$^0$ | 20$^1$ | 44.9$^{ii}$ | 51m | 3M | Functional |
| Peter Okebukola Scholarship Hostel | O4$^0$ | 56$^i$ | 42.7$^{ii}$ | 008$^0$ | 20$^1$ | 47.1$^{ii}$ | 43m | 3M | Functional |
| Sen. Nkechi Nwaogu Hostel | O4$^0$ | 56$^i$ | 39.5$^{ii}$ | 008$^0$ | 20$^1$ | 47.4$^{ii}$ | 39M | 3M | Functional |
| Female Hostel Hall 8 & 9 | O4$^0$ | 56$^i$ | 43.3$^{ii}$ | 008$^0$ | 20$^1$ | 56.5$^{ii}$ | 41M | 3M | Not functional |
| Engineering Faculty | O4$^0$ | 56$^i$ | 44.6$^{ii}$ | 008$^0$ | 21$^1$ | 02.8$^{ii}$ | 30M | 3M | Functional |
| Faculty of coucation Adm Block | O4$^0$ | 56$^i$ | 49.3$^{ii}$ | 008$^0$ | 21$^1$ | 59.9$^{ii}$ | 38M | 3M | Functional |
| Enterrenershipcentre | O4$^0$ | 56$^i$ | 49.5$^{ii}$ | 008$^0$ | 20$^1$ | 50.8$^{ii}$ | 40M | 3M | Functional |
| Management Sciences | O4$^0$ | 56$^i$ | 530.0$^{ii}$ | 008$^0$ | 20$^1$ | 53.8$^{ii}$ | 36M | 5M | Functional |
| Int'l Conference Centre | O4$^0$ | 56$^i$ | 54.2$^{ii}$ | 008$^0$ | 20$^1$ | 58.1$^{ii}$ | 51M | 4M | Functional |
| History Int'l studies | O4$^0$ | 56$^i$ | 57.6$^{ii}$ | 008$^0$ | 20$^1$ | 57.1$^{ii}$ | 45M | 4M | Functional |
| CES centre | O4$^0$ | 56$^i$ | 55.9$^{ii}$ | 008$^0$ | 21$^1$ | 01.3$^{ii}$ | 40M | 3M | Functional |
| Library | O4$^0$ | 56$^i$ | 55.8$^{ii}$ | 008$^0$ | 20$^1$ | 05.3$^{ii}$ | 38M | 4M | Functional |
| Printing press | O4$^0$ | 57$^i$ | 59.9$^{ii}$ | 008$^0$ | 20$^1$ | 57.4$^{ii}$ | 40M | 3M | Functional |
| Graduate School | O4$^0$ | 57$^i$ | 58.4$^{ii}$ | 008$^0$ | 20$^1$ | 51.4$^{ii}$ | 41M | 3M | Functional |
| Faculty of Agric | O4$^0$ | 57$^i$ | 11.9$^{ii}$ | 008$^0$ | 20$^1$ | 24.0$^{ii}$ | 66M | 3M | Functional |
| Medical centre | O4$^0$ | 57$^i$ | 17$^{ii}$ | 008$^0$ | 20$^1$ | 32.5$^{ii}$ | 64M | 3M | Functional |
| PG Male Hostel | O4$^0$ | 57$^i$ | 14.2$^{ii}$ | 008$^0$ | 20$^1$ | 34.5$^{ii}$ | 62M | 3M | Functional |
| Hall 2 Male Hostel | O4$^0$ | 57$^i$ | 15.5$^{ii}$ | 008$^0$ | 20$^1$ | 35.6$^{ii}$ | 62M | 3M | Not functional |
| CRS Community Office | O4$^0$ | 57$^i$ | 14.2$^{ii}$ | 008$^0$ | 20$^1$ | 34.5$^{ii}$ | 67M | 3M | Functional |
| VC Block | O4$^0$ | 57$^i$ | 09.0$^{ii}$ | 008$^0$ | 20$^1$ | 50.0$^{ii}$ | 57M | 3M | Functional |
| Medical centre college | O4$^0$ | 57$^i$ | 03.8$^{ii}$ | 008$^0$ | 20$^1$ | 54.9$^{ii}$ | 57M | 3M | Functional |
| central water supply station | O4$^0$ | 57$^i$ | 05.5$^{ii}$ | 008$^0$ | 21$^1$ | 05.7$^{ii}$ | 49M | 3M | Functional |
| dentistry Fac. | O4$^0$ | 57$^i$ | 060.0$^{ii}$ | 008$^0$ | 21$^1$ | 05.7$^{ii}$ | 43M | 3M | Functional |

**Source:** Authors' field work.

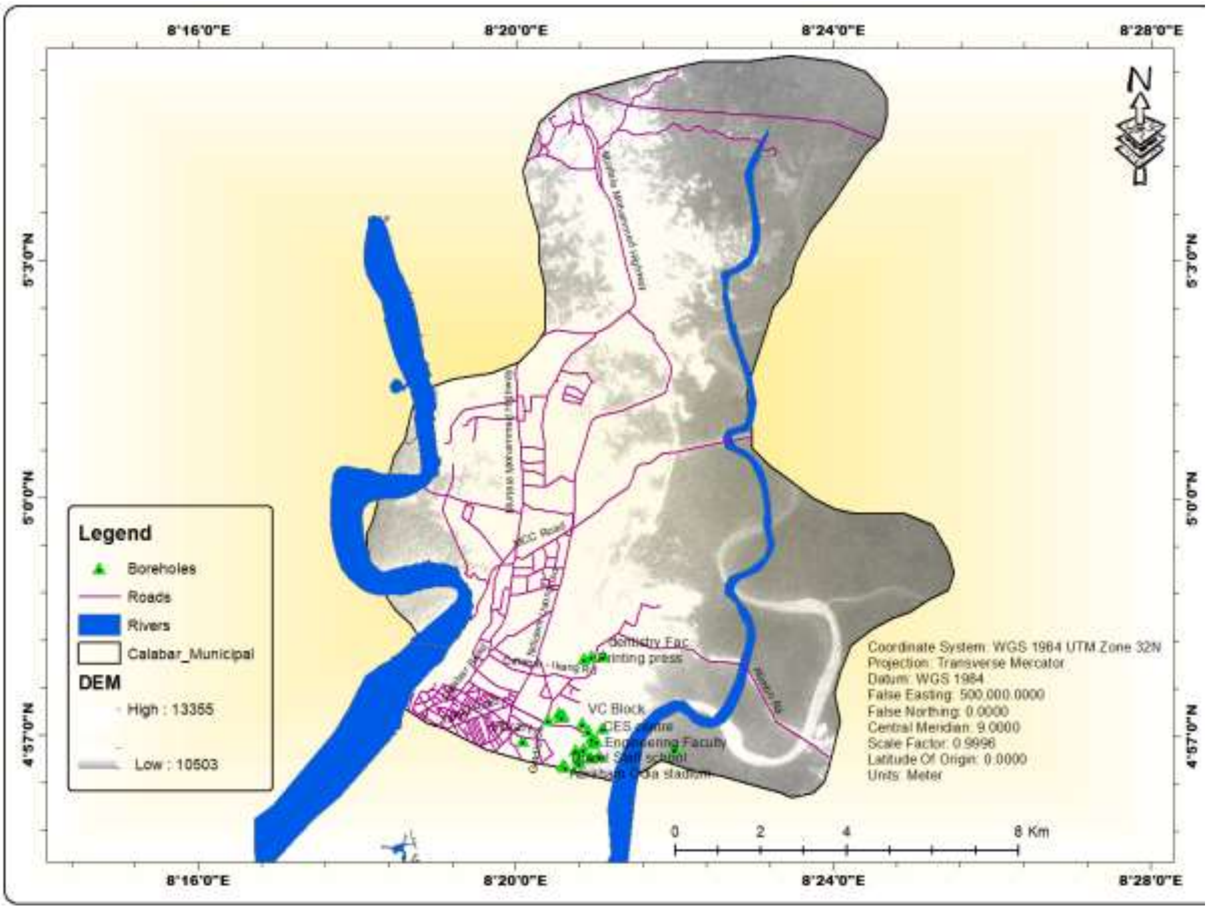


**Fig. 1** Study area showing Boreholes locations.

**Source:** GIS Lab, University of Calabar.

**Methodology**

To explore the relationship between water availability and the spread of Covid-19 pandemic, the study adopts survey research design. Thus, focus group discussion, informal discussion, field measurement and research questionnaire were deployed. A total of 308 questionnaire were distributed and 300 were completed and returned which constitute the sample size. The justification for this is that, the study was carried out when most faculties were having their students' week and many could not be reached.

The questionnaire designed in likert scale options of agreed, disagreed, strongly agreed and strongly disagreed were distributed in three faculties in the university: Faculty of Education, Faculty of social sciences and Faculty of Environmental sciences. The focus group discussion was carried out with a cross section of students in hall 4 & 5 who expressed their independent opinion on the role of water in curbing the spread of Covid-19 pandemic on campus. The study adopt Pearson product moment correlation to determine if there exist a relationship between water availability and the spread of Covid-19 in the University of Calabar.

**Results and Discussion**

**Hypothesis:** There is no significant relationship between water availability in curbing the spread of Covid-19 pandemic.

Statistical test using Pearson Product Moment Correlation is represented thus;

$$r = \frac{{}^{n}\sum xy-(\sum x)(\sum y)}{n\sqrt{(\sum^{x2})-(\sum x)^2 \quad n(\sum y^2)-(\sum y)^2}}$$

Where;
$\sum x$ is the sum of score of variable X
$\sum x$ is the sum of score of variable Y
n is the number of respondents
$\sum x^2$ is the square of the sum of score of variable X
$\sum y^2$ is the square of the sum of score of variable Y
$\sum xy$ is the sum of score of variable X and Y

**Table 2: Did you wash your hands on campus Frequently?**

| Options | Frequency | Percent |
|---|---|---|
| Frequently | 12 | 4.9 |
| Once per day | 87 | 28.8 |
| Occasionally | 159 | 52.6 |
| not at all | 42 | 13.9 |
| Total | 300 | 100.0 |

**Table 3:** Is there adequate Water circulation on campus?

| Options | Frequency | Percent |
|---|---|---|
| Agreed | 29 | 9.6 |
| Strongly agreed | 18 | 6.6 |
| Disagreed | 147 | 48.7 |
| Strongly disagreed | 106 | 35.1 |
| Total | 300 | 100.0 |

**Table 4: Correlations of water circulation and the spread of covid-19**

| | | Water circulation | frequent washing of hands |
|---|---|---|---|
| Water circulation | Pearson Correlation | 1 | -.052 |
| | Sig. (2-tailed) | | .372 |
| | Sum of Squares and Cross-products | 237.000 | -10.100 |
| | Covariance | .793 | -.034 |
| | N | 300 | 300 |
| frequent washing of hands | Pearson Correlation | -.052 | 1 |
| | Sig. (2-tailed) | .372 | |

| | | | |
|---|---|---|---|
| | Sum of Squares and Cross-products | -10.100 | 161.130 |
| | Covariance | -.034 | .539 |
| | N | 300 | 300 |

The result of the statistical test revealed no significant relationship between water availability in curbing and Covid-19. The result further shows that probability value Sig=0.372, is greater than (P value=0.05). We therefore accept the null hypothesis which states that there is no significant relationship between water availability and the spread of Covid-19. The paper corroborates the study of Bassey &Akaniyene, (2020) ‘on the ability of Nigeria to contain the Covid -19 outbreak using lessons from recent epidemics’, maintained that with insufficient water and sanitation facilities in many sectors of the economy, there is likelihood of high risk of spread of covid-19. The study further noted that if individuals do not have access to clean water, there is no relevance to continuously encouraging them to regularly wash their hands. Table 2 shows that 159 (53 percent) respondents do not regularly wash their hands on campus. This could be traceable to poor water circulation despite having functional boreholes on campus that is hampered by poor power supply. Furthermore, Table 3 revealed that 147 (48.7 percent) respondent disagreed to having sufficient water circulation on campus.

In line with Water Aid Nigeria, to further highlight the importance of hand washing with soap as vital instrument to controlling and preventing Covid-19 through education and awareness creation, University of calabar with 23 functional boreholes across the length and breadth of the campus has a challenge. Despite the availability of boreholes, access to clean water supply at entry points, offices, recreation centresis worrisome and remains a mirage especially when hand washing with soap is one effective measure to curb the spread of the pandemic. As academic and social activities resume on campus there is need for university management to ensure adequate water circulation to guarantee the safety of students. Fig.3 shows auto sanitizer gate in all the entry and exit points on campus.


**Fig 2**: Hand sanitizer in the Department of Micro Biology, donated by Mifor consult Nigeria Limited that has not been put into use as a result of poor circulation of water on campus.


**Fig 3:** Auto sanitizing gate situated at small gate of the University of Calabar.

Regrettably, the gates were not put to proper use probably because of poor water circulation. Against this backdrop, many students are unable to practice frequent handwashing thereby increasing the likelihood of being infected of the virus.

**Conclusion**

The year 2020 is a global year of quarantine against Covid-19 pandemic, as restriction on movement is observed in many nations of the world. Many safety measures were put in place to combat the spread including wearing face mask, hand sanitizer and hand washing. However, regular and proper hand washing is the most basic frontline defense against the spread of coronavirus disease. Hence, schools and other areas where crowd gather require unlimited access to hand washing facilities and water and soap for handwashing. Improved water facilities that are powered by uninterrupted power supply such as standpipes borehole, piped public convenience locations require constant flow of water to guarantee human safety.

The challenge of poor water circulation in the University of Calabar in various sensitive locations in such a time as this poses grave danger and threat to life. An institution with about 40,000 students and staff lacking regular supply of clean water is worrisome. Unfortunately, the pipes linking central water processing unit to offices and conveniences are always dried because of interrupted power supply. Until there is adequate water circulation on campus, the fight against Covid -19 pandemic remains a mirage.

**References**

A survey of operational characteristics, socioeconomic and health effects of scavenging activity in Lagos, Nigeria. DOI: 10.1177/0734242X12444894 Amasuomo, E. and Baird, J. (2016).

Abiko, A, L Cardoso, R Rinaldelli, and H Haga (2007), "Basic costs of slum upgrading in Brazil", Global urban development magazine.

Afon, A. O (2011).Residential Differentials in Behavoiur and Environmental Hazards and Risks Perception in Ile-Ife Nigeria. In: A.O Afon and O.O Aina (eds): Issues in the Built Environment of Nigeria: 52-80 Afon, A. O. (2012).

Ahmed, W, N Angel, J Edson, K Bibby, A Bivins, J O'Brien, P Choi, M Kitajima, S Simpson, J Li, B Tscharke, R Verhagen, W Smith, J Zaugg, L Dierens, P Hugenholtz, K Thomas and J Mueller (2020), "First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: A proof of concept for the wastewater surveillance of COVID-19 in the community", Science of The Total Environment, 138764.

Aiello, A, R Coulborn, V Perez and E Larson (2008), "Effect of hand hygiene on infectious disease risk in the community setting: A metaanalysis", American Journal of public health, 98(8): 1372-1381.

Alon, T, M Kim, D Lagakos and M Van Vuren (2020), "How should policy responses to the COVID-19 pandemic differ in the developing world?", IGC policy paper.

American Journal of Environmental Science, 6 (1) 26-32 Bassey E. and Akaninyene O (2020). Can Nigeria contain the COVID-19 outbreak using lessons from recent epidemics?

Anijah-Obi, F., Eneji Chris V. O., Ubom-Bassey A. E., Dunnamah, A.Y. and William, J. J (2013): Introducing Environmental Sanitation Education in the Primary School Curriculum.

Ashraf, N, E Glaeser and G Ponzetto (2016), "Infrastructure, incentives, and institutions", American Economic Review, 106(5): 77-82.

Banerjee, S. and Morella, E. (2011) "Africa's Water and Sanitation Infrastructure: Access, Affordability and Alternatives", World Bank Biran, A, W Schmidt, K Varadharajan, D Rajaraman, R Kumar, K Greenland, B Gopalan, R Aunger and V Curtis, (2014), "Effect of a behaviour-change intervention on handwashing with soap in India (SuperAmma): A cluster-randomised trial", The Lancet Global Health, 2(3): e145-e154.

Blume, S, D Nordmann, D Schäfer and R Werchota (2015), "Closing the last mile for millions: Sharing the experience on scaling up access to safe drinking water and adequate sanitation to the urban poor", Eschborn: Deutsche Gesellschaft fürInternationaleZusammenarbeit (GIZ).

Bryant, J, A Azman, M Ferrari, B Arnold, M Boni, Y Boum, K Hayford, F Luquero, M Mina, I Barraquer, J Wu, D Wade, G Vernet and D Leung (2020), "Serology for SARS-CoV-2: Apprehensions, opportunities, and the path forward".

CARE, et al. (2010). Raising clean hands. Advancing learning, health and participation through WASH in schools. Joint call to action, http://www.unicef.prgr/lac/raisingcleanhands_pdf

Curbing/Mitigating indiscriminate waste dumping through effective stakeholder relations. International Journal of Science and Research, 3(4), 107-117.

Glass Y. (2012) United Nation Water Global analysis and assessment of sanitation and drinking water: the challenge of extending and sustaining services. WHO Retrivedfrom,http://www.in.org/waterforlifedecade/PDF/glassreport2012-eng.PDF

Hazel J. (2011) WASH: improving access for all. A seminar paper presented BG Hazel of University of Loughborough UK.

International Research Journals 4 (3) 227-230 Awoso, J. A., Taiwo, A. M., Gladebo, A. M. and Arimoro, A. O. (2010). Waste Disposal and Pollution in Urban areas; A workable remedy for the Environment in Developing Countries.

Science Immunology, 5(47). Byrne, J (2018), "Know your city: Slum dwellers count", Know your city. Caruso, B, M Freeman, J Garn, R Dreibelbis, S Saboori, R Muga, and R Rheingans (2014), "Assessing the impact of a school-based latrine cleaning and handwashing programme on pupil absence in Nyzana Province, Kenya: A cluster randomized trial", Tropical Medicine and International Health, 19(10): 1185-1197.

The Concept of Waste and Waste Management. Journal of Management and Sustainability 6(4):88 10.5539/JMS.v6n4p88 Anchor, P. N., Ehikwe, A. A. and Nwafor, A.U. (2014).

# SUB-THEME 3:

# TOWRDS OPEN DEFECATION FREE (ODF) NIGERA

# IMPACT OF OPEN DEFECATION ON OKPON RIVER IN OBUBRA LOCAL GOVERNMENT AREA OF CROSS RIVER STATE, NIGERIA

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**Abstract**

*This research investigated the faecal waste disposal in Okpon River catchment in Obubra Local Government Area. Data were collected through direct field measurements, laboratory analysis and informal interviews. Water samples were collected from the downstream, midstream and upstream sections of the Okpon River and taken to the laboratory for determination of coliform concentration over a period of twelve weeks. The data were subjected to statistical tests. The results revealed significant concentration of faecal coliform in all sections of the river and between time (morning and evening). Also, through the direct field observation and informal interviews, the various methods of faecal waste disposal in the area were identified to include: Open defecation, Pit latrines, nearby bushes, aside few water cisterns. It was concluded that coliform concentration in Okpon River will continue to increase as long as the human population increases and there is continuity in the current socio-cultural habits especially open defecation method of waste disposal. In view of the above, it was recommended that modern toilet facilities together with sanitation, good hygiene, potable water, attitudinal change and regular awareness campaign on good water quality should be adopted and encouraged amongst members of the community.*

**Keywords:** Open defecation, Faecal coliform; Okpon river; Obubra Local Government Area

## Introduction

The ever-changing and ever-increasing human needs are met by the resources from the physical environment. These resources range from air, water, soil, vegetation etc. Man in ignorant of the impact of his activities (sometimes) has threatened the natural state of these resources thereby endangering him and the environment at large. One of the greatest environmental problems facing the world today is water pollution. It is asserted by Eze &Abua (2003) that water is almost available everywhere, yet pure fresh water is in short supply in both urban and rural areas. Water pollution exists when water composition has been modified by the presence of one or more substances thereby making the water unfit for a specific purpose or less suitable for that use than it was in its natural state (Fellmann, Arthur & Judith, 2005). Securing water of suitable quality is one of the leading environmental concerns of the 21$^{st}$ century. It is estimated that around 80 per cent of diseases and 33 per cent of deaths in the world are related to the consumption of contaminated water (Ye Zang, (2012) in Asouzu& Efiong 2015).

Most rural communities in Nigeria do not have functional water system that provides quality water to the inhabitants. These communities depend on such water sources as streams, lakes, ponds and rivers for its domestic and agricultural uses. In Obubra, the study area, Okpon River and its tributaries are the main sources of domestic and agricultural water supply to villages along the river banks. Unfortunately, rather than protecting this means of water supply, the inhabitants in the villages along the river banks pollute the river directly or indirectly with human faeces. These increased the risk of bacterial coliform concentration of the river water. When water from these sources (streams, ponds and river) is consumed, it results in serious health hazards. In line with this, this study aims at assessing the impact of open defecation on Okpon river and examining the variation in concentration of coliform bacteria in the River.

## Methodology

### Study area

Okpon River is located at the Eastern flank of Obubra Local Government Area of Cross River State and lies within longitudes 08º26¹E and 08º15¹ E and Latitudes 05º47¹N and 05º51¹. There are two main seasons in the area - wet and dry season. The wet season sets in from April and ends in October. The dry season starts from November and lasts till March with an annual rainfall rangebetween 2000mm and 3000mm.The annual mean maximum and minimum temperature are 30.1ºC and 22.4ºC respectively (Eni, 2011).

The area is characterized by high run off, primarily due to the underlying geology especially in the underlying crystalline basements area (Cross River Basin Development Authority, 2002). The Okpon River rises from the Cameroon region through EkokoriOwai down through Odonget (upstream), Ochon (midstream) and empties at OnyenOrangha (downstream). This River is the major source ofwater supply in the area. Hydrologically, the area has alluvial deposits recurring along the low lying swamps and banks of the riverine area. The low lands adjacent to the river through which it meanders are often water logged during the rainy seasons and even long after the rains. The people of Obubra engage in some socio-economic activities like farming, fishing, hunting, tailoring, welding, carpentry and trading. Farming is dominant amongst all. Fishing is undertaken mostly by the people who live close to the river.

**Fig 1:** Map Showing Obubra LGA and Sample Stations

### Method of data Collection

Data for this study were collected using direct field observation, informal interview and water sampling. Direct field observation was achieved with the help of a tour guide (an indigene of the community). The researcher was taken round the community observing the various methods of feacal waste disposal existing in within the area. In addition, informal interviews were carried out to collect and validate the various methods of fecal waste disposal. Water sampling was used to collect data on concentration of feacal coliform. Systematic sampling was employed in collecting the water samples for laboratory analysis. These samples were taken from the sampling stations SP1, SP2, and SP3 (which were along Okpon River) and CP1 (located at Edondon) as control point. This sampling was done once a week, mornings and evenings for a period of 12 weeks. The control point sample was taken one kilometer up stream away from the sample points for comparison. The geographic coordinates of all sample points were obtained using the GPS. The samples collected were well labeled and preserved in an ice-box at temperature of 4$^{o}$C and then transported within 24 hours to a laboratory for analysis.

## Techniques of Data Analysis

Descriptive and inferential statistics were employed in data analysis. The two-way analysis of variance (2-way ANOVA) was used to test the variations in the concentration of coliform across the three sampling stations in the study area and between two time periods (morning and evening). The one -sample t-test was used to determine if the mean of the sample is significantly different (larger or smaller) than a specified value (WHO Standard). This technique was also adopted by Efiong and Eze (2004) in their studies.

## Results and Discussion

The various methods of faecal waste disposal identified in the study area are presented in Table 1 and the concentration of coliform bacteria (cfu/100ml) at different sample locations is shown in Table 2.

**Table 1:** Methods of faecal waste disposal

| Methods of waste disposal | Individual Communities | | | Total | Percentage |
|---|---|---|---|---|---|
| | OnyenOkpon | Ochon | Odonget | Frequency | % |
| Open defecation | 60 | 30 | 20 | 110 | 56.1 |
| Pit latrine | 25 | 10 | 5 | 40 | 20.4 |
| Water cistern | 2 | 5 | 1 | 8 | 4.1 |
| Nearby bush | 20 | 12 | 6 | 38 | 19.4 |
| Total | 107 | 57 | 32 | 196 | 100 |

***Source:*** *Authors' fieldwork*

**Table 2:** Concentration of Coliform Bacteria (cfu/100ml) at Different Sample Locations

| Date | Time | OnyenOkpon (SP1)(*Downstream*) $08^0$29'E $05^0$57'N | Ochon (SP2) (*Midstream*) $08^0$27'E $05^0$56'N | Odonget (SP3) (*Upstream*) $08^0$27'E $05^0$55'N | Control (CP1) *Edondon* $08^0$26'E $05^0$54'N |
|---|---|---|---|---|---|
| Week 1 | Morning Hours | 35 | 20 | 14 | 1 |
| Week 2 | | 35 | 21 | 13 | 2 |
| Week 3 | | 34 | 24 | 15 | 1 |
| Week 4 | | 36 | 18 | 16 | 2 |
| Week 5 | | 34 | 16 | 17 | 2 |
| Week 6 | | 32 | 18 | 16 | 2 |
| Week 7 | | 38 | 19 | 18 | 1 |
| Week 8 | | 34 | 20 | 15 | 2 |
| Week 9 | | 35 | 23 | 13 | 1 |
| Week 10 | | 40 | 21 | 14 | 2 |
| Week 11 | | 33 | 19 | 15 | 4 |
| Week 12 | | 35 | 18 | 17 | 2 |
| Week 1 | Evening Hours | 40 | 29 | 25 | 3 |
| Week 2 | | 37 | 30 | 26 | 4 |
| Week 3 | | 42 | 32 | 25 | 5 |
| Week 4 | | 47 | 29 | 23 | 4 |
| Week 5 | | 35 | 30 | 26 | 5 |
| Week 6 | | 41 | 30 | 19 | 6 |
| Week 7 | | 34 | 32 | 28 | 4 |
| Week 8 | | 45 | 31 | 26 | 6 |
| Week 9 | | 41 | 28 | 24 | 7 |
| Week 10 | | 40 | 25 | 25 | 6 |
| week 11 | | 40 | 29 | 26 | 10 |
| Week 12 | | 37 | 32 | 24 | 4 |

***Source:*** *Laboratory Analysis*

The result of the 2 – way analysis of variance in table 3 showed the mean and standard deviation of faecal coliform with respect to sampling stations and time.

**Table 3:** Mean & Standard Deviation of feacal coliform with respect to sampling station & time

| Station | Time | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Odonget (Upstream) | Morning | 15.2500 | 1.60255 | 12 |
| | Evening | 24.7500 | 2.22077 | 12 |
| | Total | 20.0000 | 5.20869 | 24 |
| Ochon (Midstream) | Morning | 19.7500 | 2.26134 | 12 |
| | Evening | 29.7500 | 2.00567 | 12 |
| | Total | 24.7500 | 5.51874 | 24 |
| OnyenOkpon (downstream) | Morning | 35.0833 | 2.15146 | 12 |
| | Evening | 39.9167 | 3.80092 | 12 |
| | Total | 37.5000 | 3.90095 | 24 |
| Total | Morning | 23.3611 | 8.83226 | 36 |
| | Evening | 31.4722 | 6.95079 | 36 |
| | Total | 27.4167 | 8.88542 | 72 |

***Source:*** *Statistical Analysis*

**Table 4:** Test of between effects for bacterial coliform

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 5212.667[a] | 5 | 1042.533 | 175.156 | .000 | .930 |
| Intercept | 54120.500 | 1 | 54120.500 | 9092.795 | .000 | .993 |
| Station | 3931.000 | 2 | 1965.500 | 330.224 | .000 | .909 |
| Time | 1184.222 | 1 | 1184.222 | 198.961 | .000 | .751 |
| Station * Time | 97.444 | 2 | 48.722 | 8.186 | .001 | .199 |
| Error | 392.833 | 66 | 5.952 | | | |
| Total | 59726.000 | 72 | | | | |
| Corrected Total | 5605.500 | 71 | | | | |

***Source:*** *Statistical Analysis*

**Table 5:** Scheffe's post hoc test for variations in concentration of bacterial coliforms across the three sampling stations

| (I) Station | (J) Station | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| OnyenOkpon | Ochon | 12.7500* | .70427 | .000 | 10.9862 | 14.5138 |
| | Odonget | 17.5000* | .70427 | .000 | 15.7362 | 19.2638 |
| Ochon | OnyenOkpon | -12.7500* | .70427 | .000 | -14.5138 | -10.9862 |
| | Odonget | 4.7500* | .70427 | .000 | 2.9862 | 6.5138 |
| Odonget | OnyenOkpon | -17.5000* | .70427 | .000 | -19.2638 | -15.7362 |
| | Ochon | -4.7500* | .70427 | .000 | -6.5138 | -2.9862 |

***Source:*** *Statistical Analysis*

It can be deduced from table 2 that OnyenOkpon (downstream) had the highest coliform concentration mean values as compared to other sampling stations and the control point. This is in agreement with the study of Asouzu& Efiong (2015) that wastes in streams flow from a region of higher gradient (upstream) to lower gradient (downstream).

The test results for thebetween effect in table 4 for bacterial coliform across the three stations in Okpon River for morning and evening periods revealed that the main effect on the stations was significant, F(2, 72) = 330.224, $p< 0.001$. This means that there is a significant variation in the bacterial coliform concentration across the three sampling stations in Okpon River. Similarly, the main effect of time is significant, F (1,72) = 198.961, $p< 0.001$. This means that there is a significant variation in the concentration of feacal coliform between the morning and evening period. Also, the effect of the interaction between sampling stations and time is significant at the 0.05 level, F(2, 72) = 8.186, $p = 0.001$. In all the three cases, the results revealed significant variations because of the various anthropogenic activities that takeplace in the Okpon River and its environ during the day.

The post hoc tests in table 5, revealed that the significance in the concentration of bacterial coliform across the sampling stations was due to variations across the three stations since all comparisons revealed significant differences, with $p<0.05$.

**Table 6:** Results of one-sample test

| | Test Value = 0 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference Lower | 95% Confidence Interval of the Difference Upper |
| Onyen_Okpon | 47.094 | 23 | .000 | 37.50000 | 35.8528 | 39.1472 |
| Ochon | 21.971 | 23 | .000 | 24.75000 | 22.4196 | 27.0804 |
| Odonget | 18.811 | 23 | .000 | 20.00000 | 17.8006 | 22.1994 |
| Control | 7.691 | 23 | .000 | 3.58333 | 2.6195 | 4.5472 |

***Source:*** *Statistical Analysis*

The one -sample t-test result in table 6 showed a t-value significant difference in coliform concentration between the Okpon River and World Health Organization (WHO) test standards value of zero (0). It also revealed that there is a significant difference in feacal coliform concentration between the control station and World Health Organization (WHO) standards.

An assessment on the faecal waste disposal methods showed that the predominant methods include open defecation, pit latrines, nearby bush and water cistern. The open defecation method in the study area usually occurs by the roadside, in gutters and hidden bushes. Roadside and gutter points of defecation are usually put to use early hours of the morning and late in the evenings while the bushes are used mostly during the day as the defecator do get a little shield with the bush. The open defecation excreta are exposed to flies, rodents, birds, as well as run offs during rainfall and is eventually carried into streams, ponds, lakes, river and other water sources. Besides open defecation, pit latrines were dug indiscriminately without recourse to health implication of its users. Some are quite shallow thus, exposes excreta to flies, rodents and runoffs. It was also gathered that nearby bushes and open waste dumpsites were places where residents disposed their faecal wastes and some of these locations are close to the water body. The use of water cistern method was quite few as most of the residents see it as something for the wealthy ones.

The implication of these practices can be seen in the level of concentration of faecal coliform present in the water. According to Winifred, (2014) such practices have serious consequences on human health, dignity and security, as well as the environment, social and economic development. For instance, the WHO (2014) reported that a child dies every two and a half (2½) minutes worldwide from a disease linked to improper faecal disposal. Each year, more than 800,000 children under 5 years die needlessly from diarrhea, countless others fall seriously ill with many suffering long-term health and developmental consequences as a result of poor sanitation and hygiene. Fellmann et al, (2005) andFrancois& Maarten (2003) asserted that one of the greatest environmental problems associated with urban and rural dwellers is the issue of improper faecal waste disposal into water sources. Ingestion of water contaminated with faeces is responsible for a variety of diseases through fecal – oral route transmission. High coliform level in water raised the chances of pathogens to be present in significant number (Fresno 2009).

In addition, Hoboken and Blackwell (2013; Radhika, 2015) corroborated that improper faecal disposal is the reason 50 percent of Indian children are malnourishedand record high mortality rates in areas where its practice is high. (Winifred, 2014; Selendy, 2011) raised serious concern that; one grain of human faeces can contain more than 10 million viruses, one million bacteria, 1000 parasite cysts and 100 parasites eggs. This means that people get sick often from eating and drinking their own faeces. From the foregoing, declining water quality in Okpon River has become a serious issue of concern as the river remains the main source of water in the community. The residents depend on water from Okpon River for their drinking, domestic chores, agriculture and other necessary needs and activities. Globally, as human population grows, economic and socio-politic interaction increase, the threat to the hydrological cycle become visible by the day (UNEP &UNESCO, 2008). However, in all the cases, coliform concentration in Okpon River is very high.

The high concentration of faecal coliform in Okpon River can trigger some sicknesses like cholera, dysentery, diarrhea, typhoid and even death. Domingo, (2012) agreed that these extreme cases were predominant in countries where poor sanitary condition are the norm. Exposure to faecal pathogens tend to be greater problem to immune suppressed people like infants, the aging, and those experiencing serious illnesses like pneumonia and Acquire Immune Deficiency Syndrome (AIDS,) (WHO, 2014, Ashbolt, 2003, Doyle and Erickson 2006). Sanitation therefore remains a powerful indicator of the state of human development in any community.

**Conclusion**

Arising from the study, the practice of open defecation is still predominant in these communities even with the development of the 21st century. This practice is as a result of their poverty, belief and behavioural attitude which have been transferred across generations. Open defecation has posed serious threat to the health of the people especially through the pollution of their surface water. The presence of faecal coliform in water irrespective of the quantity renders it unfit for human consumption. There is need to work towards "Open Defecation Free" community, that is, transitioning from traditional defecation methods of open defecation, pit latrines, direct discharge to water ways, river banks and nearby bushes to improved toilet facilities. Also, improving on sanitation, hygiene and attitudinal change will be of great advantage for public health, livelihood and dignity. These advantages extend beyond households to the entire communities. On the other hand, if there is continuous defecation in the open and construction of pit latrines without environmental guidelines, it would mean that bacterial coliform concentration in Okpon River will increase the more resulting in more various health problems. Nevertheless, public health awareness, enactment of indigenous laws and participatory approach in the development of water sources by the government, NGOs and Community Leaders will help in curbing the issue of water pollution among the users of Okpon River.

**References**

Ashbolt, N. J. (2003). Drinking Water Risk Assessment. *Environmental Health Focus, 1(1),* 49-57.

Asouzu, O.E., & Efiong, J. (2015) Implication of Open Dumpsite on Groundwater Quality in Calabar Metropolis. *Journal of Geography, Environment and Earth Science International, 2(3),* 117 - 125.

Cross River Basin Development Authority (2002). Inventory of Natural sites, conditions - soil slopes, hydrology, land use and vegetation through the area of operation of the authority. *Progressive Report,* 4144.

Domingo, S. W. (2012).*Environmental Health Monitoring: Emerging Issues in Water Infection Diseases.* Retrieved from www.wikipedia.com

Doyle, M. P.,& Erickson, M. C. (2006).*Closing the Door on the Fecal ColiformAssay.* Microbe*1(4),* 162-163.

Efiong, J. and Eze B. E. (2004). Effluent discharge and stream pollutant by a rubber factory: A case study of field 20 stream in Odukpani, Cross River State. *African Journal of Educational Studies in Mathematics and Sciences, 2(2)*Pg 79-89.

Eze, B.E., Eni, D. I.,& Oko, C. (2011). Evaluation of the infiltration capacity of soil in Akpabuyo Local Government Area of Cross River State. *Journal of Geography and Geology, 3(1),*189-199.

Eze, B. E.,&Abua, A. M., (2003).*Water Resources Management*. Calabar: Ushie Printers and Publisher Co. Ltd.

Francois, B., & Maarten, B. (2003).*Linking Technology Choice with Operation and Maintenance in the Context of Community Water Supply and Sanitation.* Geneva Switzerland: World Health Organization Center.

Fresno, C. A. (2009) E.Coli or Fecal Coliform Bacteria Contamination in Your Water Supply. Fresno Country Department of Public Health. Retrieved from Wayback Machine 2011.

Fellmann, J. D., Arthur, G. & Judith, G. (2005).*Human Geography: Landscapes of Human Activities.*(8th Ed).New York: McGraw Hill.

Hoboken, N. J., & Wiley, B. (2013). Sanitation and Hygiene in Africa where do we start? International water Association. ISBN 978-1-78040-541-4.

Selendy, J. M. (2011). *Water and Sanitation-Related Diseases and the Environment: Challenges, Interventions and Preventive Measures*. USA: Horizon International.

UNEP & UNESCO (2008).*Water Quality for Ecosystems and Human Health*. 2nd (Ed.). Water research and Management: IAP Programme

World Health Organization WHO (2004).*Guidelines for Drinking Water Quality*. 3rd (Ed).*1(1)*. Geneva: WHO

World Health Organization WHO (2014). *Simple Latrine*. Facts Sheet *3(4).*

Winifred O. (2014) Leadership Newspaper, July 14, 2014.

# DETERMINANTS OF OPEN DEFECATION IN UNIVERSITY OF CALABAR, CALABAR, CROSS RIVER STATE, NIGERIA

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**Abstract**
*Open defecation has remained a serious global environmental health challenge, with Nigeria and other countries in sub-Sahara Africa and Asia being the worst hit. Hence, this study investigated open defecation in the University of Calabar, Calabar, Nigeria. Data for the study were obtained from primary source through the administration of structured questionnaire on a sample of 405 students of the University of Calabar. The questionnaire was designed to obtain data on socio-demographic attributes of the respondents, involvement in open defecation at any time in the university of Calabar and why those who had involved in open defecation at any time did so. The results showed that 53 per cent of the sample were males; 89.2 per cent were in the age bracket of 16-25 years old; 92 per cent of them still single and over 75 per cent study at levels 2 and 3 of their undergraduate programmes. Also, 75 per cent of the respondents had off-campus residence. Again, 18.77 per cent of the respondents were found to have practiced open defecation at one time or the other on campus. All measured variables on determinant of open defecation: 'toilets not available', 'I don't like using toilet on campus', 'toilets are often not clean', 'payment before using toilet', 'toilets located very far from lecture block', 'toilets not opened during night classes', 'water not available most of the time' and 'toilet not opened when needed', in a descending order were found to be true. It was then concluded that the above factors were the determinants of open defecation in the University of Calabar. The study recommended, among others, that the management of the University of Calabar should ensure that toilet facilities are available for use at any time of the day.*

**Keywords:** Determinants, Open defecation, University of Calabar, Sanitation..

## 1.0 Introduction

Open defecation is the practice of defecating in fields, forests, bushes, bodies of water, on beaches, gutters, and other open spaces or disposed of with solid wastes. It has remained one of the major environmental health challenges all over world. Reports show that over one (1) million people die annually from diseases related to poor sanitation, including open defecation (World Health Organisation, WHO, 2014). Many countries in sub-Saharan Africa, including Nigeria, are still grabbling with public health problems associated with open defecation. It should however be noted that the rate of open defecation has been reducing gradually, since the era of the Millenium Development Goals (MDGs). Be that as it may, many countries were not able to meet the target of reducing by half the proportion of the population without sustainable access to basic sanitation by 2015 (United Nations, 2015).

Open defecation is associated controllable diseases, under nutrition and poverty (Osamanu, Kojoe&Ategeeng, 2019). Moreover, the practice of open defecation is considered as an afront to societal and personal integrity. The WHO (2014) reported that 200,000 children under the age of five years die from diarrhoea and other water-related diseases because of poor sanitation, poor hygiene practices and unsafe water supplies in sub-Saharan Africa. Africa ranked second to Asia in open defecation (Appendix 1).

In Nigeria, effort is being made to ensure that the country is open defecation-free. Between the 2000 and 2017, there has been a gradual reduction in the percentage of population practicing open defecation from 26.40 to 19.80 (Appendix 2). However, Nigeria now ranks number one in the world in term of total population that is practicing open defecation. Before October, 2019, Nigeria was second to India (Adedigba, 2019). The Minister of Water Resources, Suleiman Adamu, disclosed while declaring open a two-day Private Sector Forum on Sanitation with the theme, 'Coordinating Indigenous Private Sector Initiatives to End Open Defecation in Nigeria, on Monday 28th October, 2019 in Abuja, stated that Nigeria currently ranks number one in terms of the number of people practicing open defecation in Africa. The minister further stated that:

> "We are on the brink of being ranked first globally, as approximately 47 million people do not have access to sanitation services in its most basic form. Understandably, this is a serious concern to all of us, as it has immense economic consequences and also hinders the social development of the country … As part of the efforts to address this issue with particular reference to ending open defecation, a National Roadmap towards making Nigeria Open Defecation Free (ODF) by 2025 was developed and launched in 2016. However, only minimal progress has been achieved in the implementation of the Roadmap with only 14 LGAs across the country so far being certified as open defecation free, according to the National ODF Protocol. However, it is comforting to note the positive efforts being made by my ministry in the WASH sector toward improving the living standards of our people both in the rural and urban areas. Access to Water Supply, Sanitation and Hygiene are part of the indices for socio-economic development of any nation and thus cannot be ignored".
> (https://punchng.com/open-defecation-nigeria-ranks-no-1-in-the-world-minister/).

As at 2020, only 38 LGA's out of 774 in Nigeria were certified as Open Defecation Free, an additional 24 to the previous 14 (https://www.premiumtimesng.com/health/health-interviews/428298-only-38-out-of-nigerias-774-lgas-are-open-defecation-free-minister.html).
While the number of LGAs with certification is increasing, the rate is very slow and the proportion insignificant.

Educational institutions like the universities play major roles in constructing, interpreting and reinforcing societal values into those who pass through it. The university, as a formative centre for the mind, character and physical ability of students should serve as the microcosm of an ideal society. It therefore means that societal ills and behaviours that are considered affronts to the person and society should be an aberration on University Campuses. Unfortunately, this is not the case in many campuses in Nigeria.

In the University of Calabar, open defecation is observed in her two campuses despite awareness on sanitation being created as a result of covid-19 pandemic. Many open places and nearby bushes have become 'make-shift' toilets on campus. While efforts have been made by the university management in constructing additional toilet facilities outside the main buildings, this is yet to yield any appreciable results as human feaces litter nearby bushes and open spaces (Plates 1 & 2). Studies have revealed the causes of open defecation to include, age-long practice (culture), financial constraints, long distance to public toilet, bad condition of public toilet, and so on (Osamanu, Kojoe&Ategeeng, 2019). It is not clear what the cause of open defecation in the University of Calabar are despite management efforts in making toilets and other sanitation facilities to be available. Moreover, the authors' personal communication with a medical staff of the University's Medical Centre reveals several cases of sanitation related cases among students.

Hence the study was construed to investigate the determinants of open defecation in the University of Calabar with the view to providing reasonable suggestions to curb this unhygienic practice. The overall aim is to ensure the achievement of Open Defecation-Free (ODF) Nigeria.

**Plate 1:** Open defecation behind old gas station besides a dilapidated toilet facility

**Plate 2:** Open defecation behind an uncompleted toilet toilet facility

**2**.0 **Research Methodlogy**

**2.1 Study area description**

The study was carried out in the University of Calabar (UNICAL), located in Calabar, the capital of Cross River State of Nigeria (Fig. 1). UNICAL lies within Longitudes 8°20′00′′ and 8°21′3′′ EAST of the Greenwich Meridian and Latitudes 4°55′30′′ and 4°57′30′′ North of the Equator. It covers an area of about 4km$^2$ on the eastern side of the Great Kwa River. The University was first established as Calabar Campus of University of Nigeria and became a full fledge University in 1975. The Calabar Campus started at a temporary site known as the Duke Town Campus (formerly occupied by the Duke Town Secondary School) and has the Permanent (main) Campus, just adjacent to the Duke Town campus with the Eastern Highway (now closed at one end) separating the two Campuses. With the directives from the National University Commission on retaining temporary campuses, development in the University has led to the merging of the two campuses. Unfortunately, many people still address the Duke Town Campus as the Main Campus of the University. Faculties, institutes and Departments are scattered across the two campuses with student population of about 45,000. The University has one College, 17 Faculties, 3 institutes and a Postgraduate School.

The University Management is headed by Professor Florence Banku Obi, the 11th and its first female Vice Chancellor. Rainfall in the area is high and generally falls all through the with high runoff. Such could easily transport feaces to nearby waterbodies. The major source of water on campus is groundwater and water vendors. However, the water does not flow to most of the toilets in offices and classroom blocks.

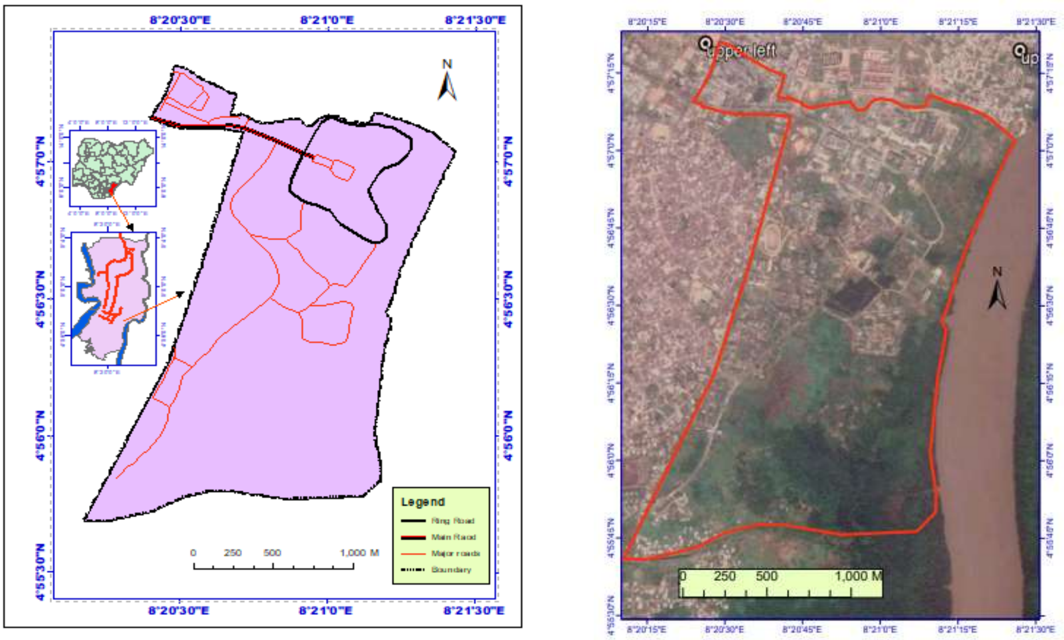



Fig. 1: Study area a). Location b). Google Earth image

## 2.2 Research design

This study adopted the quantitative approach which is best suited for survey design. Data was collected from primary source using the questionnaire. The study population consisted of the total number of students in the University of Calabar which is 45,000. From this population, a minimum sample size of 395 was determined using the Taro Yamene's (1967) formula for minimum sample determination with the level of tolerable limit of error set at 0.05. The sampling was done using the simple random method with field assistants who were themselves final year students in the Department of Environmental Resource Management, University of Calabar.

Instrument of data collection was a structured questionnaire. Items on the questionnaire included those that measure socio-demographic, participation in open defecation and determinants of open defecation. A conditional survey question (the skip logic branching) was then used to eliminate those respondents who practiced open defecation from others who do not. Subsequent questions were on reasons for practicing open defecation in University of Calabar. To ensure that the minimum sample size was not jeopardized, a total of 450 copies of questionnaire was administered using both the face-to-face and drop and pick methods. Off the 450 copies of questionnaire, 418 were retrieved with a return rate of 92.88%. During collation and sorting, it was observed that 13 copies of the returned questionnaire were not properly completed, hence they were rejected. This left a total of 405 usable copies of questionnaire which was still higher than the minimum sample size. Data was presented in Tables and analysis done using percentages and descriptive statistics.

# 3.0 Results and Discussion

## 3.1 Socio-demographic Characteristics of Respondents

Respondents' socio-demographic characteristics covered by the study (gender, age, marital status, level of study and residential type) are found in Table 1.

**Table 1:** Respondents' socio-demographic characteristics

| Characteristics | Description | Frequency | Percent |
|---|---|---|---|
| Gender | Male | 214 | 52.84 |
| | Female | 191 | 47.16 |
| Age (Years) | < 16 | 22 | 5.40 |
| | 16 – 20 | 206 | 50.90 |
| | 21- 25 | 155 | 38.30 |
| | 26 – 30 | 16 | 4.00 |
| | >30 | 6 | 1.50 |
| Marital Status | Single | 374 | 92.30 |
| | Married | 31 | 7.70 |
| | Others | 0 | 0.00 |
| Level of study | Year 1 | 30 | 7.40 |
| | Year 2 | 169 | 41.70 |
| | Year 3 | 147 | 36.30 |
| | Year 4 | 41 | 10.10 |
| | Year 5 | 12 | 3.00 |
| | Postgraduate | 6 | 1.50 |
| Residential Type | On-Campus | 101 | 24.90 |
| | Off-Campus | 304 | 75.10 |

**Source:** Authors' fieldwork, 2021.

From the data, the majority (52.84%) of the respondents were males. Though the respondents were systematically selected, this result reflects the dominance of males as students in the University of Calabar. This is also similar in most other universities in Nigeria where female education is only recently being some concerns. Age of respondents is varied with those in the 16–20 years groups constituting the majority (50.90%), followed by those in the range of 21-25 years (38.30%). Respondents above 25 years constituted 5.50% of the sample. From the data, 92.30% of the respondents were found to be single while 7.70% were married. Majority of the respondents were in their second (41.70%) and third (36.30%) years of study. Only 1.50% of respondents were in the Postgraduate level. It therefore means than majority of the sample were in the undergraduate programmes. Also, 75.10% of the respondents reside off-campus with only 24.90% being accommodated in the hostels.

### 3.2 Open Defecation Practices in University of Calabar

Table 2 shows frequency and percentage of respondents who have ever practiced open defecation in the University of Calabar. It reveals that out of the 405 respondents in the sample, 18.77 % have ever involved in open defecation in the University of Calabar. This percentage is not to far from the Country's overall percentage of the population that practices open defecation (See section 1).

**Table 2:** Respondents' involvement in Open Defecation

| Description | Frequency | Per cent |
|---|---|---|
| Yes | 76 | 18.77 |
| No | 329 | 81.23. |
| Total | 405 | 100.00 |

**Source:** Authors' fieldwork, 2021.

### 3.3 Determinants of Open defecation

Table 3 presents responses on why students practiced open defecation. These responses came from the 76 (18.77%) of students in the sample as indicated in Table 2. These are students who have practiced open defecation on campus at one point or the other. Based on the decision rules for the means of responses for each statement to be greater than or equal to 2.50 for the statement to be considered as a factor for open defecation, it was observed that the statement 'toilets not available' had a mean value of 2.79. Hence the statement was interpreted as 'TRUE" (Table 3). Similarly, 'I don't like using toilets on campus' had a mean value of 2.78 which was greater than 2.50. Hence, it was also interpreted as 'TRUE". Generally, all means of measured statements in the study were found to be greater than 2.50, hence they were interpreted as 'TRUE".

**Table 3:** Determinants of open defecation in University of Calabar

| Statement | Level of agreement | | | | Mean ($\bar{X}$) | Rank | Decision rule: ($\bar{X}$)≥2.50=True |
|---|---|---|---|---|---|---|---|
| | SA (4) | A (3) | D (2) | SD (1) | | | |
| Toilets not available | 21 | 27 | 19 | 9 | 2.79 | 6th | True |
| I don't like using toilet on campus | 24 | 25 | 13 | 14 | 2.78 | 7th | True |
| Toilets are often not clean | 36 | 27 | 8 | 5 | 3.24 | 5th | True |
| Payment before use | 56 | 18 | 2 | 0 | 3.71 | 2nd | True |
| Very far from lecture block | 21 | 28 | 26 | 1 | 2.64 | | True |
| Toilets not opened during night classes | 59 | 17 | 0 | 0 | 3.78 | 1st | True |
| Water not available most of the time | 38 | 29 | 6 | 3 | 3.34 | 4th | True |
| Toilet not opened when needed | 49 | 22 | 5 | 0 | 3.58 | 3rd | True |

**Source:** Authors' fieldwork, 2021.

Study by Osamanu et al (2019) revealed that 49.8% of households had no form of toilet facility and were either using communal/public toilets or practicing open defecation. It therefore means that absence of toilet facilities would encourage the practice of open defecation. It may not be completely true that there are no toilets in the University of Calabar. A field work around the campuses revealed number of toilets, either in main buildings or detached (Plates 3- 6).

**Plate 3**: Toilet facility near CES building at 'Pay-as-you-use" basis

**Plate 4**: Toilet facility permenently under locks in the Duke Town Campus, University of Calabar

**Plate 5**: Delapidated Toilet facility near NAT Lecture block at Duke Town Campus

**Plate 4**: Uncompleted toilet facility at Duke Town Campus, University of Calabar

However, most of these toilets are either not opened or in unusable state. Hence, the present study also found out very high mean values of responses for 'toilets not opened during night classes' (3.78) and 'toilet not opened when needed' (3.58). Figure 3 shows the percentage distribution of reasons for practicing open defecation in the University of Calabar.

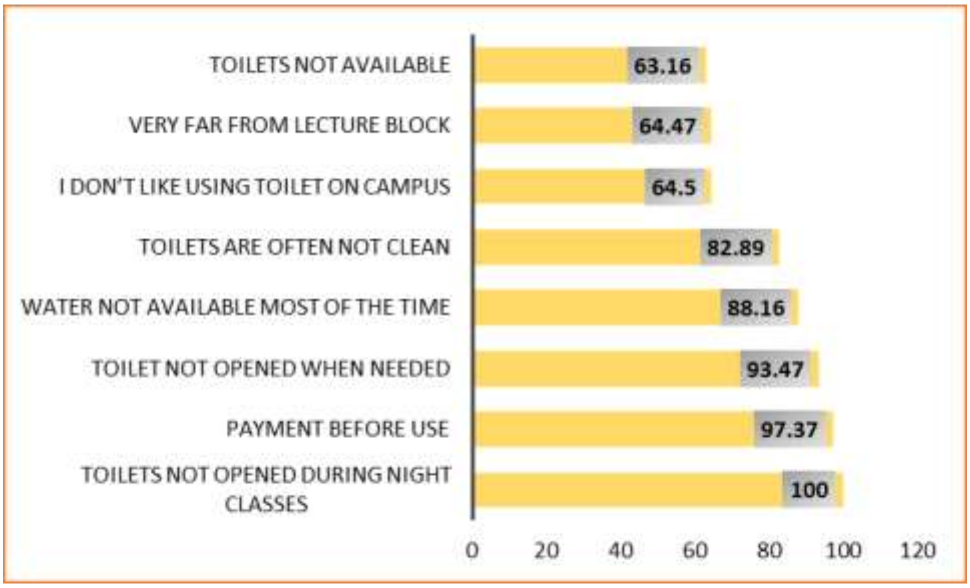



**Fig 2:** Percentage distribution of reasons for open defecation by respondents
**Source:** Authors' analysis (2021).

From Figure 2, it is clear that one of the major determinants of open defecation is non-availability of toilet facilities in the night (100 per cent). This factor also ranked 1st in Table 3. This means that students on night classes for independent and group studies do not have access to toilets when needed. Hence, they resort to open defecation. Non-availability of toilet facilities had been noted as one of the major factors of open defecation in many studies (Osumanu&Kosoe, 2013; Osumanu et al. 2019; Jenkins & Scott, 2007). This factor also collaborated with 'toilet not opened when needed' having 93.47 per cent of responses and being ranked of 3rd in Table 3. Plate 2 had revealed a toilet facility that is permanently under locks in the Duke Town Campus of University of Calabar. This may be the case of some other facilities on campus.

Another major factor identified in the study was 'payment before use' of toilets, which ranked 2nd in Table 3 with 97.37 per cent of responses. It is quite disheartening that students should be asked to pay before using toilet facilities. Such requirement should have been taken care of in their fees. It therefore means that only the rich students may be able to afford the use of toilet facilities leaving others who may not be able to afford such 'luxury' to make do with open defecation.

The non-availability of water was the 4th ranked factor (88.16 per cent) that contributed to open defecation in the study area. Water is the most essential element in sanitation and it lack would make the toilet environment to be unhygienic. Water controls the cleanliness of toilet, hence its non-availability resulted in the 5th ranked factor of 'toilets are not often clean' with 82.89 per cent responses by students.

It was interesting to know that 64. 50 per cent of students who practiced open defecation did so because they don't like using toilets. It was not clear whether the reason for such has cultural connotations or not. However, studies have shown that culture plays significant role in open defecation (Osumanu et al. 2019). Moreover, while 64.47 per cent reported that toilet facilities are very far from lecture blocks, 63.16 per cent argued that it was because toilet facilities were not found on campus that led to their involvement in open defecation. In all, it was found out that all the seven factors constituted determinants of open defecation in the University of Calabar.

## 4.0 Conclusion and Recommendations

The study was designed to investigate the determinants of open defecation in the University of Calabar with the view to providing reasonable suggestions to curb this unhygienic practice. The study revealed that all the measured variables, 'toilets not opened during night classes', 'payment before use', 'toilet not opened when needed', 'water not available most of the time', 'toilets are often not clean', 'I don't like using toilet on campus', 'toilets very far from lecture block' and 'toilets not available', constituted determinants of open defecation in the University of Calabar in descending order. The following recommendations were therefore made, that:

1. Management of the University of Calabar should ensure that toilet facilities are available for use at any time of the day.
2. The Management of University of Calabar should ensure that availability of running water at all toilet locations.
3. The Management of University of Calabar should put a stop to the act of payment before use of toilet facilities and make them accessible across social status.

The enforcement of the above recommendations shall contribute in no small measure to the overall aim of Open Defecation-Free (ODF) Nigeria.

## References

Adedigba, A. (2019). Nigeria worst African country in open defecation, second globally – Report. https://www.premiumtimesng.com/news/top-news/337023

https://www.premiumtimesng.com/health/health-interviews/428298-only-38-out-of-nigerias-774-lgas-are-open-defecation-free-minister.html

https://www.premiumtimesng.com/health/health-interviews/428298-only-38-out-of-nigerias-774-lgas-are-open-defecation-free-minister.html

Jenkins, M. W. & Scott, B. (2007). Behavioral indicators of household decision-making and demand for sanitation and potential gains from social marketing in Ghana.

Osumanu, I. K. &Kosoe, E. A. (2013). Where do I answer nature's call? An assessment of accessibility and utilization of toilet facilities in Wa, Ghana. Ghana Journal of Geography, 5, 17–31.

Osumanu, I. K, Kosoe, E. A. &Ategeeng, F. (2019). Determinants of Open Defecation in the Wa Municipality of Ghana: Empirical Findings Highlighting Sociocultural and Economic Dynamics among Households. *Journal of Environmental and Public Health Volume 2019,* Article ID 3075840, 10 pages https://doi.org/10.1155/2019/3075840.

United Nations (2015). The Millennium Development Goal Report 2015. USA: United Nations, New York, NY.

World Health Organisation, (WHO, 2014). Burden of Disease and Cost-Effectiveness Estimates, WHO, Water Sanitation and Health (WSH), Geneva, Switzerland.

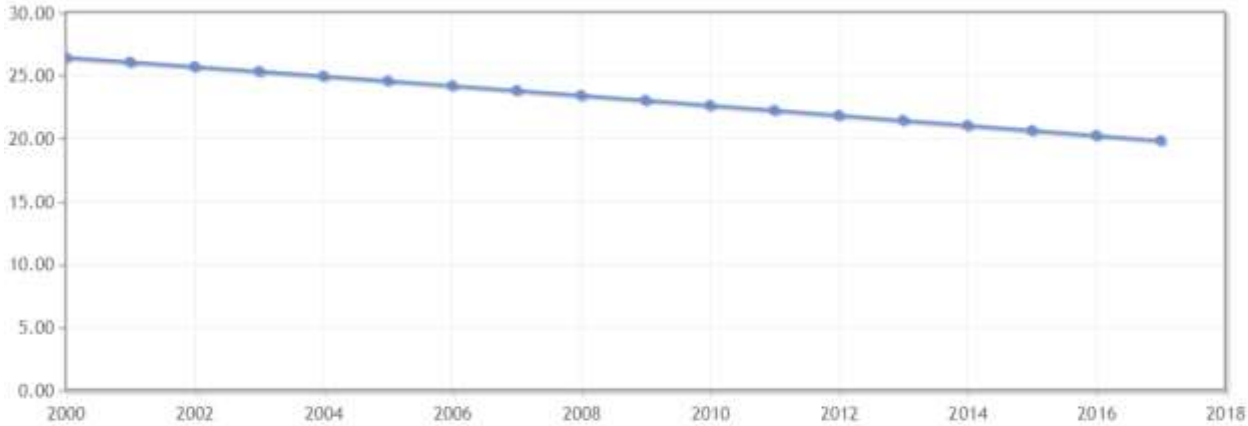
Yamene, T. (1967). Statistics: An Introductory Analysis, 2nd Edition, New York: Harper and Row

## Appendices

**Appendix 1:** Total population practicing open defecation (in thousands) across continents

| Continent | Total population practicing open defecation (in thousands) | Rank |
|---|---|---|
| North America | 0 | 7th |
| Central America and the Caribbean | 4749.900366 | 5th |
| South America | 12395.62538 | 4th |
| Europe | 41.23509757 | 6th |
| Africa | 225240.6061 | 2nd |
| Asia | 566889.8266 | 1st |
| South-East Asia and Oceania | 52884.49938 | 3rd |

Source: Modified from https://worldmapper.org/maps/housing-opendefecation-2015/



| Year | Value |
|---|---|
| 2000 | 26.40 |
| 2001 | 26.04 |
| 2002 | 25.67 |
| 2003 | 25.30 |
| 2004 | 24.92 |
| 2005 | 24.55 |
| 2006 | 24.17 |
| 2007 | 23.78 |
| 2008 | 23.39 |
| 2009 | 23.00 |
| 2010 | 22.60 |
| 2011 | 22.21 |
| 2012 | 21.81 |
| 2013 | 21.41 |
| 2014 | 21.01 |
| 2015 | 20.61 |
| 2016 | 20.21 |
| 2017 | 19.80 |

Source: WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation (http://www.wssinfo.org/).

# SUB-THEME 4:

# RAINWATER HARVESTING AND CATCHMENT MANAGEMENT

# HYDROLOGIC AND MORPHOMETRIC ANALYSIS OF ANYANG RIVER SUB-BASIN USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

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**Abstract**

*The geomorphometry of a river basin are very important factors in catchment hydrology. The morphometric analysis of the Anyang River sub-basin was carried out in this study to assess its morphologic and hydrological characteristics as well as its flood potentials based on the morphological characteristics {as floodwater from IBB and its environs will be flushed into the watershed by Nigerian Erosion and Watershed Management Project (NEWMAP). The study was carried out using remotely sensed spatial data analyzed and Geographical Information Systems (GIS). The morphometric parameters analyzed were the areal, linear, and relief aspects of the sub-basin.The main Anyang, which is a tributary of KwaIboe River is 4th order river network based on the Strahler's classification with a dendritic drainage pattern and moderate drainage texture.; values of bifurcation ratio, stream frequency, drainage density and drainage intensity were 2.0, 0.33, 0.42 and 0.13 respectively These values indicate that the sub-basin is elongated and would produce a flatter peak of direct runoff for a longer duration. Furthermore, a detailed study of the order-2 sub-catchment, which is the receiving stream of IBB storm water reveals that it covers a total area of 65.7 km$^2$with a basin relief of55m and it drains parts of Uyo, Ibesikpo and Nsit Ibom LGA in Akwa Ibom State, Nigeria. Measurements of flow velocity/discharge indicted transient/slow flow viz; 0.15, 0.34 and 0.48m/s and 0.08, 0.51 and 1.80 cubic metres/sec. respectively. The obvious conclusion is that the sub-basin is morphometrically less susceptible to flood. Hence, the research has provided a useful tool to map, monitor and assess flood prone areas at drainage basin scale.*

**KEYWORDS:** Delineation, GIS, Morphometric analysis, Anyang river sub-basin, Remote sensing

## Introduction

Urban floods menace in the undulating terrains of Uyo has assumed an endemic proportion in several depressions where storm drains, roadside gutters and floodwater from buildings are channeled into (as in the IBB Avenue) and the burden is increasing at astronomical rate due to ill-aligned storm drains and poorly maintained gutters/storm drains in cities in Akwa Ibom State (Malachy, 2016; NEWMAP, 2017). Hence the state is one of the most ecologically challenged states in Nigeria. As it is now, nothing short of a holistic intervention will appropriately address the urban flood menace at IBB Avenue and its environs. Furthermore, floods at IBB Avenue and its environs result from concentration of surface runoff following heavy rainfall the frequency, magnitude and severity of the occurrence have been more than doubled in recent years. Hence, there is an urgent need to assess the morphometric properties of Anyang River, which is the receiving stream of IBB sub-catchment to ensure sustainable urban development.

## The Study Area

IBB Avenue is located in Uyo metropolis and is an important road in the state capital. The flood menace in this environment is very devastating and has been a perennial problem. The IBB Avenue is thus synonymous with incessant flooding. The study area covers three Local

Government Areas (Uyo, IbesikpoAsutan and Nsit Ibom LGAs in Akwa Ibom State which include AtanOffot, Aka and EffiatOffot communities in Uyo LGA situate around Latitudes 05 00 774ºN and 005 01 822ºN and Longitudes 007 53 874ºE and 007 55 363ºE while Mbierebe, Ikot Akpan Abia, Ikot Oduot, Nung Oku, AfahaEtok, EbereOtu, Mbikpong Ikot Edim, Ikot Ossom, Ikot Udo Ekop and Ikot Ikere communities in IbesikpoAsutan situate around latitudes 04º55.405" N and 05º 01 014" N and longitudes 007º 53 347" E and 007º55 976"E Ikot ObioEdim, Obo Atai, Obo Ntong, Ikot Obok and Mbiakot communities in the lower sub-catchment (Nsit Ibom LGA) situate around latitudes 04º52.87"N and 04º55. 432" N and longitudes 007º52.994"E and 007º 54.567"E (Fig. 1)

There are two distinct seasons viz; four dry months (Nov. -Feb./ March and eight to nine wet months (March/April -October). Average annual rainfall for 44years (1977 – 2021) is 2566.0mm. Variability in the yearly amount of rainfall is evident with 3837.9mm in 2012 being the highest and 1,599.4mm in 1983, the lowest (Udosen, 2017). The study area is undulating and ranges from about 20-80metres. Relative humidity and temperature valuesare fairly constant and ranges between 60-85% and 26-33ºC respectively. Land use and land cover for Anyang River sub catchment indicate the following; Built-up Areas constitute 52% ($14km^2$), Scattered Farmland 46%, ($12.4km^2$); and Secondary Forest Vegetation 2% ($0.6\ km^2$) (interpreted from Landsat imagery of 30m by 30m resolution, 2016).

**Material and Method**

The required data for the entire survey was collected at three different levels that include field survey/measurement of cross sections of Anyang river channel (using frequency Leica GPS 1200. The obtained data were downloaded and processed using Leica Geo Office 8.3 and the processed data exported to Arc GIS 10.1 and Auto CAD Civil 3D V2013 for cross sections, while measurement of stream velocity/stream discharge using Global water meter model FP111; map-based analysis and interpretation of remotely sensed data from USGS Landsat Images of2016 at 30m by 30m resolution to extract data on morphometric properties of Anyang River. The pre-processing was done using ArcHydro extension in ArcGIS 10.2.2 while the actual delineation was done using HEC-GeoHMS extension in ArcGIS 10.2.2 with the DEM and drainage network as input. *Estimation of morphometric Parameters* -Areal characteristics such as basin area, perimeter, and main stream length were extracted from the attribute tables of the sub-basin and the main river in ArcGIS while the other parameters were estimated using the respective equations developed previously as shown in the appendix -Tables 1-3.

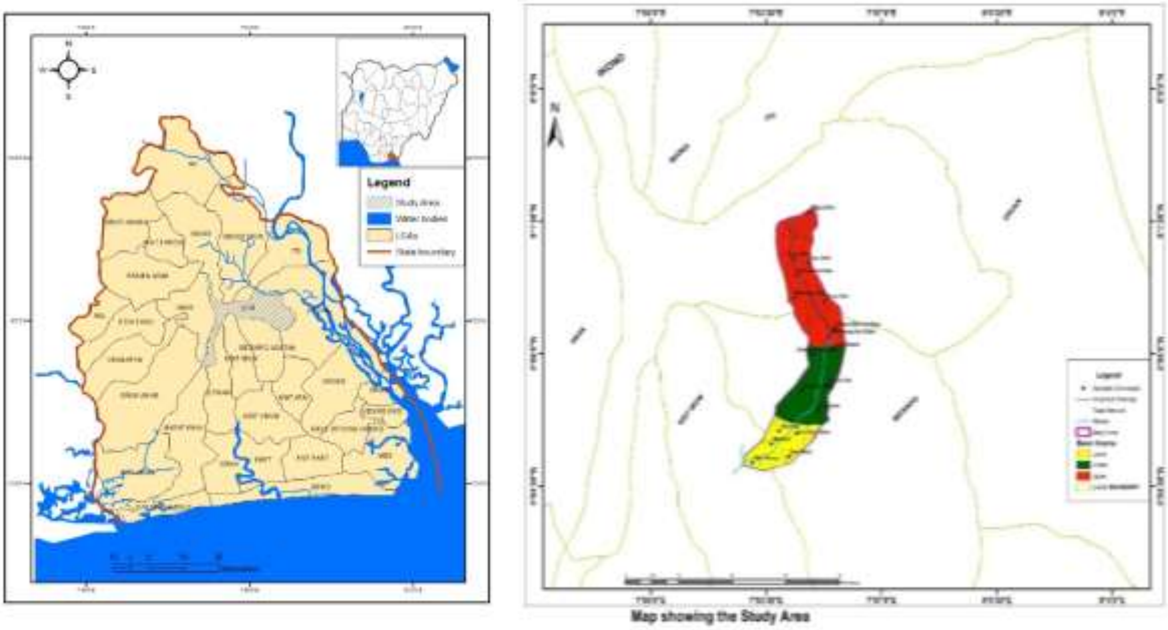



**Fig. 0:** Map of Akwa Ibom State Showing the Local Government Areas

**Result of the Study**

The Anyang River is a 4th order sub-catchment of the main Kwa Iboe River system, (before discharging into the main trunk of Kwa Iboe River at Ikot Ebiyak). Anyang river is a slow-flowing river at both upper and middle segment, with a Froude number of 0 126measured at EbereOtu and a maximum depth in the upper segment of >1.0m near Obo Ntong (Fig. 2).TheFroude number is important because it can be used to distinguish subtypes of turbulent flow called tranquil flow (Fr<1), critical flow (*Fr*=1), and rapid flow *(Fr*>1).

The details of the morphometric properties of the order- 4 segment shown in Tables 1 and 2, while the network of streams is illustrated in Fig. 2

However, in the 4th order Anyang River, indices of drainage texture were quite low (stream frequency 0.33; drainage density 0.42km/km$^2$ and drainage intensity of 0.13 (Table 2)

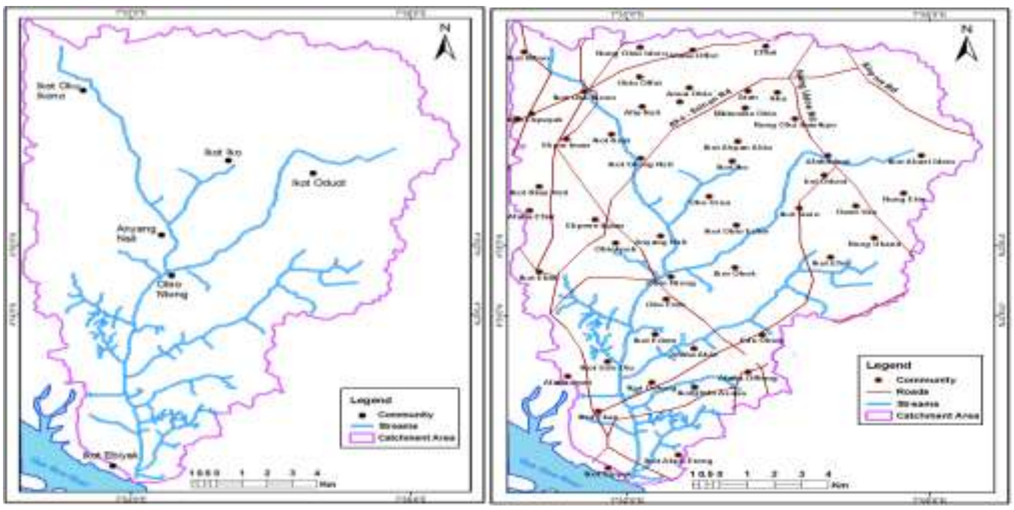


**Fig. 2:** Stream network in the fourth order Anyang River

**Table 1:** Morphometry of Order-4 Basin Draining Uyo, Nsit Ibom, Ibesikpo and Etinan LGAs

| Stream order | Number of streams (Nu) | Total length of streams (Lu) | Mean length (km) | Log Nu | Log Lu | Bifurcation ratio |
|---|---|---|---|---|---|---|
| 1st | 69 | 68.62 | 0.99 | 1.83 | 1.83 | - |
| 2nd | 19 | 28.46 | 1.49 | 1.27 | 1.45 | 3.6 |
| 3rd | 4 | 12.22 | 3.05 | 0.60 | 1.08 | 4.7 |
| 4th | 1 | 8.62 | 8.62 | - | 0.93 | 4.0 |
| Mean | - | | 3.5 | - | - | 4.1 |
| Total | 93 | 117.92 | 14.15 | - | - | - |

**Source:** Analysed from USGS Satellite image at 30m x 30m

Both stream frequency and drainage density indicate that the Anyang sub catchment has fewer number of streams per square kilometres-coarse-textured (Table 2)

**Table 2:** Indices of drainage Texture of Anyang sub catchment

| Texture Parameters | Measured Value of drainage texture | Comment |
|---|---|---|
| Bifurcation ratio | 2.0 | Very low |
| Stream frequency | 0.33 | Coarse |
| Drainage density [km/km$^2$] | 0.42 | Coarse |
| Drainage intensity or Infiltration number | 0.13 | Low |

**Source:** Analyzed from USGS Satellite image at 30m x 30m

**Longitudinal Profiles of Anyang River**

Long profiles indicate changes in elevation with increasing distance from the basin mouth. It is clear from the diagram that Anyang River exhibits convexity in its longitudinal profile which is associated with drainage basins that generate low discharge and minimal stream power (Fr<1) and therefore is unable to maintain rates of incision that equates rates of uplift. The convex channel slope also indicates enormous potential energy available for further degradational/slope wash processes,).

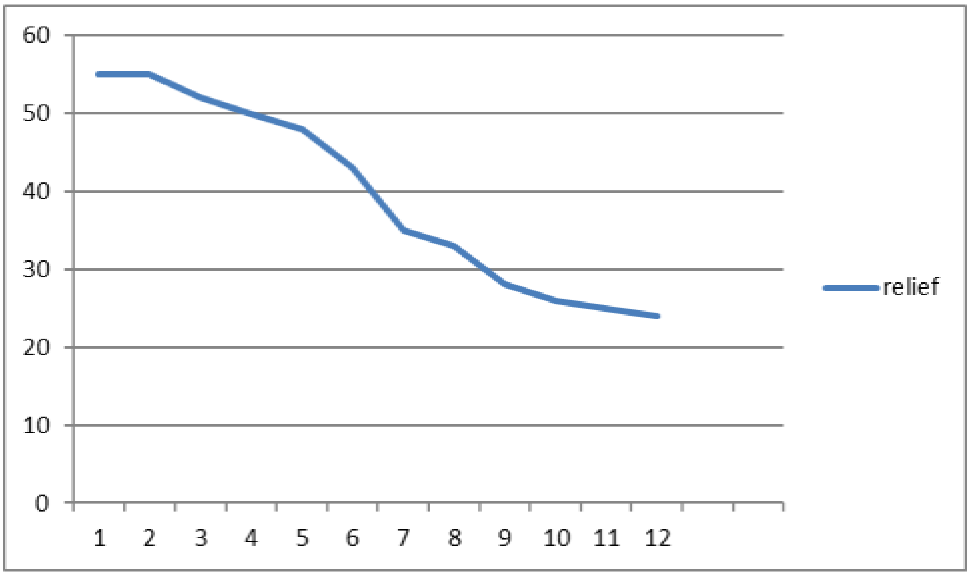



**Fig. 3:** Long profile of Anyang Riverat Ikot Oduot and other communities

Conversely, alluvial rivers (as in the downstream of Kwa Iboe River around Onna and Eket) exhibit concavities as they tend towards an equilibrium state in which the profile is adjusted to maintain rates of vertical incision that are equal to the rates of deposition/tectonic uplift. They have wide channels, high discharge values and are therefore capable of developing concave-up longitudinal profiles (Fig.4).

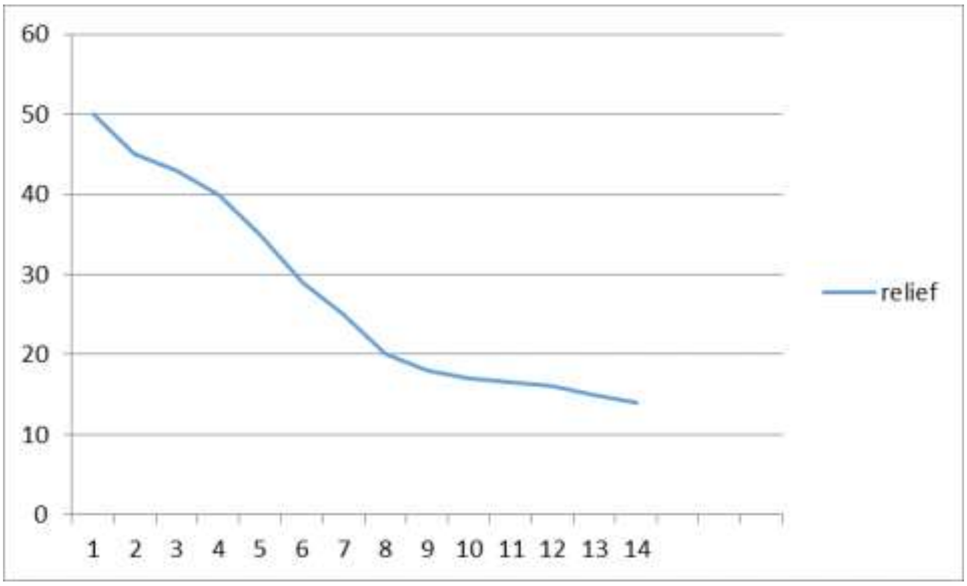



**Fig.4:** Long profile of main KwaIboe channel at Ikot Ebiyak, Ikot Ekan and Afaha Iman communities in Etinan

**Laws of Drainage Composition**

One of Horton's greatest contribution was to demonstrate that stream networks have a distinct geometric fabric called the drainage composition, in which the relationship between streams of different magnitude can be expressed in mathematical terms (Horton, 1932, 1945).The establishment of stream ordering led Horton to realize that certain linear parameters of the basin are proportionately related to the stream order and that these could be expressed as basic relationships of the drainage composition.

**Relationship between Stream order and Stream Segments**

Every basin possesses a quantifiable set of geometric properties that define the lineal, areal, and relief characteristics of the watershed (Tables3 and 4) known as the basin morphometry. These variables correlate with the stream order, and various combinations of the parameters obey statistical relationships that hold for a large number of basins. For instance, Fig. 5 indicates a strong negative relationship between stream order and the total number of streams in the order-4 sub-catchment of Kwa Iboe basin. The implication is that as the stream order increases, the total number of streams decreases. Thus, there are 69, 19, 4 and one first, second, third and fourth order streams in the watershed draining IBB Avenue and environs (Table 1).

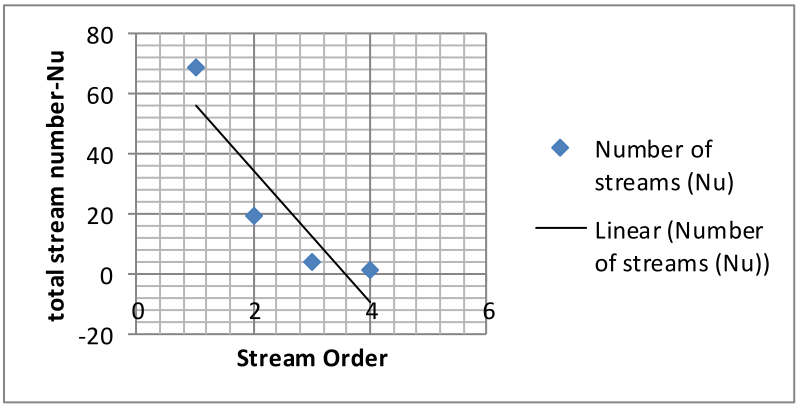



**Fig 5:** Relationship between stream order and total number of streams

**Relationship between Stream Order and Total Stream Length (km)**

Stream length is a major linear parameter and one of the most significant hydrologic features of the basin as it reveals surface runoff characteristics (Udosen, 2015;Alfa et al, 2019). Streams of relatively smaller lengths are characteristics of areas with steeper slopes and finer texture. Longer lengths of streams are generally indicative of flatter gradients. The number of streams of various order in the sub-catchment were counted and their lengths from mouth to drainage divide were measured with the help of GIS software, plot of the absolute values and logarithm of stream length versus stream order (Fig. 6) showed the inverse linear pattern which also indicates homogeneous rock materials (Coastal Plains Sands). Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases.

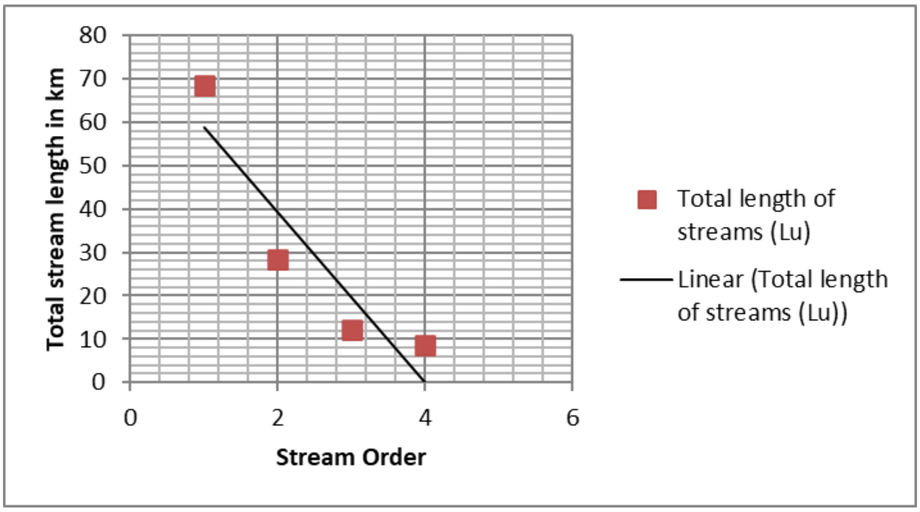



**Fig.6:** Regression of total stream lengths versus stream order

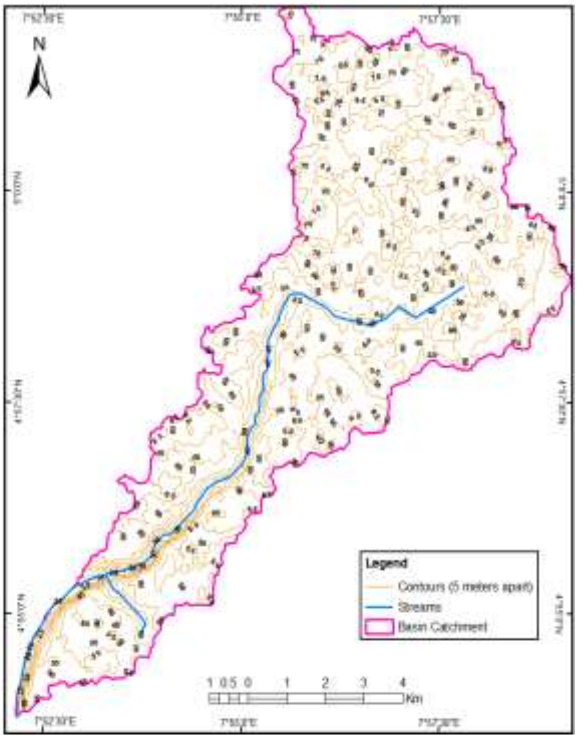
The relationships between stream order and the number and length of segments in that order have been repeatedly verified and are now firmly established (Schumm 1956; Chorley 1957; Udosen, 2015; Alfa et al, 2019 and many others).

Numerous studies have been successful in formulating relationships between basin area and discharge. One of the more important areal factors is drainage density (D), which is essential the average length of streams per unit area and as such reflects the spacing of drainage-ways. Drainage density reflects the interaction between geology and climate. As these two factors vary from region to region, large variations in *D* can be expected. However, in the 4$^{th}$ order Anyang Riverindices of drainage texture were quite low (stream frequency 0.33; drainage density 0.42km/km$^2$ and drainage intensity of 0.13 (Table 2). The lower values of Stream frequency and Drainage intensity values confirm that the surface runoff is not quickly removed from the river basin. The results reveal that the basin is well capable of absorbing water into the soil and recharging groundwater while reducing the risk of flooding. If such floods happen, they could be managed easily from this type of elongated catchments than from circular basins (see also, Alfa et al, 2019).

**Morphometry of the receiving stream-sub-catchment of Anyang Stream**

The order-2 sub-catchmentof Anyang riverdirectly draining IBB and its environs is located between latitudes 04$^o$55"N and 5$^o$ 01" N and longitudes 7$^o$ 52" E and 7$^o$58"E on an altitude of between 22 and 72m above mean sea level. The calculated basin relief of 55m above sea level translates to a basin relief ratio of 0.0029. Similarly, the sub- catchment of Anyang River flows through a fairly steep channel of 5.1 degrees, which is a characteristic channel steepness of any typical order-1 river in the humid tropical environment (Fig.7}Anyang sub-watershed covers an approximate area of close to 65.7km. $^2$ The morphometric features of the Order-2 stream are illustrated in Table 3, while the hydraulic geometry of the sub-catchment is illustrated in table 4. It is sinuous (sinuosity index of 1.28); strongly elongated (0.48) with long channel and a corresponding long length of overland flow of 18.8km and 2.17km respectively (Table 3.).

The vector flow map information on Anyang watershed, which drains IBB Avenue and its environs from the grids shows storm flow patterns (directions and magnitude) that encourage flash floods whenever it rains (Fig.7b) It is clear that storm water comes into IBB Avenue from diverse direction and much of the storm water in IBB Avenue comes as overland flows, because of inadequate drainage infrastructure in the locality.



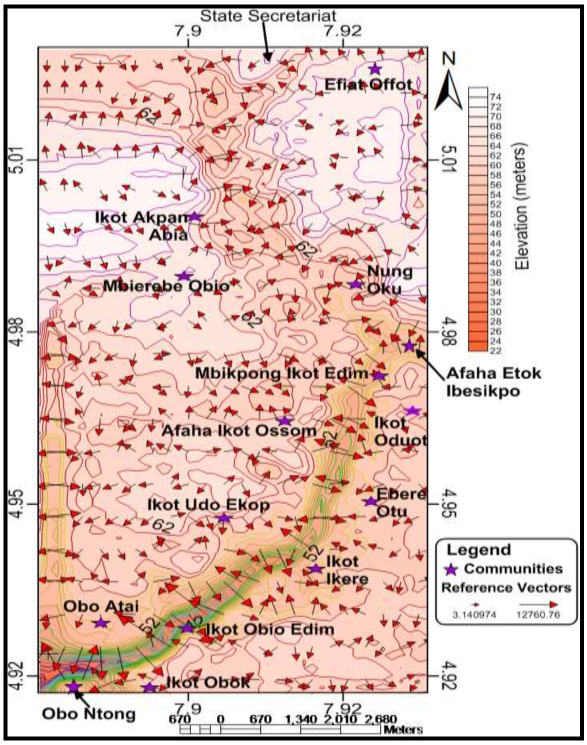




**Fig.7:** a) Topographic map of the sub-catchment b) Vector Flow Map of Anyang sub catchment Overlaid on a Filled Contour Map.

(Note: Longer arrows indicate areas of steeper slopes)

**Table 3:** Morphometry of Anyang River

| Basin property | Value | Comment |
|---|---|---|
| Basin area ($km^2$) | 65.7$km^2$ | Large compared with other order-2 basins |
| Basin relief | 55metres | Moderate relief |
| Channel gradient | 5.1$^o$ | Fairly steep |
| Stream order | 2 | - |
| Mean stream length | 18.8km | |
| Number of order-1 | 2 | Coarse |
| Bifurcation ratio | 2 | Coarse |
| Sinuosity index of Anyang R. | 1.23 | Winding channel |
| Drainage density | 0.23km/$km^2$ | Indicates that most rainfall infiltrates, rather than runoff |
| Stream frequency | 0.045 | High soil infiltrability |
| Drainage intensity | 0.01 | Permeable lithology and moderate to low relief |
| Elongation ratio | 0.48 | Strongly elongated |
| Circularity ratio | 0.21 | Sub-catchment is less circular |
| Form factor | 0.185 | The smaller number indicates elongated sub-catchment |

| | | |
|---|---|---|
| Lemniscate K-factor | 17.2 | - |
| Length of overland flow | 2.17km | Long |
| Constant of channel maintenance | 4.34 | |
| Relative relief | 0.0009 | Gentle |
| Ruggedness number | 0.0126 | |

**Source:** Analyzed from USGS Satellite image at 30m x 30m

Figs. 7 and 8 respectively show the configurations of the second order sub-catchment and the predispositions of the sub-watershed to extreme storm water events which interact with the impervious surfaces and climatic elements to generate excess surface runoff. Fig. 8 is a Digital Surface Model (DSM), that adequately captures the terrain showing its undulating nature and highlighting some steep valley-side slopes of Anyang River, particularly where it bifurcates south west of Ikot Obok. Also, portions with the dark blue coloursdepict the low-lying areas around IBB Avenue, Idongesit Nkanga Secretariat Complex and part of Abak road housing estate which is highly susceptible to flooding;

**Table 4:** Hydraulic geometry of Anyang sub-catchment

| Parameter | Upper | Middle | Lower |
|---|---|---|---|
| Location | Mbikpong Ikot Edim $4^{o}58.461N$ $007^{o}55.434E$ | EbereOtu $4^{o}57.162^{1}N$; $007^{o}$ $55.114^{1}E$, | Obo Ntong $4^{o}55.162N$ $007^{o}52.887E$ |
| Width | 1.6 | 3.9 | 3.4 |
| Depth | 0.2 | 0.39 | 1.1 |
| Width/depth ratio | 8 | 10.0 | 3.09 |
| Cross sectional area | 0.32 | 1.52 | 3.74 |
| Velocity | 0.25m/sec | 0.34m/sec | 0.48m/sec |
| Discharge | 0.08 $m^3$/sec | 0.51 (metres$^{3/}$sec) | 1.80$m^3$/sec |
| Bankful depth | 1.3 | 1.5m | 2 |
| Bankful width | 5.1 | 7.6m | 13.6 |
| Elevation | 48metres a.s.l | 41metres a.s.l. | 21metres a.s.l |

**Source:** Field survey, May, 2019

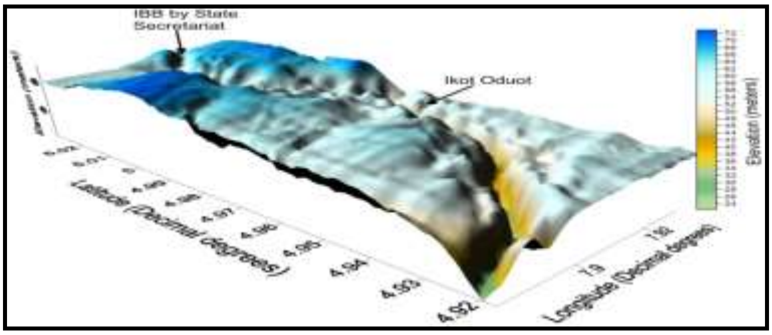



**Fig. 8:** A Digital Surface Model (DSM) of Anyang watershed

Anyang sub catchment is >18km long, 1.6-14m wide and flow on a steep slope of 5 degrees with a local relief of 40-72m and base level of <21m a.s.l. The average velocity of the stream flow at Mbikpong Ikot Edim, EbereOtu and Obo Ntong was calculated as 0.4, 0.6 and 0.7metres/sec respectively representing values for upper, middle and lower segments (Table 5). The depth of the stream channel ranges from less than 0.2m, 0.39 to over 1m in the upper, middle and lower segments respectively. The corresponding values of bankfull depth, bankfull width and discharge indicate downstream increase in discharge (Table 4).

**Table 5:** Hydraulic Geometry of Anyang sub-catchment

| Location Discharge point | Community | Elevation | Depth | Width | Velocity | Discharge |
|---|---|---|---|---|---|---|
| $4^o$ 58 480N $7^o$55 451E | Mbikpong Ikot Edim | 36 | 0.13 | 0.35 | 0.4 | 0.0182 |
| $4^o$ 58 202N $7^o$55 295E | Mbikpong Ikot Edim | 52 | 0.15 | 0.54 | 0.6 | 0.0486 |
| $4^o$ 57 927N $7^o$55 263E | Ikot Oduot | 40 | 0.46 | 0.44 | 0.5 | 0.1012 |
| $4^o$ 57 173N $7^o$55 121E | EbereOtu | 47 | 0.61 | 2.57 | 0.6 | 0.94062 |
| $4^o$ 56 689N $7^o$54 986E | Ikot Udo Ekop | 27 | 0.64 | 0.51 | 0.45 | 0.14688 |
| $4^o$ 55 6640N $7^o$553 329E | Mbiakot | 27 | 0.42 | 1.3 | 0.7 | 0.3822 |
| $4^o$ 55 164N $7^o$52 925E | Obo Ntong | 30 | 1.9 | 3.4 | 0.7 | 4.522 |

Width, depth and elevation in metres; velocity in metres/second and discharge in cubic metres/second

**Cross Profile of Anyang River at EbereOtu**

An important attribute of the cross profile at EbereOtu community is that the channel flow is restricted to a narrow valley characterized by very long valley sides. The dramatic changes in the stream geometry that will accompany the expected increase in the peakedness of the stream hydrograph following the discharge of storm water from IBBAvenue may not spill into the nearby farmlands and settlements (Fig. 9).

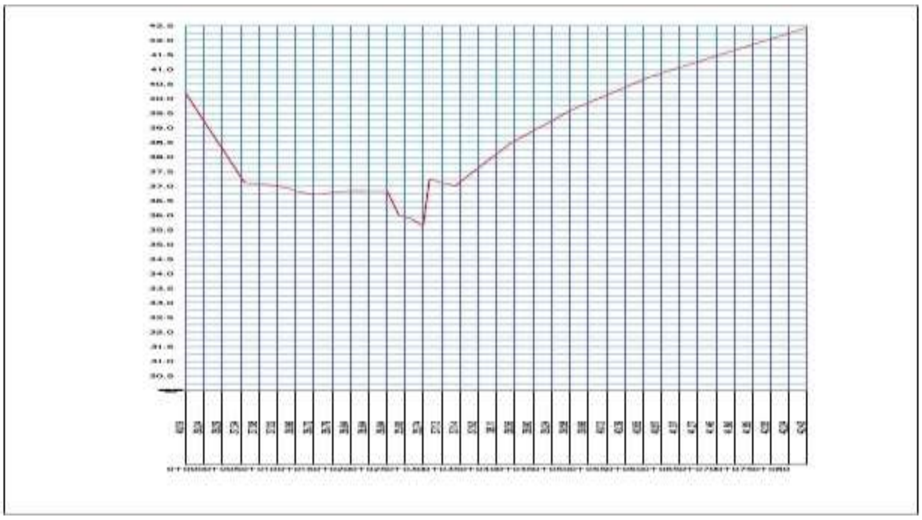


**Fig.9:** Cross Profile of Anyang R. at EbereOtu

## Conclusion and Recommendations

Uyo and several other cities in Akwa Ibom State are predisposed to severe flooding due to a number of reasons such as lack of green infrastructures that will encourage soil infiltrability, high intensity and prolonged rainstorms, undulating topography marked by localized depressionsand a notorious history of unplanned urban development. The results of the areal morphologic characteristics show that Anyang sub-catchment is inherently and morphometrically capable of reducing the flood risk but sustainable management plans should be made in advance to cope with the potential floods that can occur due to high rainfalls as has been the case with the low- lying flood plains for years.A sustained commitment is required to map, monitor and assess flood prone areas in our cities; collaborate with research institutions/universities on flood risk assessment, enforce land use regulations to protect and preserveforest reserves, parks and designated areas for green infrastructures; continued investment in population management and changes in governance that promote social stability.

## References

Alfa, M. I., Ajibike, M. A. Adie, D. B. &Mudiare O. J. (2019) Hydrologic and Morphometric Analysis of Ofu River Sub-Basin using Remote Sensing and Geographic Information System ‘’ *Nigerian Journal of Technological Development, Vol. 16, No. 2.*

Chorley, R. J.; D. E. Malm, and H. A. Pogorzelski. (1957). A new standard for estimating drainage basin shape. *American Journal of Science, 255(2), 138-141.*

Horton, R. E. (1932). Drainage-basin characteristics. Eos, Transactions American Geophysical Union, 13(1): 350-361.

Horton, R. E. (1945). Erosional development of streams and their drainage basins; hydro-physical approach to quantitative morphology. Geological society of America bulletin, 56(3): 275-370. http://www.nationsonline.org/oneworld/map/nigeria-administrative-map.htm

Malachy, O.U. (2016) Analysis of the impact of flooding on infrastructure in UyoUrban’’An unpublished M.Sc Thesis in the Dept. of Geography and Natural Resources Management, University of Uyo, Uyo, Nigeria.

NEWMAP (2017) Monitoring and evaluation baseline data for main drainage and flood relief for IBB Avenue and environs, Uyo, Local Government Area, Akwa Ibom State, Nigeria

Schumm, S. A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological society of America bulletin, 67(5), 597-646*.

Udosen C.E, [2015] Geomorphometry of a sub-catchment in Enyong Creek. Published by Pampas Lobito Ventures. Uyo, Nigeria. Pp. 80

Udosen C.E. (2017). *Rainfall Trends in a Humid Tropical Environment*. Published by AniHap Resources, Uyo, Nigeria. Pp. 243.

## Appendices

**Appendix 1:** Methods used for estimation of Areal Morphometric parameters

| Parameter | Symbol | Formula | Reference |
|---|---|---|---|
| Area | A | GIS Analysis | - |
| Perimeter | P | GIS Analysis | - |
| Basin Length | Lb | GIS Analysis | Schumm (1956) |
| Longest Flow Path | Lfp | GIS Analysis | - |
| Main Stream Length | SL | GIS Analysis | - |
| Basin Centroid Longest Flow Path | Lcfp | GIS Analysis | - |
| Elongation ratio | Re | *Re = 2√(A/n)/Lb* | Schumm (1956) |
| Circularity ratio | Rc | *Rc = 4nA)/P2* | Miller (1953) |
| Form factor | Ff | *Ff = A/Lb2* | Horton (1932) |
| Shape Factor | Bs | *Bs = Lb2/A* | Horton (1932) |
| Stream frequency | F | *F = ΣNu/A* | Horton (1945) |
| Drainage Density | Dd | *Dd = ΣLu/A* | Horton (1932; 1945) |
| Drainage Texture | Dt | *Dt = ΣNu/P* | Horton (1945) |
| Drainage Intensity | Id | *Id = F/Dd* | Faniran (1968) |
| Constant of Channel Maintenance | Cm | *Cm = 1/Dd* | Strahler (1952) |
| Length of Overland Flow | Lo | *Lo = 1/2Dd* | Langbein& Leopold (1964 |

**Appendix 2:** Methods used for estimation of linear Morphometric parameters

| Table 2: Parameter | Symbol | Formula | Reference |
|---|---|---|---|
| Stream order | U | *GIS Analysis* | Strahler (1964) |
| Stream Number | Nu | *GIS Analysis* | Horton (1945) |
| Stream Length | Lu | *GIS Analysis* | Horton (1945) |
| Mean Stream Length | Num | *Lum = Lu / Nu* | Strahler (1964) |

| | | | |
|---|---|---|---|
| Bifurcation Ratio | Rb | *Rb= Nu/Nu+1* | Schumm (1956) |
| Stream Length Ratio | RL | *RL = Lu / Lu-1* | Horton (1945) |

**Appendix 3:** Methods used for Estimation of Relief Morphometric Parameters

| Table 3:.Parameter | Symbol | Formula | Reference |
|---|---|---|---|
| Basin Relief | H | *H = Z-z* | Strahler (1957) |

# GIS-BASED MORPHOMETRIC ANALYSIS OF OTAMIRI RIVER BASIN, SOUTH-EASTERN NIGERIA

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**Abstract**

*Assessment of drainage and their relative parameters have been quantitatively carried out for the Otamiri river basin with the aid of Geographic Information System (GIS). The river runs south from Egbu through Nekede in Owerri, Imo State to Ozuzu, Etche, Rivers State, where it flows to the Atlantic Ocean. The length of the river is about 30 km. The watershed covers about 10,000 km$^2$ with annual rainfall of 2,500 mm and mean temperatures of 27°C throughout the year. The river basin is mostly covered by depleted rainforest vegetation due to intensive human and industrial activities such as farming, urbanization, sand mining, dredging etc. The study involved an evaluation of stream flow characteristic of the basin by the delineation of the watershed and determination of morphometric parameters such as the linear, aerial and relief aspects, with focus on Drainage Density (Dd), Stream Frequency (Fs), Bifurcation Ratio (Rb), Stream Order (Nu), Stream Length (Lu), Texture Ratio (T), Elongation Ratio (Re), Circulatory Ratio (Rc), Form Factor (Rf) etc. The result showed that the drainage network is dendritic type, indicating textural homogeneity and requiring less structural controls as well as variation in bifurcation ratio from 2.00 to 5.50. Elongation ratio of 7.00 depicts a basin of elongated shaped category. The stream order ranges from first to sixth order basin. The basin was found to possess low drainage density, drainage texture and stream frequency which indicates highly permeable soils and low relief. Other observed parameter such as low overland flow revealed recharge related measures, surface water augmentation measures that can be undertaken for water resource management as well as soil conservation structures in the study area. This provides inferences on the terrain parameters such as the nature of the bedrock, infiltration capacity, groundwater recharge, runoff prediction and soil erosion. The overall study and result from the findings will help in determining peak runoff which helps in managing the water resources in the basin. The implication to hydrology is the prediction of hydrologic and geomorphic processes such as flood peaks, assessment of sediment yield and erosion rates.***

**Keywords:** GIS, Morphometry, River basin, Geomorphology, Hydrology.

## Introduction

Morphometry is the quantitative evaluation of a basin and its land surface. It serves as a crucial lead into the assessment of water scarcity and availability in a river basin. River basin morphometry is a geomorphic tool that applies to physical measurements of a river form, from which can be derived quantities that explain its characteristics such as size, shape, stream network and discharge in a drainage basin.

Drainage or river basin is the fundamental landscape unit in which collection and distribution of water and sediment occur. The hydrological phenomena occurring in a drainage basin can be correlated with its physiographic characteristics such as size, shape, slope, drainage density and stream density (Waikar and Nilawar, 2014). Water availability in a river basin is influenced by the geomorphological processes that occur within the basin and play a significant role, as the patterns of basin morphometry influence the various geomorphic processes such as flood peaks, sediment yield and erosion rates occurring within it.

Assessment of the drainage network of a basin using the quantitative morphometric analysis gives information about the hydrological background of the rock formation exposed within the drainage basin. Morphometric analysis of a basin provides an indication about permeability, storage capacity of the rocks and gives an indication of the yield of the basin (Singh et al., 2013).

Most studies on the hydrological basins in Nigeria in particular and Africa in general have indicated poor understanding of the behaviour of most medium – to - large basins, due to inadequate evaluation procedures, despite the important support for livelihood activities. Commonly used procedures lack the spatial and temporal dimensions which remote sensing method offers. Geographical Information System (GIS) based evaluation using satellite image data, such as Shuttle Radar Topographic Mission (SRTM), and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), has allowed for fast and precise analysis of hydrological systems. The processed Digital Elevation Models (DEMs) are used for generating stream networks (Singh et al., 2013), which are then used to deduce morphometric parameters such as stream order, stream length, stream bifurcation ratio, mean bifurcation ratio, relief ratio, drainage density, stream frequency, drainage texture, form factor, elongation ratio, length of overland flow, constant channel maintenance, ruggedness number and shape factor.

This study is aimed at using remote sensing and GIS technologies in analyzing different parameters of morphometric characteristics of the Otamiri watershed. The computed morphometric characteristics will be used to predict characteristics such as geomorphology, topography and existing vegetation conditions in order to enhance sustainable watershed management.

## Aim and Objectives

The study is aimed at the determination of morphometric parameters of Otamiri river basin by the delineation of the watershed. Specific objectives include to:

i. generate Digital Elevation Model (DEM) of the river basin

ii. delineate and study the drainage morphometric characteristics (linear, areal and relief) of the river basin.

iii. evaluate and quantify the morphometric parameters of the basin and,

iv. recommend sustainable watershed management measures of the basin.

## Methodology

Integrated use of Remote Sensing (RS) and Geographic Information System (GIS) techniques/tools has been adopted in the present study to delineate Otamiri river basin, derive the stream network, derive and analyse morphologic parameters. NASA's Shuttle Radar Topography Mission (SRTM) mosaic Digital Elevation Model (DEM) at a resolution of 90 m has been used to delineate the Otamiri river basin. The steps adopted include DEM with fill sinks, flow direction, flow accumulation, stream definition, stream segmentation, catchment grid delineation, catchment polygon processing and requisite watershed delineation (Figs 1-3).

The longest drainage length was digitized and converted to vector data using ArcGIS 10.8. The derived basin boundary was then converted to vector data called "shapefile" from which the area and perimeter of Otamiri river basin was calculated in attribute table of ArcGIS. Stream order in accordance with Strahler (1964) and stream length for each order in Otamiri river basin were determined using ArcGIS 10.8. The formulae used to estimate morphometric parameters are shown in Table 1. The results are shown in Table 2.

**Fig. 1:** Flow Pattern (Otamiri River) (Google Earth)

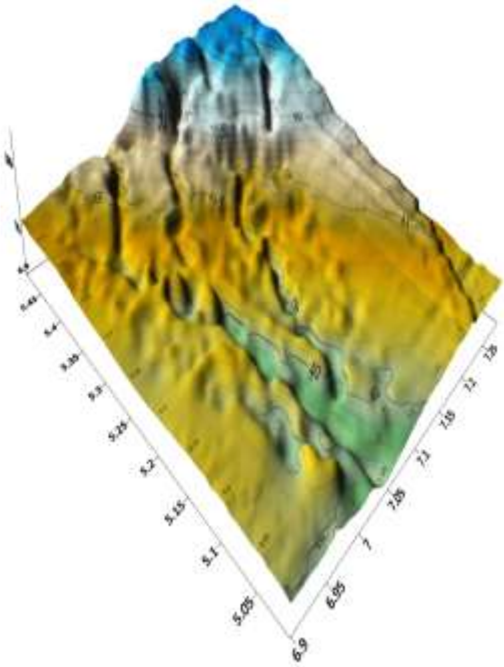

**Fig. 2:** Digital Elevation Model (DEM) (Otamiri River Basin)

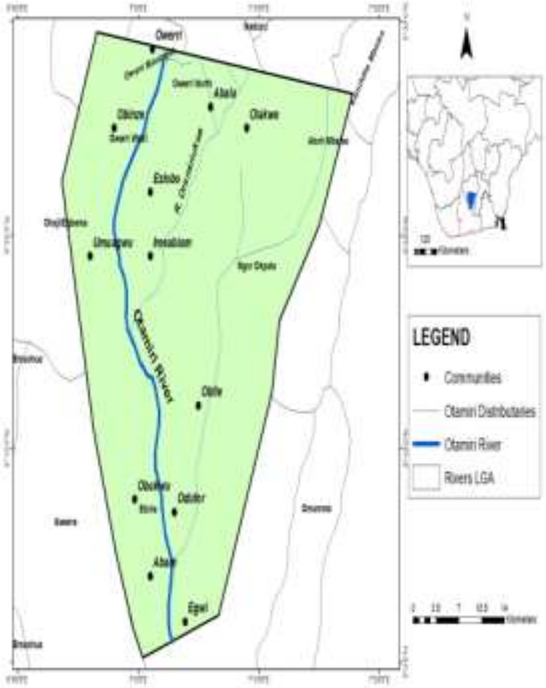


**Fig.3:** Stream Network Map (Otamiri River Basin)

**Table 1:** The Morphometric Parameters Computed in this study

| No | Morphometric parameters | Formula | Description | Reference |
|---|---|---|---|---|
| 1 | Stream order ($U$) | Hierarchical rank | - | Strahler (1964) |
| 2 | Stream length ($Lu$) | Length of the stream | - | Horton (1945) |
| 3 | Mean stream length ($Lsm$) | $Lsm = Lu/Nu$ | $Nu$ =Total number of stream segments of order $u$ | Strahler (1964) |
| 4 | Stream length ratio ($RL$) | $RL=Lu/\ L(u\text{-}1)$ | $L(u\text{-}1)$=Total stream length of the next lower order | Horton (1945) |
| 5 | Bifurcation ratio ($Rb$) | $Rb=Nu/N(u+1)$ | $N(u+1)$=Number of segments of next higher order | Schumms (1956) |
| 6 | Mean bifurcation ratio ($Rbm$) | $Rbm$ =Average Rb of all orders | | Strahler (1957) |
| 7 | Relief ratio ($R$h) | $R$h = $H/L$ | $H$ = Total relief (relative relief) of the watershed in km; $Lb$ =Watershed length | Schumms (1956) |
| 8 | Drainage density ($D$) | D= $Lu$ /A | $A$=*Watershed area* ($km^2$) | Horton (1932) |
| 9 | Stream frequency ($Fs$) | $Fs = Nu/A$ | - | Horton (1932) |
| 10 | Drainage texture ($Rt$) | $Rt$ =Nu/P | $P$= Watershed perimeter (km) | Horton (1945) |
| 11 | Form factor ($Rf$) | $Rf=A/Lb^2$ | - | Horton (1932) |
| 12 | Circularity ratio ($Rc$) | $Rc=4\pi*A/P^2$ | - | Miller (1953) |
| 13 | Elongation ratio ($Re$) | $Re=(2/Lb)*(A/\pi)^{0.5}$ | $\pi=Pi$ | Schumms (1956) |
| 14 | Length of overland flow ($Lg$) | $Lg$ =1/D*2 | - | Horton (1945) |
| `15 | Constant channel maintenance ($C$) | $C$=1/$D$ | - | Schumms (1956) |
| 16 | Shape index ($Sw$) | $Sw = Lb/A$ | - | Horton (1945) |
| 17 | Ruggedness number ($Rn$) | $Rn = B$h*$D$ | $Bh$ = Watershed relief; $D$ = Drainage density | Pareta and Pareta (2011) |
| 18 | Shape factor ($Rs$) | R$s = Pu/Pc$ | Where $Pu$ = Perimeter of circle of watershed area; $Pc$ = Perimeter of watershed | Sameena et al. (2009) |
| 19 | Compactness coefficient ($Cc$) | $Cc= 0.2821P/A^{\ 0.5}$ | - | Suresh et al. (2004) |

**Results and Discussion**

The Otamiri river basin's morphological parameters such as linear, relief and areal aspects calculated are shown below:

**Table 2:** The Results of Morphometric Parameters Computed in this Study

| S/N | Morphometric Parameters | Values for Otamiri River Basin | Unit | Morphometric Evaluation |
|---|---|---|---|---|
| 1 | Basin Area (A) | 10,000 | $km^2$ | - |
| 2 | Basin perimeter (*P*) | 425.11 | Km | - |
| 3 | Basin length (*L*) | 65.87 | Km | - |
| 4 | Basin width (*W*) | 25 | Km | - |
| 5 | Highest stream order (U) | 6 | No | - |
| 6 | No. of stream segments | 716 | No | - |
| 7 | Stream length (*L*) | 2160.7 | Km | - |
| 8 | Mean stream length | 360.11 | Km | - |
| 9 | Mean stream length ratio (*R*L) | 3.01 | No | - |
| 10 | Bifurcation ratio (Rb) | Mean 2.57 | No | - |
| 11 | Length of overland flow (*L*of) | 0.76 | Km | High |
| 12 | Form factor (*R*f) | 0.17 | No | Low |
| 13 | Texture ratio (*T*) | 1.33 | Km | Low |
| 14 | Circulatory ratio (*R*c) | 0.388 | No | Low |
| 15 | Elongation ratio (*R*e) | 7.00 | $Km^{-1}$ | Low |
| 16 | Compaction coefficient | 1.573 | No | High |
| 17 | Drainage density (*D*d) | 0.54 | No | Low |
| 18 | Constant of channel maintenance C) | 1.82 | No | - |
| 19 | Stream frequency (*F*s) | 0.165 | per sq km | Low |
| 20 | Basin relief (*B*h) | 0.90 | M | Low |
| 21 | Relief ratio (*R*h) | 0.019 | No | Low |
| 22 | Ruggedness number (*R*n) | 646 | No | High |

**Morphometric Evaluation of Otamiri River Basin**

The morphometric evaluation of Otamiri drainage basin provides quantitative description of the basin geometry that helps in understanding the geomorphological characteristics, diastrophism, and geology and basin response to various hydrological processes occurring within the basin. The evaluation and discussions of the morphometry of Otamiri river basin are made using linear, relief and areal aspects below.

**i. Linear Aspects**

The drainage pattern in Otamiri river basin is dendritic to sub-dendritic. The dendritic pattern indicates the presence of uniform resistance of rock to the drainage in the basin. Dendritic patterns tend to develop in areas where the rocks have a roughly equal resistance to weathering and erosion and are not intensely jointed (Petersen et al., 2017).

The stream order in accordance with Strahler (1964) obtained for Otamiri river basin is six, and therefore, the basin is designated as sixth-order basin. The geomorphic characteristics of Otamiri river basin confirm to Horton (1932) that the number of stream segments of different orders decreases with increase in stream order. In Otamiri basin, bifurcation ratio shows variation from 2.00 to 5.50 (with a mean of 2.57) across different stream orders (Table 1), an indication of lack of structural control.

### ii. Relief Aspects

The relief in Otamiri river basin is found to be low at 0.90 m. According to Harsha1etal. (2020), the lower relief found in a river basin indicates lesser energy available in the drainage system of the basin.

### iii. Areal Aspects

The visual examination of shape of the Otamiri river basin in (Fig. 1) shows that it is elongated. On examination of the indices/parameters shown in Table 1, it is observed that the form factor for Otamiri river basin is 0.17 which is low. Form factor would always be greater than 0.78 for perfectly circular basin and the smaller the value of form factor, the more elongated will be the basin. The circularity ratio and elongation ratio of Otamiri river basin are 0.388 and 7.00 respectively, which are low. The consequence of the confirmation of elongated nature of Otamiri river basin is the reduced peak discharge of runoff in the basin.

Drainage density of a basin evaluates the erosion status of a basin. Regions with high drainage densities possess less infiltration, increase runoff and possess at least moderately erodible surface materials. The higher the drainage density, the greater the amount of runoff and the significant the degree of channel abrasion for a given amount of rainfall (Eze and Efiong, 2010). From the results for Otamiri river basin, it is observed that the drainage density and stream frequency for the basin are low, i.e. 0.54 and 0.165 respectively, indicating highly permeable soils and low relief. The drainage density of the basin and the long concentration time are dependent not only on the relief but also dependent on the resistance of rocks across different stream orders, vegetation, rainfall and sub-surface material.

## Summary and Conclusion

Morphological characteristics of the basin indicate variation in different stream orders that confirm the anomalous basin development and local variation in topography in the basin. The dendritic to sub-dendritic pattern indicates uniform resistance to drainage pattern by major rock types in the basin such as intrusive acidic rock and banded gneissic rock. The areal aspects of the Otamiri river basin confirm that the basin is elongated and as a consequence, the river basin experiences low peak flows of runoff for longer duration despite flood risk. However, lower drainage density and length of overland flow in the basin confirm longer concentration times for runoff. Therefore, while runoff in Otamiri river basin has large scope for infiltration into the groundwater, intense flooding and erosion are expected in the river basin. Furthermore, the delineation of the drainage pattern to understand terrain parameters such as the infiltration capacity, surface run off, flood peaks, assessment of sediment yield, erosion ratesetc., will help in better understanding the status of land form and their processes, drainage management and evolution of groundwater potential for watershed planning and management and will be useful for soil and water conservation and is a positive scientific contribution for the people of Otamiri river basin area.

## References

Eze, B. E. and Efiong, J. (2010). Morphometric parameters of the Calabar River Basin: implication for hydrologic processes. *A. J. Geogr. Geol.* 2(1): 18-26.



Harsha1, J., Ravikumar, A.S, Shivakumar, B.L (2020). Evaluation of morphometric parameters and hypsometric curve of Arkavathy river basin using RS and GIS techniques. *Applied Water Science*.10:86.

Horton, R. E. (1932). Drainage basin characteristics. *Trans. Am. Geophys. Unions.* 13, 350-361.

Horton, R.E. (1945). Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. *Geological Society of America Bulletin*, (56), 275–370.

Miller, V.C. (1953). A *Quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee,* Tech. Rep. 3 NR 389-402, Columbia University, Department of Geology, ONR, New York, NY, USA, 1953.

Pareta, K., Pareta, U., 2011, Quantitative morphometric analysis of a watershed of Yamuna basin, India using ASTER (DEM) data and GIS, *International Journal of Geomatics and Geosciences* (2) 1.

Petersen, J.M, Sack, D., Gabler, R.E (2017). Physical geography. CENGAGE Learning, Boston.

Sameena, M., Krishnamurthy, J., Jayaraman, V., Ranganna, G. (2009). Evaluation of drainage networks developed in hard rock terrain, *Geocarto International* 24 (5), 397–420.

Schumms, S.A. (1956). Evolution of drainage systems and slopes in Badlands at Perth Amboy, New Jersey. *Bulletin of the Geological Society of America*, (67), 597–646.

Singh, P., Krishna, J. T. & Singh, U.C (2013). Morphometric analysis of Morar River Basin, Madhya Pradesh, India, using remote sensing and GIS techniques. *Environ Earth Sci.* 68:1967-1977.

Strahler, A. (1957). Quantitative analysis of watershed geomorphology. *Transactions American Geophysical Union*, (38), 913–920.

Strahler, A. N. (1964). Quantitative geomorphology of drainage basins and channel networks. In V. T. Chow (Ed.), *Handbook of Applied Hydrology*. 39-4,76, New York: McGraw Hill.

Suresh, M., Sudhakara, S., Tiwari, K.N., Chowdary, V.M. (2004). Prioritization of watersheds using morphometric parameters and assessment of surface water potential using remote sensing, *Journal of the Indian Society of Remote Sensing*, (32), 3.

Waikar M.L, Nilawar, A.P (2014). Morphometric analysis of a drainage basin using geographical information system: a case study. *Int. J. Multidiscip. Curr Res.* 2:179–184.

**MORPHOMETRIC ANALYSIS AND BASIN RESILIENCE: A CASE STUDY OF RIVER LAMURDE CATCHMENT AREA IN TARABA STATE**

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of Proceedings

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**Abstract**

*Across the river Benue tributaries in Taraba, river Lamurde catchment area is the most vulnerable to environmental degradation and flooding thereby impacting basin resilience. This is not unconnected to spatial scale of human alterations to land surface mostly in the form of land use and land cover change. It is on this note that this study aims at characterization of the drainage system and establishment of the morphometric behavior of the tributary to storm events. Miscellany of data and tools were used, namely thematic maps and a geographic information system (GIS).The drainage networks show that river Lamurde watershed depicts more of sub-dendritic patterns with ninth stream orders.* $L_o$ *value (0.076 km) denoting gentle slopes and longer paths network on the drainage basin. The mean* $R_b$ *for River Lamurde catchment vary between 4.0 and 6.3 indicating transitional zone of geological structure with a remarkable influence of structural disturbances. With long* $L_b$ *(83.85 km), this is an indicative of low flooding susceptibility. The longer the basin length the little the effect on the extent to which the surface runoff manipulate the basin and been lowered by agents of denudation. Catchment charaterizations of the study area from basin morphometry do not epitomize high flooding susceptibility.Environmnetal degradation through profiliration of jumbled and unrestrained development within and around the flood plain seem the cause of incessant flooding in major parts of the basin. This confirm the different level of resilience across the basins. The study recommends sustainable development within system stress-response limit. The study also present thematic maps imperative for preparation of a comprehensive micro-watershed management prioritization and implementation of mitigation measures to reduce the impact of floods in the study area.*

**Keywords:** Basin Resilience, Catchment area, Flood**,** Morphometry, River Lamurde, Taraba

## Introduction

Relevance of development and the associated benefit to livelihood cannot be overemphasized; however recognition of the implication on the environment and natural resources is crucial. This is becoming more pertinent as the climate change infiltrate and influences every sphere of the globe. Spatial scale of human alterations to land surface mostly in the form of land use and land cover change are unprecedented and so invasive that they enormously transform a large proportion of the planet's land surface, affecting key aspects of catchment area of river basin (Foley, 2005).

Across the river Benue tributaries in Taraba, River Lamurde catchment area is the most vulnerable to environmental degradation (Adelalu, et al, 2020). It is due to increasing developmental pressure as a result of spatial scale of human alterations to land surface mostly in the form of land use and land cover change. Oruonye, (2015) posited that land use along the floodplain of river Lamurde has undergone substantial level of change from open fields and fallow lands to intensively cultivated irrigation and residential areas. He added that the dominant land use types in the basins have gone beyond rain fed agriculture and irrigation farming. He observed land use activities include, excessive water extraction, deforestation for fuel wood and other domestic uses, excessive use of chemical fertilizers and land degradation due to improper agricultural practices. Where these changes are not met with complementing planning and management measures, challenges such as water pollution, high risk disaster (flood), and unstable food production are unavoidable (Adewumi, 2013), and in long run impacting the basin resilience.

Resilience is the ability of a system to maintain certain functions, processes, or populations after experiencing a disturbance (Yooinn, 2020). It is capability of a system to rebound after a remarkable disturbance. Analysis of the water potential in the state and implication for flooding for the period of 35 years (1979-2015), suggest that rainfall input volume have not significantly change over years to distressed runoff (Adelalu, et al, 2018). But now the same volume that drained the basin decades ago without much ado now pose ache! The problem is systemic. Observable influence of structural disturbances on the basin is evidence. Thus, looking into the immediate natural, social and economic importance of a typical sub watershed in a fast growing state like this, attempt to characterize the drainage system and establish the morphometric behavior of the tributary to storm events using spatial Analyst module in Arc GIS environment is long overdue. It is against this backdrop that this paper relates the morphometric characteristics of the basin to plausible environmental hazard (flood) and basin resilience in the study area.

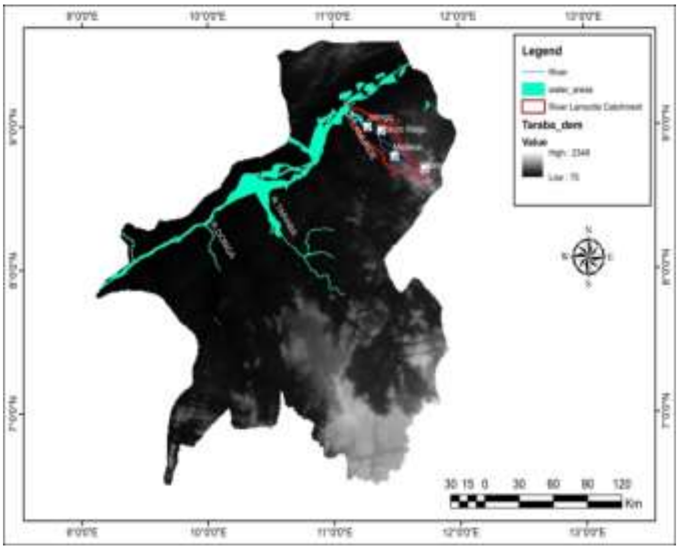
**Objectives of the Study**

The main objectives of this paper include the following:

1) To delineate river Lamurde catchment area.
2) To examine the linear, aerial and the relief characteristics of the basin.
3) To relate the morphometric characteristics of the basin to plausible environmental hazard (flood) and basin resilience.

**Materials and Methods**

**Study Area**




**Fig/ 1:** Delineated Map of River Lamurde Catchments Area

The river Lamurde catchments area lies in the northern Taraba. Geographically, it lies between longitude 11.05° E and 11.45° and latitude 8.20°N and 9.11° N . Mean annual rainfall is less than 1000 mm in the basin (Adebayo, 2012). Local lumbering, deforestation, overgrasing, bush burning (Borokini et al,2012) and several anthropogenic activities affect the terrain. The northern part of the sub-watershed is gently sloppy, whereas, the southern part is hilly terrain, located between 131 and 1440 m above mean sea level.

Quantitative and geospatial techniques were emplored to analyze the morphometric characteristics of River Lamurde Catchment Area (RLCA). Topo sheet (SHEET 215) of scale 1:50 000 of the area published (1968) from archive of Federal Surveys Department of Nigeria was used initially to demarcate the boundaries of the watersheds of RLCA, then, the ArcHydro tool was utilized to delineate the final basin boundaries and stream networks for the catchments. Other materials used for the actualization of the objectives of this work include: 30 m resolution Digital Elevation Model (DEM) of the catchment areas. This was acquired from the Shuttle Radar Topographic Mission (SRTM) available for the globe and downloaded from http://srtm.usgs.gov/data/obtaing.html. Soil image was obtained from Digital soil map of the world (DSMW) from http://Worldmap.havard.edu/data/geonade.html. Fundamental parameters and derivatives parameters were computed based on mathematical relations presented inIkusemoran et.al, (2018).

## Result and Discussion

### Linear Aspect of RLCA and Implication on Flooding and Basin Resilience

**Table1:** Linear Features of the River Basins

| S/N | Morphometric Parameters | River Lamurde Catchment |
|---|---|---|
| 1 | Stream order (U) | 9 |
| 2 | Number of Streams (Nu) Total | 225010 |
| 3 | Stream length in km (Lu) Total | 33061.59 |
| 4 | Mean stream Length ($L_{um}$) | 0.15 |
| 5 | Mean Bifurcation Ratio ($R_b$) | 3.65 |

Linear Facets of a drainage network of a basin is a measure of its Stream order, Number of streams, Stream length, Mean stream length, Stream length ratio and the Bifurcation ratio. Stream Order (U) - refers to the hierarchy of streams within an area (Adegoke and Bulus, 2015).

The stream order of the RLCA as shown in (Table 1) reveals that the basin has 9$^{th}$ order as the highest. Flood plains of sub basin with stream orders of more stream numbers are more vulnerable. Catchments of such drainage should be void of encroachment and less disturbs otherwise resilience corrupted and overstressed. Stream Number ($N_u$) - The stream number denotes the numbers of streams in each stream order. RLCA reveals a large number of first order streams (17759) with total stream number of (22501). The second and third orders follow a decreasing magnitude. This trend has implication on basin resilience and management capability.

Stream Length ($L_s$) - The main stream length of RLCA is the length of the 9$^{th}$ order. This is the principal stream. For RLCA it has a total length of 83.85km. Bifurcation Ratio ($R_b$) - is an indicator of the complexity and degree of dissection of a catchment Area (Adegoke and Bulus, 2015). In RLCA the $R_b$ ranges from 1.59 to 6.90, while Mean bifurcation ratio ($MR_b$)was 3.73. According to Adegoke and Bulus, (2015), bifurcation ratios range between 2.0 and 5.0 indicates sub basins in which the geologic structure does not exercise a dominant influence on the drainage pattern. This means large portion of RLCA basin is falling under normal basin category with practically little influence from the geological structure of the basin except the third order category. This supports the observable disparity on the basin resilience as one traverses along the river course.The stability of the geological feature is a function of basin resilience.

**Areal Features of RLCA and Implication on Flooding and Basin Resilience**

**Table 2:** Areal Features of the River Basins

| S/N | Morphometric Parameters | River Lamurde Catchment |
|---|---|---|
| 1 | Area in $km^2$ (A) | 1264.54 |
| 2 | Perimeter in km (P) | 289.47 |
| 3 | Length of the basin in km($L_b$) | 83.85 |
| 4 | Drainage density ($D_d$) | 2.61 |
| 5 | Lemniscate ratio (K) | 1.39 |
| 6 | Circulatory ratio ($R_c$) | 0.189 |
| 7 | Elongation ratio ($R_e$) | 0.478 |
| 8 | Stream frequency | 0.94 |
| 9 | Form factor ($F_f$) | 0.1799 |
| 10 | Drainage intensity ($I_d$) | 6.80 |
| 11 | Length of overland flow ($L_o$) | 0.076 |

Table 2 shows arealfeatures of RLCA. Area aspect is a measure of the basin geometry. It has important control over the geometry of the stream network thus influence the shape of the hydrograph (Ayoade, 1988). Ikusemoran et.al, (2018) had described the various indices of portrait of a watersheds' geometry.

The circularity ratio ($R_c$) of 0.189 is an indication that the RLCA is not circular in shape. The elongation ratio ($R_e$) of 0.478 is a confirmation of the fact that the basin is not circular. Sule and Bilewu (2017) gave classification index for elongation ratio. The index ranges from less than 0.5 – 1.0. Chow (1988) had earlier noted that strongly elongated basins have circularity ratios of between 0.40 and 0.50. It has been concluded that a circular basin is more efficient in runoff than is an elongated one (Singh and Singh 1997). $R_e$ value for RLCA is less than 0.5 (0.478). This value corresponds to an elongated or less elongated basin with low relief and mild slopes (Singh and Singh 1997). This implies that catchments show longer time to peak. It means basins produce a flatter peak of direct runoff for a longer duration. The question that is mindboggling now is "What then brings about the continuous yearly flooding of ever increasing magnitude"?

Form factor ($F_f$) and Stream frequency ($F_s$) Morphological characteristic of a watershed like form factor has powerful impacts on watershed hydrology. Form factor ($F_f$) parameter has been elaborated by Horton (1945) to forecast theflow intensity of a given river basin. Catchments with low ($F_f$) value tend to be elongated, which give low peak flows for longer duration, and thus reduce the chance for the basin to flood. On the other hands, catchments with high ($F_f$) values experience high peak flow of short duration. This give flood of stronger and higher velocities associated with greater erosion capacities. The ($F_f$) value for RLCA is however very small (0.1799). This value indicates that catchment under study is elongated in shape with expectedly low peak flows of longer duration. Stream frequency ($F_s$) is the total number of stream segments of all orders within the basin per unit area (Horton, 1932). It is a suggestive of stream network distribution over the river basin. According to Sreedevi, et.al,(2013), high (Fs) means more percolation with respect to drainage density and thus more groundwater potential.

The observed stream frequency ($F_s$) value for the RLCA is thus very high (17.79). This implies mild slopes, with medium permeability rocks, thus facilitating moderate infiltration and less surface flow and obviously, less flooding potential. Horton, (1945) define drainage density ($D_d$) as the total length of stream per unit area divided by the area of the watershed. High $D_d$ values denote high runoff and low infiltration rate (Farhan and Ayed, 2017). Drainage density has been associated to the presence of impermeable underlying materials, spare vegetation, and hilly relief. Conversely, low drainage density implies low runoff, high infiltration and groundwater recharge. The derived value of $D_d$ for RLCA is 26.3 km / km$^2$. Vegetation cover plays a significant role in determining hydrograph response of a basin and invariably the basin resilience. Analysis of the DEM of the catchment area reveals that more than half of the basin is denuded. 45.7% is bare land, 9% is built up area (Table 3).

**Table 3:** Land Use types of RLCA

| River Lamurde Catchments | | |
|---|---|---|
| Types | Area (km$^2$) | Percentage% |
| Vegetation | 567.4284 | 44.9 |
| Bare Land | 577.5264 | 45.7 |
| Built Up Area | 113.8509 | 9.0 |
| Water Body | 5.6556 | 0.4 |
| Total | 1264.539 | 100 |

One can say to some reasonable extent that in nature there exist some degree of orderliness, pattern and predictability. More slash of natural cover will pave way for more splashes of direct rainfall and consequently leading to erosion and flooding. As the amount of vegetation decreases and density of development increases, there is likelihood of increased erosion and flooding. Little wonder why places like Balang and Maikwai, in the Upland of the study area are less prone to depression and degradation on the other hand, in Nukkai, MayoiDassa, Magami and Kogi Muri where denudation and encroachment permit erosion and environment hazard. The land covers are natural resources, natural biofilters, and erosion stabilizers protecting the land from direct punch of rainfall, reducing the sedimentation load and runoff that would have find their course unto the river consequently leading to flooding.

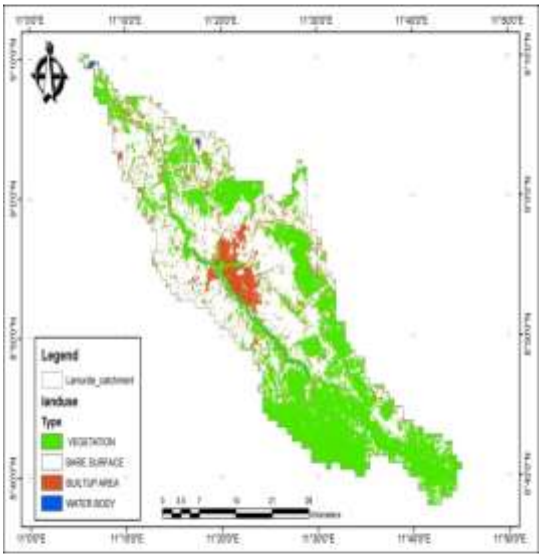



**Fig. 2:** Land use Map of RLCA

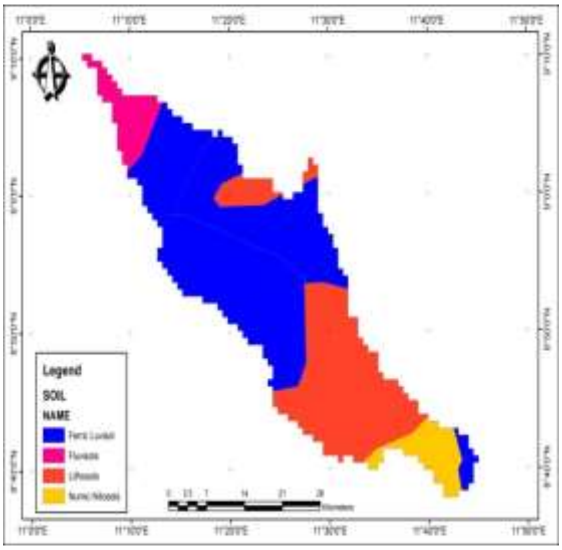



**Fig. 3:** Soil Types in RLCA

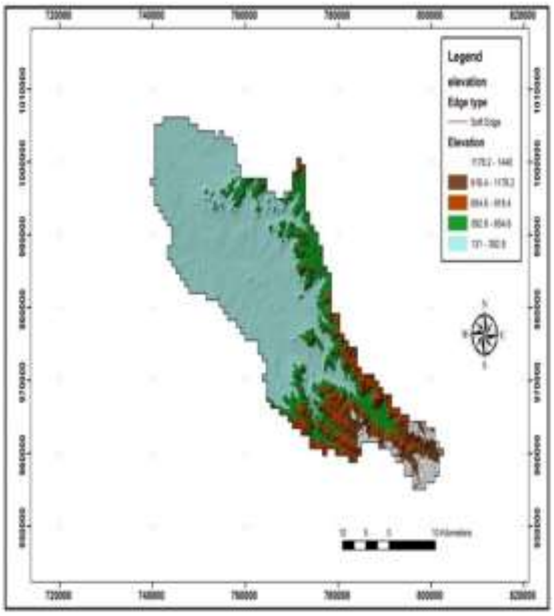



**Fig. 4:** Digital Elevation Model of RLCA

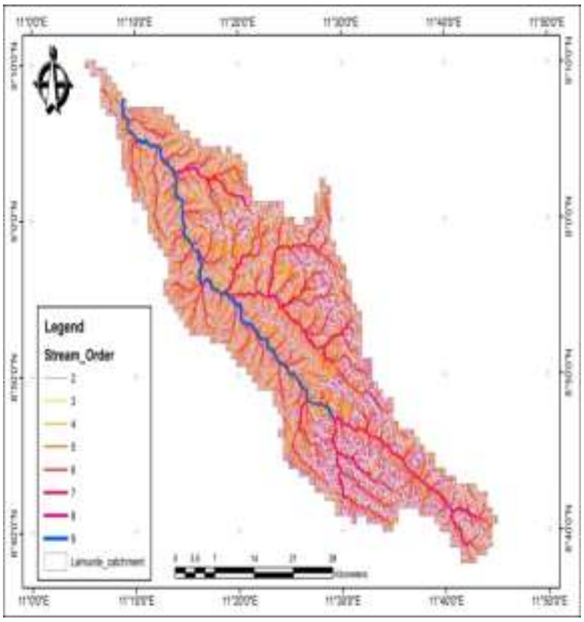



**Fig. 5:** Stream order of the RLCA

**Relief Features of RLCA and Implication on Flooding and Basin Resilience**

Relief Aspects is a measure of the basin relief (H), Relief ratio ($R_h$), relative relief ($R_{hp}$) and ruggedness number ($R_n$).

Table 4 shows the relief features of RLCA. Basin Relief (H) the highest and lowest elevation of the RLCA as revealed in fig 5 is 1440 and 118 respectively. Quantitatively, since Basin Relief is the difference in elevation between the highest and the lowest point in a drainage basin, therefore the Basin Relief is 1322 m above mean sea level. Relief Ratio ($R_h$) is the dimensionless height–length ratio between the basin relief and the basin length (Bharadwaj, Pradeep, Thirumalaivasan, Shankar and Madhavan, 2014). The relief Ratio of RLCA is 14.35. Relief ratio determines the steepness of an entire drainage basin. It determines erosion occurrence and vulnerability especially on the slope of a drainage basin. The high relief ratio as present in RLCA is not unconnected to the presence of highland areas especially parts of Shebshi areas in Yorro, part of Zing LGA, Balang, Maikwai and Jauro Magu within the basin.

**Table 4:** Relief Aspects of the River Basins

| S/N | Morphometric Parameters | River Lamurde Catchment |
|---|---|---|
| 1 | Basin relief in m (H) | 1327 |
| 2 | Relief ratio ($R_h$) | 14.35 |
| 3 | Ruggedness Numbers ($R_n$) | 3.46 |

**Conclusion**

In this process-response study, it has been discovered that the catchments of river Lamurde are more elongated. High values of bifurcation ratio in the basin indicate transitional zone of geological structure with a remarkable influence of structural disturbances (*i.e.*, warping, alternating high rounded hills and intervening flat topped ridges). Present variations in morphometric and morphological characteristics of this watershed have minimal impact in the potential of flash floods occurrence in RLCA. With long $L_b$ (83.85 km), this is an indicative of low flooding susceptibility. The longer the basin length, the little is the effect of the surface runoff manipulates the basin resilience. However with high value of $N_u$ total (225010),susceptibility increases when the carrying capacity of the basin is exceeded through continuous overgrazing, deforestation, heavy lumbering without replacement and basin infringement. Vegetation cover plays a significant role in determining hydrological response of a basin and invariably the basin resilience.

**Recommendation**

It is recommended that human activities that could impact negatively on the drainage network should be discouraged. Governments should curb influx to buffer and exploitation of the drainage basin in the study area.

**References**

Adebayo, A.A (2012). Evidence of Climate Change in Taraba State: A Preliminary Report. A Paper Presented at the Faculty of Science Seminar Series, Taraba State in Jalingo 13th of September 2012.

Adegoke, K. M. and, Bulus L. G. (2015). Hydrological and morphometric analysis of upper Yedzaram catchment of Mubi in Adamawa State, Nigeria. Using geographic information system (GIS). World environment 5(2): 63-69.

Adelalu, T.G., Ibrahim, A., Ezekiel., and clement, Y.G. (2020). Comparative Morphmetric Analysis of the Major Tributaries of river Benue in Taraba State using Geospatial Techniques. London journal of Research in Humanities and social Sciences. Vol.20, Issue 2 Compilation 1.0 Pg 11-24.

Adewumi, A.S (2013). "Analysis of land use/land cover pattern along the River Benue channel in Adamawa State, Nigeria," Academic Journal of Interdisciplinary Studies, vol. 2, pp. 95 – 108, 2013

Ayoade, J. O. (1988). *Tropical hydrology and water resources.* London: Macmillan.

Bharadwaj, A.K., Pradeep, C., Thirumalaivasan, D., Shankar, C.P. and Madhavan, N. (2014). IOSR Journal of mechanical and civil engineering (IOSR-JMCE) e -ISSN: 2278-1684, p-ISSN: 2320–334X. pp71-77.

Borokini, T.I., Babalola, F.D., Amusa, T.O, Invande, S.T., Wala, Z.J., Jegede, O.O., Tanko, D. and Ihuma, J.O (2012). Community- based Forest reources Maanagement in Nigeria: A case Study of Ngel nyaki Forest Researve, Mambila Plateau, Taraba State Nigeria. Journal of tropical Forestry and Environment vol.2, No. 1. Pp69-76.

Chorely, R., Donald, M. and Pogorzelsk, H. (1957). A New Standard for Estimating Drainage Basin Shape. *American Journal of Science*, 255, 138-141. http://dx.doi.org/10.2475/ajs.255.2.138

Farhan, Y. and Ayed, A. (2017) Assessment of Flash-Flood Hazard in Arid Watersheds of Jordan. Journal of Geographic Information System, 9, 717-751. https://doi.org/10.4236/jgis.2017.96045

Foley, J. A., (2005). Global consequences of land use. Science, 309(5734), 570. https://doi.org/10.1126/science. 1111772.

Horton, R. E . (1932). Drainage-basin characteristics. Trans. Am. Geophys. Union, 13, 350-361.

Horton, R. (1945) Erosional Development of Streams and Their Drainage Basins: Hydrological Approach to Quantitative Morphology. Geological Society of America Bulletin, 56, 275-370. https://doi.org/10.1130/0016-7606(1945)56[275:EDOSAT]2.0.CO;2

IkusemoranM , Manu H. Y, Abdussalam B. (2018). Geospatial Analysis of Morphometric Characteristics of River Hawul Basin, North-East Nigeria. Resources and Environment , 8(3): 103-126 DOI: 10.5923/j.re.20180803.03

Oruonye, E. D ( 2015). Assessment of the Impact of Land Use Changes along the Floodplains of River Lamurde, Jalingo LGA, Nigeria. Journal of Forests, 2(1): 1-13

Singh, S. and Singh, M.C. (1997) Morphometric Analysis of Kanhar River Basin. *National Geographical Journal of India*, 43, 31-43.

Sule, B.F,&Bilewu S.O. (2017). A morphometric study of five selected drainage basins in Nigeria. FuLafia Journal of Science & Technology, 3(1).

Sreedevi, P.D., Sreekanth, P.D., Khan, H.H and Ahmad, S. (2013) Drainage Morphometry and Its Influence on Hydrology in anSemi Arid Region: Using SRTM Data and GIS. *Environmental Earth Sciences*, 70, 839-848. http://dx.doi.org/10.1007/s12665-012-2172-3

Yooinn, H (2020). Resilience and state: The metaphor of a ball in a basin. A paper presented at the e- Education Institute Pennsylvania State University on Resilience and stability from 14th to 17th June 2020. https://www.e-education.psu.edu. Accessed on 14/2/2021.

# ASSESSMENT OF THE QUALITY OF HARVESTED RAINWATER IN KARU LGA, NASARAWA STATE, NIGERIA

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**Abstract**

*Rainwater as it falls from the sky is soft, and is among the cleanest of water sources. However, contamination may result from the environment, roof materials and containers which are used for rainwater storage. This study therefore examined rainwater harvesting techniques used in Karu LGA of Nasarawa State. The study made use of both questionnaire and laboratory techniques to determine the suitable rainwater harvesting techniques as well as quality of rain water in underground storage tanks for the period of twelve weeks in the study area. A total of 200 questionnaires were administered as well as 63 water samples from underground storage tank 'entry points for analysis. Results show that 45% of the respondents practiced roof water harvesting techniques followed by underground storage tanks (36.1%) while 1.6% adopted water pans. The boreholes were the lowest preferred technique as reported by 50% of the respondents. This was followed by shallow wells as well as terracing. Water harvested using ~~underg~~round tank technique was used for domestic (39%), livestock (38%), and crop cultivation (23%). Roof water tank was used for domestic (42%), livestock (3 0%), and crop production (28%). Mean total hardness of plastic tank water was 1.82 mg/I which remained the same as the entry point water after 12 weeks of storage. The mean faecal coliform count (FCU 67.33/100mi) for metal tank water was significantly different (7.32, P<0. 05) from the entry point water after 12 weeks of storage. The use offirst flush diverters and filters like the "guinea worm filters" should be promoted and incorporated in storage tanks. The filters could be used to treat the supplementary contaminated water supplies.*

**Keywords:** Quality, harvested, Rain, Water, Chemical

## Introduction

Lack of water of adequate quality and quantity is a major constraint to development in many areas of the world. It affects every aspect of human life: health, agricultural yields, food security, technical development, and the economy of states. Water scarcity and water quality problems are of particular concern in the tropical regions of the world where many countries are less deve1oped (Nelly, 2010).

Water that is easily available and affordable is a prerequisite to good hygiene, sanitation and is central to the general welfare of all living things. In addition, access to safe water and sanitation fundamental to gender equity with 71 % of household water collected by women or girls (UN 2008a). Several factors affect water supply. For instance, divisions in wealth, class and socioeconomic status is correlated with the degree of planning and provision of adequate infrastructure for water.

Due to variability in rainfall, some rainwater harvesting techniques have been tried in recent years both in Nigeria and in other water-stressed nations, with the aim to abate drought and water shortages. Nigeria is classified as a water scarce country with annual water supplies below 1000m3 /person UNEP (2002).

The World Health Organisation (WHO) estimates 1.8 million deaths each year due to lack of access to safe water, sanitation and hygiene. Out of these deaths, 99.8 % occur in developing countries and 90 % are children (Nath et al., 2006). The WHO and United Nations International children‘s Education Fund Joint Monitoring Programme for water supply and sanitation estimate1.5 million deaths of children from diarrheal diseases resulting from lack of access to safe water and sanitation (UN, 2008b).

The selling point for rainwater harvesting is that the methods are less complicated and can be easy adopted at individual or community level. According to Rebeka (2006), rainwater havesting techniques can be applicable in all agro climatic zones. However, it is more suitable in arid and semi-arid areas where the average annual rainfall is from 200 to 800 mm (rarely exceeding 800 mm). In such an environment, rain-fed crop production is usually difficult without rainwater harvesting.

## Materials and Methods

Both Primary and Secondary Data were used for this Study. Descriptive and Inferential Statistics were used for the study.

## Result and Discussion

### Rainwater Harvesting Techniques adopted by Households in Karu LGA

**Table 1:** Type of Rain water harvesting techniques practiced by households

| Harvesting techniques | Frequency | Percentage |
|---|---|---|
| Roof water tanks | 26 | 43.3 |
| Underground tanks | 23 | 38.3 |
| Runoff from terraces | 7 | 11,7 |
| Water pans | 4 | 6.7 |
| Total | 60 | 100 |

Source: Field Survey 2021

Table 1 shows that the majority (43.3%) of the respondents covered by this study practiced roof water harvesting techniques followed by underground tank (38.3%). Minority of the respondents (6.7%) adopted water pans. The considerable application of roof water tanks by most households in this area was attributed to the fact that most of them were supported to buy the tanks by organizations and Non- governmental organizations (NGOs). This is in addition to 1he ease of its implementation by rural dwellers. Nelly (2010) found that, many roof water tanks have been implemented by NGOs in rural areas of Onitsha north such as Ogbeozala, these tanks regarded to be of the best quality and increasing water quantity and availability at the implemented sites.

The second most widely practiced water harvesting technique was the underground storage tanks.

This was attributed to easy of its construction and suitability of the natural landscape of the area in construction of underground tanks. This is in addition to its provision of a large amount of water for people, livestock and plants during the dry season. Similar studies have found that underground tanks indirectly benefit up to thousands of people, as the use of the stored water is never restricted to the people who built the technique. Moreover, the underground tank has potential to provide a large amount of water for up to 1,200 people, animals, tree nurseries and vegetable gardens Jacob (2001).

Adoption of other techniques such as terracing (11.7%), water pans (6.7%), were found to be inappropriate in this area. Technique of water pans was appropriate and adopted by many people in Karu LGA, rather than other techniques Mararaba (2000). However, minority of people in the study area collect water using terraces which is different from people in other communities who collect runoff water using pans which is more reliable than using terrace. This was due to the relatively flat topography and soil characteristics that are highly sandy. While the adoption of other technique of borehole adopted by a very few farmers in Karu LGA due to high cost of construction and need technical knowledge. ICRC (2010) found that, the technology needed to construct boreholes can be quite complex in its construction, requiring engineering skills.

**Table 2:** Preference and rating of adopted water harvesting techniques

| Harvesting techniques | Highest | High | Moderate | Low | Lowest |
|---|---|---|---|---|---|
| Roof water tank | 7.8 | 15.7 | 41.2 | 11.8 | 23.5 |
| Underground tanks | 14 | 39.5 | 30.2 | 11.6 | 4.7 |
| Shallow wells | 11.1 | 2.2 | 10 | 22.2 | 44.4 |
| Runoff terracing | 9.8 | 4.9 | 19.5 | 24.4 | 41.5 |

**Source:** Field Survey 2021

Table 2: reveals the respondents preference and ranking of adopted techniques, the boreholes were found to be the lowest preferred technique as reported by 50% of the respondents covered by the study. This was followed by shallow wells as well as terracing. Furthermore, roof water tanks (41.2%) were ranked as moderately preferred techniques, whereas, only sand dam was highly preferred technique (39.5%).

The high preference for underground water tank (39.5%) was attributed to its simple construction and affordability compared to other techniques. It also harvests a large amount of water to satisfy most of the respondents in their main needs such as domestic, livestock and cultivation consumptions. These results are similar to those of Mati (2006) who reported that the technique of underground tank was simple and cost effective hence it was gaining popularity as more and more stakeholders adopt it.

The roof water tank was ranked as moderate techniques (41.2%). This was due to its accessibility and provision of clean water within the homestead. Worm (2006), indicated that rooftop rainwater harvesting at the household level is most commonly used for domestic purposes. It is popular as a household option as the water source is close to people and thus requires a minimum of energy to collect it. In that regards, the harvested water from rooftop can be realistic as well as clean and save a walk of many kilometres to the nearest clean water source. An added advantage is that users own maintain and control their system without the need to rely on other conrmunity members Worm (2006).

Households in this area ranked the technique of terracing lower (4 1.5%) in terms of preferences. This was because the topography is relatively flat and not appropriate to implement such technique in this area. However, Mitiku (2002) found that in Northern Darfijr of Sudan, terracing was used to control soil erosion resulting from surface runoff both in agricultural and grazing land and was used for both water conservation and soil erosion control, found. These differences can most likely be due to the nature of the soil, topography, the sample size of study area.

Shallow wells were ranked as the lower techniques by most of the households. This is because these techniques are more complex in their implementation and need funds as well as the inadequate technical knowledge and skills that the community have about such the techniques.

Among other factors that influence adoption of the techniques, the study found that most farmers (46.7%) lacked technical knowledge and skills to implement and subsequent adoption of the water harvesting techniques. According to the related studies of those ICRC (2010) who demonstrated that, the technology needed to construct boreholes and shallow wells and can be quite complex, requiring engineering skills.

## Conclusion

The results of descriptive studies show that roof tanks and underground storage tanks were practiced by the most of the households in this area. However, rooftop tanks were considered to be ranked as moderate preferred techniques. Only underground storage tanks technique were ranked as high preferred technique by most respondents while the borehole as well as shallow wells was ranked as the techniques in term of their preferences to the communities.

The result also showed that except for conductivity, plastic tanks had lower value pH, total alkalinity, turbidity, nitrite and total hardness which fell within the WHO acceptable limits of drinking water. The pH, total alkalinity, total hardness and iron was higher whilst EC, turbidity and nitrite level fell below the guideline values in metal tanks. Iron level in metal tanks was high due to the corrosion problem. Due to leaching of $CaCo^3$ from the walls, pH level, total alkalinity, and total hardness of stored rainwater in concrete tanks was high. The results from the analysis also indicated that all the storage tank material did not contribute to faecal coliform in the store water. Faecal contamination occurred during collection, storage and drawing of water. Therefore, the type of storage tank has direct impact on the physico-chemical quality of stored water.

## References

Abu-Awwad, A. M. and Shatanawi. M. R., 1997. Water harvesting and infiltration in arid areas affected by surface crust: examples from Jordan. Journal of Arid Environments 37, pp. 443-452.

Abdul-Hameed (2008). Rainwater Harvesting for Domestic Uses in two Palestinian Rural Areas with Emphasis on Quality and Quantity Master's thesis, Birzeit University, Palestine. 1 2-26pp.

African Development Bank (AfDB), 2007. Assessment of best practices and experiences in rainwater harvesting. Rainwater Harvesting Handbook. Tunis: AfDB.

Alem, G.2003, Water Harvesting: A Water Security Strategy For Mitigating The Impact Of Drought In Ethiopia. Water Security in the 21' Century. pp 1-5.

Arjen de Vries, 2002. River bed water storage - low cost and sustainable. Availability:

http//:www.aqfax.net. Reporting science in Affrica. Kitui district, Kenya December 2002.

# RAINWATER HARVESTING AND CATCHMENT MANAGEMENT IN RESIDENTIAL SUBURBS AND URBAN FRINGES OF CALABAR METROPOLIS

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**Abstract**
*Rainwater harvesting is the practice of collecting, storing, conveying, and purifying rainwater that runs off from different basement surfaces for domestic or agricultural purposes. It has become an important aspect of water supply chain in many parts of the world even whenthis vital resource base is often ignored by many concerned authorities. This study thus explored the nature of rainwater harvesting in Calabar Metropolis as well as its role in the management of catchment areas and water supply chain in the region. Data for this study were obtained through questionnaires administration, observations and interview sessions. Five catchment areas were selected from the study area using the stratified random sampling technique. Therein, forty (40) households were selected randomly from each of the selected urban fringes with the view to ascertaining the nature of rainwater collection systems in Calabar Metropolis. Data obtained from the field were analyzed usingdescriptivestatistics. The results of the analysis revealed that rainwater harvesting is still at the household levels where household utensils and small sized tanks are the principal tools for rainwater collection and storage. More so, the study revealed that the highest volume of rainwater (5200.4liters) collected in Calabar corresponds with the peak period of rainfall in the area. The result of the Pearson's analysis shows that a significant relationship exists between household sizes and the quantity of water demanded. Based on this, it was recommended that large scale rainwater harvesting units, adequate rainwater treatment, p be developed for the city of Calabar.*

**Keywords:** Rainwater, Harvesting, Catchment, Management, Calabar Metropolis, Urban fringes

## Introduction

Water is an indispensable substance required for the continuity of life on earth. It is utilized by all living organisms including microbes, plants, animals and humans for all daily biological and physiochemical processes across different ecosystems. Water is particularly essential in food production processes, domestic consumption, industrial operations, transportation among other economic development of any region (Eckardt et al., 2009; Pati, 2015; Rasul, 2016). The continuous availability of this precious ingredient on earth is sustained by the hydrological cycle wherein water molecules are converted into different forms and transported from land surface through the atmosphere and back to the earth's surface. Rainfall from where rainwater is a derivative is an important aspect of the hydrological cycle in that it provides water in usable forms for plants, animals and as well agricultural and industrial operations (Yosef & Asmamaw, 2015). Different societies have learned to tap rainwater for different economic and domestic purposes. China, Britain, Eritrea, Egypt and Libya for instance have harnessed rainwater to support her agricultural sector with the view to providing the food requirement of her citizens.

Rainwater harvesting is the practice of collecting, storing, conveying and purifying rainwater that runs off from roof, parks, gardens, roads or open grounds for domestic and agricultural purposes as well as in flood and erosion control. It is an expertise for the collection and efficient storage of rainwater from different basement areas like rooftops of residential buildings, ground areas and rock catchment (Pradhan & Sahoo, 2020). It is one of the simplest and oldest methods of self-supply of water usually financed by the users (Pacey & Adrian, 1986). This goes to show that rainwater harvesting is traced to the establishment of sedentary settlements when water demands for domestic chores and agricultural operations grew steadily. Rainwater harvesting and catchment management are not newconcepts in Nigeria and Cross River State in particular because there are rich literatures on indigenous knowledge and technology currently in use in our traditional communities that had also proved efficient to complement water demand and supply chain.

Rainwater harvesting is an essential component of human community and ecosystem functionality. This is due in part to the fact that rainwater harvesting does not only ameliorate spatio-temporal water scarcity for domestic consumption and agricultural development but also, improved soil moisture content in arid and semi- arid environments as well as an important mechanism for the reduction of flood incidence in humid environments like Calabar (Yosef et al., 2015). Similarly, rainwater harvesting is an inevitable approach for sustainable planning of cities such as Calabarthat are susceptible to flood related problems especially during this current global environmental changenarratives occasioned by climate change, flood disasters and accelerated rate of soil erosion (Ngigi, 2003). This is true in that a reduction in the volume of runoff greatly reduces the frequency and intensity of flood related problems such as soil nutrient loss and poor agricultural output. Moreover, since over 78% of water consumed by plants comes directly from rainfall, rainwater harvesting therefore remains a potential source for feeding the current huge world's population especially now that there are limitations to the expansion of irrigation-fed agriculture (Rockstrom, 2003; Yosef et al., 2015). Besides, the dwindling nature of public water supplies and failure of urban water networks in Calabar as it is in many other urban areas have informed the urgent need for diversification of water supply systems with rainwater harvesting as a principal component (Omolara & David, 2015).

Basically, the fundamental principle of rainwater harvesting is to conserve rainwater where it falls according to local needs, geophysical conditions, cultural inclination and technological development. Rainwater harvesting is categorized according to the type of catchment surfaces (including roof catchment system, rock catchment system and ground catchment system) from where rainwater is collected and stored in tanks ponds and other reservoirs for various uses(Olaniran, 2002). The capturing and collection of rainwater from the roofs of buildings can easily take place within rural areas, towns and cities with a minimal apparatus. This often revolves around channeling the flow of rainwater from roof gutters to rainwater storage tanks or reservoirs from where the collected water is used for domestic and agricultural purposes. Mohammed et al. (2018) posited that simple rainwater collection techniques such as jars and pots were commonly employed in most part of Africa and Nigeria in particular to collect rainwater for drinking, cooking, washing and other domestic chores. However, the accelerated architectural designs of buildings and innovative engineering structures have introduced increasing connections of roof catchments with gutter and down-pipe systems to deliver rainwater to bigger collection units such as tanks, drums and in most cases underground reservoirs (Olaniran, 2002; Ikhile&Aifesehi, 2011). This goes to show that rainwater harvesting has undergone tremendous innovative changes across several countries including China, India, Israel, Turkey and African countries where the most recognized utilization is done (Yazar & Ali, 2016).

Rainwater harvesting is adopted in most societies because of some noticeable advantages such as being simple to install and operate having few environmental impacts compared to other water supply projects technologies (Mohammed et al., 2018). However, initial capital outlay, uncertainty in rainfall regime orchestrated by climate change scenarios and water quality and health related issues have acted collectively and individually to undermine large scale rainwater harvesting and utilization in most regions of the world.

This study is therefore informed by the need to exploit various mechanisms for rainwater harvesting in Calabar Metropolis with the view to providing alternative water supply chain for the region especially as she battles with intermittent and unreliable water supply by water board management agencies. More so, the study sought to examine effective rainwater harvesting as a strategy for flood controls and river catchment management particularly around Calabar urban fringes that previously acted as the city's green areas. This is apt in that the current urban sprawl and the growing exploitation of the region's aquifer to provide for the water need of the inhabitants have necessitated the development of sustainable alternative water supply systems with diverse ecological benefits.  Rainwater harvesting need to be given priority attention and revived as an alternative to the traditional water supply in urban centers as well as integrated environmental management (Mohammed et al., 2018; Oyebande, 1987).

## Materials and Methods

### Study Area

This study is centered in the suburbs and urban fringes of Calabar Metropolis the region lies between latitudes 4º 54′ 00″ and 5º 04′ 00″North of the Equator and longitudes 8º 15′ 00″ and 8º 24′ 00″ East of the Greenwich Meridian. The region has an area of over 164 $km^2$ and it is bounded in the North by Odukpani Local Government Area, great Qua River to the East, West by the Calabar River and South by the estuary which empties into the Atlantic Ocean. (See figure 1). Calabar Metropolis has a typical tropical climate with an average annual temperature of 27ºC. The region experiences intense rainfall in most months of the year with a relatively short dry season of scanty rainfall. Having an average annual rainfall of about 3000.08mm, Calabar has been considered one of the heaviest rainfall regions of the world (Ewona& Udo, 2011). The absence of adequate water control and management system in Calabar Metropolis coupled with the locational attributes and social configuration of the region have acted collectively to accelerate the rates and frequencies of gully formation, soil erosion, nutrient loss, flood incidences among other environmental problems that threaten the inhabitants of the area (Ewona et al., 2008; NIMET, 2006). Such problems are expected to increase principally because of the current trends in global climate change, population growth and urban expansion as well as infrastructural development exemplified by large scale concretization and asphalting of land surfaces which increase the volume of run off while diminishing the infiltration capacity of soils (Ekpoh, 2014).

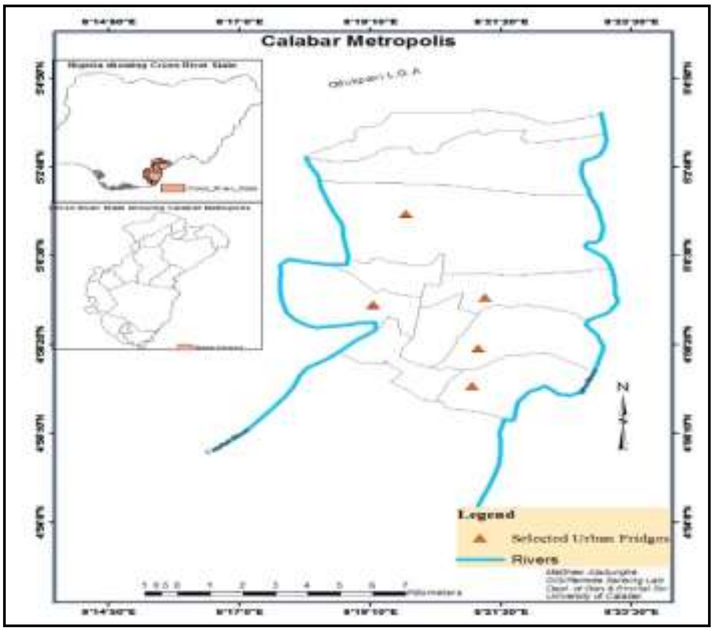


**Fig. 1:** Map of Calabar Metropolis
**Source:** GIS Unit, Department Geography and Environmental Science, University of Calabar.

This study employed the survey approach of investigation with questionnaire, interview and participant observation as means of data collection. The stratified random sampling technique was used to break down the study area into five distinctive urban fringe catchment areas to include satellite town, Ikot-Omin, Ikot-Effanga, Ikot-Ansa and Nyaghasan. Therein, forty (40) households were selected from each urban fringe to form two hundred (200) sampled respondents. Among the data collected from the field were household demographics, available rainwater collection receptacles and rainwater consumption as well as the challenges confronting rainwater patronage in the Metropolis. Besides, the volumetric capacity of the rainwater harvesting tanks was estimated from the field. The data were analyzed using inferential and descriptive statistics such as frequency tables

**Result and Discussion**

Table 1 shows that the quantity of rainwater collected in the study area grew steadily from March and peaked in July (with over 5200.4 liters of rainwater collected) with a decline in the volume of rainwater collected in September (2570.7 liters), 2185.4 liters in November and a downward drop of about 1002 liters in December. January and February had less than significant volume of rainwater harvested (60.9 and 54.0 liters respectively). Thus many households had to depend on the volume of rainwater harvested and stored in the previous months while complementing domestic water supply from boreholes, hand dug wells and urban water supply from the Cross River State water Board Limited. These water sources are augmentative and shredded with uncertainties of water quality and environmental health issues.

**Table 1:** Average monthly rainwater collected in the study between 2019 and 2020

| Months | Average monthly rainwater harvested in liters |
|---|---|
| January | 60.9 |
| February | 54.0 |
| March | 1250.0 |
| April | 2020.6 |
| May | 3400.4 |
| June | 3500.8 |
| July | 5200.4 |
| August | 4500.3 |
| September | 2570.7 |
| October | 3215.5 |
| November | 2185.4 |
| December | 1002.8 |
| Total | 28965.8 |

Table 2 shows the water sources that people utilize in the study area. The table reveals that 17.5% of the respondents depend on the Cross River State water board agency for their water need, 75% relied on private bore holes, 18.5% utilized the rainwater harvested and stored during the rainy season while only a small fraction (5%) employs the stream systems for domestic water supplies. This implies that the unreliable nature of public water supply systems makes people to source randomly for available water supplies as can be found in the exponential rise in the number of boreholes and hand dug wells in the metropolis. The aftermath of this is the continued stress of the crustal plates and the reduction of the strength of the aquifer.

**Table 2:** Alternative water sources in Calabar Metropolis

| Alternative water sources | Frequency | Percent % | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| water board | 35 | 17.5 | 17.5 | 17.5 |
| Bore holes | 118 | 59.0 | 59.0 | 76.5 |
| Streams | 10 | 5.0 | 5.0 | 81.5 |
| Stored rainwater | 37 | 18.5 | 18.5 | 100.0 |
| Total | 200 | 100.0 | 100.0 | |

It can be gleaned from table 3 that 50% of the sampled households have more than six (6) members, 33% has between four (4) and six (6) members while only 17% has three members. It further revealed that there is direct relationship household size and the estimated volume of water consumed by the households in each cohort. The estimated daily water consumed in the study area was also presentable in table 4. The data reveals a positive relationship between household sizes and the quantity of water consumed such that large family sizes tend to consume more quantity of water than do relatively small families.

**Table 3:** Household sizes and daily quantity of water consumed

| Household Sizes | Frequency | Percent % | Estimated Daily quantity of water consumed (liters) |
|---|---|---|---|
| 3 | 34 | 17.0 | 240 |
| 4-6 | 66 | 33.0 | 600 |
| >6 | 100 | 50.0 | 8400 |
| Total | 200 | 100.0 | 9240 |

Similarly, table 4 presents the challenges confronting rainwater patronage in Calabar Metropolis. It revealed that 25% of the respondents pointed to the poor quality of catchment areas as the reasons for the low patronage. Also, 37.5% of the respondents attributed the low patronage to the unreliability in rainfall pattern, 32.5% said the low patronage is caused low investment in rainwater harvesting facilities while 10% of the respondents held unto the perceived health risks brought about by the consumption of rainwater as the factor undermining the potential patronage in the city.

**Table 4:** Challenges confronting rainwater patronage in Calabar metropolis

| Challenges | Frequency | Percentage (%) |
|---|---|---|
| Surface flow and runoff loss | 34 | 17.0 |
| Poor Quality of Catchment Surfaces | 18 | 9.0 |
| Low level of awareness | 50 | 25.0 |
| Unreliability of Rainfall | 32 | 16.0 |
| Small sized Harvesting Units | 47 | 23.5 |
| Perceived Health Risks | 19 | 9.5 |
| Total | 200 | 100.0 |

## Conclusion and Recommendations

To meet up with our daily demand for water, efficient rainwater and catchment management should be given a top priority in suburbs and urban fringes of Calabar taking into cognizance potential runoff losses from non-harvesting, the probability of errant rainfall behavior in some months of the year as well as the unreliability and in some cases, non-existence of urban water supply system in these areas. In-situ rainwater harvesting offers tremendous scope to augment water availability and use in an effort to bridge the gap between rainwater availability, runoff and surface flow losses that are not harvested and, in some cases, exacerbates flooding and soil erosion. It is thus imperative from this study that sustainable rainwater harvesting system should be conceptualized and implemented in Calabar Metropolis with the view to providing alternative water supply chain for the region especially as she battles with intermittent and unreliable water supply by water board management agencies. Besides, such development will help in the reduction of the volume of runoff and the consequent cases of soil erosion, gully formation and flood disasters in the region.

**References**

Eckardt, N. A; Corninelli, E; Galbaiti, M. & Tonelli, C. (2009). The Future of Science: Food and Water for Life. The Plant Cell, 21: 368-372

Ekpoh, I. J. (2014). Recent Severe Flooding In Calabar, Nigeria: Causes, Consequence And Possible Remedies. *International Journal of Sciences* 3(1) 102-105.

Ewona, I. O & Udo, S.O (2008) Characteristic Pattern of Rainfall in Calabar, A Tropical Coastal Location. *Nigerian Journal of Physics*, 20:1

Ewona, I. O & Udo, S.O (2011).Climate Condition of Calabar as Typified by Some Meteorological Parameters. *Global Journal of Pure and Applied Sciences*

Ikhile, C. I., and Aifesehi, P. E. E. (2011). Geographical Distribution of Average Monthly Rainfall in the Western Section of Benin-Owena River Basin, Nigeria. *African Research Review*, 5(4), pp. 493-500.

Mohammed, I U (2018) Rainwater Harvesting For Water Supply and Integrated Development of Rural and Semi-Urban Areas. *Nigerian Research Journal of Engineering and Environmental Sciences* 3(1) 287-304.

Ngigi, B.N (2003). What Is The Limit Of Up-Scaling Rainwater Harvesting In A River Basin? *Journal of Physics and Chemistry of the Earth* 28: 948-950

Olaniran, O. J. (2002). Rainfall Anomalies in Nigeria: The Contemporary Understanding. 55$^{th}$Inaugural Lecture Series, University of Ilorin, Ilorin, Nigeria.

Omolara, L. & David, O. (2015). Rainwater Harvesting In Ibadan City, Nigeria: Socioeconomic Survey and Common Water Supply Practices. *American Journal of Water Resources* (3) 67-78.

Oyebande, L. (1987). Urban Water Supply and Planning in Nigeria. *Geojournal*, 2(5), 403-412. Retrieved June, 2021, from https:www.jstor.org/stable/41142135

Pati, R (2015) Water: An Essential Element for Life. *10$^{th}$ Intercultural Human Rights Law Review*. 291.`

Pradhan, R & Sahoo, R. (2020).Smart Rainwater Management: New Technologies and Innovation. In Bobek, V. (Eds), *Smart Urban Development*. https://doi:org/10.5772/intechopen.86336

Rasul, G (2016) Managing the Food, Water And Emerging Nexus For Achieving The Sustainable Development Goals In South Asia. *Journal of Environmental Development*, 18: 14-25.

Rockstrom, J. (2003) Water for Food and Nature in the Tropics: Vapour Shift in Rain-fed Agriculture. *Phi. Trans. Research in Soc.Land*, 358: 1997-2009

Yazar, A & Ali, A. (2016).Water Harvesting in Dry Environment. In Farooq, M & Siddique, K (Eds).*Innovations in Dry Agriculture*. Cham; springer.

Yosef, B. A & Asmamaw, D. K (2015) Rainwater Harvesting: An Option for Dry Land Agriculture in Arid and Semi-Arid Ethiopia. *International Journal of Water Resources and Environmental Engineering*, 7(2)17-28

# ASSESSMENT OF RAINFALL POTENTIALS FOR WATER ALLOCATION USING THE SYNTHETIC UNIT HYDROGRAPH AT THE NIGER SOUTH CATCHMENT

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**Abstract**
*The research on the assessment of rainfall potentials for water allocation using the synthetic unit hydrograph at the Niger South Catchment was successfully conducted. The ArcGIS 10.1 software was utilized for calculation, delineation and morphometric analysis of the watershed from SRTM DEM. The morphometric attributes and runoff relationship was explored for the return periods of 25yr, 50yr, 75yr, and 100yr to generate hydrographs rainfall yields in the catchment. The return periods of 25yr had the lowest peak runoff with 2883.89m3/s while the 100yr return period has the highest peak runoff of 3616.19m3/s. The results indicated that the catchment have the potentials to sustain hydrological investments and accommodation of more investments. The catchment length of 146.8km with a low slope of 1.29 implies a long residence time of flood and this calls for structural and non-structural measures in the management of runoff in order to avert flood disasters in the area.*

**Keywords:** Catchment, discharge , flood, GIS, formula, Lower, Morphometric Parameters, Niger, peak flow, Stream Flow, Rainwater, River, Slope, stream , soil conservation service, Synthetic unit hydrograph

## 2.0 Material and Methods

The evaluation of rainfall potentials was carried out by employing the tool of the Geographical Information System (GIS) and 40 years (1971-2010) rainfall data of the catchment. The remotely sensed data was geometrically rectified and the digitization of dendritic drainage pattern was carried out in Arc GIS 10.1 software. The software was used for the delineation of the Niger South Catchment, of the lower Niger River as shown in fig 2.1. Consequently, information in table 2.2 were derived as by-products of the Digital Elevation Model (DEM). The derived morphometric parameters, Snyder's and Soil Conservation Service (SCS) methods and other relevant models were applied to generate the hydrographs.

## 2.1 Literature Review

### 2.1.1 Peak Flow Formula

Numerous methods are available for predicting peak flood (the maximum flood discharge) required for design application in small and rural watersheds. Some of the methods are empirical or by correlating the flow rate with simple drainage basin characteristics such as slope, length, or area whereas some are based on rational analysis of the rainfall-runoff process Mustafa (2012).

**a. Rational Formula**

The rational formula for estimating peak runoff rate was introduced by Emil and the formula is

Qp = 0.00278CiA (2.1)

Where Qp= the peak flow rate = (m3/s)

C= runoff coefficient assumed to be dimensionless

i = average rainfall intensity (mm/hr), lasting for a critical period of time

A= size of the drainage area (ha)

C = the net rain intensity (mm/hr) at t=tc (tc is the time of concentration)

The formula is valid for small urban basin and agricultural land between 100-200ha in area.

Typical C value for storm of 5-10 years in return periods are provided in table 2.4

The use of rational formula is based on rainfall intensity and it is used for peak runoff determination. This runoff peak is determined using the elapsed time tc, and time of concentration. The following steps are used in determining peak flow rate.

i. Estimation of the time of concentration of the drainage area

ii. Estimation of the runoff coefficient, C

The designed storm must have duration equal to tc. The desired intensity is read from a locally derived Intensity Duration Curve (IDC) using rainfall duration equals to the time of concentration. If the IDC are not available for the catchment and a maximum precipitation of P cm occurs during a storm period of tr hours, then the design intensity i=ic can be obtained from

Ic = $t_r = \frac{P}{t_r}\left(\frac{t_{r+1}}{t_{c+1}}\right)$ (2.2)

If tc is not known, ic can be approximated from ic= p/tr. Recurrence intervals are normally of the order of 10-25years.

**Table 2.1:** Typical Coefficients for 5-10 year frequency

| Description of Area | Runoff Coefficients |
|---|---|
| Business | |
| Down town areas | 0.7-0.95 |
| Neighbourhood areas | 0.5-0.70 |
| Residential | |
| Single family areas | 0.3-0.5 |
| Multiunit, detached | 0.4-0.6 |
| Multiunit, attached | 0.6-0.75 |
| Residential (suburban) | 0.25-0.40 |
| Apartment dwelling areas | 0.50-0.70 |
| Industrial | |

| | |
|---|---|
| Light areas | 0.50-0.80 |
| Heavy areas | 0.60-0.90 |
| Parks, cemeteries | 0.10-0.25 |
| Play grounds | 0.20-0.35 |
| Rail road yard areas | 0.20-0.40 |
| Unimproved areas | 0.10-0.30 |
| Street | |
| Asphaltic | 0.70-0.95 |
| Concrete | 0.80-0.95 |
| Bricks | 0.70-0.85 |
| Walks | 0.75-0.95 |
| Roofs | 0.75-0.95 |
| Lawns; sandy soil: | |
| Flat, 2% | 0.05-0.10 |
| Average, 2-7% | 0.10-0.15 |
| Steep, 7% | 0.15-0.20 |
| Lawns; heavy soil: | |
| Flat, 2% | 0.12-0.17 |
| Average, 2-7% | 0.18-0.22 |
| Steep, 7% | 0.25-0.35 |

Source: Mustafa 2012

### b. Estimation of Time of Concentration

Observed values of time of concentration are rarely available. Designers normally make estimates of tc using empirical formula such as the one developed by Kirpich, (1940) for small agricultural basins. (A<50ha)

$$tc = \frac{L^{1.15}}{3080H^{0.38}} \qquad (2.3)$$

where tc = time of concentration (hr), L= maximum travelling distance in the basin (m) H= difference in elevation over the above distance (m).

The time of concentration may also be derived by dividing the travelling distant, L, by the velocity of flow, V, i.etc = L/V

$$tc = \sum \frac{L_i}{V_i} \qquad (2.4)$$

where Li and Vi respectively represent the travelling distance and the velocity of flow in the individual reaches. The velocity of flow in the drainage canals may be estimated using Maning's formula (Mustafa, 2012).

### c. Empirical Formula

A multitude of peak flow formulae relating the discharge to the drainage area and other basin characteristics have been proposed and applied. Chow and Gray have listed 35 such formulae and compared many others. Example of such is

QP = CAm (2.5)

Where m and C, are regression constants, A= drainage area, Qp = the peak discharge associated with a given return period; m is usually between 0.5 and 1.2

$$Q = 175\sqrt{A} \qquad (2.6)$$

**d. Curve Number Method**

The curve number method is applicable to basins larger than the areas considered by the rational method. The method is applicable to several thousand hectares of land and complete hydrograph of stream flow can be generated to obtain the design storm. The method developed by the United States Soil Conservation Service (USSCS) involves the following steps:

Based on catchment characteristics, rainfall is converted into surface runoff using curve number graph.

Discharge is converted into a basin hydrograph using USSCS dimensionless unit hydrograph.

Determination of design discharge Qdesign as Qdesign = q x A where q is the drainage coefficient taken as the peak of the hydrograph and A is the basin area

**2.1.2 Runoff forecasting from Flood Frequency Analysis**

The design of any hydraulic structure is based on hydrologic events which are random in nature due to the uncertainties in their occurrences. It is frequently required to estimate the maximum possible discharge of a particular river in order to size spillway, reservoir capacity, bridge etc.

**2.1.3 Probability of Flood Event**

The average return period or recurrence interval T is defined as the time which on average elapses between two events which equal or exceed a particular event. Mathematically it can be represented as

$$T = \frac{1}{P(F)} = \frac{1}{1-P(F^1)} \qquad (2.7)$$

Where P(F1) is the probability that F will not occur in any year. The reciprocal of T is also the P(F) i.e

$$P(F) = \frac{1}{T} \qquad (2.8)$$

and

$$P(F1) = 1-P(F) = 1-\frac{1}{T} \qquad (2.9)$$

The probability that F will not occur for n successive years is

P1 (F1) xP2 (F1).....Pn (F1) = P (F1)n or

$$P(F1)^n = \left(1-\frac{1}{T}\right)^n \qquad (2.10)$$

The probability R called Risk that F will occur at least once in n successive years is given as

$R = 1- \left[1-\frac{1}{T}\right]^{n}$ = 1-(P(F1))n (2.11)

## 2.2 Unit Hydrograph Methods

Two different methods of unit hydrographs are described and can be used to synthesize the peak runoff. The methods include: Snyder's and Soil Conservation Service (SCS).

### a. Snyder's Method

Ramirez (2000) reported that the hydrograph characteristics are the effective rainfall duration, tr, the peak direct runoff rate Qp, and the basin lag time, tp. from the given relationships, five characteristics of a required unit hydrograph for a given effective rainfall duration may be calculated. The five characteristics are the peak discharge per unit of watershed area, q'p, the basin lag time, t'l, the base time, tb, and the widths, w ( in time units) of the unit hydrograph at 50 and 75 percent of the peak discharge. The unit hydrograph parameters are estimated in accordance to Ramirez (2002) and Arora (2004).

**i Lag time, tp**

$$t_p = C_t(LL_c)^{0.3} \qquad (2.12)$$

Where tp is the lag time (hr) and Ct is a coefficient representing variations of watershed slope and storage. (Values of Ct range from 1.0 to 2.2, Arora (2004)). Equation (2.23) gives the lag time tp for the watershed.

**ii. Unit-hydrograph duration, $t_r$ (storm duration)**

$$t_r = \frac{t_p}{5.5} \qquad (2.13)$$

From equation (2.24) the duration of the storm can be obtained. However if other storm durations are intended to be generated for the watershed, the new unit hydrograph storm duration (t'r), the corresponding basin lag time (t'p) can be obtained using equation (2.14)

$$t'_p = \frac{t'_r - t_r}{4} \qquad (2.14)$$

**iii Peak discharge, $Q_{'p}$**

The peak discharge ($Q'_{'p}$) can be obtained using Equation (2.15)

$$Q_p = \frac{2.78 * C_p * A}{t_p} \qquad (2.15)$$

Where, Cp is the coefficient accounting for flood wave and storage conditions. (Values of Cp range from 0.3 to 0.93 Arora (2004).

**iv Base time (days)**

The base time in days can be obtained from Equation (2.16)

$$t_b = 3 + 3\left\{\frac{t_p}{24}\right\} \quad (2.16)$$

The time width W50 and W75 of the hydrograph at 50% and 75% of the height of the peak flow ordinate can be obtained using Equations (2.17) and (2.18) respectively in accordance to U.S Army Corps of Engineer (Arora, 2004). The unit of the time width is hr. also the peak discharge per area (cumec/km2) is given by Equation (2.19)

$$W_{50} = \frac{5.9}{(q'_p)^{1.08}} \quad (2.17)$$

$$W_{75} = \frac{3.4}{(q'_p)^{1.08}} \quad (2.18)$$

$$q'_p = \frac{Q_p}{A} \quad (2.19)$$

**b. Soil Conservation Service (SCS) Method**

The peak discharge, the time to peak and the lag time can be determined in accordance to SCS (1972), Viessman et al (1989) and Ogunlela and Kasali (2002).

Peak discharge:

The peak discharge can be obtained through the equation (2.20), (Ramirez, 2002).

$$q_p = \frac{2.08A}{t_p} \quad (2.20)$$

where,

$q_p$= peak discharge (m3/s/cm)
A = watershed area (km2)
$t_p$= time to peak(hr)

**Time to peak and lag time**

$$t_p = \frac{t_r}{2} + t_L \quad (2.21)$$

or

$$t_p = \frac{t_c + 0.133t_c}{1.7} \quad (2.22)$$

where;

$t_C$= time of concentration (hr)
$t_R$= storm duration (hr)
$t_L$ = lag time (hr)
$t_c$ = time of concentration (hr) (Kirpich's equation)

$$= 0.06628\left\{\frac{L^{0.77}}{S^{0.385}}\right\} \quad (2.23)$$

where;

L = length of channel (stream) in km
S = Slope of channel (m/m)
$t_L$= Lag time (hr)

$$t_L = 0.6t_c \tag{2.24}$$

$$t_r = \frac{t_L}{5.5} \tag{2.25}$$

The estimated values for both the peak discharge qp and time to peak tp are applied to the dimensionless hydrograph ratios to obtain points for the unit hydrograph. The coordinates for the SCS dimensionless unit hydrograph are given in Table 2.2.

**Table 2.2**: Coordinates of SCS dimensionless unit hydrograph

| t/tp | q/qp |
|---|---|
| 0 | 0 |
| 0.1 | 0.015 |
| 0.2 | 0.075 |
| 0.3 | 0.160 |
| 0.4 | 0.280 |
| 0.5 | 0.430 |
| 0.6 | 0.600 |
| 0.7 | 0.770 |
| 0.8 | 0.890 |
| 0.9 | 0.970 |
| 1.0 | 1.000 |
| 1.1 | 0.980 |
| 1.2 | 0.920 |
| 1.3 | 0.840 |
| 1.4 | 0.750 |
| 1.5 | 0.660 |
| 1.6 | 0.560 |
| 1.8 | 0.420 |
| 2.0 | 0.320 |
| 2.2 | 0.240 |
| 2.4 | 0.180 |
| 2.6 | 0.130 |
| 2.8 | 0.098 |
| 3.0 | 0.075 |
| 3.5 | 0.036 |
| 4.0 | 0.018 |
| 4.5 | 0.009 |
| 5.0 | 0.004 |

Source: Viessman et al (1989)

**I Estimation of design storm (runoff) hydrograph**

The estimated synthetic unit hydrograph from SCS method is used to develop the runoff hydrographs due to annual peak daily rainfall event over the sub-basin. The design runoff hydrographs for selected rainfall of recurrence intervals of 25 year, 50 year, 75 year and 100 year would be developed through hydrograph convolution. Hydrograph convolution involves multiplying the unit hydrograph ordinates by incremental rainfall excess, adding and lagging in a sequence.

**ii Estimation of Rainfall Excess**

The term rainfall excess or net rain is used to denote a simple numerical subtraction of losses from the precipitation volume.

In the SCS method the excess rain volume, Q, depends on the volume of precipitation, P, and the volume of the total storage, S, which includes both the initial abstraction, Ia, and the total infiltration F. the relation between rainfall excess and total rainfall (on twenty-four hour basis) is then (McCuen andBondelid, 1983)

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \qquad (2.26)$$

$$P = \frac{P^*}{24} * P_T \qquad (2.27)$$

where,

P = accumulated rainfall (mm)
$P_r$ = rainfall recurrence interval of the sub-basin (mm)
P* = precipitation ratio, given in Table 2.6 below
S= volume of total storage (mm)

Note that equation (2.26) contains only one unknown, the storage parameter S. This parameter in (mm) can be obtained from

$$S = \frac{25400}{CN} - 254 \qquad (2.28)$$

Where;

CN is runoff curve number and can be obtained in Table 2.3 below.
CN value of 75 was adopted based on the soil type and land use of the study area.

: Useful in estimation of excess rainfall

**iii Hydrograph Convolution (Runoff hydrograph development)**

The discrete convolution equation allows the computation of direct runoff Qn.
Let R=incremental rainfall excess (cm)
U= unit hydrograph ordinate (m3/s/cm)

The equations of the ordinates are given in the form of equation below,
Generally:

$$Q_n = R_1U_n + R_2U_{n-1} + R_3U_{n-2} \qquad (2.29)$$

**Hydrological forecasting**

Gumbell's Extreme value type I: The probability of occurrence of a magnitude being equal to or greater than any value QT is expressed as:

$$P = 1 - e^{-e^{-y}} \qquad (2.30)$$

Where

e= base of Napierian logarithm

y= reduced variate

$$y = -In\left[-In(1-\frac{1}{T})\right] \quad (2.31)$$

$$P = \frac{1}{T} \quad (2.32)$$

The event R of the return period T year is defined as:

$$R = R_{av} + \sigma(0.78y - 0.45) \quad (2.33)$$

Where;

R= Peak annual daily rainfall with magnitude with return period T
$R_{av}$=average value of peak annual daily rainfall
N= number of years of records
σ = standard deviation

$$R = \frac{\sum R_{max}}{N} \quad (2.34)$$

$$\sigma = \sqrt{\frac{N}{N-1}\left(\frac{\sum R^2{}_{max}}{N} - R_{av}{}^2\right)} \quad (2.35)$$

**2.3 Study Area**

The catchment is between longitude 6oE and latitude 8o36'N North West, longitude7°37.8'E and latitude7o37.2'Nnortheast, longitude5°26.4'E and latitude50 6’N southwest, longitude7°0.6'E and latitude4o25.8'Nsoutheast. States in the hydrological area include: Delta, Rivers, Bayelsa, parts of Edo, Anambra and Kogi States.

Vegetation of the area can be classified into four types. Namely: the Guinea Savannah, Tropical Rainforest, Fresh water Swamp and the Salt water Swamp.

The climate of the Niger South Catchment is characterized by a long rainy season from March-April through October-November. The precipitation increases from the north of the catchment (with an average of 1,500 mm around Lokoja) to the coastal area of the Niger Delta where mean annual rainfall averages around 4,000 mm, making it one of the wettest areas in Africa.

The soils of the Niger South Catchment fall into three zones - (a) interior zone of laterite soils (parts of Kogi State), (b) zone of alluvial soils (parts of Kogi, Edo, Delta, Anambra, Bayelsa, and Rivers States, and (c) southern belt of forest soils (parts of Edo, Delta, Anambra, Bayelsa, and Rivers States).The soils are all of fluviatile origin, except for the Coastal Barrier Islands that consist of marine sand overlain with an organic surface layer.

### 3.1 Data Analysis

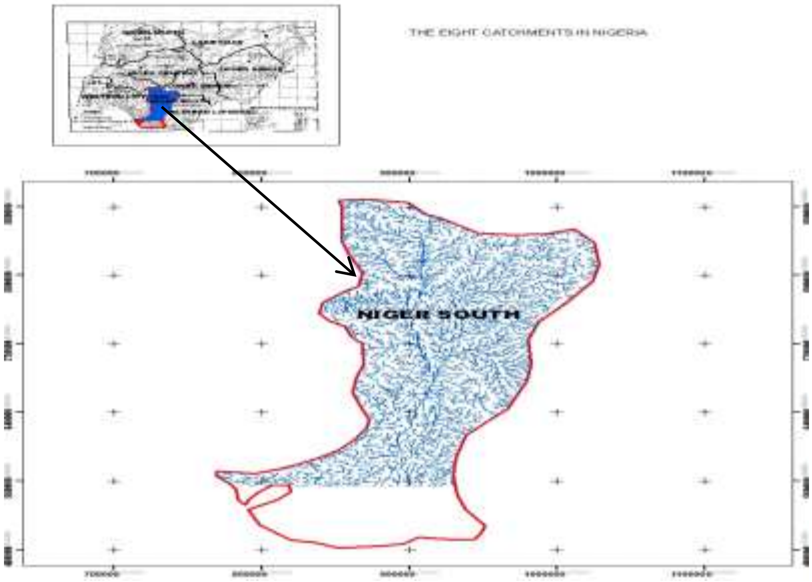


**Fig. 3.1:** Digital Map of Niger Delta showing all the stream

### 3.2 Estimation of Peak Runoff

The synthetic unit hydrograph from SCS method was used to develop the runoff hydrographs due to annual peak daily rainfall event over the watershed. The design runoff hydrographs for selected rainfall of recurrence intervals of 25 year, 50 year, 75 year and 100 year are developed through hydrograph convolution. Hydrograph convolution involves multiplying the unit hydrograph ordinates by incremental rainfall excess, adding and lagging in a sequence.

#### 3.2.1 Application of SCS method to obtain unit hydrograph ordinates

The method is based on a dimensionless hydrograph, which relates ratios of time to ratios of flow, it involved the slope S, time of concentration, tc, the time to peak, tpand the peak flow Qp. The parameters used for analysis are, area (A), length (L), and catchment slope (S) as presented in table 3.3

**Table 3.3:** Parameters for the generation of unit hydrograph

| L(km) | A(km2) | Sc(slope) | tc(hr) | tL(hr) | tp(hr) | Qp(m3/s/cm) |
|---|---|---|---|---|---|---|
| 146.80 | 496.80 | 1.29 | 3.49 | 2.09 | 2.28 | 452.63 |

The time and the corresponding flow ordinates for the sub-catchments are determined based on the relationship between time and flow presented in Table 2.1. The ordinates and corresponding time for the sub-catchments are presented in Tables 3.4. The corresponding unit hydrograph are presented in Figures 3.2 for the watershed.

**Table 3.4:** Unit Hydrograph Ordinates for the watershed

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| t/tp | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 |
| t(hr) | 0 | 1.14 | 2.28 | 3.42 | 4.57 | 5.71 | 6.85 | 7.99 | 9.13 | 10.27 | 11.41 |
| q/qp | 0.00 | 0.43 | 1.00 | 0.66 | 0.32 | 0.16 | 0.08 | 0.04 | 0.02 | 0.01 | 0.00 |
| q(m3/s/cm) | 0.00 | 194.63 | 452.63 | 298.73 | 144.84 | 70.16 | 33.95 | 16.29 | 8.15 | 4.07 | 1.81 |

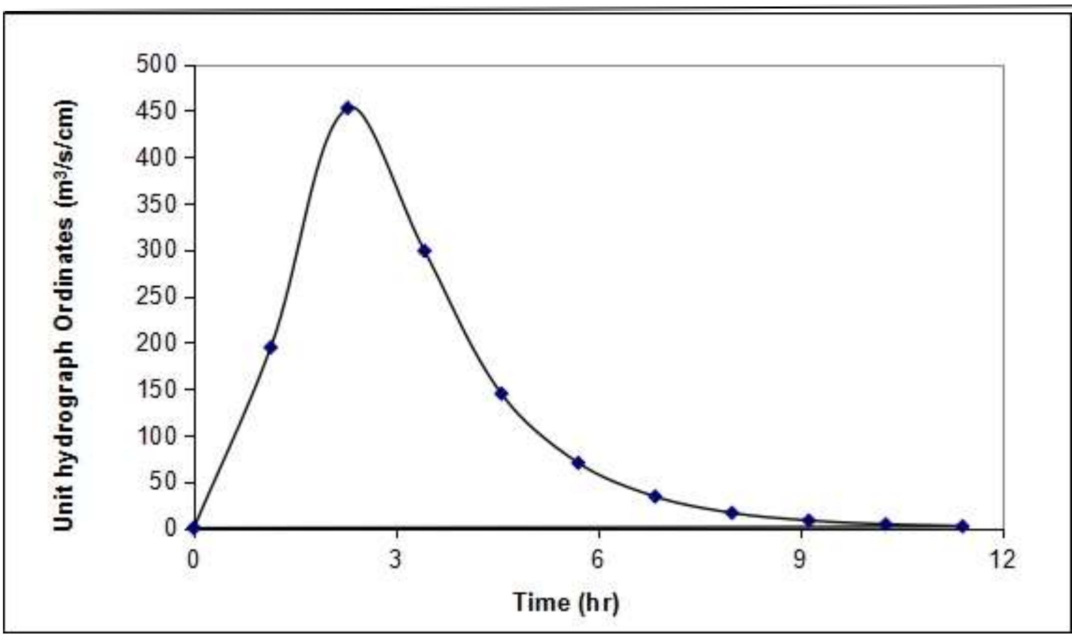


**Fig.** 3.2 Unit hydrograph ordinates versus time for the watershed

### 3.2.2 Determination of rainfall depth of different return periods

To analyze the rainfall data for recurrence intervals of 25 year, 50 year, 75 year and 100 year for the study area. Gumbel's Extreme value type I distribution system was adopted based on equation (2.33). The Gumbel model developed for peak annual daily rainfall for Warri is presented in equation (3.1) with the mean value of 117.19 mm and standard deviation of 25.46 mm.

$$R_T = 117.19 + 25.46(0.78y - 045) \qquad (3.1)$$

In order to determine the rainfall depth of different return periods such as 25yr, 50yr, 75yr and 100yr, equation (2.31) was adopted to estimate the reduced variate (y) while equation (3.1) was adopted to determine the corresponding rainfall value as presented in Table 3.5.

**Table 3.5**: Corresponding rainfall depth for different return period

| Recurrence Interval | Rainfall(mm) |
|---|---|
| 25-year | 169.27 |
| 50-year | 183.17 |
| 75-year | 191.12 |
| 100-year | 197.07 |

**a. Estimation of Rainfall Excess for different return periods**

Equations (2.26) – (2.28) were used to estimate the rainfall excess, other parameters used include the rainfall depth for different return period and curve number (CN) selected from Table 2.6 based on soil distribution and land use of the study area. Tables 3.8 -3.11 presents the results of excess rainfall for different return period. Curve Number, CN = 75, S=84.67 and Ia= 16.93.

**Table 3.6:** Estimated rainfall excess for 25yr, 24-hr storm P=169.27mm

| Time (hr) | Precipitation Ratio (P*/24) | Precipitation P (mm) | Cumulative Rainfall Excess Qd (mm) | Incremental Rainfall Excess (mm) | | |
|---|---|---|---|---|---|---|
| 25 yr, 24-hr storm; PT = | | | 169.27 | Mm | | |
| 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | |
| 3 | 0.0350 | 5.9245 | 0.0000 | 0.0000 | Runoff Coeff | |
| 6 | 0.0800 | 13.5416 | 0.0000 | 0.0000 | C= | 0.58 |
| 9 | 0.1470 | 24.8827 | 0.0000 | 0.0000 | | |
| 12 | 0.6630 | 112.2260 | 50.4597 | 50.4597 | | |
| 15 | 0.8540 | 144.5566 | 76.7238 | 26.2641 | | |
| 18 | 0.9210 | 155.8977 | 86.3525 | 9.6286 | | |
| 21 | 0.9650 | 163.3456 | 92.7672 | 6.4147 | | |
| 24 | 1.0000 | 169.2700 | 97.9162 | 5.1490 | | |

**Table 3.7:** Estimated rainfall excess for 50yr, 24-hr storm P=183.17mm

| Time (hr) | Precipitation Ratio (P*/24) | Precipitation P (mm) | Cumulative Rainfall Excess Qd (mm) | Incremental Rainfall Excess (mm) | |
|---|---|---|---|---|---|
| 50 yr, 24-hr storm; PT = | | | 183.17 | Mm | |
| 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | |
| 3 | 0.0350 | 6.4110 | 0.0000 | 0.0000 | Runoff Coeff |
| 6 | 0.0800 | 14.6536 | 0.0000 | 0.0000 | C=0.60 |
| 9 | 0.1470 | 26.9260 | 0.0000 | 0.0000 | |
| 12 | 0.6630 | 121.4417 | 57.7349 | 57.7349 | |
| 15 | 0.8540 | 156.4272 | 86.8062 | 29.0714 | |
| 18 | 0.9210 | 168.6996 | 97.4187 | 10.6125 | |
| 21 | 0.9650 | 176.7591 | 104.4788 | 7.0600 | |
| 24 | 1.0000 | 183.1700 | 110.1405 | 5.6618 | |

**Table 3.8:** Estimated rainfall excess for 75yr, 24-hr storm P=191.12mm

| Time (hr) | Precipitation Ratio (P*/24) | Precipitation P (mm) | Cumulative Rainfall Excess Qd (mm) | Incremental Rainfall Excess (mm) | |
|---|---|---|---|---|---|
| 75 yr, 24-hr storm; PT = | | | 191.12 | mm | |
| 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | |
| 3 | 0.0350 | 6.6892 | 0.0000 | 0.0000 | Runoff Coeff |
| 6 | 0.0800 | 15.2896 | 0.0000 | 0.0000 | C=0.61 |
| 9 | 0.1470 | 28.0946 | 0.0000 | 0.0000 | |
| 12 | 0.6630 | 126.7126 | 61.9786 | 61.9786 | |
| 15 | 0.8540 | 163.2165 | 92.6555 | 30.6769 | |
| 18 | 0.9210 | 176.0215 | 103.8299 | 11.1745 | |
| 21 | 0.9650 | 184.4308 | 111.2585 | 7.4286 | |
| 24 | 1.0000 | 191.1200 | 117.2131 | 5.9546 | |

**Table 3.9:** Estimated rainfall excess for 100yr, 24-hr storm P=197.07mm

| Time (hr) | Precipitation Ratio (P*/24) | Precipitation P (mm) | Cumulative Rainfall Excess Qd (mm) | Incremental Rainfall Excess (mm) | |
|---|---|---|---|---|---|
| 100 yr, 24-hr storm; PT = | | | 197.07 | mm | |
| 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | |
| 3 | 0.0350 | 6.8975 | 0.0000 | 0.0000 | Runoff Coeff |
| 6 | 0.0800 | 15.7656 | 0.0000 | 0.0000 | C=0.62 |
| 9 | 0.1470 | 28.9693 | 0.0000 | 0.0000 | |
| 12 | 0.6630 | 130.6574 | 65.1904 | 65.1904 | |
| 15 | 0.8540 | 168.2978 | 97.0685 | 31.8782 | |
| 18 | 0.9210 | 181.5015 | 108.6633 | 11.5947 | |
| 21 | 0.9650 | 190.1726 | 116.3674 | 7.7041 | |
| 24 | 1.0000 | 197.0700 | 122.5408 | 6.1735 | |

### 3.3 Hydrograph Convolution (Runoff hydrograph development)

The convolution equations are obtained by computing the direct runoff Qn using equation (2.29), ordinates obtained for the watershed from Tables 3.4 and incremental rainfall excess from Tables 3.6 -3.9. The results of the peak runoff hydrograph are presented in Tables 3.10-3.13 for the four return periods 25yr, 50yr, 75yr and 100yr return period respectively. The summary of the peak storm runoff for various return periods are also presented in Table 3.14. In order for pictorial illustration, the relationships of the synthetic unit hydrograph and the storm runoff hydrograph was also presented in Figure 3.3 – 3.6 respectively for 25 yr, 50 yr, 75 yr and 100yr. The combine hydrographs for various return periods are also presented in Figure 3.10.

**Table 3.10:** Peak runoff hydrograph for 25yr return period

| Time (hr) | UH ordinate Un (m3/s) | P1Un | P2Un | P3Un | P4Un | P5Un | Storm Hydrograph Qn (m3/s) |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.00 | 0.00 | | | | | 0.00 |
| 1.14 | 194.63 | 982.10 | 0.00 | | | | 982.10 |
| 2.28 | 452.63 | 2283.96 | 511.29 | 0.00 | | | 2795.25 |
| 3.42 | 298.73 | 1507.41 | 1189.05 | 187.43 | 0.00 | | 2883.89 |
| 4.57 | 144.84 | 730.87 | 784.77 | 435.88 | 124.95 | 0.00 | 2076.47 |
| 5.71 | 70.16 | 354.01 | 380.50 | 287.68 | 290.59 | 100.23 | 1413.01 |
| 6.85 | 33.95 | 171.30 | 184.30 | 139.48 | 191.79 | 233.10 | 919.97 |
| 7.99 | 16.29 | 82.22 | 89.18 | 67.56 | 92.99 | 153.85 | 485.80 |
| 9.13 | 8.15 | 41.11 | 42.81 | 32.69 | 45.04 | 74.59 | 236.24 |
| 10.27 | 4.07 | 20.56 | 21.40 | 15.69 | 21.79 | 36.13 | 115.58 |
| 11.41 | 1.81 | 9.14 | 10.70 | 7.85 | 10.46 | 17.48 | 55.63 |
| 12.56 | 0.00 | 0.00 | 4.76 | 3.92 | 5.23 | 8.39 | 22.30 |
| 13.70 | | | 0.00 | 1.74 | 2.62 | 4.20 | 8.55 |
| 14.84 | | | | 0.00 | 1.16 | 2.10 | 3.26 |
| 15.98 | | | | | 0.00 | 0.93 | 0.93 |
| 17.12 | | | | | | 0.00 | 0.00 |

**Table 3.11:** Peak runoff hydrograph for 50yr return period

| Time (hr) | UH ordinate Un (m3/s) | P1Un | P2Un | P3Un | P4Un | P5Un | Storm Hydrograph Qn (m3/s) |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.00 | 0.00 | | | | | 0.00 |
| 1.14 | 194.63 | 1123.79 | 0.00 | | | | 1123.79 |
| 2.28 | 452.63 | 2613.47 | 565.79 | 0.00 | | | 3179.26 |
| 3.42 | 298.73 | 1724.89 | 1315.79 | 206.70 | 0.00 | | 3247.37 |
| 4.57 | 144.84 | 836.31 | 868.42 | 480.69 | 137.60 | 0.00 | 2323.02 |
| 5.71 | 70.16 | 405.09 | 421.05 | 317.26 | 320.01 | 110.16 | 1573.56 |
| 6.85 | 33.95 | 196.01 | 203.95 | 153.82 | 211.20 | 256.19 | 1021.17 |
| 7.99 | 16.29 | 94.08 | 98.68 | 74.51 | 102.40 | 169.08 | 538.76 |
| 9.13 | 8.15 | 47.04 | 47.37 | 36.05 | 49.60 | 81.98 | 262.04 |
| 10.27 | 4.07 | 23.52 | 23.68 | 17.30 | 24.00 | 39.71 | 128.22 |
| 11.41 | 1.81 | 10.45 | 11.84 | 8.65 | 11.52 | 19.21 | 61.68 |
| 12.56 | 0.00 | 0.00 | 5.26 | 4.33 | 5.76 | 9.22 | 24.57 |
| 13.70 | | | 0.00 | 1.92 | 2.88 | 4.61 | 9.41 |
| 14.84 | | | | 0.00 | 1.28 | 2.31 | 3.59 |
| 15.98 | | | | | 0.00 | 1.02 | 1.02 |
| 17.12 | | | | | | 0.00 | 0.00 |

**Table 3.12:** Peak runoff hydrograph for 75yr return period

| Time (hr) | UH ordinate Un (m3/s) | P1Un | P2Un | P3Un | P4Un | P5Un | Storm Hydrograph Qn (m3/s) |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.00 | 0.00 | | | | | 0.00 |
| 1.14 | 194.63 | 1206.32 | 0.00 | | | | 1206.32 |
| 2.28 | 452.63 | 2805.38 | 597.12 | 0.00 | | | 3402.51 |
| 3.42 | 298.73 | 1851.55 | 1388.66 | 217.60 | 0.00 | | 3457.81 |
| 4.57 | 144.84 | 897.72 | 916.52 | 506.04 | 144.61 | 0.00 | 2464.89 |
| 5.71 | 70.16 | 434.83 | 444.37 | 333.98 | 336.30 | 116.00 | 1665.49 |
| 6.85 | 33.95 | 210.40 | 215.24 | 161.93 | 221.96 | 269.77 | 1079.30 |
| 7.99 | 16.29 | 100.99 | 104.15 | 78.44 | 107.62 | 178.05 | 569.24 |
| 9.13 | 8.15 | 50.50 | 49.99 | 37.95 | 52.13 | 86.33 | 276.89 |
| 10.27 | 4.07 | 25.25 | 25.00 | 18.22 | 25.22 | 41.81 | 135.50 |
| 11.41 | 1.81 | 11.22 | 12.50 | 9.11 | 12.11 | 20.23 | 65.17 |
| 12.56 | 0.00 | 0.00 | 5.55 | 4.55 | 6.05 | 9.71 | 25.87 |
| 13.70 | | | 0.00 | 2.02 | 3.03 | 4.86 | 9.91 |
| 14.84 | | | | 0.00 | 1.35 | 2.43 | 3.77 |
| 15.98 | | | | | 0.00 | 1.08 | 1.08 |
| 17.12 | | | | | | 0.00 | 0.00 |

**Table 3.13:** Peak runoff hydrograph for 100yr return period

| Time (hr) | UH ordinate Un (m3/s) | P1Un | P2Un | P3Un | P4Un | P5Un | Storm Hydrograph Qn (m3/s) |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.00 | 0.00 | | | | | 0.00 |
| 1.14 | 194.63 | 1268.79 | 0.00 | | | | 1268.79 |
| 2.28 | 452.63 | 2950.68 | 620.48 | 0.00 | | | 3571.16 |
| 3.42 | 298.73 | 1947.45 | 1442.98 | 225.77 | 0.00 | | 3616.19 |
| 4.57 | 144.84 | 944.22 | 952.36 | 525.05 | 150.06 | 0.00 | 2571.69 |
| 5.71 | 70.16 | 457.35 | 461.75 | 346.53 | 348.98 | 120.28 | 1734.90 |
| 6.85 | 33.95 | 221.30 | 223.66 | 168.02 | 230.32 | 279.72 | 1123.02 |
| 7.99 | 16.29 | 106.22 | 108.22 | 81.38 | 111.67 | 184.62 | 592.12 |
| 9.13 | 8.15 | 53.11 | 51.95 | 39.38 | 54.09 | 89.51 | 288.04 |
| 10.27 | 4.07 | 26.56 | 25.97 | 18.90 | 26.17 | 43.36 | 140.96 |
| 11.41 | 1.81 | 11.80 | 12.99 | 9.45 | 12.56 | 20.98 | 67.78 |
| 12.56 | 0.00 | 0.00 | 5.77 | 4.73 | 6.28 | 10.07 | 26.85 |
| 13.70 | 0.00 | 0.00 | 0.00 | 2.10 | 3.14 | 5.04 | 10.28 |
| 14.84 | 0.00 | 0.00 | 0.00 | 0.00 | 1.40 | 2.52 | 3.91 |
| 15.98 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12 | 1.12 |
| 17.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 3.14:** Peak storm runoff hydrograph for various return period

| Time (hr) | Synthetic UH ordinate (m3/s/cm) | Peak Storm runoff hydrographs (m3/s) 25-yr,24-hr | 50-yr,24-hr | 75-yr,24-hr | 100-yr,24-hr |
|---|---|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.14 | 194.63 | 982.10 | 1123.79 | 1206.32 | 1268.79 |
| 2.28 | 452.63 | 2795.25 | 3179.26 | 3402.51 | 3571.16 |
| 3.42 | 298.73 | 2883.89 | 3247.37 | 3457.81 | 3616.19 |
| 4.57 | 144.84 | 2076.47 | 2323.02 | 2464.89 | 2571.69 |
| 5.71 | 70.16 | 1413.01 | 1573.56 | 1665.49 | 1734.90 |
| 6.85 | 33.95 | 919.97 | 1021.17 | 1079.30 | 1123.02 |
| 7.99 | 16.29 | 485.80 | 538.76 | 569.24 | 592.12 |
| 9.13 | 8.15 | 236.24 | 262.04 | 276.89 | 288.04 |
| 10.27 | 4.07 | 115.58 | 128.22 | 135.50 | 140.96 |
| 11.41 | 1.81 | 55.63 | 61.68 | 65.17 | 67.78 |
| 12.56 | 0.00 | 22.30 | 24.57 | 25.87 | 26.85 |
| 13.70 | | 8.55 | 9.41 | 9.91 | 10.28 |
| 14.84 | | 3.26 | 3.59 | 3.77 | 3.91 |
| 15.98 | | 0.93 | 1.02 | 1.08 | 1.12 |
| 17.12 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Max | | 2883.89 | 3247.37 | 3457.81 | 3616.19 |
| Mean | | 749.94 | 843.59 | 897.73 | 938.55 |

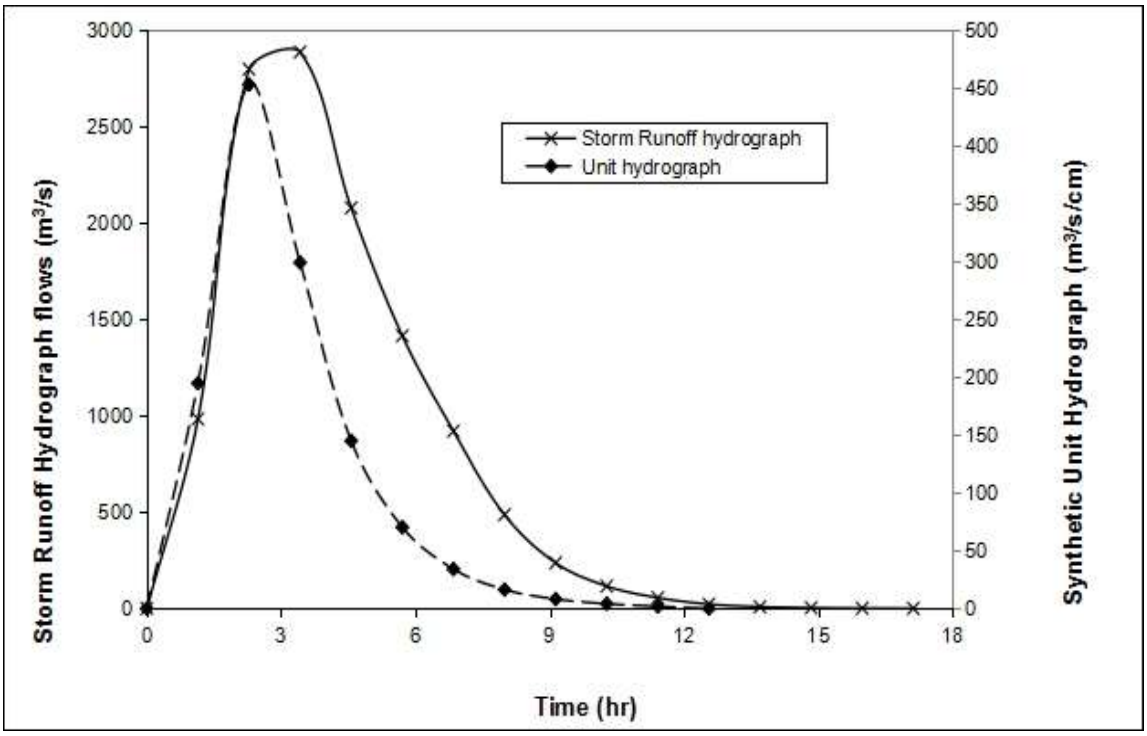


**Figure 3.3**: Synthetic Unit and 25-yr, 24-hr Storm Runoff Hydrographs

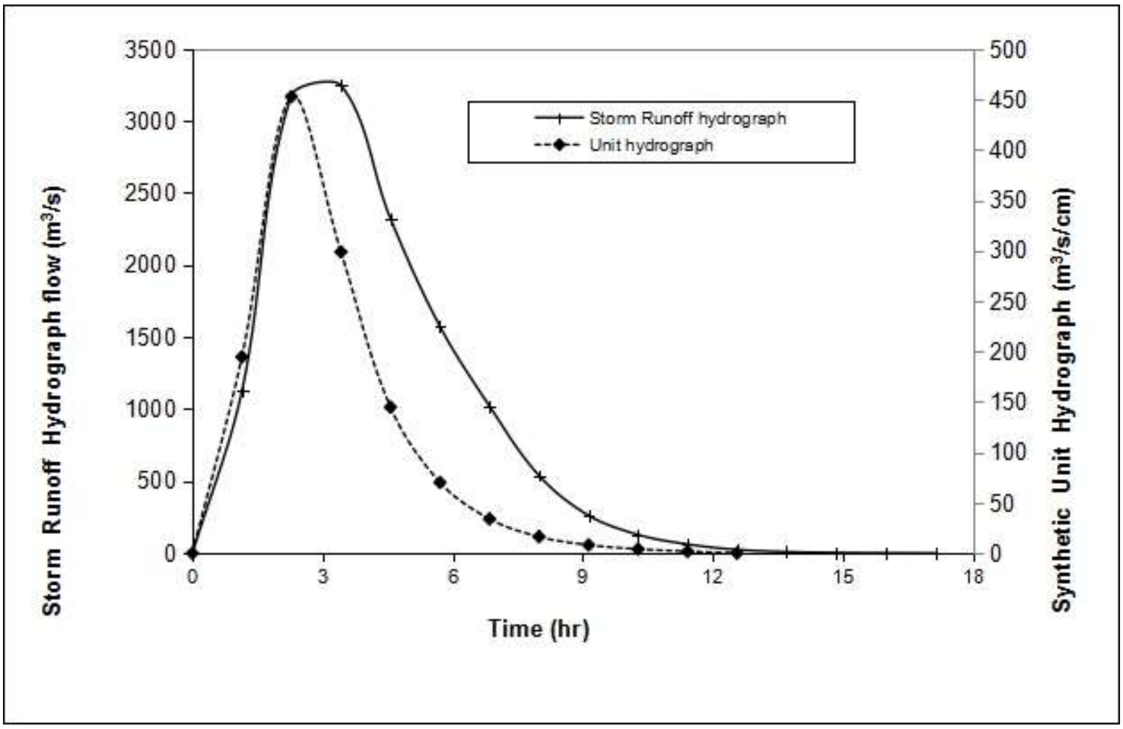


**Figure 3.4:** Synthetic Unit and 50-yr, 24-hr Storm Runoff Hydrographs

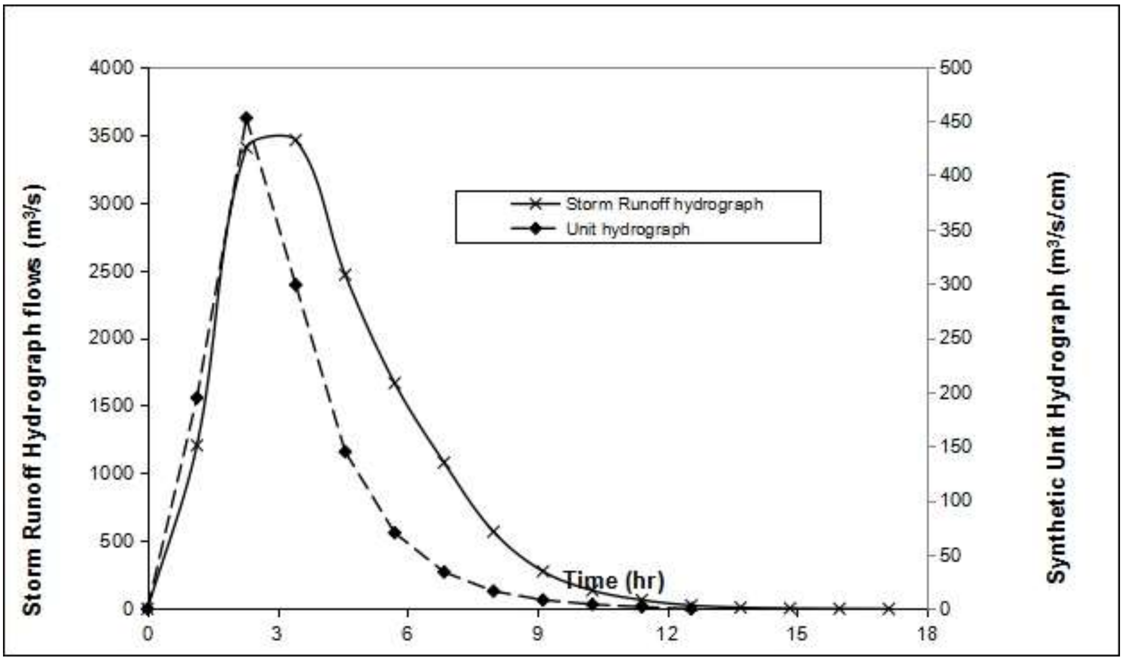


**Figure 3.5**: Synthetic Unit and 75-yr, 24-hr Storm Runoff Hydrographs

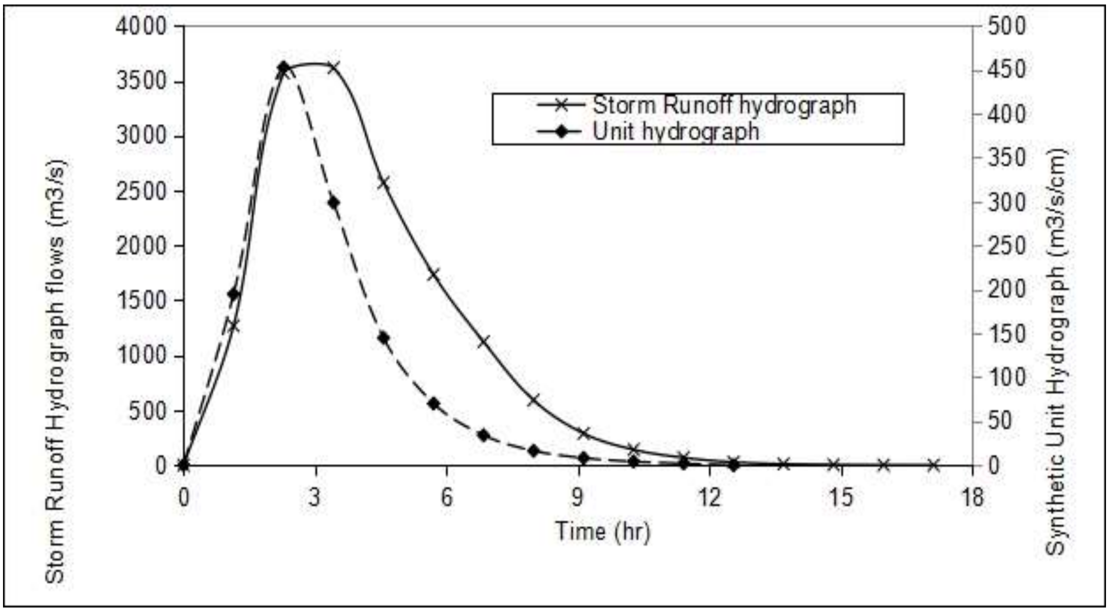


**Figure 3.6:** Synthetic Unit and 100-yr, 24-hr Storm Runoff Hydrographs

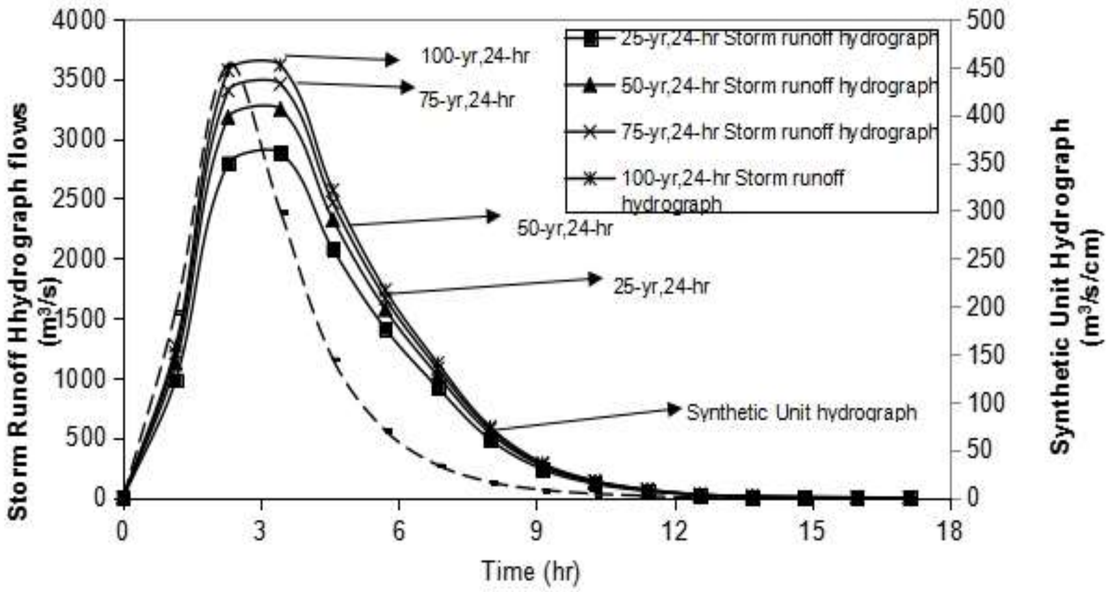


**Figure 3.7:** Synthetic Unit hydrograph and storm hydrographs of different return periods

## 4.0 Results and Discussion

### 4.1 Linear Aspects

The results indicated a dendritic pattern and varies from first orders to sixth orders. The mean bifurcation ratio of 2.17 indicates that the drainage has not been affected by structural disturbances

### 4.1.2 Areal Aspects

The low drainage density of 0.3 indicates towards a very coarse drainage pattern with sub-humid limate of the study area. The elongated catchment with low Form factor indicates that the basin will have a flatter peak of flow for longer duration and conducive for more groundwater recharge.

### 4.1.3 Relief Aspects

The relief ratio (Rh) value of 1.29 indicated that the major portion of the HA5 is having a gentle slope.

### 4.2 Flood Design discharge

The obtained watershed attributes was used with the synthetic unit hydrograph adopted to determine the peak runoff for the various return periods. The peak runoff obtained varied from 2883.89m3/s to 3616.19m3/s.

The catchment length of 146.8km with a low slope of 1.29 implies a long residence time of flood and this calls for structural and non-structural measures in the management of runoff in order to avert flood disasters in the area.

## 5.0 Conclusion

The hydrograph for the determined return periods determine the rainfall yields from the catchment that is available for allocation for various water uses. The hydrographs are useful for water resources planning, design of hydraulic structures, and forecast of future flood events in the catchment. The peak runoff obtained varied from 2883.89m3/s to 3616.19m3/s for the catchment.

### 5.1 Recommendations

i. The morphometric attributes observed can be used for site suitability analysis of soil and water conservation structures.

ii. The study recommends hydrogeological and geophysical investigation in future for proper water management and selection of artificial groundwater recharge

## References


Babita Pal, Sailesh Samanta and Pal, D. K. (2012), Morphometric And Hydrological Analysis And Mapping For Watut Watershed Using Remote Sensing And Gis Techniques, https//:www.researchgate.net

Bilewu, S.O, Sule, B.F and Ayanshola, A.W (2015) "optimum parameter selection for the morphometric description of watersheds: a case study of central Nigeria", www.jeeng.net/pdf-59344-3089?filename=OPTIMUM%20PARAMETE

Eze B.E & Joel Efiong, 2010, Morphometric Parameters of the Calabar River Basin: Implication for Hydrologic Processes, joel_efiong@yahoo.com

Faith Ekong, 2012, Water Resource Management in the Niger Delta Region of Nigeria: The Role of Physical Planning, faith_ekong@yahoo.com

Javed, A., Khanday, M.Y. and Ahmed, R. (2009) Prioritization of Sub-Watersheds Based on Morphometric and Land Use Analysis Using Remote Sensing and GIS Techniques. Journal of Indian Society of Remote Sensing, 37, 261-274.





Kirpich, Z.P., 1940, as cited in Suvendu Roy and Biswaranjan (2013) Mistri Estimation of Peak Flood Discharge for an Ungauged River: A Case Study of the Kunur River, West Bengal, Geography Journal, Volume 2013 (2013), Article ID 214140, 11 pages.

Kuldeep Pareta, 2011, Quantitative Morphometric Analysis of a Watershed of Yamuna Basin, India using ASTER (DEM) Data and GIS, kuldeep.p@spatialdecisions.in

Lambert, David, (1998), The Field Guide to Geology. Checkmark Books, pp. 130131.

McCuen andBondelid, 1983, relation between rainfall excess and total rainfall (on twenty-four hour basis)

Mustafa, S. M. Yusuf, A (2012), Textbook of Hydrology And Water Resources,, p.53. elibrary.nils.gov.ng

Nigerian Meteorological Agency, 2014, seasonal rainfall prediction, www.nimet-srp.com,

Ogunlela A.O and Kasali. M.Y. (2002 Evaluation of four methods of storm hydrograph development for an ungaged watershed. Published in Nigerian Journal of Technological development. Faculty of engineering and Technology, University of Ilorin, Ilorin, Nigeria. (2); 25 – 34

Pallard, B. Castellarin, A. and Montanari, A. (2015)A look at the links between drainage density and flood statistics, Hydrology and Earth System Sciences, P. 1019,

Prafull Singh, Ankit Gupta, Madhulika Singh, (2014) Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques,

Ramirez J.A. (2000) Prediction and Modeling of Flood Hydrology and Hydraulics. Chapter 11 of Inland Flood Hazards: Human, Riparian and Aquatic ommunities. Edited by Ellen Wohl; Cambridge University Press.

Sharkh, M.S.A. (2009) Estimation of Runoff for Small Watershed Using Watershed Modeling System (WMS) and GIS. Proceedings of the Thirteenth International Water Technology Conference (IWTC), Hurghada, 12-15 March 2009

Tesfaye, T. K. (2015), Analysis of Watershed Attributes for Water Resources Management Using GIS: The Case of Chelekot Micro-Watershed, Tigray, Ethiopia, Waikar, M.L. and Aditya P. N, (2014) Morphometric Analysis of a Drainage Basin Using Geographical Information System

WMO (2011), Manual on Flood Forecasting and Warning, www.wmo.int

ViesssmanW,Knapp J.W and Lewis G.L (1989) as cited in Ali Ercan and Levent, M. K,(2016) "Numerical Solution and Application of Time-Space Fractional Governing Equations of One-Dimensional Unsteady Open Channel Flow Process, www.hydrol-earth-syst-sci-discuss.net/hess-2016-364/

# MODELING BLUE AND GREEN WATER RESOURCES IN UPPER PART OF OGUN RIVER BASIN, NIGERIA

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**Abstract**

*The Upper part of the Ogun River Basin in south west Nigeria is a pure agrarian state where most of the food crops produced are traded off to the lower part of the basin (especially Lagos). Farmers are unaware that they are effectively outsourcing water in the form of crops cultivated and traded off because they do not fully understand the long term implications of unsustainable water use from aquifers. In order to quantify the amount of water resources available in this area, a hydrological modeling approach was applied. The SWAT (Soil and Water Assessment Tool) model which is a physically based model that can represent real life situations, computationally efficient and use readily available inputs and realistic data was used to model the available green and blue water flow within the basin for a period of 29 years (1990 – 2018). The SWAT model was able to estimate the number and variation of hydrological response units (HRUs) for the entire Upper part of the Ogun drainage basin. It simulated the available blue and green water resources flow and modeled the scenario for the available average daily and annual water balance in the various hydrological storage phases. The model predicted excess water yield with an average runoff curve number (CN) of 81.26mm.This means that the rate of sediments yields for the period of study is high; hence the basin is prone to erosion, mostly due to the various modifications of the Land surfaces especially due to agricultural practices. The water balance ratios for stream flow/precipitation is 0.39, base flow is 0.31, surface runoff is 0.69, percolation is 0.16, deep recharge is 0.01 while evapotranspiration is 0.56 (all units in mm). The model further predicts 30 days of water stress, 1 day of Temperature stress, 25 days of Nitrogen stress and approximately 2 days of Phosphorus stress, annually. This study therefore provides information for optimal utilization and management of water resources in the Upper part of Ogun River basin.*

**Keywords:** Blue water; Green water; SWAT; Upper part of Ogun River basin, Water, balance, Stress

## 1.0 Introduction

The Move towards attaining a sustainable future in which all can live well within ecological means is fast becoming a deep social challenge (Onoja, Achike and Enete, 2018); thus, quantifying available water resources for natural ecosystem and society hasbecome an important focus for hydrologists (Madani and Shafiee-Joo, 2020; Adeaga, Bello and Akinbaloye,2019). Simulation and modeling of water resources is a vital factor for resolving practical water resources management and planning issues, despite the degree of uncertainty in their predictions through approximation of the real-world system (Adeaga, Mahe,Dieulin,Elbaz-pouliche,Rouche, Seidel, and Servat, 2012). Hydrological models are tools used for simulations and modeling. Indeed, the Soil and Water Assessment Tool (SWAT) is a physicallybased, and time continuous mathematical hydrological model that is designed toestimate water quantity and quality under different conditions over time in small and large catchments with satisfactory accuracy (Golmohammadi, Rudra, Dickinson, Goel, and Veliz, 2017). The SWAT model has been widely used in various parts of the world to support decision making on water management and has proved its efficiency in many arid and semi-arid areas even when different economical activities are held in the watershed (Youssef, Aziz, Rachid, and Lahcen, 2018).



Zongxue and Depeng (2014)carried out the simulation of blue and green water resources in the Wei River basin, in China using the SWAT model. The water resources components of blue and green water flow, and green water storage were estimated at the HRU (Hydrological Response Unit) scales. The analysis further showed that at the sub-basin river catchments, and then city/region scale, there is a decrease inblue water resources between the 1960s and 2000s, with a minimum value in the 1990s. The study providesstrategic information for optimal utilization of water resources and planning of cultivating seasons in the Wei River basin.Another research by Faramarzi, Abbaspour, Schulin and Yang (2009) used the SWAT model to simulate the blue and green water resources in Iran and the impacts of different irrigation practices on the water balances of areas with irrigated agriculture. The study showed the importance of modeling water resources in arid and semi-arid areas.

Green water is denoted as effective rainfall or soil moisture that is used directly by plants, while blue water is that which is in the rivers, lakes, aquifers, or reservoirs (Mekonnen, and Hoekstra, 2015). Balancing green and blue water resources especially to reduce water stress for food production and societal use is a must, particularly in data scarce regions of the world. Hence, the main objectives of this study was to determine the various hydrological response units (HRUs) for the upper part of Ogun Basin in order to simulate the available blue and green water resources and estimate the annual average water balance within the basin from 1991 to 2018. This study, therefore, serves as a base for further study on sustainable water use efficiency, water stress management, water resources budgeting, planning and management.

## 2. 0 Methodology

The methodological approach adopted in this study is based on the need for the modeling of blue and green water resources in Upper part of Ogun River basin, Nigeria

### 2.1 Study Area

The Ogun river basin is located in south west Nigeria, bordered geographically by latitudes 6$^o$ 26' N and 9$^o$ 10'N and longitudes 2$^o$ 28'E and 4$^o$ 8 'E. This basin can be divided into two parts of a high slope (average 15%) terrain as the upper part covering about19,885.22 km$^2$ land area (Figure 1), while the lower part is of extremely low slope (< 1%) characterized by flooding with marshes and swamps (Oke, Martins, Idowu and Aiyelokun, 2015). The divide of the upper part of the basin is from the source at Igaran hills at an elevation of about 530m above the mean sea level to about 9km upstream of Abeokuta town (Oke, Martins, Idowu and Aiyelokun, 2015).

The basin's relief is generally low, sloping in the North-South direction, and the major tributaries of Ogun River are the Oyan, Ofiki and Opeki rivers. Two seasons are distinguishable in Upper part of Ogun basin; a dry season from November to March and a wet season between April and October. The two major vegetation zones that can be identified on the watershed are the high forest vegetation and the derived Savannah (Ayeni, Kapangaziwiri, Soneye, and Engelbrecht, 2015). The geology of the study area can be described as a rock sequence that starts with the Precambrian Basement, which consists of quartzites and biotite schist, hornblende-biotite, granite and gneisses (Oke, Martins, Idowu and Aiyelokun, 2015).

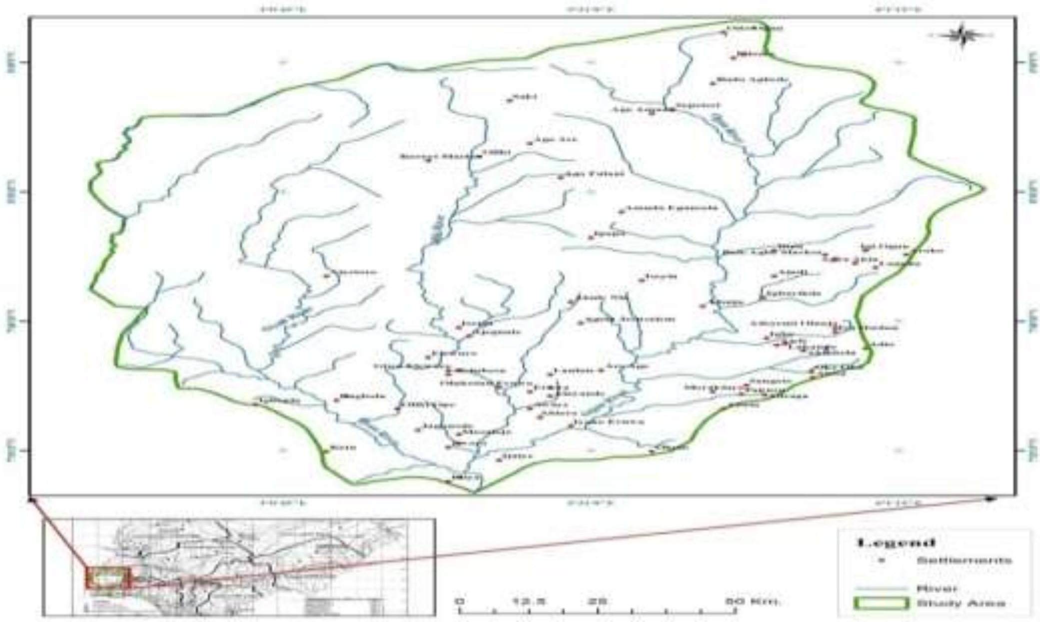


**Fig. 1:** Upper part of Ogun River Basin

### 2.2 Data, data source and characteristics

The source and characteristics of the spatial data used in this study are presented in Table 1.

**Table 1:** Spatial data source and characteristics

| Data Type | Characteristics | Scale | Source |
|---|---|---|---|
| Satellite Imagery | Global Land use map (2010 - 2018) | 30 meters | Via Satellite (www.earthexplorer.org.usgs) |
| SRTM | Digital Elevation Model (DEM) | 20 x 20m | Via Satellite (www.earthexplorer.org.usgs) |
| Soil map | Upper part of Ogun river basin | 1:5,000,000 | Digital soil map of the world Esri shape file format from Food and Agricultural Organization (1961). |
| Meteorological data | Maximum and minimum Air Temperature ($^0$C), Rainfall (mm) | Daily mean (1990to 2018) | OORBDA, NASA power data |

**Source:** Author 2021

### 2.3 Methods and Procedures

The Soil and Water Assessment Tool (SWAT) model which has a combination of ArcSWAT 2012 version and ArcGIS10.4 was used in this study. The model delineated the DEM that was divided into Subbasins, and with the overlaying of the generated global land use imagery, and Soil maps observed on a single slope plain, hydrological response unit for the entire basin was generated. Finally, with the input of the daily hydro-climatic data for the four (4) synoptic stations in the basin, the simulations for the period under study (1990 and 2018) was then displayed in the TxtInOut folder of the scenarios folder of the SWAT model. The average annual water balance of the basin was computed from the SWAT simulations results using the water balance equation (Clarke et al., 1973): $\Delta S = I - O \;\dots\dots\dots\dots . Eqn\ 1$

I = water inflow into systems (rainfall), O = outflow water (evapotranspiration)and ΔS = change in water storage.

### 3.0 Result and Discussion

The hydrological response units (HRUs) are the smallest units used by the soil water and atmospheric tools (SWAT) model in calculating the hydrological properties of a catchment area (Yang, Xue, He, Wang, and Long, 2017). The ArcSWATinterface for SWAT model, calculated the area occupied by each HRUs in a sub-basin from the soil and land use map on a single slope as imported into the model. For the period of study, upper zone of Ogun drainage basin exhibited a total of 97 HRUs within the 30 subbasins that were delineated from the imported digital elevation model (Figure 2).

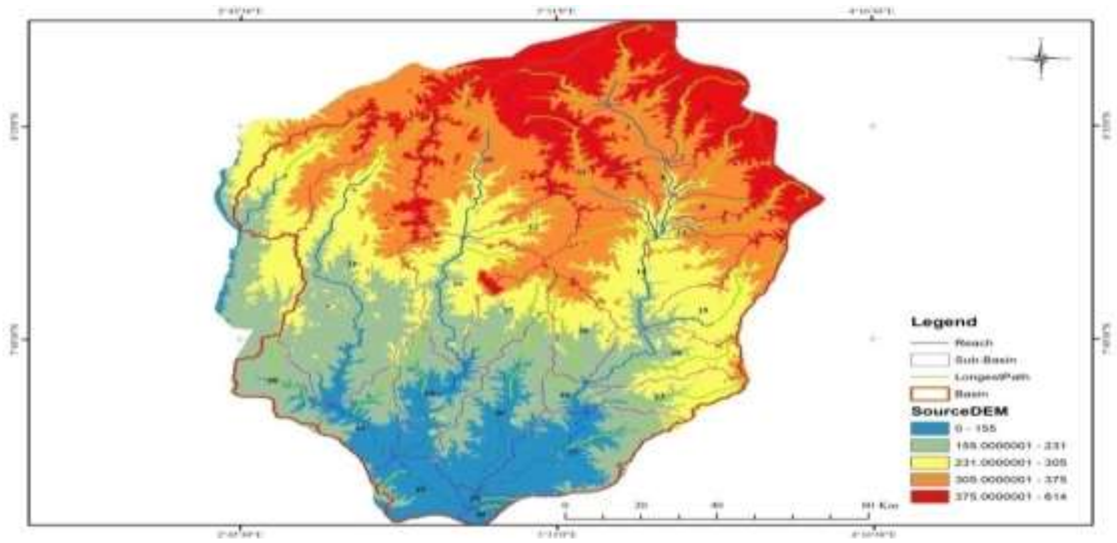


**Fig. 2:** DEM over subbasins of the Upper zone Ogun basin

The 97 HRUs within the basin (Figure 3) showed a synergy in its responses due to the land cover/ landuse pattern graduation and soil types. Upper zone of Ogun basin has the Sandy-clay-loamy soil types which are very good for agriculture. Sandysoil allows for good drainage of water and all crop types benefit from this soilbecause addition of organic matter increasesits fertility.Clay soil is composed of tiny, very tightly packed particles; though it holds water well and does not lose it easily. The loamy soil is every farmer's favorite and dream; it contains a balance of all three soil materials (silt, sand and clay) plus humus. The Landuse pattern across the basin showed that about 70% of the total land area is being used as mixed Agricultural land (i.e. Crop cultivation and settlements); about 5% is covered by mixed Forest, another 3% by Evergreen forest, and Wetland of about 17%, all spread across the 30 subbasins to form the 97 HRUs.

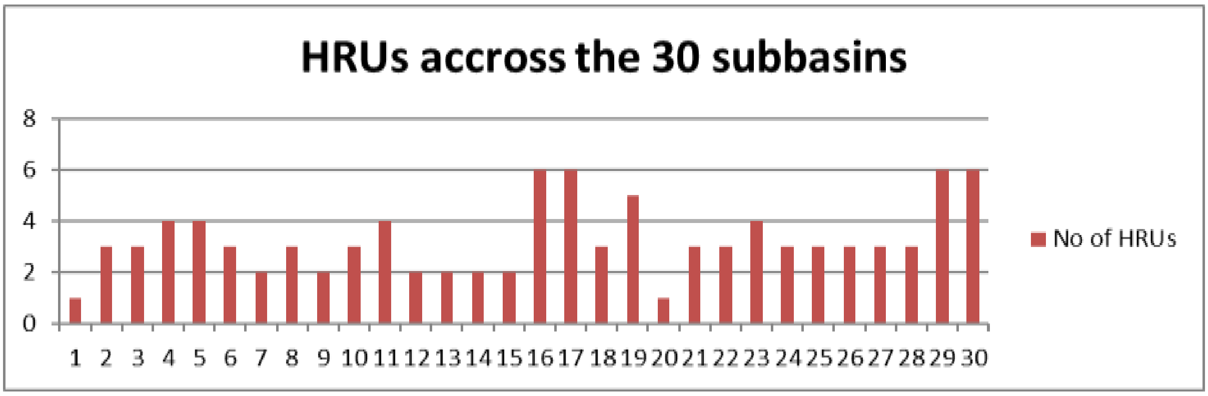


**Fig. 3:** Distribution of the HRUs across the Upper zone of Ogun drainage basin

The blue water considered for this study are the amount of surface runoff contribution from stream flow (SURQ) from the HRUs; the lateral flow contribution to stream flow in the basin (LATQ is base flow in the basin) and also the groundwater contribution to stream in the basin (GWQ). The green water Identified for this research is the PERCOLATE (Infiltrated water) and SW (Amount of water stored in soil profile as soil moisture in the Upper zone of Ogun basin). The study showed that all through the period of study,the upper zone of Ogun basin hadenough water; this explains why rainfed agriculture is a major type of farming supported within the basin. The similarity between the GWQ and PERCOLATE water curve from the graph (Figure 4) shows the permeability of the soil.Infiltration rate is moderately high (0.15–0.30 and 3.8–7.6 mm per hour)due to the soil type, land use types and the basin's slope. This also accounts for the consistent value of the base flow (LATQ) as it is continually being recharged.
The soil moisture (SW) response for the basin has its annual average as 66.5mm.This conforms to the conclusion that a well drained soil should have a maximum range of water storage in 1m of soil not more than 200mm (Brandt, Johnson, Elphinston, and Ratnayaka, 2017; Balogun, 1998). The amount of surface runoff (SURQ) contribution from stream flow in the basin shows that the soil type, landuse and slope are major factors affecting its value. The SURQ curve in this study (figure 4) flows very similar to the GWQ and PRECOLATE. The SURQ values in this study show that the basin has capacity to generate excess overland flow.

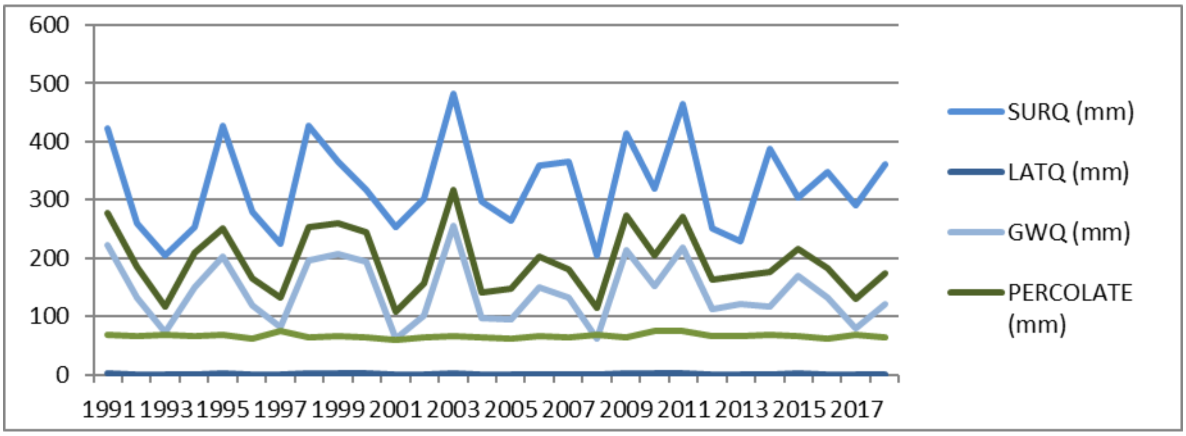


**Fig. 4:** Available Blue and Green water within Upper zone Ogun Basin 1991 to 2018

The model carried out a simulation length of 29 years between January, 1990 and December, 2018 and the first year for the simulation was used as warm-up by the model; while the subsequent years were used to generate scenario on the hydrology of the basin. The responses depict that the basin generates excessive water yield,with an annual daily average runoff curve number (CN) of 81.26mm. The rate of sediments yield for the period of study is high; hence, the basin is prone to erosion due to the various modifications of the Land surfaces. The daily average water balance ratios for stream flow/precipitation is 0.39, base flow is 0.31, surface runoff is 0.69, percolation is 0.16, deep recharge is 0.01 and Evapotranspiration is 0.56 (units in mm) as shown in figure 5.

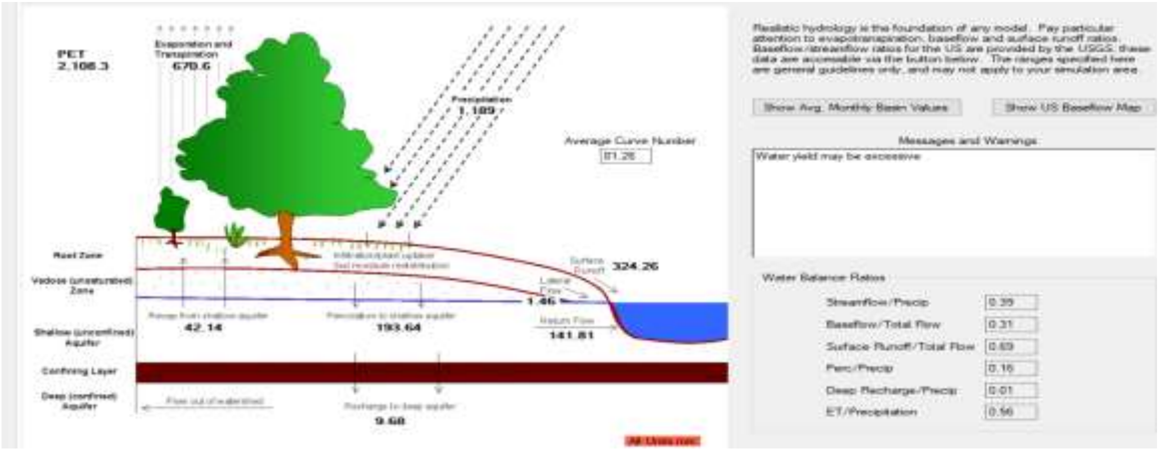


**Fig. 5:** Average daily available water balanceScenario in study area 1991 to 2018

Upon inputting the hydro-climatic data for the period of study, the average annual water balancefor the years studied within the upper zone of Ogun basin was then evaluated using the Clark's equation for water balance computation as shown in Figure 6.

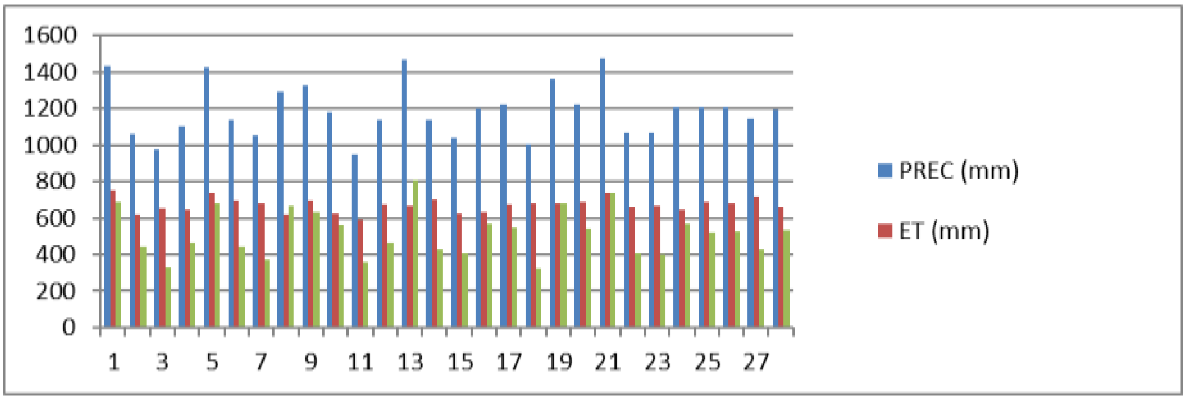


**Fig. 6:** Change in Average Annual Water Balance

All through the 29 years, the upper zone of Ogun basin continued to receive copious amount of rainfall as input. The years, 1991, 1995, 2003 and 2011 had very high average rainfall (above 1500mm/year), while the years 1993 and 2001 had average rainfall below 1000mm/year. The evapotranspiration rate (output) showed a consistent average of between 580mm to 750mm per year. The difference between the input and output is the annual change in storage for the water balance in the basin which ranges from an annual average of 360mm/year to 800mm/year. In a total of days, the SWAT model predicted that the Upper zone of Ogun basin annually, on the average, experiences 30 days of water stress, 1 day of Temperature stress, 25 days of Nitrogen stress and approximately 2 days of Phosphorus stress. These facts are proofs why a water budget and efficiency use plan is required within this drainage basin.

## 4.0 Conclusion

In this study the SWAT model was successfully applied todetermine the various hydrological response units (HRUs) for the upper part of Ogun Basin in order to simulate the available blue and green water resources and estimate the annual average water balance storage within the basin from 1991 to 2018.The upper zone of Ogun drainage basinin the southwest of Nigeria is a region that receives an average annual rainfall of about 1500mm. The various alteration of the land surface due to agricultureand other anthropogenic activities have continued to alter the hydrological response outputs that affect the average annual water balance storages within the basin. The basin over the years studied has continued to generate excess water yield with high sedimentation.This maybe a major factor to soil nutrients erosion, flooding, poor agricultural crop yield, and water stress due to its quantity and quality. Consequently, the results from this study show that there is a need for efficiently utilizing and allocating the water resources and planning of the agricultural crop cultivation system in this basin.

## Reference

Adeaga, O.A, Bello, A.A, and Akinbaloye, T. (2019): "Water Resources Uncertainty in Yewa River Basin, Ogun state, South-West Nigeria." *World Scientific News 131 (2019) pages 37-53*

Adeaga, O., Mahe, G., Dieulin, C., Elbaz-pouliche, F., Rouche, N., Seidel, J., and Servat, E. (2012): "Rainfall-Runoff Simulation in Part of Lower Niger Basin". *Journal of Environmental Science and Engineering B 1 (2012) pages 812-819:*Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

Ayeni, A.O., Kapangaziwiri, E., Soneye, A. S. O., and Engelbrecht, F.A. (2015): "Assessing the impact of global changes on the surface water resources of southwestern Nigeria." *Hydrological Sciences Journal, 60:11, 1956-1971,* DOI: 10.1080/02626667.2014.993645

Balogun, I.I (1998): "Soil water Balance and Relations in SokotoFadamas of Nigeria's Sudano-Sahelian Zone". (Ph.D Thesis. University of Lagos, Nigeria).

Brandt, M. J., Johnson, M. K., Elphinston, A. J., and Ratnayaka, D. D. (2017): "Soil moisture Measurement: Hydrology and Surface supplies". Twort's Water Supply (Seventh Edition), *2017.*Pages 65-116

Clarke R.T., Leese M., and Newson A.J. (1973): "Analysis of data from the PlynlimonRaingauge Networks, 1971-1973". *Report no. 27 (Inst. Hydrology, Wallingford, Oxfordshire, UK.,* 1973.

Faramarzi, Abbaspour, Schulin and Yang (2009):"Simulation of the blue and green water resources in Iran".*Hydrological Processess, Vol.23, Issue 3*. Pages 486 – 501.

Golmohammadi, G., Rudra, R., Dickinson, T., Goel, P. and Veliz, M. (2017): "Predicting the temporal variation of flow contributing areas using SWAT". *Journal of Hydrology, v. 547, pages. 375-386,* https://dx.doi.org/10.1016/j.jhydrol.2017.02.008

Madani, K., and Shafiee-Jood, M. (2020): Socio-Hydrology: A New Understanding to Unite or a New Science to Divide? *Water 2020, 12, pages. 1941*

Mekonnen, M.M., Pahlow, M., Aldaya, M.M., Zarate, E. and Hoekstra, A.Y. (2015): "Sustainability, efficiency and equitability of water consumption and pollution in Latin America and the Caribbean." *Sustainability, 7(2):* Pages. 2086-2112.

Oke, M.O., Martins, O., Idowu, O.A., and Aiyelokun, O. (2015): "Comparative analysis of groundwater recharge estimation value obtained using empirical method in Ogun and Oshun River basin." *Ife Journal of Science vol. 17, no. 1 (2015)*

Onoja, A. O., Achike, A. I. and Enete A.A. (2018): "Climate Change and Sustainable Green Growth in Nigeria: Challenges and Opportunities." *Nigerian Agricultural Policy Research Journal (NAPReJ) pp 1-12.* Agricultural Policy Research Network (APRNet) Vol. 4. Iss. 1.

Yang, G., Xue, L. Q., He, X. L., Wang, C., and Long, A. H. (2017): "Change in land use and evapotranspiration in the Manas River Basin China long-term water saving measures". *Sci Rep. 2017; vol: 7:17874*doi: 10.1038/s41598-017-18030-5.

Youssef, B., Aziz, A., Rachid, B., and Lahcen, B. (2018): "SWAT stream-flow modeling for hydrological components' understanding within an agro-sylvo-pastoral watershed in Morocco". *J. Mater. Environ. Sci., 2018, Volume 9, Issue 1, Pages 128-138*

Zongxue, X., and Depeng, Z. (2014): "Simulation of blue and green water resources in the Wei River basin, China". Evolving Water Resources Systems: Understanding, Predicting and Managing Water–Society.*Interactions Proceedings of ICWRS2014, Bologna, Italy, June 2014 (IAHS Publ. 364, 2014)*

# SUB-THEME 5:

# FLOOD, DROUGHT AND CLIMATE CHANGE

# GEOSPATIAL ASSESSMENT OF THE IMPACT OF URBANIZATION ON DROUGHT IN MAIDUGURI, BORNO STATE, NIGERIA

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**Abstract**
*The rapidity of urbanization in Maiduguri has led to the increased conversion of Savannas and other vegetative cover, which are generally unpaved and porous, to paved surfaces covered by concrete and tars, which are generally impervious to percolation and as a result reduces groundwater recharged, which ultimately leads to water scarcity and it's attending problems in human existence such as drought. Hence, this study assessed the impact of urbanization on drought formation in Maiduguri, Borno State, using geospatial techniques. The land use land cover analysis and soil moisture index analysis were adopted in assessing the impact of urbanization on drought. Satellite imagery of the study location was obtained from Landsat 8 ETM+ and band 4 and band 5 were adopted in carrying out the soil moisture analysis and land use land cover analysis. The finding of the study averred that as land use changes in the direction of increasing urbanization, unpaved surface becomes paved surface and ground water recharge potential decreases, hence drought. It was thus recommended that the government should control urbanization through urban regulation and renewal.*

**Keywords:** Hydrology; GIS; Drought; Urbanization

## Introduction

Maiduguri, the administrative capital of Borno state, since 1967 till date, was formerly a large extent of land habited by wild animals (Mayomi & Mohammed, 2014). Currently, the city is a vast metropolitan area located in the semi-arid region of North East.

The rapidity of urbanization in Maiduguri can be linked with the demographic development. Maiduguri since the 1960s has been expanding in landmass and population. For instance, the population of Maiduguri was formerly 10,000 in 1910, but this figure rose to 139, 965 in 1963 and 654, 400 in 1991 (Kwaka 2002). The 2006 Population Census put the total population of the Maiduguri urban (MMC and Jere LGA) at 749,123. The impact of this population growth is manifested in expansion of the city center to accommodate the growing masses. What this means to environmental sustainability is that more trees will be fell to give room for infrastructural development such as residential buildings, institutional buildings, roads, market centres, and other urban structures. Evidently, Mayomi & Mohammed, (2014) noted that, Maiduguri is blessed with multiple infrastructures to accommodate the growing population in the city. Essentially, the growth of urban population will lead to the growth of infrastructures which then will result in the decrease of environmental greenery.

Amidst the multiple impact of urbanization on environmental sustainability, agricultural drought is one of the most striking implications of urbanization within the NorthEast region that has attracted the interest of this study. According to Szilassi (2020), agricultural drought is a type of drought that occurs when there isn't enough moisture to support average crop production on farms or average grass production on range land. Although agricultural drought often occurs during dry, hot periods of low precipitation, urbanization has also made significant contributions to the exaggeration of the problem (Jata, Khareb , Gargc & Shankar, 2008).

Although there has been abundance of literature concerning the relationship between urbanization and drought, however, only few studies have been able to look at the issue from a geospatial context. For instance, Bello (2019), noted that changes in land use and land cover could be an essential tool for monitoring urban activities and resolving the negative consequences of urban growth. Also, Dami, Adesina and Garba (2011) concluded that a semi-arid environment where water supply is grossly inadequate, poses a lot of challenges in urban management. These studies applied GIS in examining the correlational effect of urbanization on agricultural drought.

Geographic Information System (GIS), has been adopted in studying the relationship between urbanization and drought. However, Jata, Khareb, Gargc and Shankar (2008) noted that conventional surveying and mapping techniques are extremely expensive, time consuming, and sometimes geographically limiting for examining the relationship between urbanization and drought. Hence, increased research interests, adopting remote sensing and geographic information system (GIS) techniques is being directed for the mapping and monitoring of urban growth, land use/cover and hydro-geomorphological characteristics (Epstein, Payne, & Kramer, 2002).

One important remote sensing and GIS technique adopted by researchers in observing drought dynamics is the soil moisture index. According to Saha, Patil, Goyal and Rathore (2018), soil moisture is a key parameter which directly or indirectly influences the water cycle. Agriculture production in rainfed areas mainly depends on it as well as irrigation practices based on it. Although in situ measurements can be used to observe the soil moisture content. Some researchers such as Saha, Patil, Goyal and Rathore (2018), have adopted geospatial techniques in understanding the correlation between urbanization and agricultural drought, using soil moisture stress analysis. Hence, this study would be designed to assess the relationship between urbanization and agricultural drought occurrence.

**Aim and Objectives**

The aim of the study was to assess the impact of urbanization on agricultural drought in Maiduguri, Borno State, Nigeria. The specific objectives were to;

1. assess the urban land-use change for 10 consecutive years
2. assess the soil moisture change for 10 consecutive years
3. to compare the soil moisture change with land use change.

**Study Area description**

Maiduguri is the capital of Borno state in the North-Eastern region of Nigeria. It is located on latitudes 11°50′N and 11.83°N, and longitudes 13°09′E and 13.15°E, lying on relatively flat terrain of about 350m above sea level. The city is bounded in the north by Jere LGA, in the west, south and south-west by Konduga LGA, in the north-west by Mafa LGA. The city has an area of 550 km2 with a population estimated at 1,197,497 (World Gazetteer, 2009). Maiduguri has mean annual maximum temperature of 34.8 with mean temperature ranging between 30 and 40 C. The months of March and April are usually the hottest months, while November and January are the cold and dry periods of harmattan. The city receives rainfall from June to September. However in rainy years, the city records rainfall earlier than June and later than September. Being a nodal city, trading is the major occupation of the inhabitants with few agrarian practices. The city is situated in a plain area. One of the problems confronting the geography of Maiduguri urban is the non-availability of a standard boundary of the urban.

## Literature Review

### Assessment of land use change

Mayomi and Mohammed (2014) assessed the rate and pattern of urban expansion within the last one decade. Google images of 2002 and 2012 of Maiduguri urban were downloaded from Google Earth Pro, the images were then referenced, classified and reclass into four main classes of undeveloped areas, developed areas, water body and bare surfaces. The area module of the Idrisi Andes was then used to calculate the area of the classes calculated areas were then used to derive the trends, magnitudes and the annual changes of the urban during the study period, while the image calculator module of the Idrisi Andes was used to delineate the actual places where built that a total land area of 15.1km2 revealed that most of the expansion in the urban took place at the periphery of the urban notably, the University and its environs, Baga road, Bulumkutu/ Ngomari area, the land area between Biu and Damboa road as well as some areas in old Maiduguri. It was recommended that constant urban monitoring should be undertaken by the government so as to have an in rate and pattern of urban growth for proper planning and sustainable development.

Likewise, Dami, Adesina and Garba (2011) examined the trends in land use changes in the Maiduguri urban area between 1961 and 2002 and the implications of these in environmental management. These were based on the use of GIS and Remote sensing techniques. Remote sensing data that were made available for this study include black and white aerial photographs of 1961 and 1972 at scale of 1:10,000 and 1:25,000 respectively and SPOT (panchromatic) at a scale of 1:40,000 with 10m resolution. These were interpreted to generate the land use maps for 1961 and 1972, and 1990. The land use map for 1990 on which the field observation of land use changes between 1990 and 2002 was used as the base data. The four land use maps were then digitized and analyzed in a GIS environment using ILWIS 3.0 and ARCINFO 3.8. The total land area delimited in the study area within which changes were monitored over the period was 13,389 hectares. The study revealed among others that the land use changes trend in the city showed that Maiduguri grew at a fast rate. Consequently, it was concluded that such a high growth in a semi-arid environment where water supply is grossly inadequate, poses a lot of challenges in urban management. Therefore, there is a need to put in place procedures for regular acquisition of remotely sensed data that will make it possible to track the changes happening to land in the urban areas in Nigeria.

### Assessment of soil moisture change

Saha, Patil, Goyal and Rathore (2018) explained how to calculate the soil moisture index and the role of soil moisture. The objective of this study is to assess the moisture content in soil and soil moisture mapping by using remote sensing data in the selected study area. The study adopted the remote sensing technique which was based on the moisture index (SMI) which uses the data obtained from satellite sensors in its algorithm. The relationship between land surface temperature (LST) and the normalized difference vegetation index (NDVI) are based on experimental parameterization for the soil moisture index. Multispectral satellite data (visible, red and near-infrared (NIR) and thermal infrared sensor (TIRS) bands) were utilized for assessment of LST and to make vegetation indices map. Geographic Information System (GIS) and image processing software were utilized to determine the LST and NDVI. NDVI and LST are considered as essential data to obtain SMI calculation. The statistical regression analysis of NDVI and LST were shown in standardized regression coefficient NDVI values are within range −1 to 1 where negative values present loss of vegetation or contaminated vegetation, whereas positive values explain healthy and dense vegetation. LST values are the surface temperature in °C. SMI is categorized into classes from no drought to extreme drought to quantitatively assess drought. The final result is obtainable with the values ranging from 0 to 1, where values near 1 are the regions with a low amount of vegetation and surface temperature and present a higher level of soil moisture. The values near 0 are the areas with a high amount of vegetation and surface temperature and present the low level of soil moisture. The results indicate that this method can be efficiently applied to estimate soil moisture from multi-temporal Landsat images, which is valuable for monitoring agricultural drought and flood disaster assessment.

In addition, Afzal and Ragab (2019) assessed the impact of climatic change on water resources is commonly investigated at catchment scale where the measurements are taken, and water management decisions are made. For this study, the From catchment in the UK was investigated as an example of midland England. The DiCaSM model was applied using the UKCP09 future climate change scenarios. The climate projections indicate that the greatest decrease in groundwater recharge and streamflow was projected under high emission scenarios in the 2080s. Under the medium and high emission scenarios, model results revealed that the frequency and severity of drought events would be the highest. The drought indices, the Reconnaissance Drought Index, RDI, Soil Moisture Deficit, SMD and Wetness Index, WI, predicted an increase in the severity of future drought events under the high emission scenarios. Increasing broadleaf forest area would decrease streamflow and groundwater recharge. Urban expansion could increase surface runoff. Decreasing winter barley and grass and increasing oil seed rape, would increase SMD and slightly decrease river flow. Findings of this study are helpful in the planning and management of the water resources considering the impact of climate and land use changes on variability in the availability of surface and groundwater resources.

**Methodology**

The study consisted entirely of a geospatial research design. The geospatial research design is a research design that adopts remote sensing, spatial statistics, global positioning system (GPS), geographic information system (GIS), cartography and geo-visualization to acquire data (satellite imageries), analyze, process and present put and understand complex situations (ESRI, 2014).

**Types of data**

The continuous data would be adopted for this study. As categorized by Otto and Rolf (2009), the continuous data types such as land Surface Temperature (LST), satellite imagery of Band Red and Near Infrared (NIR), NDVI and LULC.

**Secondary data sources**

The secondary data sources would encompass existing official and unofficial statistics from publications including journals, articles, theses, books, conference papers and reports from renowned organizations from both paper and virtual platforms. In addition, data on LST and LULC analyses, satellite imageries would be acquired from Landsat Imagery band on ESRI Landsat.

**Technique of data analysis for LULC**

In the remote sensing procedure, the imageries were classified into several land uses, needed for the Land Use Land Cover analysis, geo-referencing of the imageries was relevant since the internal coordinate of the imageries compared to real ground coordinate is not the same. The images were geo-referenced to WGS84 UTM Zone $32^0$ North. After the images were geo-referenced, the outputs were clipped according to the boundary of the study area, using the clip tool in the QGIS platform. The clipped images for the years 2000 and 2010.

A post classification comparison of the change detection techniques was utilized in order to detect the changes within 2000 and 2010. The advantage of post classification techniques is that it bypasses the associated difficulties with the analysis of images acquired at different times. The classification of the images was carried out using ERDAS imagine pixel-based classification. An unsupervised classification was performed. The two images were classified into different land cover types. This method of classification involves the procedure of identifying pixels possessing the same spectral features automatically (Wakirwa, 2015). ERDAS imagine software was used in digitally processing and identifying the spectral clusters on the Landsat images and QGIS was used for the final embellishment of the ERDAS outputs.

The classified raster output was converted to vector (polygons) to allow for measurements to be done. The areas coverage of each of the LULC (Land Use Land Cover) classes were measured (in Square Kilometers [sqkm]) for each of the years under consideration using the export geometry tool in QGIS platform. A comparison of the land cover statistics assists in identifying the change in percentage, trend and rate of change in Maiduguri, Borno State over the periods of 2000, 2010 and 2020.

The various land-use/land-cover (LULC) types are modified and generalized into 2 classes, which include: built up areas and other land uses. This classification method was used to give a full understanding of the impact of urbanization growth on other land uses.

**Technique for Normalized Difference Water Index**

The Normalized water Index is used to monitor the changes in water content of water or soil using green and NIR wavelength. It is defined by McFeeters (1996):

NDWI= (Xgreen-Xnir)/ (Xgreen+Xnir).
The NDWI values lie between -1 to 1, where water bodies lie within 0.5, vegetation has smaller values and built up lies between 0 to 0.5.

**Results and Discussion**

Land use scenario of 2000 and Normalized Difference Water Index of 2000

The assessment of urbanization impact on drought facilitated the examination of the changes in the land use of the study area. The following tables and figures displayed the land use change scenarios and water index change scenario of Maiduguri between the period of 2000, 2010 and 2019.

Table 1 depicts the land use land cover scenario of Maiduguri in 2000. Based on the table it was thus ascertained that built-up area covered an estimate of 76.6 sq km (13.9 per cent) of the total land cover area of land use scenario of 2000, while other land uses covered a total of 473.4 sq km (86.07 per cent).

**Note**: The development of built up areas is one of the measures of urbanization. Hence in assessing the growth or expansion of urban land use, it was thus relevant for the research to adopt a two-class system where built up area is separated from other land use classes and the remaining land use classes are grouped in one class. This will provide a vivid picture of the growth of urbanization through the expansion of built up areas over other land uses.

Table 2 shows the land use change scenario of 2010. This is 10 years apart from the first land use scenario in Table 1.10 years is a considerable amount of time for change given all things considered. Hence, the land use scenario shows that built up area increased to 102.3 sq km (18.6 percent) from its previous land size, while other land use shrunk at 447.7 sq km (81.4 percent).

Lastly, Table 3 shows the land use scenario of Maiduguri in 2019. The land use shows that built up area further increased to 122.3 sq km (22.23 per cent) while other land uses increased to 427.7 per cent (77.76 per cent).

Figure 1, 3 and 5 provide further evidence for the land use change between built up area increase (coloured yellow) and other land use area decrease (coloured brown). This provides a context on urbanization in Maiduguri.

The next assessment carried out in order to achieve the aim of the study, was the assessment on the water index of the study area. To assess the water index of the study area, the normalized difference water index was executed. Using the NDWI, a map of water stressed regions. Based on the figures, regions that are blue show areas with less water stress, while deep white shows regions with high water stress. It was noted that the regions with high water stress are within the urbanized area hence providing evidence that increase in urbanization results in increase in water stress.

To further support the finds of the NDWI and LULC, a raster-based correlation analysis was executed, which is displayed in table 4. The analysis showed a correlation result of $p(0.0489) < 0.05$. *

**Table 1:** Land Use Scenario of Maiduguri 2000

| Land Use | Area (sqkm) | Percent |
|---|---|---|
| Built Up Area | 76.6 | 13.92727 |
| Other Land use | 473.4 | 86.07273 |
| Total | 550 | 100 |

**Source:** Authors' analysis, 2020

**Table 2:** Land use scenario of Maiduguri 2010

| Land Use | Area (sqkm) | Percent |
|---|---|---|
| Built Up Area | 102.3 | 18.6 |
| Other Land use | 447.7 | 81.4 |
| Total | 550 | 100 |

Source: Authors' analysis, 2020

**Table 3:** Land use scenario of Maiduguri 2019

| Land Use | Area (sqkm) | Percent |
|---|---|---|
| Built Up Area | 122.3 | 22.23636 |
| Other Land use | 427.7 | 77.76364 |
| Total | 550 | 100 |

**Source:** Authors' analysis, 2020

**Land use scenario and Normalized Difference Water Index 2000**


**Figure 1:** LULC Maiduguri, 2000

**Source:** Authors' analysis, 2020

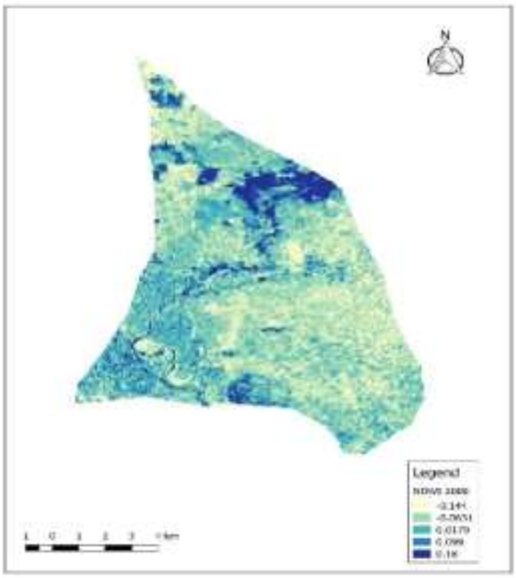


**Figure 2:** NDWI Maiduguri, 2000

**Source:** Authors' analysis, 2020

**Land use scenario and Normalized Difference Water Index 2010**

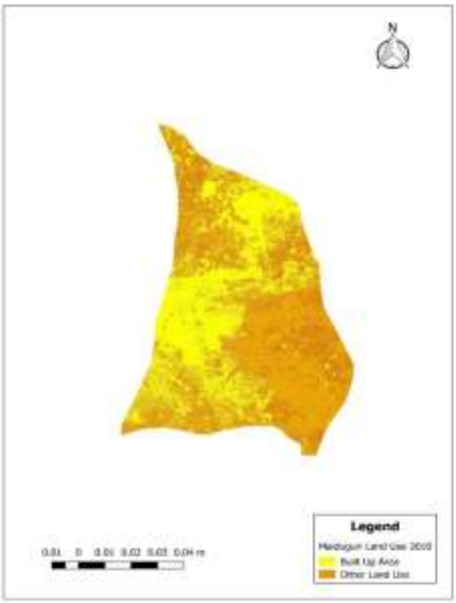



**Figure 1:** LULC Maiduguri, 2010

**Source:** Authors' analysis, 2020

**Figure 2:** NDWI Maiduguri, 2010

**Source:** Authors' analysis, 2020

**Land use scenario and Normalized Difference Water Index 2019**

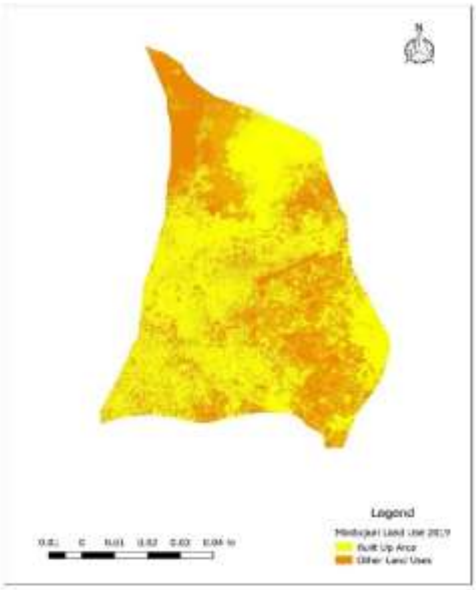



**Figure 1:** LULC Maiduguri, 2019

**Source:** Authors' analysis, 2020

**Figure 2:** NDWI Maiduguri, 2019

**Source:** Authors' analysis, 2020

**Table 4:** Spatial Correlation Result between Land Use and NDWI

| | Land Use | NDWI |
|---|---|---|
| Land Use | 1 | 0.0489 |
| NDWI | 0.0489 | 1 |

## Conclusion and Recommendation

It was thus concluded that the development of urbanization further exacerbated the drought situation in Maiduguri. Hence, the following recommendations were put forth to mitigate further impacts.

i. It is important that the land use planning department of Maiduguri should update their policies on urbanization and urban growth

ii. The land use plan department must ensure that developers must follow the land use planning guidelines and regulate urban development

iii. Residents should reduce the rate of using concrete in developing their properties. That, as concretes are usually impervious to infiltration of water. Hence, green spaces should be encourage so as to allow infiltration of water

## References

Zhan Z., Qin Q. and Wang X. (2004). The Application of LST/NDVI Index for Monitoring Land Surface Moisture in Semiarid Area. Geoscience and Remote Sensing, IGARSS ‘04. Proceedings 2004 IEEE International, 3:1551 – 1555

Wang L. and Qu J. (2009). Satellite remote sensing applications for surface soil moisture monitoring: A review. Front. Earth Sci. China 3: 237 – 247. doi:10.1007/s11707-009-0023-7

Parida B. R., Collado W. B., Borah R., Hazarika M. K., and Samarakoon L. (2008). Detecting Drought-Prone Areas of Rice Agriculture Using a MODIS-Derived Soil Moisture Index. GIScience & Remote Sensing, 45, No. 1, p. 109 – 129. doi: 10.2747/1548-1603.45.1.109

Zeng Y., Feng Z. and Xiang N. (2004). Assessment of soil moisture using Landsat ETM+ temperature/vegetation index in a semiarid environment. Geoscience and Remote Sensing Symposium, IGARSS '04. Proceedings. 2004 IEEE International, Volume: 6, 4306 – 4309. doi: 10.1109/IGARSS.2004.1370089.

Otto H. & Rolf, A. (2009). Principles of Geographic Information Systems, an introductory textbook. The International Institute for Geo-Information Science and Earth Observation, Fourth Edition, ITC, pp. 69-72.

World Gazetteer (2009).Retrieved 6th April 2015

Epstein, J., Payne, K., & Kramer, E. (2002). “Techniques for mapping suburban sprawl”. Photogrammetric Engineering & Remote Sensing, 63 (9), 913–918

Jata, M.K., Khareb ,D., Gargc, P.K. & Shankard, A. (2008). “Remote sensing and GIS-based assessment of urbanisation and degradation of watershed health: A case study”. Urban Water Journal Vol. 00 (0); PP1–19

Kawka Rupert (2002) From Bulamari to Metropolitan Maiduguri: Interdisciplinary of the Capital of Borno State. Rudiger Koppe Verlag Koln, Germany.

National Population Census (2006)

Mayomi, I. & Mohammed, J.A. (2014). "A decade of assessments of Maiduguri Urban Expansion (2002-2012) : A Geospatial Approach". Global Journal of Geography, Geo Management Vol 14(2)

Szilassi, P. (2020). "Assessment of the connection between drought and agricultural land use changes in Hungary". A conference University of of Szeged, Department of Physical Geography and Geoinformatics, Hungary.

# AN ASSESSMENT OF FARMERS' PERCEPTIONS AND ADAPTATION TO CLIMATE CHANGE IN KALGO LOCAL GOVERNMENT AREA, KEBBI STATE, NIGERIA.

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**Abstract**

*The study was carried out to assess farmers' perceptions and adaptation to climate change in Kalgo Local Government Area, Kebbi state, Nigeria. The objectives were to examine farmer's perception of climate change in the study area, examine farmers' socio-demographic characteristics, identify the influence of climate change on farming activities and examine strategies adopted by farmers to cope with the effects of climate change. A multistage method of data collection was used to obtain data for the study through questionnaire administration. Overall, a total of 160 questionnaires were administered to respondents. Results obtained were summarized and presented in simple percentages and charts. A four point Likert scale was used to analyze respondents' perceptions of the severity of climate change, while respondents' coping strategy was calculated using the Rank Scoring method. The results show that farming in the study area is male dominated with only about 6% females. Majority of the respondents are between the active age groups of 21- 50 years, married and characterized by large household sizes. Respondents' ranked late onset of rains first with a mean score of 3.75, early cessation of rains ranked second with a mean score of 3.54 while poor crop yields ranked third with a mean score of 3.37. Major coping strategies include the use of improved varieties of seeds (44%) and engaging in other sources of income (24%). Recommendations include adoption of policies and strategies which promote rural education, credit access and improved agricultural extension services.*

**Keywords:** Adaptation, climate change, farmers, result.

## Introduction

Climate change has been and remains a topical issue because of the impact it has on man and the environment. Some of the adverse effects of climate change include warmer/cooler temperatures, excessive rainfall and flooding, erosion, drought, etc. The effects of climate change are particularly felt in the agricultural production sector because rural livelihoods are strongly linked to agriculture for food and income (Ifeanyi-Obi *et al.*, 2012; Yakubu *et al*., 2020). For sub-Saharan Africa, climate change poses a serious threat to the sustainability of food production among small holder rural farmers, resulting in food insecurity. This is because climate change affects productivity with several negative socio-economic impacts (Yakubu *et al*., 2020).

To mitigate the impact of climate change on agriculture, several adaptation strategies are being adopted by farmers all over the world. The Intergovernmental Panel on Climate Change (IPCC) defines human adaptation as the process of adjusting to actual or expected climate variability and its effects to moderate harm or exploit beneficial opportunities (Atube *et al*., 2021). Adaptation to climate change involves changes in agricultural management practices in response to local climate change conditions (Ifeanyi-Obi *et al.*, 2012; Atube *et al*., 2021). This adaptation to location-specific impacts of climate change is necessary to ensure livelihoods of agrarian economies.

However, the capacity to adapt to climate change is influenced by socio-economic and environmental factors (Atube *et al*., 2021). For example, low levels of education and extreme poverty have been observed to be major impediments in adopting improved technologies and sustainable soil management practices in the Sub-Saharan region (Yakubu *et al*., 2020; Atube *et al*., 2021). Specifically, the objectives of this study were to examine farmer's perception of climate change in the study area, characterize farmers' socio-demographic characteristics, identify the influence of climate change on farming activities and examine strategies adopted by farmers to cope with the effects of climate change.

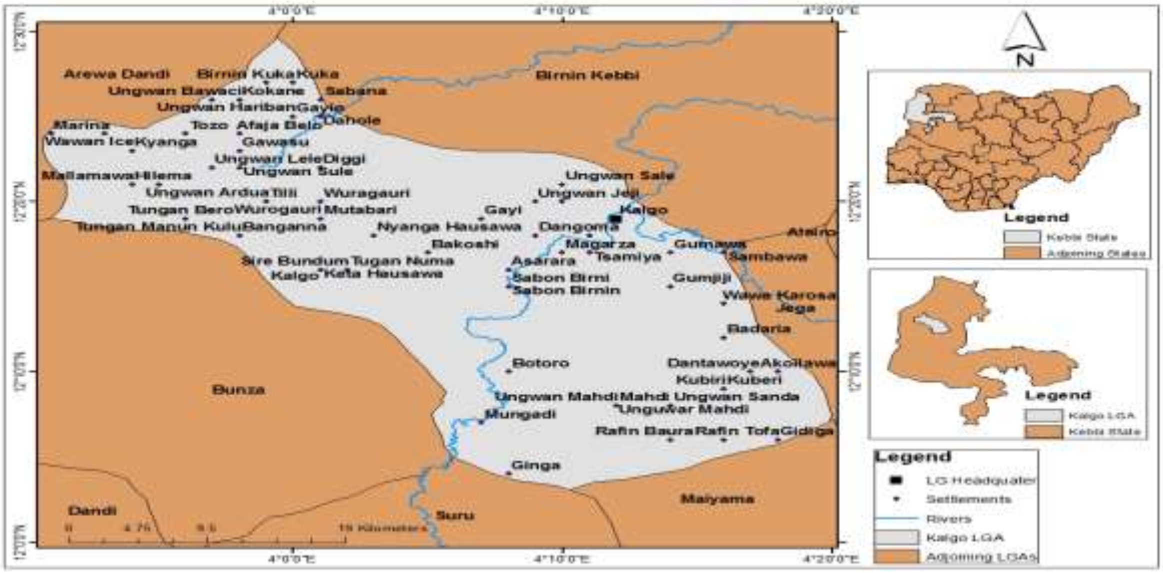


**Fig. 1:** Geographical Location of Study Area

## Materials and Methods

### Study Area

Kebbi state is located between latitude $10^{\circ}2^{'}.90^{''}$N to $13^{\circ}15^{'}.00^{''}$N and longitude $3^{\circ}26^{'}.80^{''}$E and $6^{\circ}55^{'}50^{''}$E (Fig.1). The climate is dominated by two air masses, Tropical Maritime and Tropical Continental which determine the two dominant seasons of wet and dry. Rainfall is highly seasonal and controlled by movement of Inter-Tropical Front. Average temperatures range from 21°C to 40 °C (70 to 104 °F) between April and June. Geologically, Kebbi State is dominated by two formations; Precambrian Basement Complex in the South and South East and young sedimentary rocks in the north.

The natural vegetation of the study area is the Sudan Savannah and consists of open woodland with scattered trees such as a*cacia aibida* (*gawo*), *Parkia Clappertoniana*, *Porassus* and drum palms (*goriba*). Major groups of soils in the study area are the upland and fadama soils. While the upland soils are sandy and well drained, the fadama soils are generally clayey and hydromorphic. The predominant economic activity in the study area is rain fed and irrigation farming along *fadamas* and river basins. Major crops produced include rice, millet and sorghum.

### Data Collection and Analysis

A multistage method of data collection was used to obtain data for the study using structured questionnaires in five wards. The lists of farmers in the selected villages were collected through the assistance of village heads and field survey (Table 1). A simple random sampling method was used to select respondents from a total of 1245 farmers in the five villages. 13% of the sample frame (1245) was used as the sample size. Out of the 162 questionnaires administered, 160 were returned and used for the study.

**Table 1:** Distribution of Farmers in the Study Area

| Villages | Sample Frame | Sample Size (13%) |
|---|---|---|
| Kalgo | 287 | 37.3 |
| Unguwar jeji | 264 | 34.3 |
| Gayi | 247 | 32.1 |
| Magarza | 219 | 28.5 |
| Dangoma | 228 | 29.6 |
| Total | 1245 | 161.9 |

**Source:** Field Survey, 2019.

Data collected was summarized and presented in percentages, tables and charts. A four point Likert scale (1 = mild, 2= moderate, 3= severe, 4= very severe) method was used to analyze respondents perception of the severity of climate change, while respondents' coping strategy index was calculated using the Rank Scoring method. A base score of 2.0 was taken below which a severity and strategy index was considered not serious.

## Results and Discussion

### Socio-demographic characteristics of the respondents

The statistics of the socio-demographic characteristics of the respondents are presented in Table 2. The results show that 34.4% of the respondents are in the 31-40 years age bracket. This indicates that majority of the respondents are within the active age group. The result indicates that agriculture is male dominated as only about 6% of the respondents were females. This may be due to the cultural and religious practices such as female sequestration or purdah practiced by the people of the study area. This is supported by studies (Pandey *et al*., 2010; Aminu and Bamidele, 2015) which have shown that religious practices and property rights limit female participation in agricultural production. Similarly, the result also shows that 83.6% of the respondents are married. Igboji *et al*., (2015) observed that the high percentage of married people engaged in agricultural activities reflects the need for more resources and food to take care of their families. Household sizes are generally large with about 41.3% of the respondents having between 6-10 household members. The generally large household sizes may be due cultural and religious factors such as early marriage and polygamy practiced in the study area. Large household sizes also serve as cheap sources of labour on the farmlands (Aminu and Bamidele, 2105; Igboji *et al.,* 2015). The analysis of the education level of the respondents shows that 42.5% of the respondents have Qur'anic education.

**Table 2:** Socio-demographic characteristics of the respondents

| Characteristics | Frequency (n) | Percentages (%) |
|---|---|---|
| **Age group** | | |
| ≤ 20years | 6 | 3.8 |
| 21-30years | 40 | 25.0 |
| 31-40years | 55 | 34.4 |
| 41-50years | 35 | 21.9 |
| 51 and above | 24 | 15.0 |
| **Gender** | | |
| Male | 151 | 94.4 |
| Female | 9 | 5.6 |
| **Marital status** | | |
| Single | 26 | 16.3 |
| Married | 134 | 83.7 |
| **Household Size** | | |
| 1-5 | 44 | 27.5 |

| | | |
|---|---|---|
| 6-10 | 66 | 41.3 |
| 11-15 | 29 | 18.1 |
| 16 and above | 21 | 13.1 |
| **Level of Education** | | |
| Qur'anic Education | 68 | 42.5 |
| Adult Education | 45 | 28.1 |
| Primary | 16 | 10.0 |
| Secondary | 24 | 15.0 |
| Tertiary | 7 | 4.4 |
| **Membership of Agric Asso** | | |
| Yes | 64 | 40 |
| No | 96 | 60 |
| **Sources of Information** | | |
| Radio | 88 | 55.0 |
| Extension services | 13 | 8.1 |
| Farmer/Community based organization | 36 | 22.5 |
| All of the above | 23 | 14.4 |
| **Land ownership** | | |
| Owned | 21 | 13.1 |
| Rented | 139 | 86.9 |
| **Length of Farming** | | |
| <5 Years | 25 | 15.6 |
| 6-10 | 21 | 13.1 |
| 11-15 | 35 | 21.9 |
| 16-20 | 35 | 21.9 |
| >20 Years | 44 | 27.5 |

Low levels of formal education among farmers may limit knowledge and adoption of climate change mitigating strategies as similarly observed by Atube *et al*., (2021). The results also show that only 40% of the respondents are members of farmers association. The farmers' association is very important to the famers because it provides access to information and credit facilities. Major sources of information on climate change are radio (55%) and farmers' association (22.5%). The result shows that 87% of the respondents rent their farmlands. This may have implications for adoption of climate change mitigating strategies because productivity has been found to be higher over owned farmlands than rented farmlands (Aminu and Bamidele, 2015; Yakubu *et al*, 2020). The result shows that 27.5% of the respondents have been engaged in farming activities for over 20years. Although longer years of farming experience might enhance farmers' production skills (Iheke and Chikezie, 2016), ageing and longer years of farming experience may make farmers resistant and hardened to adopting new innovations and technologies (Igboji *et al*., 2015; Oladimeji *et al.,* 2020).

**Farmers Perceptions of Climate Change**

Farmers' awareness of climate change, perceptions of the effect and severity of climate change are presented in Table 3.

**Table 3:** Farmers Perceptions of Climate Change

| Farmers Perceptions of Climate Change | Frequency (n) | Percentage (%) |
|---|---|---|
| Climate change awareness | | |
| Aware | 149 | 93.1 |
| Not aware | 11 | 6.9 |
| Effect of Climate Change on Agricultural Production | | |
| Late onset of rains which affects planting dates | 54 | 33.8 |
| Late cessation of rains which destroys crop yields | 28 | 17.5 |
| Loss of soil fertility through erosion and flooding | 16 | 10.0 |
| Increased cost of farm input | 27 | 16.9 |
| Poor crop yields | 35 | 21.8 |

The results show that 93% of the respondents are aware of climate change, while major effects of climate change on agricultural production identified by respondents are late onset of rains which affects planting dates (34%), poor crop yield (22%) and late cessation of rains which destroy crop yields. Farmers' perceptions of the severity of the effect of climate change on agricultural production are presented in Table 4.

**Table 4:** Severity of Climate Change on Production

| S/N | Perceived Effects | =1 Mild | =2 Moderate | =3 Severe | =4 Very severe | $\bar{x}$ Score |
|---|---|---|---|---|---|---|
| 1. | Late onset of rains | 3 | 4 | 23 | 130 | 3.75 |
| 2. | Late cessation of rains | 5 | 38 | 23 | 94 | 3.29 |
| 3. | Early cessation of rains | 11 | 15 | 11 | 123 | 3.54 |
| 4. | Poor yield of crops | 3 | 18 | 56 | 83 | 3.37 |
| 5 | Excessive heat | 2 | 21 | 55 | 82 | 3.36 |
| 6 | Excessive rain | 7 | 43 | 61 | 49 | 2.95 |
| 7 | Desert encroachment | 40 | 60 | 27 | 33 | 2.33 |

Source: fieldwork, 2019.

Late onset of rains ranked highest with a mean score of 3.75, early cessation of rains ranked second with a mean score of 3.54, while poor crop yields ranked third with a mean score of 3.37. The result shows that all perceived effects had severity index more than the base score of 2.0. This suggests that farmers are generally aware of climate change and understand its implication on agricultural production in the study area.

## Agricultural Production

The statistics on farming practices of respondents and most used agricultural production systems are presented in Table 5.

**Table 5:** Agricultural Production

| Agricultural Production | Frequency (n) | Percentage (%) |
|---|---|---|
| Farming Practices of the Respondents | | |
| Mixed farming | 78 | 48.8 |
| Mono cropping | 60 | 37.5 |
| Poultry | 9 | 5.6 |
| Livestock production | 13 | 8.1 |
| Most Used System of Agricultural Production | | |
| Upland farming | 82 | 51.3 |
| Lowland farming | 21 | 13.1 |
| Both upland and lowland farming | 57 | 35.6 |

| | | |
|---|---|---|
| Choice of Agricultural Production influenced by Climate Change | | |
| Yes | 120 | 75 |
| No | 40 | 25 |
| Production Constraints | | |
| Unpredictable temperature and rainfall regimes which affect planting and harvesting | 56 | 35.0 |
| Extinction of species | 2 | 1.3 |
| Poor yields | 31 | 19.3 |
| Erosion | 15 | 9.4 |
| Water logging | 14 | 8.7 |
| Obsolete technology | 6 | 3.8 |
| Bad roads and high cost of transportation | 10 | 6.2 |
| Lack of credit facilities | 26 | 16.3 |

As shown in Table 5, mixed farming is the dominant farming practice at 48.8%. The result from the table indicates that upland farming (51%) is a major system of agricultural production in the study area while 35.6% of the respondents used both of the systems. The result from the table also shows that 75% of the respondents in the study area agree that climate change is responsible for the agricultural system they practice, while 25% do not agree that climate change influences their choice of agricultural production.

The major constraints associated with agricultural production in the study area are unpredictable temperatures and rainfall regimes which affect planting dates and harvesting (35% ), poor yield (19.4% ), lack of credit facilities (16.3%), erosion (9.4%), water logging (8.8%), bad roads and high cost of transportation (6.3%), obsolete technology (3.8%) and extinction of species (1.3%).

### Coping Strategies Adopted Against the Effects of Climate Change

The coping strategies adopted by the respondents against the effects of climate change are presented in Table 7.

**Table 7:** Coping Strategies Adopted

| Coping Strategy | Frequency | Percentage |
|---|---|---|
| Improved varieties of seeds | 71 | 44.4 |
| Improved varieties of animal species | 4 | 2.5 |
| Reduce farm size | 16 | 10.0 |
| Engage in other sources of income | 38 | 23.8 |
| Improved soil conservation practices | 31 | 19.3 |
| Total | 160 | 100.0 |

**Source:** Fieldwork, 2019.

The results show that major coping strategies adopted by farmers in the study area are improved varieties of seed (44.4%), improved varieties of animal species (2.5%), reduce farm size (10%), engaged in other source of income (23.8%) and improved soil conservation practices (19.4%). The coping strategies have implications for sustainable agricultural production in the study area. For example, reducing farm size as a measure of countering the effects of climate change affects farmers' net returns (Owosu, *et al.*, 2017; Oladimeji *et al.*, 2020) and this decline in overall production raises crop prices.

### Conclusion and Recommendations

This study aimed at an assessment of farmers' perceptions of climate change and coping strategies adopted in Kalgo Local Government Area. The study affirmed that respondents were generally aware of climate change and its implication for sustainable production. Although low levels of western education may have implications for adoption of new technology, the findings indicate that farmers are generally aware of climate change and the effects of climate change which include late onset of rains which affects planting dates (33.7%), poor crop yield (21.9%) and late cessation of rains which destroy crop yields (17.5%). The study therefore, recommends adoption of policies and strategies which promote rural education, credit access and improved agricultural extension services.

## References

Aminu, Z**.** and Bamidele, C. (2015): An Assessment of Farmers' Perceptions of Soil Degradation and Coping Strategies Adopted in Lapai Area, Niger State, Nigeria: Proceedings of the International Conference of the Nigerian Meteorological Society (NMetS), 23rd – 26th November, 2015).

Ifeanyi-obi, C.C., Etuk, U. R., and Jike-Wai, O. (2012) Climate Change, Effects and Adaptation Strategies, Implications for Agricultural Extension System in Nigeria. *Greener Journal of Agricultural Sciences*. 2 (2), 53-60.

Igboji, C., Anozie, R.O and Nneji, C.P (2015). Analysis of Socio-Economic Factors and Profitability of Rice Production among Small Scale Farmers in Ebonyi State. *IOSR Journal of Agriculture and Veterinary Science*. 8 (2), 20-27.

Iheke, O. R. and Chikezie, H. (2016). Effects of Tenancy Status on the Productivity of Rice Farmers in Bende Local Government Area of Abia State, Nigeria. *Management, Economic Engineering in Agriculture and Rural Development*. 16 (3), 139-144.

Oladimeji, Y.U, Aminu, R and Aminu, Z (2020). Effect of Transaction Costs on Rice Production Output and Fuel Hike Nexus in Kaduna State, Nigeria. *Agricultural Economics and Extension Research Studies (AGEERS)*. 8 (1), 39-49.

Owosu, B.A, Yankson, W.K and Frimpong (2017). Smallholder Farmers' Knowledge of Mobile Telephone Use: Gender Perspectives and Implications for Agricultural Market Development. *Progress in Development Studies*. 18 (1), 36-51.

Pandey, S., Byerlee, D., Dawe, D., Dobermann, A., Mohanty, S., Rozelle, S. and Hardy, B. (2010). Rice in the Global Economy: Strategic Research and Policy Issues for Food Security (Eds). IRRI. 477 Pp.

Atube, F, Malinga, G.M, Nyeko, M, Okello, D.M, Alarakol, S.P and Okello-Uma, I (2021). Determinants of smallholder farmers' adaptation Strategies to the Effects of Climate Change: Evidence from Northern Uganda. *Agriculture & Food Security*. 10 (6), 1-14.

Yakubu, D.H, Akpoko, J.G, Akinola, M.O and Abdulsalam, Z (2020). Climate Change Adaptation Practices and Rice Farmers' Level of Living in North-West Nigeria. *Journal of Agricultural Extension*. 24 (3), 49-60.

# VICTIMS' PERCEPTION OF DRIVERS AND PROBLEMS OF FLASH FLOODS IN UYO, AKWA IBOM STATE

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**Abstract**

*Managing the risk of flooding in cities is a major environmental challenge world- wide. In Uyo, the capital of Akwa Ibom State, the problem is aggravated by both natural and anthropogenic factors which predispose low terrains to flooding. Information on perception of residents about flood hazards through structured questionnaire interviews of 1101 respondents viz; 68.69% in the upper;13.1% and 18.3% in the middle and lower $km^2$ IBB sub catchment were analyzed using descriptive statistics and ANOVA was employed to determine if the nature of the causes of floods as perceived by respondents vary from those directly impacted in the upper IBB sub-catchment and respondents located along the receiving Anyang River in the middle and lower segments. It became quite evident that 29.7% of the respondents attributed the key factor of the flood menace to ill aligned drains followed by 23.0% who perceived high intensity of rainstorms as being critical while 15.7% of the respondents considered blockage of drains/poor waste management to be the major factor of flooding in the area. Similarly, 11.1% of the respondents attributed flash floods in the area to low relief/topography, while another 10.0% linked it to unplanned urbanization. As would be expected flood risk assessment and concrete roads were perceived as inconsequential (7.0% and 3.7%respectively). This study has also demonstrated that the most prevalent disease in the catchment area is malaria which accounts for 41.3%; followed by typhoid with 38.7%; diarrhea 12.3% and 3.4% for cholera. The high frequency of malaria in the area is occasioned by stagnant water and ponds present in the flooded segment of IBB Avenue sub-catchment. It is recommended that findings of this study be used by policy makers to formulate policies that will be geared towards sustainable flash flood control/ management.*

## Introduction

The hydro-meteorological disasters around the globe are on the rise {Birch, et al 2011; Ding et al, 2013; Mumuni, 2013; Tempest et al, 2017; Udosen, 2017; Okaka and Odhiambo, 2019). Floods are also a recurrent phenomenon in major cities in Nigeria. for instance, urban floods of 2012 were most severe in terms of financial loss and area affected (Salami, et al,.2017}. Researchers expect that in the coming decades, the floods would be more frequent and would cause more damages than the past, if proper measures for preparedness and mitigation are not taken. Urban floods menace in the undulating terrains of Uyo has assumed an endemic proportion in several depressions where storm drains, roadside gutters and floodwater from buildings are channeled into (as in the IBB Avenue) and the burden is increasing at astronomical rate. [Newmap, 2017}]. These damages will have long-term repercussions for governance, communities and the natural environment.

As revealed by satellite image of IBB Avenue and environs (see Fig. 3 in the appendix), Idongesit Nkanga Secretariat Complex, Women Development Centre, Ibom Metropolitan Polytechnic, the Champion Breweries, Plastocrown factory and other buildings were found around IBB Avenue flash flood prone area. Also, a preliminary survey revealed that IBB Avenue flood site became noticeable around 2002 (as confirmed by residents of Atan Offot The Atan Offot community is now essentially a sprawling section of Uyo Urban. With sustained in-migration, the community is presently in transition with the forestlands and farmlands on Atan sub-catchment undergoing rapid land conversions. This pattern was observable in both Effiat and Aka communities in Uyo LGA as well as the neighbouring communities in Ibesikpo Asutan LGA  Hence studies on the perception of flood risk and health impact of exposure to flooding in this flood prone settlement is very important

In this regard, this paper focuses on public perception of drivers and associated health implications of flash floods in a flood prone terrain within Uyo urban.

## Study Area

The study area is Uyo, the Capital of Akwa Ibom State and is located on latitudes $4^o55^o02^1$N and $5^o02^1$N and by longitudes $7^o33^1$ and $7^o41^1$E (Fig.1). It is underlain by the loose, unconsolidated Coastal Plains Sands. Uyo enjoys equatorial climate with a mean temperature of $28^0$C and narrow range in temperature of 26-$32^0$C. Rainfall ranges from 1599.6mm in 1979 to 3855.7 mm in 2012, with an average annual of 2566.0mm recorded between 1977 and 2020 i.e 44 years (updated from Udosen, 2017). The population of the town was 309,543 (NPC, 2006). The soil is coarse-textured in the undulating (38-82m a.s.l. lowland disturbed rainforest with shallow depression around IBB Avenue, and Mbiabong area along Oron road (which are prone to flooding)

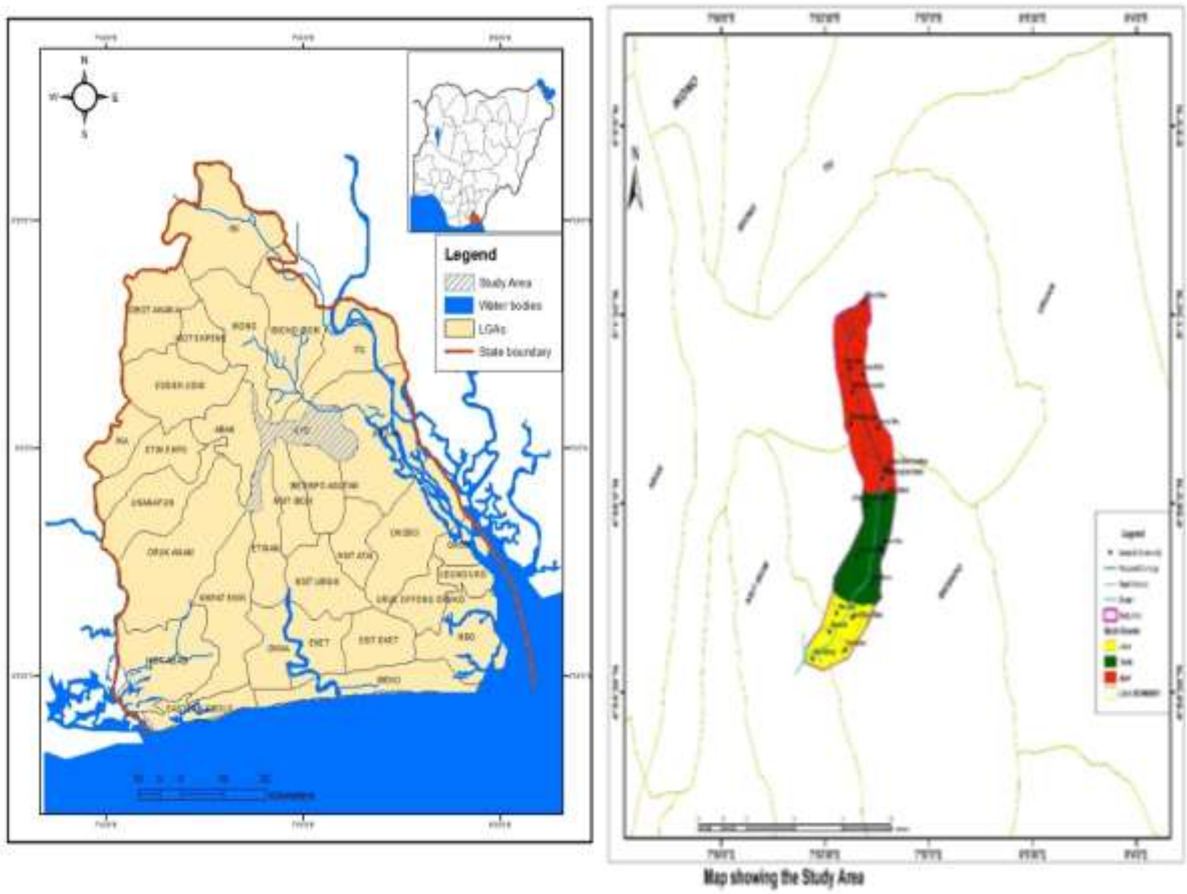


**Fig. 1:** Location of the study area

Among the land conversions are new houses built at Abak road Housing estate, Abasima Housing Estate, Idongesit Nkanga Secretariat Complex and other built-up areas with dense roofed infrastructure and paved landscapes. Also, Atiku Abubakar road, Abak road-towards mechanic village, several other streets/roadside drains discharge urban storm water into the IBB Avenue flood site.

**Methodology**

**Sample Size and Sampling Frame**

The population size of the respondents was sourced from projected population figures based on NPC (1991) census. These figures constitute the sample frame, while the sample size is 2.5% of the working population figures. Table 1 below show sample size distribution and return rates of enumeration instruments.

**Table 1.0:** Sample Frame and Sample Size Distribution

| Name of Community | Sample Frame | Sample Size (%) | No. of Questionnaire Distributed | No. of Questionnaire Returned | %age Return Rate | No. Valid Questionnaire | %age Valid Questionnaires |
|---|---|---|---|---|---|---|---|
| Atan community | 5588 | 2.5 | 139 | 133 | 95.7 | 128 | 92.1 |
| Aka community | 5547 | 2.5 | 138 | 136 | 98.6 | 131 | 94.9 |
| Effiat community | 6895 | 2.5 | 172 | 170 | 98.8 | 154 | 89.5 |
| Mbierebe | 3918 | 2.5 | 98 | 96 | 93.8 | 95 | 96.9 |
| Nung Oku | 3907 | 2.5 | 97 | 95 | 97.9 | 92 | 94.8 |
| Ikot Akpan Abia | 2105 | 2.5 | 53 | 52 | 98.1 | 51 | 96.2 |
| Ikot Oduot | 1470 | 2.5 | 36 | 35 | 97.2 | 33 | 91.7 |
| Ebere Otu | 802 | 2.5 | 20 | 18 | 90.0 | 17 | 85.0 |
| Mbikpong Ikot Edim | 2388 | 2.5 | 60 | 57 | 95.0 | 55 | 91.7 |
| Ikot Osom | 993 | 2.5 | 25 | 24 | 96.0 | 22 | 88.0 |
| Ikot Udo Ekop | 1130 | 2.5 | 28 | 25 | 89.3 | 24 | 85.7 |
| Ikot Ikere | 1355 | 2.5 | 53 | 51 | 96.2 | 48 | 90.6 |
| Mbiakot | 731 | 2.5 | 18 | 17 | 94.4 | 16 | 88.9 |
| Afaha Etok | 2078 | 2.5 | 52 | 50 | 96.2 | 49 | 94.2 |
| Ikot Obio Edim | 305 | 2.5 | 8 | 8 | 100.0 | 7 | 87.5 |
| Obo Akai | 3203 | 2.5 | 80 | 76 | 95.0 | 75 | 93.8 |
| Ikot Obok | 1970 | 2.5 | 49 | 47 | 95.9 | 45 | 91.8 |
| Obo Ntong | 2510 | 2.5 | 63 | 61 | 96.8 | 59 | 93.7 |
| Total | 46,895 | - | 1189 | 1151 | Ẍ= 95.8 | 1101 | Ẍ= 91.5 |

**Source:** Extrapolated from NPC, (1991)

A sample size of 2.5% was extracted from the sample frame of 46,895, giving a total of 1189 questionnaires which were distributed. The return rate is as follows: whereas 1151 were sampled, 1101 were returned as valid questionnaires, which translate to between 85.0% at Ebere Otu community and 96.9% at Obo Ntong with a mean of 91.5% as valid questionnaires.

**Results and Discussion**

Analysis of data shows that, 68.6% of the respondents in the IBB sub-catchment are found in the upper watershed in the various communities found in the watershed. The middle segment of the watershed accounts for 13.1% of the respondents, while the lower watershed accounts for 18.3% Data set for the composition of household heads in IBB catchment depicts that 43.9% of the household heads fall within the age range of 40-59 years followed by 34.1% for the range of 20-39 years. 60-79 years range make up 19.1% while 80 years and above constitute 2.9%. In a nutshell, about 78.0% of the household heads in the sub-catchment are relatively within the active age population structure while 22.0% are aged. Comparatively, there are more households in the upper watershed. This is occasioned by the fact that the upper watershed is an urban centre. The age distribution of household members shows that 43.2% of household members fall within 15-44 years of age, 25.6% of the household members falls within 0-14 years of age, 17.8% of the household members fall within the age bracket of 45-64 while only 11.1% are within the age bracket of 65. The sex distribution of household members across the entire watershed shows that 53.4% of the household members are males while about 46.6% are females. The distribution of educational levels of the household heads in the catchment shows that 38.5% of the household heads have attended secondary school. About 30.1% have completed primary education, 21.6% have attended tertiary institution while only 9.8% are functionally literate

**Perception of Factors of flooding in IBB catchment**

Table 2 unveils that 29.7% of the respondents attributed the key factor of the flood menace to ill aligned drains closely followed by 23.0% for high intensity of rainstorms. Consequently, 15.7% of the respondents considered blockage of drains/poor waste management to be the major factor of flooding in the area. 11.1% of the respondents attributed it to relief/topography, 10.0% linked it to unplanned urbanization in the area while 7.0% and 3.7% attributed it to poor flood risk assessment and concrete roads respectively. This is shown in Fig.2.

**Table 2:** Perceived Factors of flooding in IBB catchment

| Factors of Flooding | | Upper | Middle | Lower | Total | Ranking |
|---|---|---|---|---|---|---|
| Ill aligned drains, poor /uncoordinated storm drains | Frequency | 630 | 86 | 112 | 828 | |
| | Percent (%) | 31.9% | 26.4% | 22.8% | 29.7% | 1 |
| High intensity rainstorms | Frequency | 440 | 93 | 107 | 640 | |
| | Percent (%) | 2.2% | 28.5% | 21.8% | 23.0% | 2 |
| Blockage of drains & poor waste mgt. | Frequency | 295 | 64 | 79 | 438 | |
| | Percent (%) | 15.1% | 19.6% | 16.1% | 15.7% | 3 |
| Relief/Topography | Frequency | 178 | 32 | 99 | 309 | |
| | Percent (%) | 9.0% | 9.8% | 20.2% | 11.1% | 4 |
| Concrete road median/ Low infiltration | Frequency | 91 | 5 | 7 | 103 | |
| | Percent (%) | 6.3 | 1.3 | 1.4 | 3.7 | 7 |
| Poor flood risk Assessment | Frequency | 141 | 19 | 34 | 194 | |
| | Percent (%) | 7.1% | 5.8% | 6.9% | 7.0% | 6 |
| Unplanned urbanization | Frequency | 199 | 27 | 53 | 279 | |
| | Percent (%) | 10.1% | 8.3% | 10.8% | 10.0% | 5 |
| Total | | 1974<br>100.0% | 326<br>100.0% | 491<br>100.0% | 2791<br>100.0% | |

**Source:** Analyzed from field survey, (2020)

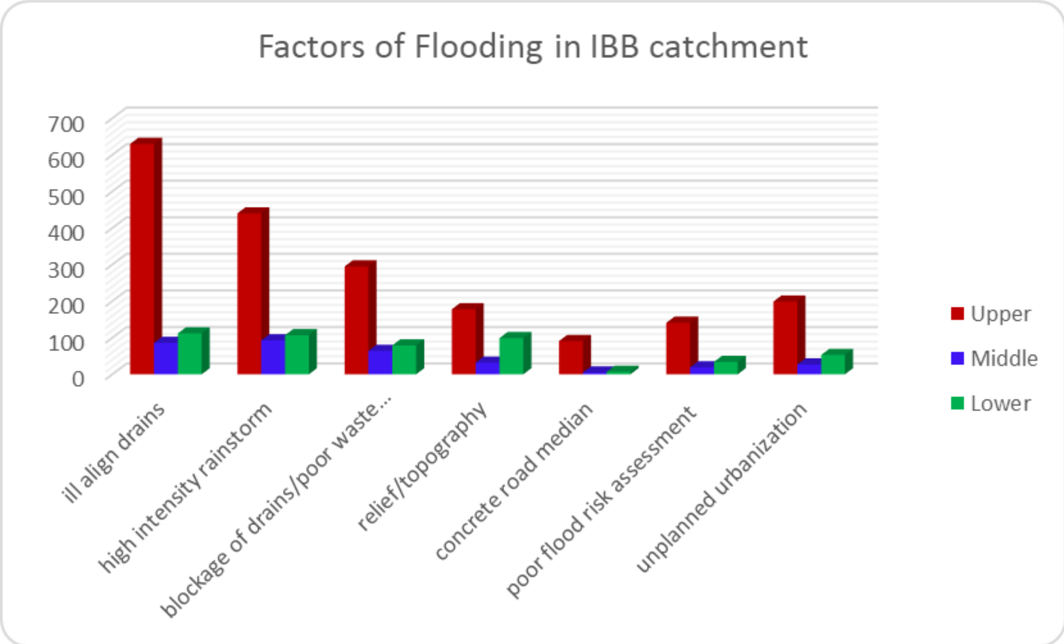


**Fig. 2:** Perceived causes of flooding by respondents

The analysis of variance (ANOVA) was used to determine if the nature of the causes of floods as perceived by respondents varies from those directly impacted in the upper IBB sub-catchment and respondents located downstream the receiving Anyang River in the middle and lower IBB sub catchment. The result of the ANOVA analysis shows $F(2, 18) = 2.908$, $p = 0.080$). This indicates that there is no significant difference in the perceived causes of flash floods at 95% confidence level. Thus, there is no statistical differences in the drivers of flash flood in the study area. For instance, 31.9% of respondents in the upper sub-catchment perceived ill-aligned drains/poor uncoordinated storm drains as the most important driver of flash floods which is in sharp contrast to 22.8% and 26.4% of respondents in the lower and middle sub-catchments respectively. These minor differences were not statistically significant.

**Health implication of frequent flash floods**

**Common Water-borne Diseases treated in the last 12 months**

The data set in Table 3 reveals that the most prevalent disease in the catchment area is malaria which accounts for 41.3% as captured in the questionnaire. This is closely followed by typhoid with 38.7% of the people responding affirmatively, 12.3% accounts for diarrhea and 3.4% for cholera. The high frequency of malaria in the area is occasioned by stagnant water and ponds present in the flooded segment of IBB Avenue sub-catchment.

**Table 3:** Common Water-borne Diseases treated in the last 12 months

| Water Related Diseases | | Upper | Middle | Lower | Total | Ranking |
|---|---|---|---|---|---|---|
| Diarrhea | Frequency | 167 | 30 | 34 | 231 | |
| | Percentage (%) | 11.9% | 15.0% | 12.6% | 12.3% | 3 |
| Malaria | Frequency | 590 | 75 | 107 | 772 | |
| | Percentage (%) | 42.1% | 37.6% | 39.9% | 41.3% | 1 |
| Cholera | Frequency | 41 | 11 | 12 | 64 | |
| | Percentage (%) | 2.9% | 5.5% | 4.4% | 3.4% | 4 |
| Dysentery | Frequency | 22 | 4 | 5 | 31 | |
| | Percentage (%) | 1.5% | 2.0% | 1.8% | 1.6% | 5 |
| Guinea worm | Frequency | 17 | 5 | 6 | 28 | |
| | Percentage (%) | 1.2% | 2.5% | 2.2% | 1.5% | 6 |
| Typhoid | Frequency | 550 | 72 | 102 | 724 | |
| | Percentage (%) | 39.3% | 36.1% | 38.0% | 38.7% | 2 |
| Others(specify) | Frequency | 12 | 2 | 2 | 16 | |
| | Percentage (%) | 0.9% | 1.0% | 0.7% | 0.8% | 7 |
| Total | Frequency | 1399 | 199 | 268 | 1866 | |
| | Percentage (%) | 100.0% | 100.0% | 100.0% | 100.0% | |

**Source:** Analyzed from field survey, (2020)

The analysis of variance (ANOVA) was employed to determine associated health hazards of floods as perceived by respondents in the upper, middle and lower IBB sub-catchment. The F-ratio value was computed to be $F(2, 18) = 2.775$, $p = 0.089$) which indicates no significant difference in the perceived prevalent of water borne diseases at 95% confidence level. For instance, 42.1% of respondents in the upper sub-catchment perceived malaria as the most prevalent water-borne disease, while 37.6% and 39.94% of respondents in the middle and lower sub-catchments respectively. However, the perceived prevalent water borne diseases are ranked as follows; malaria, typhoid, diarrhea, cholera, dysentery and guinea worm respectively.

In a similar study on Households' Perception of flood risk and health impact of exposure to flooding in flood prone settlement in the coastal city of Mombasa, Kenya. Okaka and Odhiambo (2019), observed that malaria accounted for 58% of waterborne diseases of their study. This was closely followed by diarrhea 56.2%, skin disease 28.3%, typhoid is 16.7% etc. However, unlike in the current study they ranked diarrhea as being the most prevalent waterborne disease (compared to Typhoid) due to proximity of the informal settlement close to the coast. The findings of the study show that floods can trigger outbreak of mosquitoes-borne diseases such as malaria, typhoid, fever and other diseases by creating new breeding grounds and increasing the mosquitoes breeding range, thus enabling them multiple faster Brown and Murray (2013).

## Conclusion

Flooding in IBB Avenue and its environs limits development and perceived causes vary from ill-aligned drains, unplanned urban expansion, poor High intensity rainstorms/uncoordinated storm drains blockage of drains to poor waste management etc. As would be expected poor flood risk assessment and concrete roads were perceived as inconsequential in urban flooding, but we do know that flood risk assessment is critical for sustainable urban development. The study therefore highlights the limitations of overdependence on community perception instead of experts' advice based on risk assessment studies in any environmental hazard such as floods, landslides and gully erosion. It is recommended that findings of this study be used by policy makers to formulate policies that will be geared towards sustainable flash flood control/ management.

## References

Birch, T.H., Quang, L., Ha, L.T., Hanh, T.T. and Guha-Sapir, D. (2011), "Impacts of flood on health: epidemiologic evidence from Hanoi, Vietnam", Global Health Action, Vol. 4 No. 1, pp. 6356.

Brown, L. and Murray, V. (2013), "Examining the relationship between infectious diseases and flooding in Europe: a systematic literature review and summary of possible public health interventions", Disaster Health, Vol. 1, No. 2, pp. 1-11.

Ding, G., Zhang, Y., Gao, L., Ma, W., Li, X., Liu, J., Liu, Q. and Jiang, B. (2013), "Quantitative analysis of burden of infectious diarrhea associated with floods in northwest of Anhui province, China: a mixed method evaluation", PLoS ONE, Vol. 8 No. 6, p. e65112.

Haque, M.A., Yamamoto, S.S., Malik, A.A. and Sauerborn, R. (2012), "Household's perception of climate change and human health risks: a community perspective", Environmental Health, Vol. 11 No. 1.

Mumuni, A. (2013), "Flooding and diarrhoeal disease incidence in urban poor communities in Accra, Ghana: investigating the effects of risk perception measures", Doctoral thesis, University of Ghana, Accra.

Nigerian Erosion and Watershed Management Project (Newmap), (2017). "Monitoring and Evaluation Easeline Data for Main Drainage & Flood Relief for IBB avenue & environs", Uyo Local Government Area, Akwa Ibom State, Nigeria.

Okaka, F.O. and Odhiambo, B.D.O. (2019), "Households' perception of flood risk and health impact of exposure to flooding in flood-prone informal settlements in the coastal city of Mombasa*", International Journal of Climate Change Strategies and Management, Vol. 11 No. 4, pp. 592-606. https://doi.org/10.1108/IJCCSM-03-2018-0026*

Salami, R.O., Von Meding, J.K. and Giggins, H. (2017), "Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria", Jàmbá: Journal of Disaster Risk Studies, Vol. 9 No. 1.

Tempest, E.L., Carter, B., Beck, C.R. and Rubin, G.J. (2017), "Secondary stressors are associated with probable psychological morbidity after flooding: a cross-sectional analysis", European Journal of Public Health, Vol. 22 No. 27, pp. 1042-1047.

Udosen C.E. (2017) ''Rainfall Trends in a Humid Tropical Environment". Published by AniHap Resources, Uyo, Nigeria.

## APPENDIX

***Causes***

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 891314.667 | 2 | 445657.333 | 2.908 | .080 |
| Within Groups | 2758167.143 | 18 | 153231.508 | | |
| Total | 3649481.810 | 20 | | | |

***Flood control measures adopted by respondents***

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1053855.583 | 2 | 526927.792 | 31.508 | .000 |
| Within Groups | 351194.375 | 21 | 16723.542 | | |
| Total | 1405049.958 | 23 | | | |

**Common Water-borne Diseases treated in the last 12 months**

**Description**

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Upper | 7 | 199.8571 | 258.67833 | 97.77122 | -39.3804 | 439.0947 | 12.00 | 590.00 |
| Middle | 7 | 28.4286 | 32.19139 | 12.16720 | -1.3435 | 58.2006 | 2.00 | 75.00 |
| Lower | 7 | 38.2857 | 46.47119 | 17.56446 | -4.6930 | 81.2644 | 2.00 | 107.00 |
| Total | 21 | 88.8571 | 165.88740 | 36.19960 | 13.3461 | 164.3682 | 2.00 | 590.00 |

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 129710.571 | 2 | 64855.286 | 2.775 | .089 |
| Within Groups | 420662.000 | 18 | 23370.111 | | |
| Total | 550372.571 | 20 | | | |


**Fig. 3:** Satellite image of IBB Avenue and its environs

# RISK PERCEPTIVE APPROACH TO FLOOD VULNERABILITY ASSESSMENT IN UYO, SOUTH EASTERN NIGERIA

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Conference Book
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9 – 12 August, 2021
pp 314-324

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**Abstract**
*In Uyo, Akwa Ibom State, urban floods are aggravated by rapid and unplanned urbanization, high population growth rate, changing rainfall pattern and undulating topography which predisposes low terrains to flooding. The study adopts a holistic approach to flood risk management rather than a narrow techno-centric approach often employed. Information on land use types (NDVI LULC analysed from remotely sensed source); topography (GIS-DEM generation, channel cross sections, slope/relief maps, vector flow maps etc); perception of residents about flood hazards/vulnerability through FGD and structured questionnaire interviews were assessed in isolation and combined into a single vulnerability map using multi-criteria techniques. The flood vulnerability map indicates that 62.2% of the study area are highly vulnerable to flood disaster, 35.8% are least vulnerable while only 2.0% are moderately vulnerable to flood incidence in Anyang sub-catchment. Communities at risk are Atan Offot, Efiat Offot, Aka Offot in Uyo LGA; Ikot Akpan Abia, Mbierebe Obio and Ikot UdoEkop in Ibesikpo/Asutan LGA and only Ikot Obok in Nsit Ibom LGA. This study recommends the enforcement of land-use regulations against illegal sand mining as it modifies stream morphology leading to inundation of settlements near stream channels.*

**Keywords**: rainfall variability, flood vulnerability, perception, land use, relief

## Introduction

Urban planners require up to date information (often from remotely sensed sources) to effectively manage infrequent occurrences of natural disasters such as urban floods, gully erosion menace, landslides etc. We do know that geographical information systems and remote sensing are constantly evolving and the trend towards the integration of the two technologies vis-a vis studies on perception stems from the improvement in the availability of high- resolution digital elevation models (Wilson & Gallant, 2000). Given the abundant access to these high- resolution topographic data, generation of spatial scenarios for flood vulnerability assessment is possible over a considerable geographic area (Sørensen, R., & Seibert, J. (2007). The analytical hierarchy process (AHP) is a unique tool which allows the user to identify areas that could be adversely affected by ponding and flooding caused by rainfall events (Ouma & Tateishi, 2014). The utilization of the AHP provides planners with the capability of identifying potential risks and the ability to plan for urban flood management practices in the early stages of development (Ologunorisa & Abawua, (2015). Hence, there is an urgent need to employ risk perceptive approach to flood vulnerability assessment of the study area to ensure sustainable urban development since. The flood menace in this environment is very devastating and has been a perennial problem.

## The Study Area

The study area is located between latitudes 4°55<sup>I</sup> and 5° 01<sup>1</sup> N North of the Equator and longitudes 7°52<sup>I</sup> and 7° 54<sup>1</sup> N East of the Greenwich Meridian. The climate and weather of Uyo-IBB Avenue and its environs, as in other parts of the State is contingent both on the position/location of the inter- tropical discontinuity [ITD] and the influence of the Atlantic Ocean [which is several kms away]. The two prevalent air masses that blow over the area are the warm, humid tropical maritime [mT] and the dry and dusty tropical continental (cT).

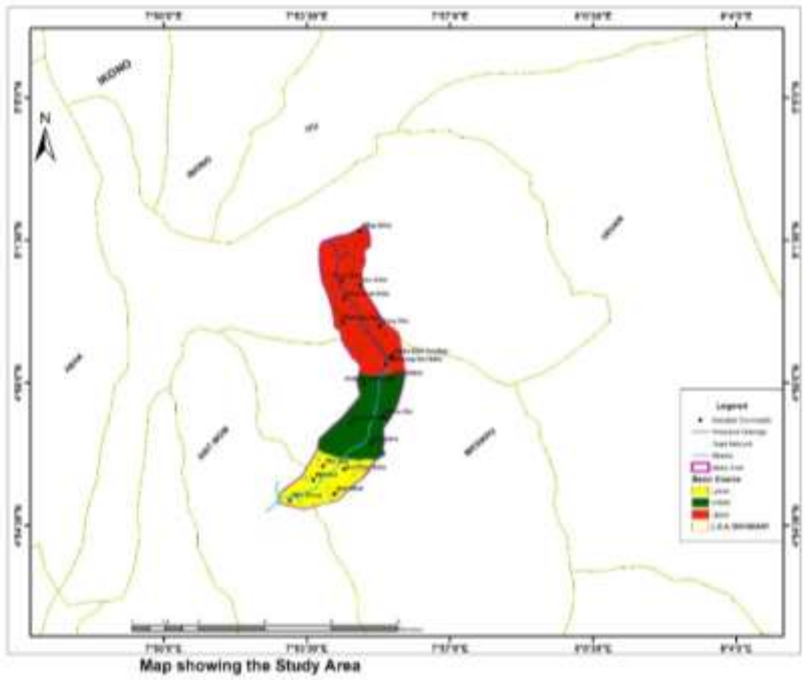



**Fig.1:** Location of the study area

There are two distinct seasons viz; four dry months (Nov. -Feb./ March and eight to nine wet months (March/April -October). Average annual rainfall for 44years (1977 – 2021) is 2566.0mm. Variability in the yearly amount of rainfall is evident with 3837.9mm in 2012 being the highest and 1,599.4mm in 1983, the lowest (Udosen, 2017). The IBB Avenue is thus synonymous with incessant flooding during years with above mean annual rainfall, particularly between June and October. The study area is undulating and ranges from about 20-80metres above sea level. Relative humidity and temperature values are fairly constant and ranges between 55-85% and 26-33$^{o}$C respectively. Land use and land cover for the study area indicate the following; Built-up Areas constitute 52% (14km$^2$), Scattered Farmland 46%, (12.4km$^2$); and Secondary Forest Vegetation 2% (0.6 km$^2$) (interpreted from Landsat imagery of 30m by 30m resolution, 2016).

## Material and Method

In this study, various basic thematic layers were created from different source including, field study/interaction with affected residents, satellite image and digital elevation model

## Sample Size and Sampling Frame

The distribution of respondents sample and return rates are presented in Table 1.

**Table 1:** Sample Frame and Sample Size Distribution

| Name of Community | Total (1991) | Sample Frame (2017) | Sample Size (%) | No. of Questionnaire Distributed | No. of Questionnaire Returned | %age Return Rate | No. Valid Questionnaire | %age Valid Questionnaires |
|---|---|---|---|---|---|---|---|---|
| Atan community | 3387 | 5588 | 2.5 | 139 | 133 | 95.7 | 128 | 92.1 |
| Aka community | 3362 | 5547 | 2.5 | 138 | 136 | 98.6 | 131 | 94.9 |
| Effiat community | 4179 | 6895 | 2.5 | 172 | 170 | 98.8 | 154 | 89.5 |
| Mbierebe | 2375 | 3918 | 2.5 | 98 | 96 | 93.8 | 95 | 96.9 |
| Nung Oku | 2368 | 3907 | 2.5 | 97 | 95 | 97.9 | 92 | 94.8 |
| Ikot Akpan Abia | 1276 | 2105 | 2.5 | 53 | 52 | 98.1 | 51 | 96.2 |
| Ikot Oduot | 891 | 1470 | 2.5 | 36 | 35 | 97.2 | 33 | 91.7 |
| EbereOtu | 486 | 802 | 2.5 | 20 | 18 | 90.0 | 17 | 85.0 |
| Mbikpong Ikot Edim | 1447 | 2388 | 2.5 | 60 | 57 | 95.0 | 55 | 91.7 |
| Ikot Osom | 602 | 993 | 2.5 | 25 | 24 | 96.0 | 22 | 88.0 |
| Ikot Udo Ekop | 685 | 1130 | 2.5 | 28 | 25 | 89.3 | 24 | 85.7 |
| Ikot Ikere | 821 | 1355 | 2.5 | 53 | 51 | 96.2 | 48 | 90.6 |
| Mbiakot | 443 | 731 | 2.5 | 18 | 17 | 94.4 | 16 | 88.9 |
| AfahaEtok | 1484 | 2078 | 2.5 | 52 | 50 | 96.2 | 49 | 94.2 |
| Ikot ObioEdim | 185 | 305 | 2.5 | 8 | 8 | 100.0 | 7 | 87.5 |
| Obo Akai | 1941 | 3203 | 2.5 | 80 | 76 | 95.0 | 75 | 93.8 |
| Ikot Obok | 1194 | 1970 | 2.5 | 49 | 47 | 95.9 | 45 | 91.8 |
| Obo Ntong | 1522 | 2510 | 2.5 | 63 | 61 | 96.8 | 59 | 93.7 |
| Total | - | 46,895 | - | 1189 | 1151 | $\ddot{X}$= 95.8 | 1101 | $\ddot{X}$= 91.5 |

- Sample frame is projected population of project affected communities for 2017

Table 1 shows that out of sample frame of 46,895, a sample size of 2.5% was extracted and sampled, proportionately giving a total of 1189 questionnaires which were distributed during the field survey. The return rate is as follows: whereas 1151 respondents were sampled,1101 were returned as valid questionnaires, which translates to between 85.0% at EbereOtu community and 96.9% at Obo Ntong with a mean of 91.5% as valid questionnaires.

Using ArcGIS 10.8 and ERDAS IMAGINE 2014 software, several maps were prepared including landuse, elevation map and residents' perception map. The administrative map was obtained from the Surveyor General of Akwa Ibom State. The elevation map was extracted from Aster DEM with resolution 30 m using spatial analyst tools. The respondents' perception map was prepared from the data collected during field interaction with residents of the area and was interpolated using Inverse distance weighted method (IDW). The structure types (land use) map was extracted from USGS satellite imagery 30m by 30m resolution.

**Normalized Difference Vegetation Index (NDVI)**

The normalized difference vegetation index values at IBB Avenue and its environs are categorized into three showing:

- Built up areas with values – 1 to 0.2 µm (indicated by red colour)
- Sparsely vegetated areas with values – 02 to 0.3 µm (indicated by yellow colour)
- Vegetation with values 0.3 to 0.4 µm. (indicated by green colour)

## AHP vulnerability map

The final level of analysis was the generation of flood vulnerability map of the study area based on multicriteria analysis method Vulnerability expresses the level of foreseeable consequences of a natural phenomenon on issues and on the other hand is the most crucial component of risk in that it determines whether or not exposure to a hazard constitutes a risk (Ouma, Y.O. & Tateishi, R. 2014). In this study, weight would be assigned to the different thematic indicators classes and layers based on their relative influence and contribution to flash flood hazards. The overlay technique would be employed to the indicators to determine hazard and vulnerability level across the area. Analytical Hierarchy Process (AHP) would be used in evaluating the criteria and their weights would be determined according to their importance (Saaty, 1980). All processes were done in ArcGIS using raster calculator as spatial analyst tool. The use of analytical hierarchy process (AHP) provides important information at very low cost and is an excellent planning tool.

## Results and Discussion

### Land Use/Land Cover in the study area

Land use and land cover for IBB Avenue and its environs were analyzed. The results indicate the following; Built-up Areas constitute 52% (14km$^2$), Scattered Farmland 46%, (12.4km$^2$); and Secondary Forest Vegetation 2% (0.6 km$^2$) as shown in Table 2. In summary, the land use/ land cover analyses indicate that the study area is devoid of primeval vegetation- the lowland rainforest, hence it is heavily degraded (Fig2a and 2b)

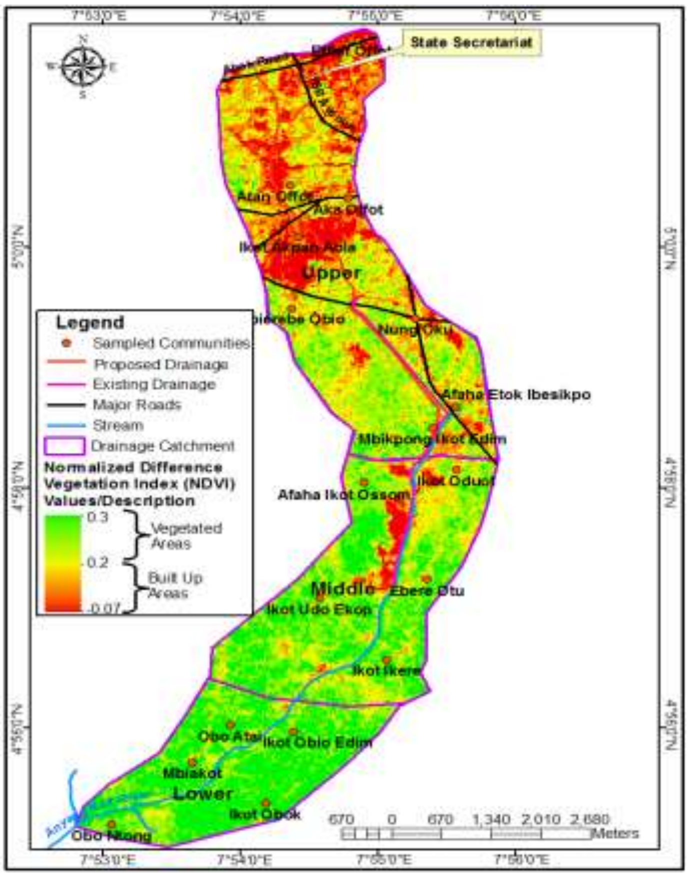
**Table 2:** Percentage coverage of land use/land cover of IBB Avenue and Its environs

| S/No | Land Use/Land Cover Class | Coverage Area (Km$^2$) | % Coverage |
|---|---|---|---|
| 1. | Built Up Area | 14 | 52 |
| 2. | Scattered Farmland | 12.4 | 46 |
| 3. | Secondary Forest | 0.6 | 2 |
| | Total | 27 | 100 |

**Source:** Extracted from 30m Resolution Landsat TM 7 Imagery

It is clear from Table 2 that the land use types include scattered farming and oil pam bush/plantations and fishing and logging are not part of the livelihood activities in the community. Only seasonal hunting and sand/gravel harvesting were noticed during field survey. It was also observed that the valley-side slopes are relatively unstable as a result of soil degradation and the fallouts of river bank collapse/subsidence processes accompanying mechanized sand mining. The land use/land cover analysis presented here is for 2016

At the built-up areas the original rainforest vegetation has been seriously degraded by human activities, such as urbanization, commercial and industrial developments and massive road construction leading to deforestation in the study area.



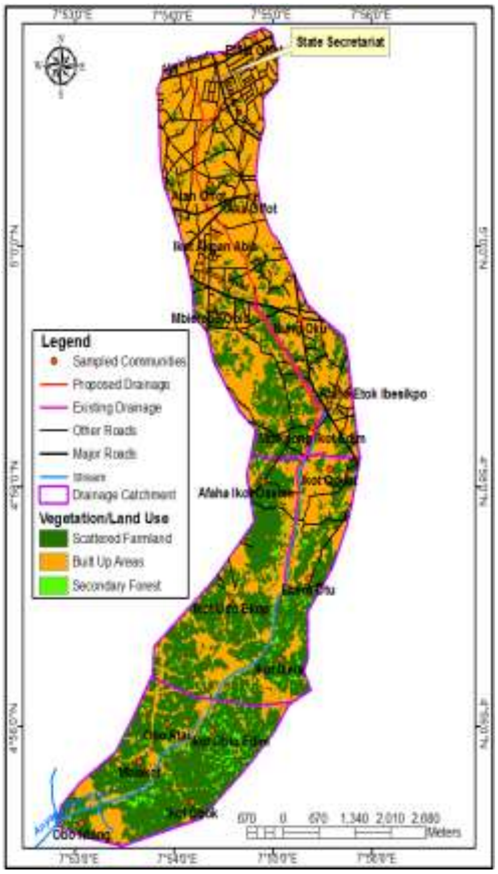




**Fig 2a:** NDVI of IBB Avenue Flood Site

**2b;** Landuse/landcover map of study area

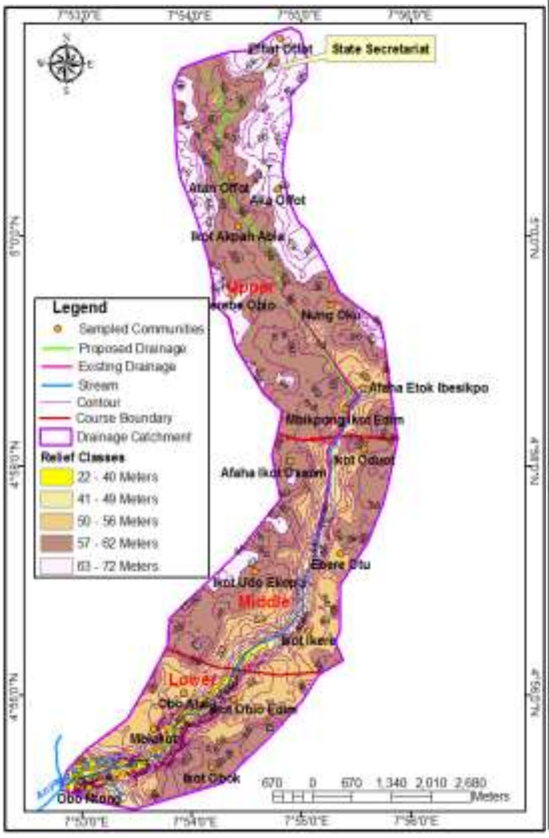
Source: Extracted from 30m Resolution Landsat 7 ETM Imagery from United State Geological Surveys – USGS, 2016

The places categorized as built-up areas include housing estates, schools, churches, Champion Breweries Ltd, Idongesit Nkanga Secretariat Complex with their grounds mostly paved with concrete material and no vegetation components whatsoever are found in the built -up area. The sparsely vegetated surfaces fringe the proposed main drainage corridor (Fig. 2a and 2b) and are represented in yellow colour, while red colour denotes built up areas

The range in vegetation index values shows that the vegetation is sparse around IBB Avenue and is dotted with small gardens, few cultivated farmlands, patches of protected and preserved individual trees and the floristic composition is more in the lower Anyang watershed. Communities in Nsit Ibom LGA have high vegetation index value as represented by the green colour (Fig. 2b).

Topography and Terrain Analysis of the study area

The topography and incremental roofed development amplify storm water energy/intensity in the locality. Storm water runoff harvest is also intensified by impervious road median/widespread impervious surfaces. Figs 3a and 3b respectively show the configurations of the sub-catchment and the predispositions of the sub-watershed to extreme storm water events which interact with the impervious surfaces and climatic elements to generate excess surface runoff. At IBB Avenue, the topography is undulating, and ranges from 50m a.s.l to over 72m a.s.l, several communities in the middle and lower segments of Anyang sub catchment such as Mbiakot, Ikot Obo Edim, Ikot Ikere and EbereOtu have relatively lower relief values of less than 56m a.s.l. while the base level is approximately22m a.s.l. (Figs 3a and 3b).



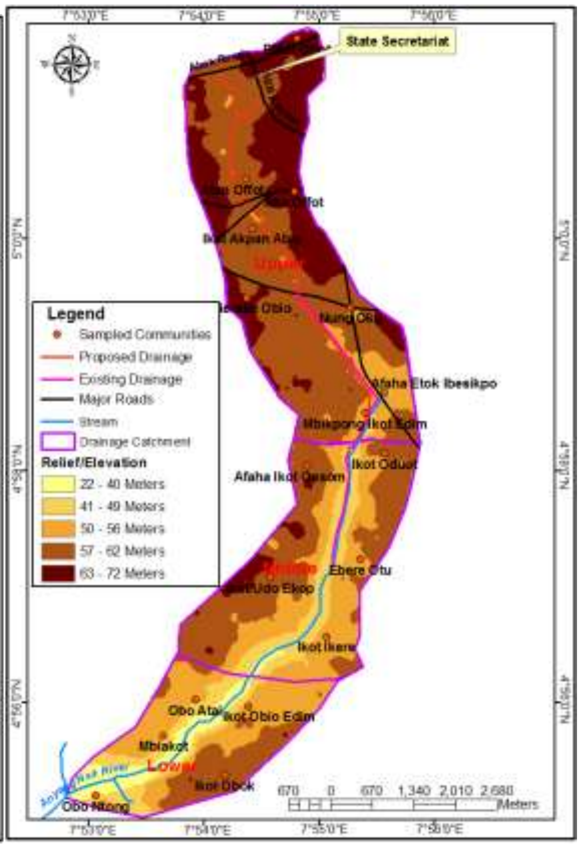
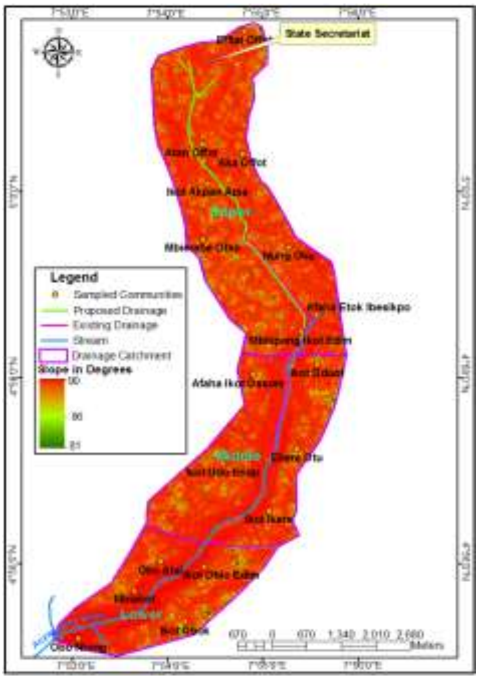




**Fig. 0a:** Contour map

**Fig. 3b** Relief map of IBB Avenue and its environs, Uyo

On the other hand, the slope map of Anyang sub-catchment is illustrated in Fig. 4a, while a cross profile of Anyang River at Nung Oku Ebere Otu shown in Fig. 4b vividly explains why settlements may not be inundated as the channel flow is confined to a narrow valley with very steep valley side slopes.



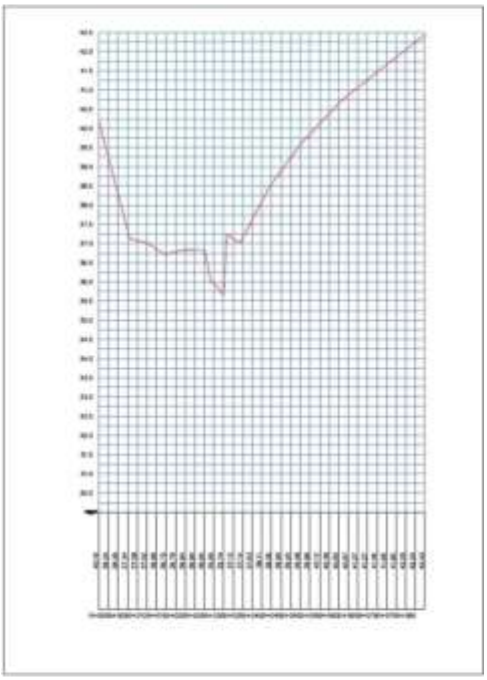



**Fig.4a**: Slope map

**Fig. 4b**: Cross profile of Anyang sub catchment

Fig. 5 is a Digital Surface Model (DSM), that adequately captures the terrain showing its undulating nature and highlighting some steep valley-side slopes of Anyang River, particularly where it bifurcates south west of Ikot Obok. Fig. 5 depicts a Wireframe Plan, with the dark blue colours showing the lower-lying areas around IBB Avenue, Idongesi tNkanga Secretariat Complex and part of Abak road housing estate which is highly susceptible to flooding.

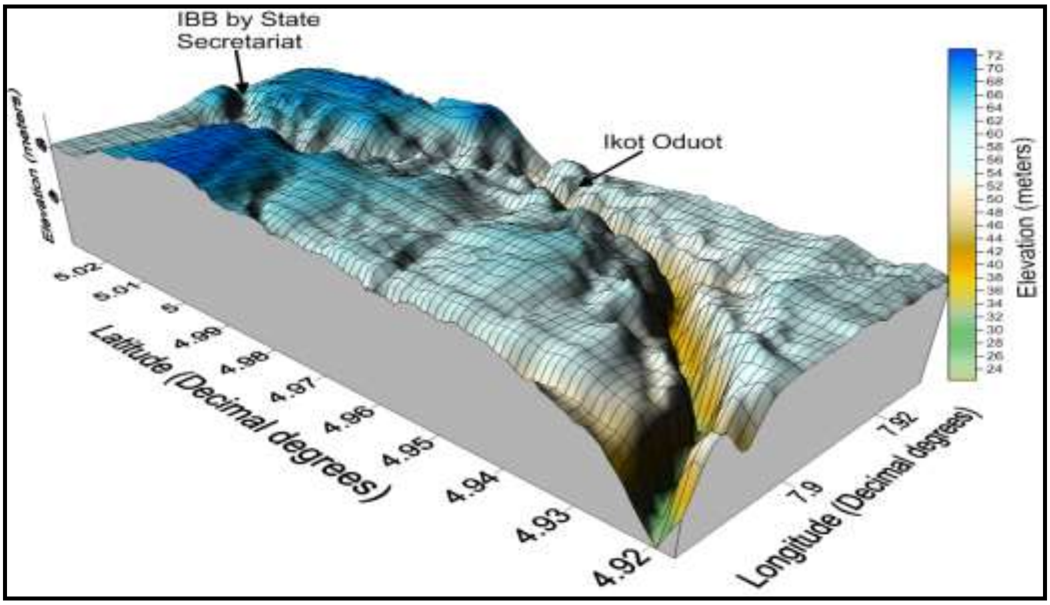



**Fig.5:** A 3-D Wireframe Plan of Anyang sub watershed

An important aspect of urban land use that affects the hydrological response of the sub catchment to a particular rainfall event is the ratio of the total impervious area to the total area of a defined sub catchment such as Anyang watershed. This has been found to have direct relationships with the volume of surface discharge and increase in flood peakedness (Akintola, 1974). The vector flow map information on Anyang watershed, which drains IBB Avenue and its environs from the grids shows storm flow patterns (directions and magnitude) that encourage flash floods whenever it rains (Fig. 6) It is clear that storm water comes into IBB Avenue from diverse directions and much of the storm water in IBB Avenue comes as overland flow because of inadequate drainage infrastructure in the locality.

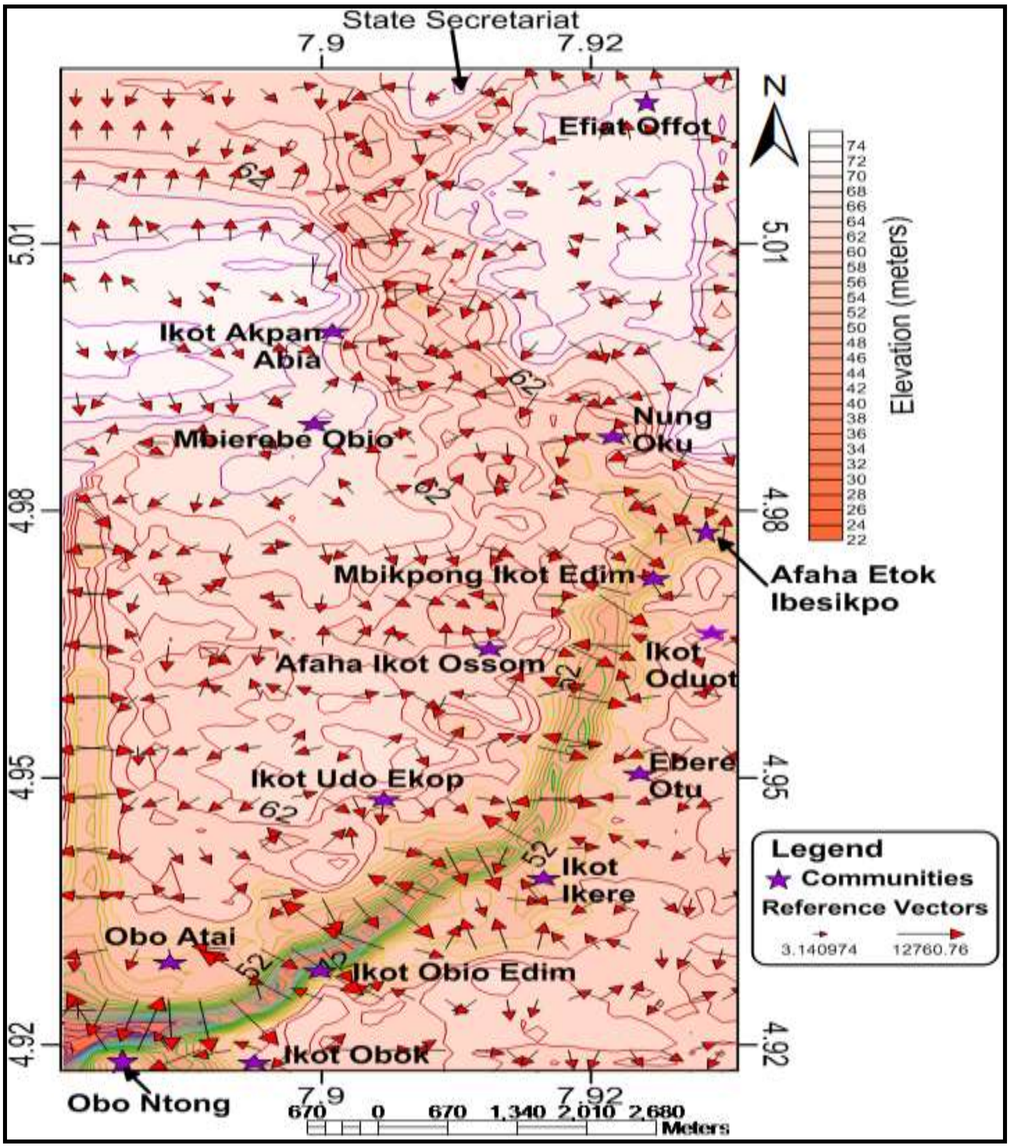



**Fig.6:** Vector flow map of Anyang sub watershed overlaid on a filled contour map. (Note longer arrows indicate areas of steeper slopes)

**Perception of residents on factors of flooding**

A questionnaire interview was conducted to inquire about the perception of residents about the causes of flooding in the study area. The results gleaned from 1101 valid questionnaire are shown in Table 3. Table 3 reveals that 29.7% of the respondents attributed the key factor of the flood menace to ill-aligned drains closely followed by 23.0% for high intensity of rainstorms. Consequently, 15.7% of the respondents considered blockage of drains/poor waste management to be the major factor of flooding in the area. 11.1% of the respondents attributed it to relief/topography, 10.0% linked it to unplanned urbanization in the area while 7.0% and 3.7% attributed it to poor flood risk assessment and concrete roads respectively.

**Table 3:** Perceived Factors of flooding in IBB catchment

| | | | | | |
|---|---|---|---|---|---|
| Ill aligned drains, poor /uncoordinated storm drains | Frequency | 630 | 86 | 112 | 828 |
| | % of Total Sum | 31.9% | 26.4% | 22.8% | 29.7% |
| High intensity rainstorms | Frequency | 440 | 93 | 107 | 640 |
| | % of Total Sum | 2.2% | 28.5% | 21.8% | 23.0% |
| Blockage of drains & poor waste mgt. | Frequency | 295 | 64 | 79 | 438 |
| | % of Total Sum | 15.1% | 19.6% | 16.1% | 15.7% |
| Relief/Topography | Frequency | 178 | 32 | 99 | 309 |
| | % of Total Sum | 9.0% | 9.8% | 20.2% | 11.1% |
| Concrete road median/ Low infiltration | Frequency | 91 | 5 | 7 | 103 |
| | % of Total Sum | 6.3% | 1.3% | 1.4% | 3.7% |
| Poor flood risk Assessment | Frequency | 141 | 19 | 34 | 194 |
| | % of Total Sum | 7.1% | 5.8% | 6.9% | 7.0% |
| Unplanned urbanization | Frequency | 199 | 27 | 53 | 279 |
| | % of Total Sum | 10.1% | 8.3% | 10.8% | 10.0% |
| Total | Frequency | 1974 | 326 | 491 | 2791 |
| | % of Total Sum | 100.0% | 100.0% | 100.0% | 100.0% |

**Source:** Field survey, (2021)

**Flood Vulnerability Mapping**

The flood vulnerability map of IBB Avenue and its environs is illustrated in Fig.7. In Fig. 6, the highly vulnerable are those in the green colour, while patches of red colour denote moderately vulnerable area and blue colour depict areas that are not vulnerable to floods. The map indicates that 62.2% of the study area are highly vulnerable to flood disaster, 35.8% are least vulnerable while only 2.0% are moderately vulnerable to flood incidence in Anyang sub-catchment. Communities at risk are Atan Offot, Efiat Offot, Aka Offot in Uyo LGA; Ikot Akpan Abia, Mbierebe Obio and Ikot UdoEkop in Ibesikpo/Asutan LGA and only Ikot Obok in Nsit Ibom LGA.

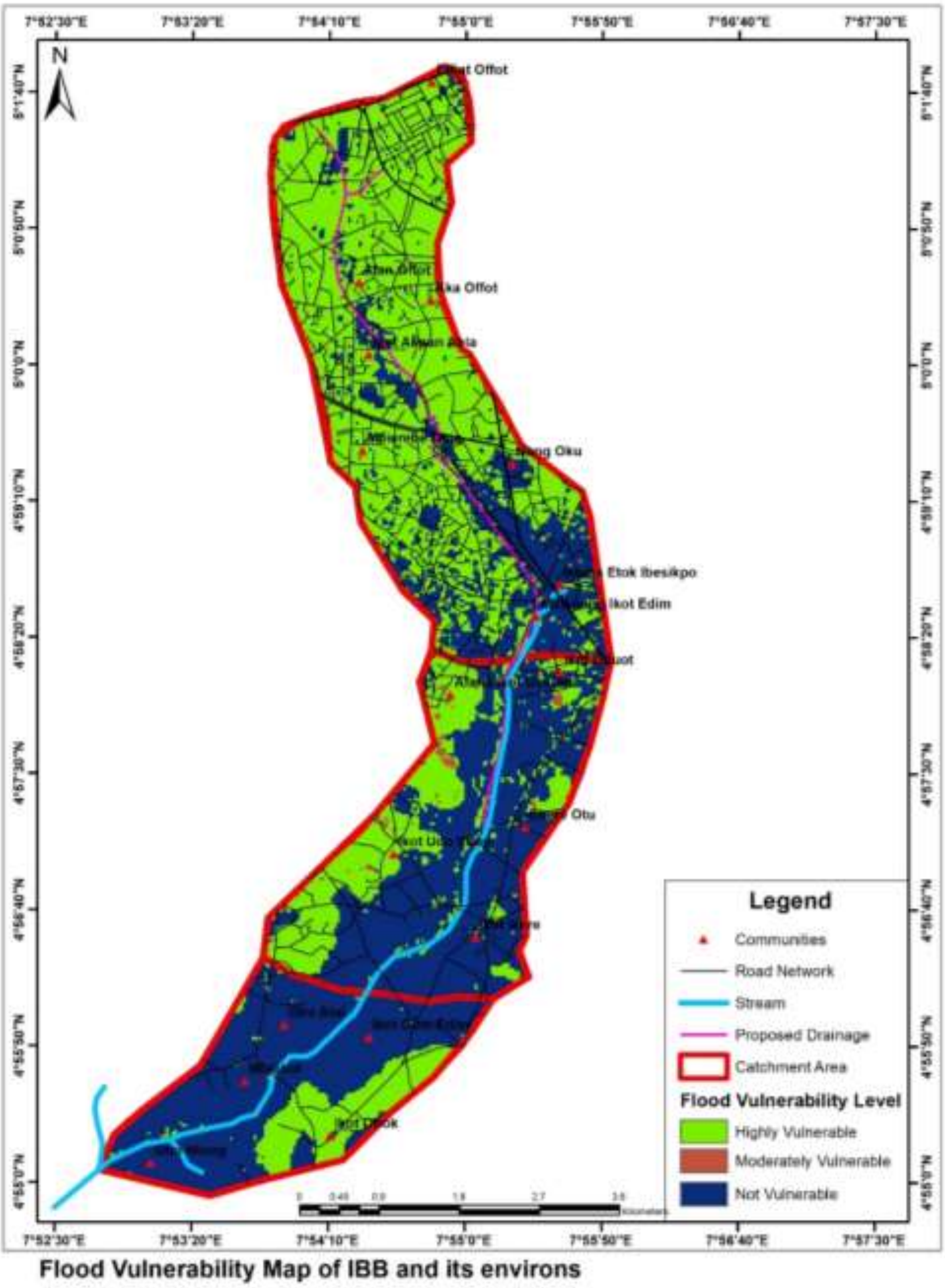



**Fig.7: Flood Vulnerability map of IBB Avenue and its environs**

These results corroborate findings from both previous observed flood events and relevant studies viz; Malachy, (2016} and NEWMAP, (2017. Though our results provide a good contribution to the understanding of flood risk in Anyang river sub-catchment.

## Conclusion

The study employed a holistic approach to flood risk management rather than a narrow techno-centric approach often employed. This study has demonstrated an attempt to combine quantitative and qualitative data. The hazard assessment shows that the low-lying terrain extending from Atiku Abubakar down to IBB Avenue/Secretariat complex are highly vulnerable to flood hazard. The assessment also reveals that communities in Uyo LGA are more vulnerable than communities in Ibesikpo/Asutan and Nsit Ibom LGAs. The obvious conclusion to draw is that development programmes that enhance community resilience to flood hazard may reduce their vulnerability overtime. On the other hand, Illegal sand mining which is rampant in the study should be discouraged as it modifies the morphology of Anyang sub-catchment leading to inundation of settlements l around the river channel. The study strongly recommends the enforcement of land se legislation on illegal mining in Anyang sub-catchment.

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**References**

Malachy, O.U. (2016) Analysis of the impact of flooding on infrastructure in Uyo Urban'' An unpublished MSc Thesis in the Dept. of Geography and Natural Resources Management, University of Uyo, Uyo, Nigeria.

NEWMAP (2017) Monitoring and evaluation baseline data for main drainage and flood relief for IBB Avenue and environs, Uyo, Local Government Area, Akwa Ibom State, Nigeria

Ologunorisa, T.E. and Abawua, M.J. 2005 'Flood risk assessment; A review, Journal of Applied Sciences and Environmental Management, 9(1) pp57-63.

Ouma, Y.O and R. Tateishi. 2014. Urban flood vulnerability and risk mapping using integrated multi-parametric AHP and GIS: Methodological overview and case study assessment. Water, 6(6): 1515–1545.

Saaty, T. L. 1980. The Analytic Hierarchy Process: Planning, Priority setting, Resource allocation, Mc Graw-Hill, New York, 19.

Sørensen, R., & Seibert, J. (2007). Effects of DEM resolution on the calculation of topographical indices: TWI and its components. *Journal of Hydrology*, *347*(1), 79–89.

Udosen C.E. [2017] ''Rainfall Trends in a Humid Tropical Environment. Published by AniHap Resources, Uyo, Nigeria. Pp. 243

Wilson, J. P., & Gallant, J. C. (2000). Digital terrain analysis. *Terrain analysis: Principles and applications*, 1–27.

## ECOLOGICAL PERSPECTIVE TO URBAN FLOODS MITIGATION IN YAOUNDÉ VII, CENTRE REGION, CAMEROON

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**Abstract**

*As cities continue to urbanized, severe flooding events persist, highlighting the vulnerability of urban settlements. This study examined and compared the effectiveness of ecological and structural (non-natural) measures in Yaoundé VII. Primary data included first-hand information generated through structured and unstructured questionnaire and key informant interviews. The study employed cross sectional and descriptive designs. Purposive, stratified, and systematic sampling techniques were used for questionnaire administration with a sample of 400 drawn from the population. Data generated were analysed descriptively and inferentially. The tested hypothesis using Student t test at 0.05 significance level showed a statistically significant difference between ecological control (p-value =0.001) and physical (non-natural) control (P-value= 0.72) measures. This indicated that significant ecological flood control measures are put in place over physical control measures by council authorities to control flooding in Yaoundé VII Municipality. Based on the findings, the study recommended the municipal council to organize massive campaign against improper dumping of refuse in the drainage system and creates awareness on flooding issues among city dwellers for sustainable flood control in the Yaoundé VII municipality.*

**Keywords:** Ecological, Urban floods, Mitigation, Yaoundé VII, Cameroon

### Introduction

Urban environments offer a common place where people will like to spend their lives. More than half of the world's population live in urban centres and the proportion will obviously increase in coming decades (United Nations Human Settlements Programme, 2020). As cities continue to urbanize, severe flooding events will persist (Zhou et al. 2019). Borelli et al. (2018) described the essential role urban ecology elements must play in meeting global commitments on sustainable city development.

Nature Conservancy (2014), Di Baldassarre et al. (2013), and World Bank (2012c), opined that the standard tools of flood management have been structural/non-natural solutions like dams, levees, drains, pumping stations, walls, but noted that such solutions are not an answer, and can in some cases increase flood risk. Exploration of complementary approaches to non-ecological infrastructure has led scholars like Sambe et al. 2019, Escobedo et al. 2019, Meerow and Newell, 2017, Solecki et al 2017, United Nations Office for Disaster Risk Reduction 2012a, World Bank, 2011 and Gill et al. 2007, to ecological/natural practices. Urban ecological measures are recognized as a vital component in the sustainability of cities (Grove, 2009; Duinker et al. 2015).
In Cameroon, flooding is recurrent and the effectiveness of measures to combat these urban floods is inefficient and thus necessitates an assessment. Therefore it is necessary to compare the effectiveness of ecological and structural (non-natural) measures of flood management in Yaounde VII.

## Materials and Methods

Yaoundé VII, situated on the western part of the Centre Region of Cameroon was created in April 2007 by Presidential decree N°2007/117. The sub-division is located between latitude 3°50' to 3°53" North of the equator and longitude 11°27' to 11°30" East of the meridian (figure 1). It covers an area of 34.9 km2 with a population estimated at 440 000 inhabitants (Council Development Plan 20018). It is surrounded to the West by Mbankomo; to the North by Okola and Lobo and to the East, by Yaoundé II and Yaoundé IV.

The descriptive design was adopted for the study. The study combines both secondary and primary set of data which enabled the researchers to collect information on urban flooding mitigations in the study matrix. The study population was estimated at 440 000 as of 2018 (Council Development Plan 2018). A sample of 400 was determined from this population using Taro Yamane formula. Purposive and systematic sampling techniques were used for the survey. The raw data was analysed descriptively and inferentially using SPSS software. The student t test at, 0.05 significance level was used for hypothesis testing. Results are presented in the form of tables, graphs, and figures for better understanding.

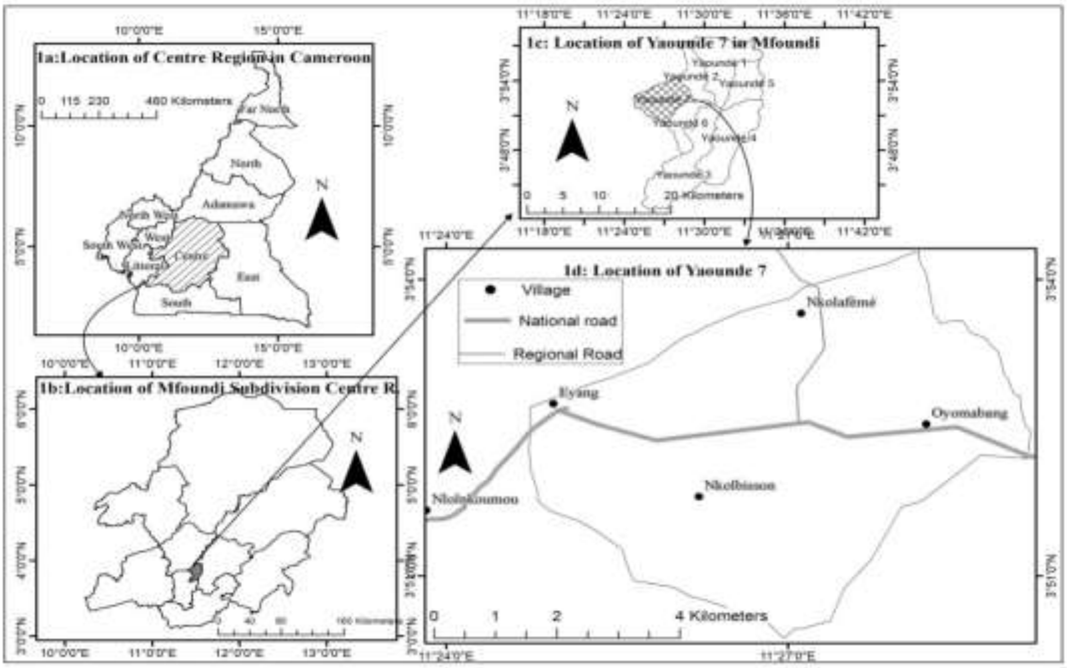


**Fig 1:** Location of Yaoundé VII in the Centre Region of Cameroon

## Results and Discussions

Flood victims and the Municipal Council of Yaoundé VII have developed a good number of strategies to control flooding in the area. These measures include ecological (Street trees planting, forest parks, growing vegetation parks) and structural non-natural measures (concrete walls and gutters). This notwithstanding, the persistent floods in the area in recent years makes one feels as if no action has been taken in the municipality. The level of effectiveness of flood control measures within the area was perceived with the five-point Likert's scale (table 1).

### Structural Non-natural flood mitigation measures in Yaoundé VII

The standard flood risk management measures as observed in Yaoundé VII have been structural non- natural engineering such as drains, concrete walls, local embankment, improve river channels and cemented channels. The main issue with such measures as observed during field survey is that, much time and money is spend each year to fortify them against the impacts of floods. While these structural/non-natural measures are needed in many circumstances, they are not a proper panacea and can in some cases increase rather than reducing flooding. Moreover, these non-natural measures provide less adaptability to future flooding. The perception from the sample population indicates general negative responses as regarding its role in floods risk mitigation in the Yaoundé VII Municipality. The results from table 1 on structural non-natural measures indicates strong negative agreements levels from improve river channels (33.7%), drains construction (71.8%), concrete walls (68.5%), cement channels (25.0%) and local embankment (78.5%). These sample expressions from sample respondents is an indication that structural non-natural measures has little significant intervention in flood risk mitigation in Yaounde VII Municipality.

**Ecological measures of flood Mitigation in Yaoundé VII**

Ecological solutions to flood risk management in the study matrix focuses on the management of wet-weather impacts by using natural processes. Such measures in the study area are amongst others, street trees planting, forest parks, residential gardens, community forest, shrub conservation and planting of hedgerows. Field observation revealed that ecological measures are more cost effective and environmentally friendly compared to structural non-natural measures. Street tree and forest parks measures are managed by the municipal council and this is seen around Major Streets at Nkolbisson, Nkomassi Oyom-Abang, and along streets leading to the Senior Divisional Officer's Office and the Municipal Council. Forest parks are observed along most urban streets and roundabouts in Yaoundé VII. Urban Street trees according to local vendors helps a lot in run-off abatement during heavy downpours; the tree roots encore the soil and prevents water erosion.

**Table 1:** Agreement index on measures to combat flooding in Yaoundé VII

| Structural non-natural flood measures | Rating/Frequency | | | | | Effective | Percentage rating (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA | A | I | D | SD | | SA | A | I | D | SD |
| Improved river channels | 108 | 86 | 7 | 135 | 64 | 400 | 27.0 | 21.5 | 1.7 | 33.7* | 16.0 |
| Drains | 2 | 69 | 40 | 287 | 2 | 400 | 0.5 | 17.3 | 10.0 | 71.8* | 0.5 |
| Concrete wall construction | 67 | 43 | 5 | 11 | 274 | 400 | 16.8 | 10.8 | 1.3 | 2.8 | 68.5* |
| Cement channels | 87 | 93 | 34 | 100 | 84 | 400 | 21.7 | 23.2 | 8.5 | 25.0* | 21.0 |
| Local embankment | 9 | 60 | 12 | 314 | 5 | 400 | 2.3 | 15.0 | 3.0 | 78.5* | 1.2 |
| | Total | | | | | 400 | | | 100% | | |
| Ecological flood measures | SA | A | I | D | SD | Eff | SA | A | I | D | SD |
| Street trees planting | 338 | 50 | 8 | 2 | 2 | 400 | 84.5* | 12.0 | 2.0 | 0.5 | 0.5 |
| Forest parks | 320 | 63 | 11 | 3 | 3 | 400 | 74.8* | 20.8 | 2.0 | 1.5 | 1.0 |
| Residential Gardens | 325 | 57 | 11 | 5 | 2 | 400 | 81.3* | 14.3 | 2.8 | 1.3 | 0.5 |
| Community forest | 312 | 72 | 10 | 5 | 1 | 400 | 78.0* | 18.0 | 2.5 | 1.3 | 0.3 |
| Growing vegetation parks | 290 | 83 | 19 | 6 | 2 | 400 | 72.5* | 20.8 | 4.8 | 1.5 | 0.5 |
| Shrub conservation | 261 | 99 | 25 | 13 | 2 | 400 | 65.3* | 24.8 | 6.3 | 3.3 | 0.5 |
| Tree gardening | 252 | 86 | 31 | 22 | 9 | 400 | 63.0* | 21.5 | 7.8 | 5.5 | 2.3 |
| Planting of hedgerows | 274 | 43 | 5 | 11 | 67 | 400 | 68.5* | 10.8 | 1.3 | 2.8 | 16.8 |
| | Total | | | | | 400 | | | 100% | | |

Source: Author's Field Survey, 2021.

Note: SA: Strongly Agree; A: Strongly Disagree; I: Indifferent; D: Disagree, and SD: Strongly Disagree.

Table 1 shows the agreement levels of the surveyed population during field investigation. As described on the table, the control measures with highest percentage rating for those households who strongly agreed was street trees planting 84.5% while the least in the category was tree gardening which recorded 63.0% rating. The control measure with the highest level of households who agreed to a particular flood control method was conservation of shrubs at swampy areas; this was confirmed by a sample representing 24.8% while the lowest figure stood at10.8% attributed to planting of hedgerows. For those who claimed indifferent and that they knew nothing as far as mitigating measures are concerned, the most elevated level was 7.8% attributed to tree gardening while the lowest control measures as to the disagreement level was planting of hedgerows with 2.8%. The highest proportion for the perception levels of strongly disagreed and disagreed were 5.5% for tree gardening and 16.8% for planting of hedgerows.

**Table 2:** Student t test result for ecological and structural non-natural measures of flood mitigation in Yaounde VII

| Variables | Mean diff. | t | df | Sig. (2-tailed |
|---|---|---|---|---|
| Improved river channels (SNNM) | .04787 | .4232 | 110 | .055* |
| Drains (SNNM) | .05974 | .5210 | 137 | .072* |
| Concrete wall construction (SNNM) | .00947 | .8034 | 119 | .065* |
| Cement channels (SNNM) | .07321 | .6420 | 113 | .059* |
| Local embankment (SNNM) | .07673 | .6531 | 114 | .060* |
| Street trees planting (EM) | .00116 | .03055 | 1 | .000** |
| Forest parks (EM) | .00062 | .03480 | 1 | .000** |
| Residential Gardens (EM) | .00071 | .04019 | 1 | .000** |
| Community forest (EM) | .00100 | .04976 | 1 | .000** |
| Growing vegetation parks (EM) | -.00152 | .07453 | 1 | .000** |
| Shrub conservation (EM) | .00058 | .03672 | 1 | .000** |
| Tree gardening (EM) | -.00055 | .03721 | 1 | .000** |
| Improved river channels (EM) | .00126 | .05540 | 1 | .000** |

NB: SNNM= Structural Non Natural Flood Measures
EM = Ecological Measures
Source: Author's computation from the results of analysis, 2021

The test of the hypothesis indicates that there is a statistically significant difference between structural non-natural flood mitigation measures and ecological measures. The null hypotheses are rejected at calculated p-value of 0.05 significance levels. Thus, the results from the test of hypothesis shows ecological control (p-value =0.001) and physical (non-natural) control measures at (P-value= 0.72). This indicated that there exist significant ecological flood controls measures put in place over physical control measures by council authorities and dwellers to control flooding in Yaoundé VII Municipality.

**Conclusion and Recommendations**

This study examined the structural non-natural flood mitigation measures and the ecological measures in Yaoundé VII. The findings indicated a mixed understanding between the two flood preventative measures adopted by the authorities and populations of Yaoundé VII. Though the ecological measures receive laudable applause from the sample population, we think that they are not sufficient enough given the unprecedented climate change phenomenon. Therefore, as recommendation, the researchers strongly urged city authorities not only in Yaoundé VII but the entire nation to introduce land use regulation, flood forecasting and warning mechanisms, flood preparedness and response teams be created in all nationwide sub-divisions. In this way, flooding events can be sustainably managed to reduce the impacts in communities.

**References**

Borelli et al, (2018). Urban forests in the global context: *An international journal of forestry and forest industries, Vol. 69*

CDP (2018). Council Development plan, Yaounde VII

Di Baldassarre, G. D., A. Viglione, G. Carr, L. Kuil, J. L. Salinas, and G. Bl€oschl. (2013). Socio-hydrology: Conceptualising human–flood interactions. Hydrology and Earth System. Sciences, 17 (8),3295–303. doi: 10. 5194/hess-17-3295-2013

Yu, D. J., M. L. Schoon, J. K. Hawes, S. Duinker Peter, Camilo Ordóñez Barona, James Steenberg, Kyle H. Miller (2015). Trees in Canadian Cities: Indispensable Life Form for Urban Sustainability. VL - 7 DO - 10.3390/su7067379 JO - Sustainability ER.

Escobedo FJ, Giannico V, Jim CY, Sanesi G, Lafortezza R (2019) Urban forests, ecosystem services, green infrastructure and nature-based solutions: nexus or evolving metaphors? Urban For Urban Green 37:3–12. https ://doi.org/10.1016/j. ufug.2018.02.011

Gill SE, Handley JF, Ennos AR, Pauleit S (2007) Adapting cities for climate change: the role of the green infrastructure. Built Environ 33(1):115–133

Grove, J. M. (2009). Managing densely settled social-ecological systems. In F. S. Chapin, G.

P. Kofinas, and C. Folke (Eds.) *Principles of ecosystem stewardship* (pp. 281-294). New York, NY: Springer.

Meerow S, Newell JP (2017) Spatial planning for multifunctional green infrastructure: growing resilience in Detroit. Landsc Urban Plan 159:62–75. https ://doi.org/10.1016/j.landu rbpla n.2016.10.005

Nature Conservancy. (2014) "A Flood of Benefits Using Green Infrastructure to Reduce Flood Risk." Nature Conservancy, Arlington, VA.

Samba G, Mofor G. Z and Chianebeng J. K (2020). The Role of Urban Forest in Flood Risks Management in Yaoundé VII, Centre Region of Cameroon. Current Journal of Applied Science and Technology 39(11): 28-37, 2020; Article no.CJAST.55912 ISSN: 2457-1024

UNISDR (United Nations Office for Disaster Risk Reduction). ( 2012a). How to Make Cities More Resilient: A Handbook For Local Government Leaders. Geneva: UNISDR.

UNHPSP (2020) United Nations Human Settlements Programme (UN-Habitat). WORLD

CITIES REPORT 2020Website: www.unhabitat.org

World Bank (2012c) "Vietnam Urban Briefs—Disaster Risks in the Urban Environment." World Bank, Washington, DC.

World Bank (2011) Cities and Flooding. A Guide to Integrated Urban Flood Risk Management for the 21st Century. Washington, DC: World Bank.

Solecki, M., M. Pelling, and M. Garschagen. (2017). Transitions between risk management regimes in cities. Ecology and Society 22 (2):38. doi: 10.5751/ES- 09102-220238.

Zhou, Q.; Leng, G.; Su, J.; Ren, Y (2019). Comparison of urbanization and climate change impacts on urban flood volumes: Importance of urban planning and drainage adaptation. Sci. Total Environ, 658, 24–33.

# URBAN FLOODING PROBLEMS, PERCEPTION AND PROJECTIONS IN THE CITY OF DOUALA, CAMEROON

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**Abstract**
*The persistent nature of flooding in Cameroon especially during the rainy season has made urban flood problem an issue of growing concern in the Douala metropolis, where despite efforts at controlling this hazard, floods have been recurrent in many parts of the city. It is against this backdrop that this study is carried out to investigate the nature of floods in the city, its impacts, suitability and adequacy of present flood measures. The study investigates this research problem in three districts of Douala, (Douala 1, Douala II and Douala III). Local perceptions were evaluated through the administration of a total of 900 copies of structured questionnaires with 300 for each sub division using stratified sampling technique. Interviews and focus group discussion sessions were held. Projected areas at risk were analysed using the Geographical Information System Geo-processing query. Data on perception was analysed using simple percentages and information from group discussion were summarised. Additionally, the Chi square ($X^2$) statistical tests were performed to compare responses to survey questions across districts. Findings reveal that causes of flooding hazards were highly significant ($p < 0.000$) across districts except for deforestation. The Douala 1 perceived the will of God (47.7 %), Blocked drains (43.7%) and building along drainage paths (41.9%) for Douala IV and V to be more important. Rainstorms, tidal effects and flooding were perceived to be the most devastating hazards in Douala I, IV and V as they were highly significant ($p<0.000$). All perceived socio-economic impacts of flooding in the study area were highly significant ($p<0.000$), with deaths (36.6%), migration (44.4%) and obstruction/restriction of movement (38.6%) being more important for Douala IV. Bare ground (132.21 and 446.82 $km^2$) and settlement (152 and 476.5 $km^2$) classes of land cover will be more affected by a 5 to 10m projected flood levels. This study therefore suggest that the government should make major investments to improve the data base of climate change variables of the coastlines of Douala and the entire nation since information from these databases will form the basis for the development of adaptation strategies to any future flooding hazards. Though efforts are being made to put in place appropriate and suitable drainage facilities, over delay, poor implementation and especially the minimal attention given to anthropogenic factors will be a hindrance. As such, suggestion is made, that these bottlenecks be taken into cognisance by the respective institutions responsible and checked if anything meaningful is to be achieved with the present flood mitigation programmes.*

**Keywords:** Flooding problems, Perception, Projections, Douala city

## Introduction

Urban flood damages are one of the rapidly growing problems in most cities of developing countries. Flood hazards in Cameroonian cities are increasing in the last ten years despite huge awareness of the causes, impacts and control of flood and erosion. The problem is still escalating and compounded with urban expansion into the fringes, reclamation of wetlands without adequate provision of drainage facilities. The rapid growth of Douala has led to the urbanisation of low-lying areas by the resource limited population vulnerable to flooding by storm surge, salt water intrusion, inundation, erosion and contamination of shallow wells. The industrialised areas, including the seaport and the airport are located at elevations of not more than 10 metres above sea level, making them vulnerable to the vagaries of coastal flooding. Additionally, predictions of increasing rise in sea level in the area (Fonteh *et al*., 2009; Ndenecho and Fonteh, 2012) and associated hazards in the region may put the area under risks. Furthermore, these areas are susceptible to increased runoff due to increased construction thereby creating more impermeable zones and reduced rainwater infiltration at higher elevations. This has resulted in higher discharge peaks in the creeks and rivers draining into the sea with consequent flooding events with relatively low levels of precipitation. Flooding is further exacerbated by high tide events, which effectively reduce storm water evacuation in the low lying areas. It is against this background that this paper examined perceptions of flooding and potential flooding problems in the city of Douala.

## Methodology

This study was carried out in Douala, the largest city and the economic capital of Cameroon. It is located between latitudes 4º 03' and 4º 57' north of the equator and longitudes 9º 35' and 9º 80' east of the Greenwich Meridian (Figure 1).

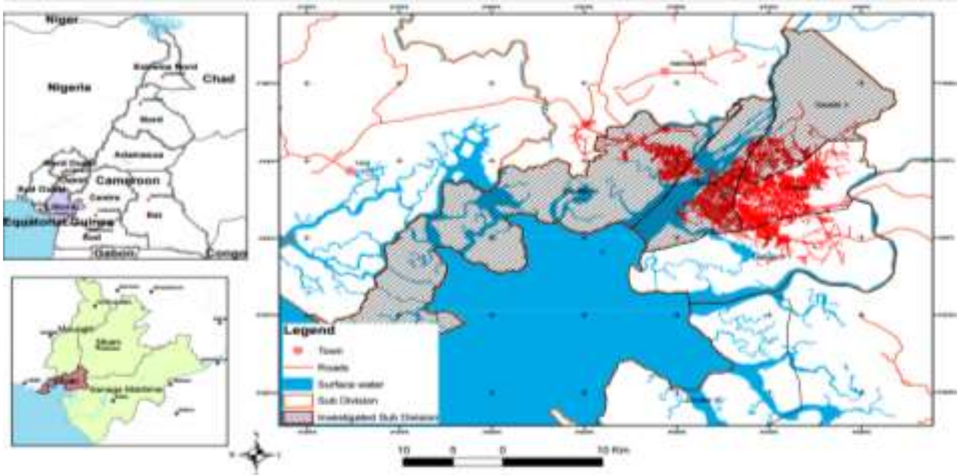


**Fig. 1:** Douala showing the three sub divisions (Douala 1, IV and V)

The rainy season extends from April to November, followed by a short dry period typically occurring between December and March. Its annual rainfall totals are generally high with values of up to 4000mm in August and lower values in the month of February. It has yearly average rainy days of 180 days. Temperatures are high averaging between 24°C and 27°C.

Three sub divisions of Douala (Douala 1, IV and V) potentially exposed to coastal hazards were selected based on their proximity to the sea and rivers as case study (Figure 1. Based on the combined population size of the three districts which was slightly more than two million. This study takes the confidence level of 95% to ensure the accuracy, and the corresponding $Z$ value is 1.96; $\delta$ is the overall standard deviation, and takes 0.5; and $d$ is the sampling error range. A total of 900 questionnaires were distributed with 300 for each sub division. 702 (78 %) completed survey responses were received which is greater than the minimum valid sample size. This satisfies the basic requirements for sample size. Stratified purposive sampling technique as recommended by Monroe and Monroe (1993) was used to administer the questionnaires.

The obtained land use land cover (LULC) of the study area by Fonteh *et al*. (2016) which represent an initial requirement for the analysis of hazards of SLR were converted to shape files with the help of the ENVI software. These shape files of the LULC of the areas prone to flooding hazards were overlaid on the digital elevation model (DEM) of the study area using values of flooding levels by Fonteh *et al*. (2009). Hence an appreciation of potential areas at risk of flooding in the near future were obtained.

## Results and Discussion

### a) Flooding problems perception

Table 1 shows the sampled populations' perception of the causes of flood in Douala 1, Douala IV and Douala V respectively. This reveals a lot of similarities, with excessive rainfall perceived to be the most important cause of flooding in the Douala metropolis. The major causes of flooding hazards related concerns show significant differences in their distribution except for deforestation as a cause of hazard that is similar across the sub divisions.

Little or no drainage network, building along drainage paths, sea level rise and blocked drains and poor water disposal were also perceived as some of the significant causes of flooding in the Douala city as seen on Table 1. Deforestation, the will of God and cemented urban surfaces were perceived to be the least important. However, cemented urban surfaces (44.4 %) and the will of God of God (47.7%) was attributed as being the most influential cause of flooding hazards in Douala I. Blocked drains (22.8%) and topography (25.1 %) were perceived to be the least important in terms of causes of flooding hazards. The majority of Douala IV dwellers attributed blocked drains (43.7 %), topography (42.6%) and development on vulnerable lands (40.7 %) as the main causes of hazards, with the will of God (25%), deforestation (25.4%) and cemented urban surfaces (25.7 %) considered as not too important in exacerbating flooding hazards. Paradoxically, the Douala V respondents perceived deforestation (41.5), building along drainage paths (41.9) and little or no drainage (37.1 %) to be the most important causes of flooding hazards.

**Table 1:** Major cause of hazards

| | Douala I (%) | Douala IV (%) | Douala V (%) | $X^2$ | *p* |
|---|---|---|---|---|---|
| Cemented urban surface | 76 (44.4) | 44(25.7) | 51 (29.8) | 16.349 | 0.003 |
| Building along drainage path | 122 (29.9) | 115 (28.2) | 171 (41.9) | 14.277 | 0.001 |
| Little or no drainage network | 121 (26.0) | 172 (36.9) | 173 (37.1) | 34.938 | 0.000 |
| Excessive rainfall | 162 (28.0) | 215(37.1) | 202 (34.9) | 28.66 | 0.000 |
| Soil type | 99 (31.8) | 121(38.9) | 91 (29.3) | 31.145 | 0.000 |
| Blocked drains | 129 (22.8) | 146 (43.7) | 112 (36.0) | 17.154 | 0.000 |
| Topography | 76 (25.1) | 173 (42.6) | 126 (33.5) | 72.55 | 0.000 |
| Development of vulnerable lands | 97 (27.0) | 146 (40.7) | 116 (32.3) | 41.071 | 0.000 |
| Sea level rise | 114 (28.2) | 154 (38.1) | 136 (33.7) | 37.624 | 0.000 |
| Deforestation | 95 (33.1) | 73 (25.4) | 119 (41.5) | 2.699 | 0.259 |
| Will of God | 82 (47.7) | 43 (25) | 47 (27.3) | 24.396 | 0.000 |

Probably, because Douala I is an administrative area, with well drained gutters and there are no development of vulnerable lands as opposed to the Douala IV area which is a residential area, poorly drained and because of its low lying nature, flooding frequently occurs here. However, the influence of urbanisation, with most of its surfaces cemented further accounts for flooding problems in Douala I. This has more than accounted for the causes of floods in the area but not perceived by the sampled population as such because considering the educational status of a majority of the residents, they were more inclined to perceive the causes of floods more as a function of lack of physical drainage facilities rather than an improper development of lands. The degree of imperviousness was identified as the most important factor in expatiating on urban flooding in a study conducted in Benin city and the percentage of built up area was the second most important. These activities range from the development of vulnerable lands without proper observance of land-use regulations by private and corporate bodies without adequate provision for drainage to the negligence of town planning rules.

Additionally, bad cultural habits have led to the blocking of drains, silt accumulation, cutting down of trees in the upland areas among others. Consequently, there has been a shift from the more important to the less important cause of floods as perceived by the sampled population of the flood-hazard zones and this is a vital point in developing suitable policies for flood control in the city. There is no doubt that the increased intensity of rainfall generating much surface run-offs especially where there are no drainage facilities are also responsible for the causes of floods in the Douala city as shown in Table 1. This is also closely tied to urbanisation where open lands for water infiltration have been covered up by impervious layers. Given the enormous volume of water generated under severe storm conditions occasioned by temperature increases with special reference to urban flood situation in a developing country like Cameroon and the economic hub of the country Douala, it is opined in this study that as there will be continuous energy in the atmosphere and as severe storm events increases in response to global warming (Fonteh, 2020) and human activities becomes domineering in causing floods, redesigning urban land management options with the construction of storm sewers and drainage network to mitigate floods and its associated impacts becomes imperative. Whatever, slight variations exist in response as to the causes of floods in Douala I, IV and V maybe a matter of individual perception, level of education and occupation which maybe right or wrong.

Table 2 shows the major hazards perceived by the sampled population. The major hazards related concerns show significant differences in their distribution except for coastal erosion as a hazard that is similar across the sub divisions. Rainstorms, flooding and tidal effects are perceived as the most devastating hazards in the area by the respondent while Landslides and wave action are the least perceived as a hazard by the overall ranking of the hazards.

**Table 2:** Perception of major hazards

| | **Douala I (%)** | **Douala IV (%)** | **Douala V (%)** | $X^2$ | ***p*** |
|---|---|---|---|---|---|
| Coastal erosion | 97 (38.6) | 56(22.3) | 98 (39) | 9.962 | 0.007 |
| Flooding | 146 (28.2) | 200 (38.6) | 172 (33.2) | 41.304 | 0.000 |
| Landslides | 86 (40.8) | 47 (22.3) | 78 (37.0) | 8.167 | 0.017 |
| Tidal effects | 93 (32.1) | 118(40.7) | 79 (27.2) | 43.296 | 0.000 |
| Wave action | 100 (43.9) | 45 (19.7) | 83 (36.4) | 17.687 | 0.001 |
| Rainstorm | 172 (32.5) | 187 (35.3) | 171 (32.3) | 27.164 | 0.000 |

Table 3 illustrates the perceived socio-economic impacts of floods by the sampled population during a questionnaire survey and response were corroborated by information elicited from participants in focus-group discussions sessions that were held in the study area. The losses suffered by residents in flood prone areas in the city have been both tangible and intangible.

**Table 3:** Impacts of hazards

| | Douala I (%) | Douala IV (%) | Douala V (%) | $X^2$ | *p* |
|---|---|---|---|---|---|
| Livelihood and business slowdown | 160 (28.5) | 199 (35.5) | 202 (36) | 30.235 | 0.000 |
| Damage to buildings | 156 (27.2) | 205 (35.7) | 213 (37.1) | 56.154 | 0.000 |
| Deaths | 167 (33.8) | 181 (36.6) | 146 (29.6) | 38.619 | 0.000 |
| Pollution of water resources | 159 (29.3) | 194 (35.6) | 189 (34.9) | 34.858 | 0.000 |
| Health | 163 (28.6) | 203 (35.7) | 203 (35.7) | 22.455 | 0.000 |
| Migration of people | 116 (27.4) | 188(44.4) | 119 (28.1) | 89.327 | 0.000 |
| Obstruction and restriction of movement | 141 (30) | 182 (38.6) | 148 (31.4) | 32.759 | 0.000 |

All the impacts of the hazards on the population show statistically significant differences in their distribution (Figure 3). Of these differences, the majority of the respondents of Douala IV indicated that, deaths (36.6 %), migration (44.4%) and the obstruction/restriction of movement (38.6%) were more important than in Douala I and V. However, the Douala V respondents perceived damage to buildings (37.1%) to be more important as opposed to Douala I and IV respondents. This has probably led to a high rate of migration and evacuation from flood prone areas to areas perceived to be flood resistant.

A trend that can draw from the data collected on the impacts of flooding hazards in the study area show that Douala I receive less impact in comparison with Douala IV and V, while Douala IV has a higher impact, this is probably due to the location of the Douala IV inhabitants which is quite close to the coastline and therefore susceptible to tidal effects could explain their level of awareness as observed in this study. These therefore, calls for immediate attention on these areas where construction activities are going on uncontrolled without appropriate development policies incorporated to mitigate floods (Fonteh *et al*., 2016). Botkin and Keller (1982) highlighted that the understanding of how people try to perceive various natural hazards is an important endeavour because the success of any hazard reduction programme depends on the attitude of the people likely to be affected by the hazard.

Regarding, what people perceived to be government's measures to check such hazards; "no action" was observed to be similar in all the regions, with the Douala I respondents with very high percentage of (52.5) However, the majority of the Douala IV respondents perceived land use planning (41.2%), Legislation and policies (38.1%), drainage clearance/construction (37.5%) and dredging/shore protection (39.2 %) as more important when compared with Douala I and V in their adaption to flooding hazard impacts. On the other hand, respondents of Douala V think that the development of educational programmes (36.5%) and awareness campaigns (36.4%) respectively should be the major approaches of adaptation to such hazards.

**Table 4:** Adaptation measures to flooding hazards

| | Douala I (%) | Douala IV (%) | Douala V (%) | $X^2$ | *p* |
|---|---|---|---|---|---|
| Early warning | 146 (29.2) | 177 (35.4) | 177 (35.4) | 30.111 | 0.000 |
| Development of educational | 158 (29.4) | 183 (34.1) | 196 (36.5) | 29.215 | 0.000 |
| programs | 174 (29.7) | 198 (33.8) | 213 (36.4) | 26.274 | 0.000 |
| Awareness campaign | 106 (28.9) | 140 (38.1) | 121 (33.0) | 36.831 | 0.000 |
| Legislation and policies | 115 (24.7) | 192 (41.2) | 159 (34.1) | 68.816 | 0.000 |
| Land use planning | 125 (27.5) | 178 (39.2) | 151 (33.3) | 48.749 | 0.000 |
| Dredging and shore protection | 149 (27.1) | 206 (37.5) | 194 (35.3) | 43.950 | 0.000 |
| Drainage construction | 21 (52.5) | 5 (12.5) | 14 (35.0) | 12.486 | 0.041 |
| No action | | | | | |

**b) Projected areas at risk of flooding**

The results of a 5m flooding situation was linked with a risk of flooding of swampy vegetation (34.6km$^2$), mangroves (64.5 km$^2$), settlement (132.21 km$^2$) and bare-ground (152.6 km$^2$), For the 10 m inundation scenarios, critical elements at risk of inundation for the same LULC classes were: settlement (446.82 km$^2$), bare-ground (476.5 km$^2$), mangroves (542.4 km$^2$) and swampy vegetation (125.3 km$^2$) as shown on Table 5 respectively for settlement and bare-ground land use classes. Figure 2 shows potential settlement and bare ground areas at risk of 10m flooding.

**Table 5:** Potential areas at risk of 5 and 10 m inundation scenario in Douala

| Critical elements | 5 m flooded area km$^2$ | 10 m flooded area km$^2$ |
|---|---|---|
| Settlement | 132.21 | 446.82 |
| Bare-ground | 152.6 | 476.5 |
| Mangroves | 64.5 | 542.4 |
| Swampy vegetation | 34.6 | 125.3 |

From the 5 and 10 m inundation scenarios for this study area, it is clear that the greatest threat to the assessed LULC classes will be incurred by bare-ground followed by settlement. These are followed by mangroves and swampy vegetation. Hence, a significant damage could be incurred on the water resources in this area. Other activities could be directly or indirectly affected as a result of these inundated areas for the study area.

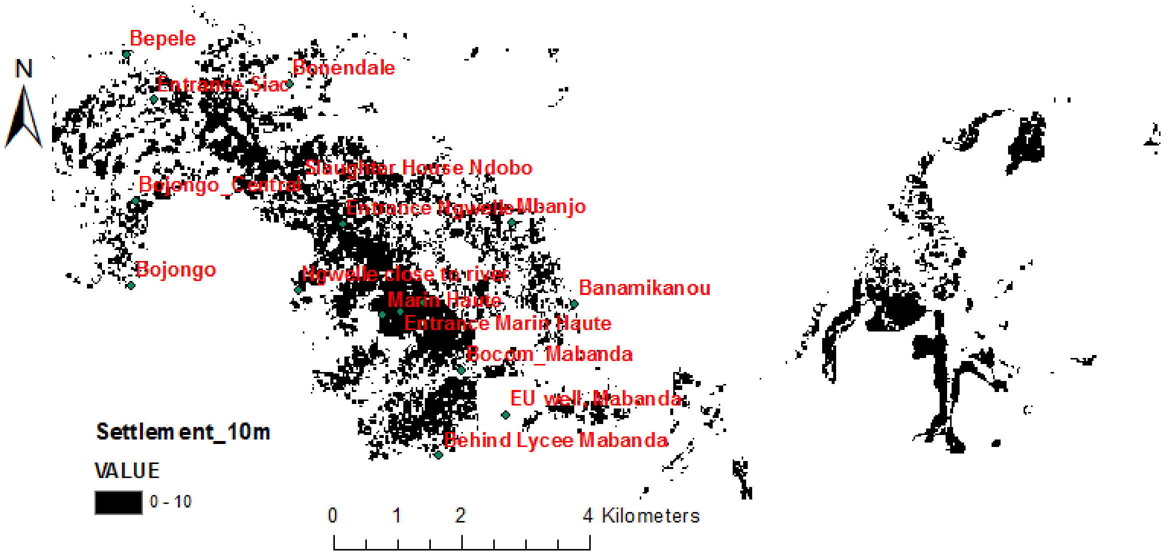


**Fig. 2:** Settlement area at risk of 10 m inundation

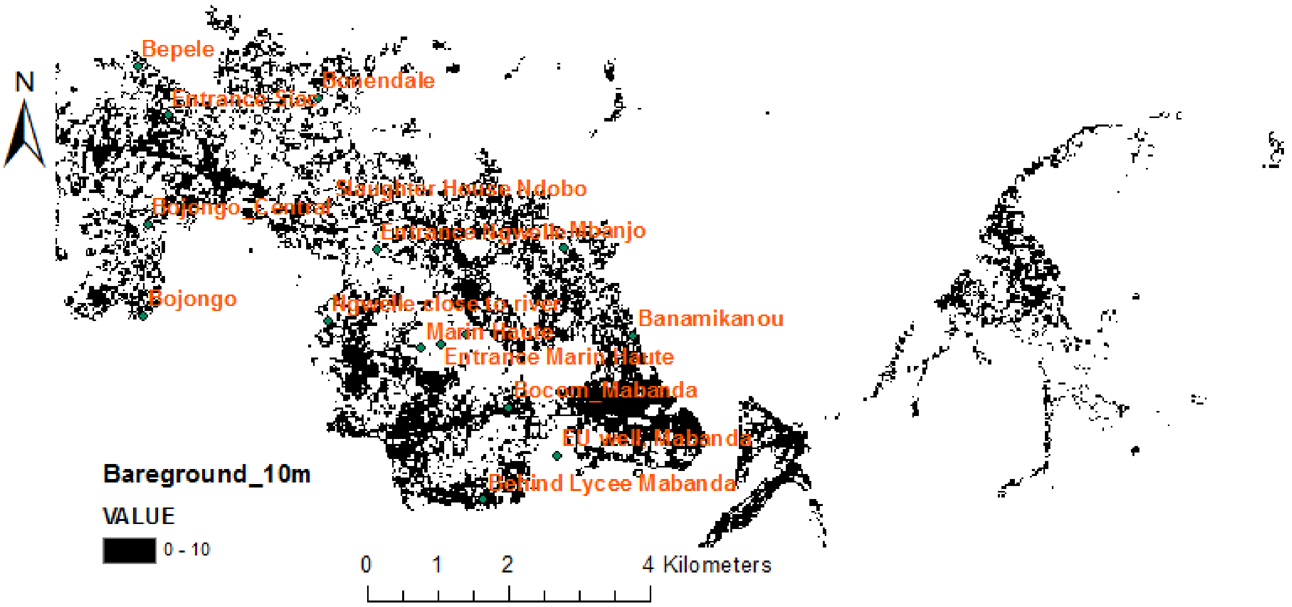


**Figure 3:** Bare ground areas at risk of 10 m inundation

## Conclusions and Recommendations

The causes of floods in the city of Douala though perceived by the sampled population basically as a function of cemented urban surface, blocked drains and building along drainage paths or the inadequacy of it is more from the findings made in this study, due to anthropogenic factors. Ignorance on the other hand and lack of education of the general populace has led to poor cultural practices and habits which equally serve to generate floods. The major devastating flood hazards are landslides, tidal effects, with impacts of these hazards perceived to be very high across the three districts. Bare-ground and settlement classes will be more impacted due to inundation. The use of remote sensing, GIS tools and DEM tools has enabled the quantification of risky areas to the impacts of SLR. The high population density of this and its vital economic sectors make the potential impacts of SLR hazards impact on its water resources of particular concern especially ground water resource quality. The government should make major investments to improve the data base of climate change variables of the coastlines of Douala and the entire nation since information from these databases will form the basis for the development of adaptation strategies to any future flooding hazards.

**References**

Fonteh, M., Esteves, L.S., Gehrels, W.R. (2009). Mapping and valuations of ecosystems and economic activities along the coasts of Cameroon: Implications of future sea level rise. *Coastline reports*, 13:47 - 63.

Fonteh, M. L., Fonkou, T., Lambi, C. M., Main, R., Ramoelo, A., & Cho, M. A. (2016). Assessing the Utility of Sentinel-1 C Band Synthetic Aperture Radar Imagery for Land Use Land Cover Classification in a Tropical Coastal Systems When Compared with Landsat 8. Journal of Geographic Information System, 8**-**., http://www.scirp.org/journal/jgis doi.

Fonteh, M. L. N. (2020), Floodplains and Socio-Economic Factors of Flood Risk Vulnerability in Bamenda City, Cameroon. International Journal of resource and environmental management. Vol. 4 No. 2

Ndenecho, E. N., & Fonteh, M. L. (2012), Freshwater and Coastal Resource Management in Cameroon: Building Resistance and Resilience to Climate Change, Bamenda, Agwecams Printers Bamenda. ISBN: 978-9952-621-06-4. 328 pp.

## PERCEPTION OF THE IMPACTS OF CLIMATE VARIABILITY ON WATER SUPPLY AND MANAGEMENT IN KANO STATE, NIGERIA

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***Abstract***
*Climate variability contributes toward many global challenges associated with water, thereby accelerating various disasters such as draught and flooding in many communities. It usually impacts the quantity and quality of both surface and ground water across the globe. This research seeks to understand the extent to which local communities understand and perceive climate variability and their related impact to the supply and management of water for effective sustainable development. Data were obtained through Focus Group Discussions (FGDs) undertaken within 30 communities choosing systematically from six Local Government Areas (LGAs)of Kano state. Qualitative data from FGDs was analysed using thematic framework. Major findings show that, Participants associated the growing incidence of droughts and flooding to climate variability. The study also shows that, about 31% of the participants (Kano north) frequently made mention of the surface water as element that were impacted by climate variability, this was followed by rain with 25% and groundwater with 23% while 21% made mention of all. About 78% of the participants identify negative impacts of climate variability on water management while 22% identified its positive impacts. It is therefore, concluded that climate variability impacts the quantity and quality of water resources, hence, farmers and other local communities are supposed to be educated on adaptation and mitigation strategies to climate change and variability.*

**Keywords**: - Climate, Variability, Water, Perception

### Introduction

According to Asante and Amuakwa (2014) climate variability becomes a topical issue globally, as the physical and biological systems on all continents are being affected by recent changes in climatic conditions. The variability is having direct and indirect impacts on ecological systems such as surface and underground water worldwide. Variability is defined as an inherent dynamic nature of climate on various temporal scales which could be monthly, seasonal, annual, decadal, periodic, quasi-periodic or non-periodic (Odjugo, 2010). The direct impacts originate from climate – related hazards such as storms, droughts, heat waves and floods (Watts *et., al.* 2018) while the indirect impacts occur as a result of impacts of climate variability on secondary factors such as human activities. These impacts resulted to changes in the availability and quality of water supply. Hence, the needs to conduct studies that considers the linkages between climate variability and water supply and management, in areas such as Kano State which have different climatic condition, the semi-arid, Northern Guinea Savanna and Sudan Savanna, so as to have a better understanding of the nature of the relationship.

Public perception was conducted in this study together relevant information because it can contribute to the successful implementation of water shortage adaptation strategies. According to Duinen, Filatova, Geurts, and van der Veen (2014) an understanding of the public perception of the way water shortage relate to climate variability has the potential to tackles all related problems.

## Study Area and Methodology

### Study Area

The study area (Kano State) extends from Latitude 10°3′ N to 12°3′ N and Longitude 7°35′ E to 9°20′ E (Figure: 1), it has a total land area of about 20,760sq km (Research and Documentation Directorate Kano, 2009). The area made up of 44 Local Governments Areas. Its climate characteristic is tropical continental climate with alternating wet and dry seasons. It is classified as Aw, according to Koppen's classification scheme, implying dry and wet type with the rainy season lasting from mid-May to mid-October whereas the dry season is from mid-October to mid-May (Abaje, Ndabula and Garba, 2014). Rainfall decreases from South to Northern part ranging from 1100mm to about 800mm (Nabegu, 2014). The temperature of Kano State usually varies from warm to hot seasons. The major source of water supply for rural communities have been surface water such as river and dams while for urban areas are open well and bore hole.

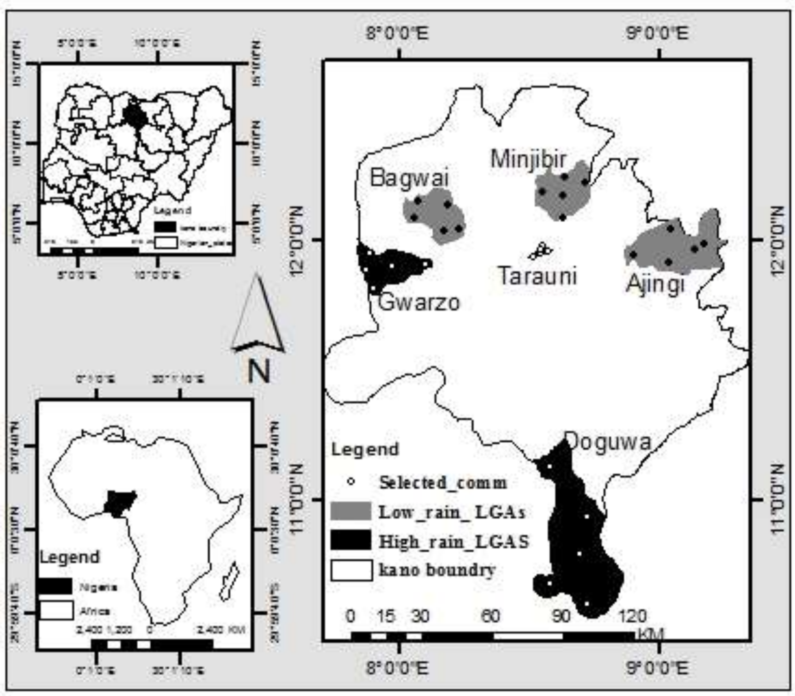


**Fig. 1:** Map of the study area

### Methods of Data Collection

Data used for this research was gathered from FGDs undertaken in thirty communities choosing from six LGAs of Kano state between 21st of May to 19th of June, 2020. Three of the LGAs are those with lowest annual rainfall as at 2019 selected from three senatorial zones and other three are those with highest rainfall. Sixty FGDs were conducted; two each in each of the thirty study communities. Total of fifteen participants were selected by community leaders to represent them in each FGDs. The discussions were conducted with the help of note-taker using a pre-designed FGDs guide and recorder.

### Methods of Data Analysis

Thematic analysis was conducted on the qualitative data obtained from FGDs. This is through familiarization, and identification of thematic frameworks; indexing; charting; and interpretation. In the first instance the note taken during the discussions were read entirely, so as to get familiar with the information gathered, this help to identify the dominant themes that emerged during the discussions. In the second stage, coding has been made to identify different topics that were discussed, this help to come out with the themes that are in line with the objectives of the study. In the third step information recorded were listen and type in form of Microsoft word format. Interpretations of the information were finally conducted based on the context, comments, and words of the participants.

## Results and Discussion

### Climate Variability

Analysis show that participants generally displayed a high level of awareness of variations in climatic variables mainly temperature and rainfall in their localities. They all believe that dry season which spans from November to June is longer than it used to be. They also stated that the heat experienced in recent times is much more severe than in the past. One of the participants from Kano North stated that:

> "The weather is now not stable and difficult to predict when the seasons will begin and end. Some years ago, the rains would start in April and reaches December, and the dry season continues from there. But now rain season seems to begin by the end of June. This is seriously affecting us, because we rely on the rains for farming and other domestic activities"

According to the participants from Bagwai LGA rain does not fall at the expected time these days. It falls at a time we don't expect. Rain pattern changed, the volume increases and decreases. In fact, climate variability is happening all around our environment due to rising temperatures and declining rainfall which resulted to various disasters.

### Impacts on Draught and Flooding

About 93% of the participants associated the phenomenon of climate variability to the growing incidence of droughts and floods. According to them floods are becoming an annual phenomenon. Participants from Kano South cited an example to what happen in River Wudil while those in Kano central cited an example of what happen this season where about 200 houses in Gwale LGA were reported to have been flooded due to excessive rain.

> "At one time we experience very heavy rainfall over a very long time which leads to floods, and at other times it only drizzles over a couple of days, causing droughts which leads to inadequate water supply. These are the challenges we are facing in this community and we cannot do anything about it". (Lawan Ibrahim, Kano South)

### Impacts on Water Quantity

Participants identified changes in the availability of water supply from various water bodies such as dams, rivers, open wells and boreholes. The most frequently mention by those from Kano North were impact on the quantity of surface water with 31%, this was followed by rain with 25% and groundwater with 23% while 21% made mention of all. In general, about 74% of the participants in this study, made mention on the reduction of surface water while 23% of them made mention of the reduction of underground water due to climate variability. Some of the participants stated that,

> "We could remember in our childhood, we don't need to dig our wells deep before water can be assess, just in few meters water is available, but now a days we have to dig several meters before getting water"

**Impacts on Water Quality**

Majority (64%) of the participants stated that, because of inadequate availability of water, the same water they used for domestic activities were also used for their animals which consequently resulted to damaging of the water quality. Some are of the view that, difficulty in assessing water from wells in dry season changes the colour and the quality of the water. This result is in line with that of Martins (2001) who stated that, the quality of water required for activities is influence mainly by variables such as climate and precipitation

According to the participants (42%) rising of temperature resulted to higher evapo-transpiration which consequently leads to inadequate water supply and therefore changing its quality. But, 58% of the participants associated the problems of water quality in their areas with other climatic factors such as inadequate rainfall and wind and human activities.

**Impacts on Water Management**

About 78% of the participants identify negative impacts of climate variability on water management. According to them, when there is heavy rainfall erosion and flooding took place, thereby damaging sources of water supply such as dams and rivers.

Participants are of the view that, a significant decrease of rainfall due to variability of climate leads to falling of water levels in opens wells, which resulted into the need to look for other source of water for domestic and irrigation activities.

Participants of the discussion also stated that, climate variability negatively affects the management of water resource, especially source of water for domestic activities. For example, according to participants from Kano central, heavy rainfall transport wastewater and pollute our dams and rivers such as River Challawa, while inadequate rainfall increases the use of untreated wastewater for irrigation farming. The finding of this research is supported by that of Urama and Ozor (2010) who reported that climate change leads to drying up of rivers, poor water quality in surface and groundwater systems. This result is also in line with that of UN water (2019) that stated that, climate change leads to more-frequent combined sewer to overflows and pollute receiving waters, while drought can increase the use of poorly treated wastewater for peri-urban agriculture.

But, about 22% of the participant recognized some positive impacts of climate variability on water management, according to them; inadequate rainfall which leads to insufficient water resulted to more efficient water use. One of the participants from Kano central stated that,

> "In the case of water for domestic activities, we try as much as possible to restrict overuse of water by buying what we thinks is enough from water vendors"

**Conclusion and Recommendations**

Detail information on the local perceptions of the impacts of climate variability on water resource supply and management in Kano State is inadequate. In this research FGDs have been used to assess the views of the participants from thirty communities within the study area. In conclusion the finding of this study revealed that, heat experienced in recent times is much more severe than in the past and the weather is now unstable and difficult to predict when the seasons will begin and end. In conclusion, it is also revealed that, the phenomenon of climate variability in the study area resulted to the growing incidence of droughts and floods. The result of the study also concluded that, climate variability also brings about inadequate water supply with poor quality and difficulty in the management of the water resource. It is therefore, recommended that, farmers and other local communities are supposed to be educated on adaptation and mitigation strategies to climate change and variability.

**References**

Abaje, I.B., Ndabula, C. and Garba, A.H. (2014). Is the Changing Rainfall Patterns of Kano State and Its Adverse Impacts an Indication of Climate Change? *European Scientific Journal*, 10:192-206.

Asante, F. A. and Amuakwa, M.F. (2014). Climate change and variability in Ghana: Stocktaking. *Climate*, 3, 78e99.

Duinen, R.V.; Filatova, T.; Geurts, P.; van der Veen, A (2014). Coping with drought risk: Empirical analysis of farmers' drought adaptation in the South-West Netherlands. *Regional Environmental Change* 15:1081–1093.[CrossRef].

Martins, M. (2001). Water resources management and development in Nigeria- issues and challenges in a new millennium. An inaugural lecture delivered at the University of Agriculture on the 22nd of August, 2001.

Nabegu, A.B. (2014). Analysis of Vulnerability to Food Disaster in Kano State, Nigeria. *Greener Journal of Physical Sciences*, 4:22-29.

Odjugo, P.A.O. (2010). Regional evidence of climate in Nigeria. *Journal of Geography and Regional Planning*, 3(6): 142-150.

Research and Documentation Directorate (2009) About Kano, in Kurawa I.A (Eds): A Publication of Kano State Govt.

UN Water (2019). Climate Change and Water, UN Water Policy Brief, *UN-Water Technical Advisory Unit*, unwater@un.org l www.unwater.org.

Urama, K. C. and Ozor, N. (2010). Impacts of Climate Change on Water Resources in Africa: the Role of Adaptation, African Technology Policy Studies Network (ATPS), Research gate, 1: 29: downloaded from https://www.researchgate.net/publication/26721 88 99

Watts, N., Amann, M., Ayeb-Karlsson, S., Belesova, K., Bouley, T., Boykoff, M., Byass, P., Cai, W., Campbell-Lendrum, D. and Chambers, J. (2018). The Lancet Countdown on health and climate change: From 25 years of inaction to a global transformation for public health. Lancet, 391:581–630.

# ADAPTATION OF PLANKTON AND BENTHIC SPECIES TO CLIMATE CHANGE IN THE TROPICAL AQUATIC ECOSYSTEM: A REVIEW

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**Abstract**

*Climate change, a global environmental phenomenon, is recognized as a major threat to survival of species and integrity of ecosystem world-wide. Adaptation strategies by species assemblages in an ecosystem are therefore aimed at reducing mortality, while they are expected to increase survival flexibilities of the species or group of species to a given climate variability scenario. These scenarios are known to impact directly and/or indirectly on the distribution, abundance, diversity, reproduction, growth and species composition. This paper reviews the adaptive strategies that will or are expected to enhance the survival of phytoplankton, zooplankton on and benthic communities/assemblages in the tropical and sub-tropical coastal waters, their community structure, life processes and roles in the ecosystem.*

**Keywords:** Climate change, phytoplankton, zooplankton, benthos, fish, adaptation, tropical, coastal ecosystem.

## Introduction

Climate change has been known even during the pre-industrial age though with little or no profound effects on the environment (Hofmann and Todgham, 2010). It is now an established scientific reality, with a variety of emergent challenges for the Earth system (aquatic, terrestrial and arboreal) (IPCC, 2007). The oceans play a major role in modulating the climate system through storage and transport of heat (Barnett *et al.,* 2005), and through the uptake and sequestration of carbon dioxide (Doney et al.,2009; Huertas et al.,2015). As the release of excess $CO_2$ to the atmosphere will continue, the planet and some critical ocean regions may soon be warmer than at any time in the past million years (Hansen et al.,2006; Belkin, 2009). It has been predicted that by the end of the 21st century, the sea surface might experience a temperature augmentation between 1.10$^{o}$C (Low $CO_2$ emission scenario) and 6.4$^{0}$C (high $CO_2$ emission scenario) (Huertas et al., 2011). Warming will also be experienced by large freshwater bodies, with a rise of 1.7$^{0}$C in surface water temperatures due to the predicted doubling of atmospheric $CO_2$ concentration (Huertas et al., 2011).

## Plankton, benthic and other aquatic species

Despite their microscopic size, phytoplankton support about half of the global primary production, drive essential biogeochemical cycles and represent the basis of the aquatic food web (Huertas*et al.,* 2011). At present, it is known that phytoplankton are important targets and, consequently, harbingers of climate change in aquatic systems. Therefore, considering the polyphyletic complexity of the phytoplankton community, different responses to increased temperature including photoperiod are the main interplaying factors influencing them to adapt to the climate change effects (Huertas et al.,2015; Muren et al.,2005). The possible explanations supporting species adaptation to new conditions through genetic change based on the process of evolution are that, beneficial mutation of the genes allows survival at increasing temperatures. This adaptive feature however cuts across the three assemblages (phytoplankton, zooplankton and benthos) (Huertas et al.,2005; Sniegowski and Lenski, 1995) Drifting life forms, whose spatial distribution is primarily determined by the motion of the water column (such as those integrating the plankton community, particularly some larval forms of benthos (which are zooplankton at that stage (i.e. larval stage) and bottom-dwelling (i.e. benthos at adult stages), rely on the last two mechanisms to cope with the increased temperatures, considering the environmental selection forcing (rising temperature and photoperiod) (Huertas et al.,2015; Muren et al.,2005; Marva et al.,2010).

There will be generally, a swift towards a dominance of small-celled phytoplankton communities (that would have its primary origin in a temperature – driven environmental process, such as nutrient supply or potential grazing, owing to the impact of warming on zooplankton, rather than in a direct thermal effect on the phytoplankton metabolism (Huertas et al.,2015; Marva et al.,2010).

**Benthic Community**

Benthic communities and constituent species are sessile or have low mobility. However, they are capable of responding to climate change by way of developing or being able to develop adaptation strategies which enable them maintain their population and ecological roles (Dam and Baumann, 2017).With their sessility, some basic adaptive strategies have been reported. In considering the adaptation of the benthos to climate change, the polychaetes belonging to the family Nereidae are reviewed. Nereidae are semelparous (Lawrence and Soame, 2004). This means that gametes are developed and released once in a lifetime, after which the adult dies. Typical Nereidae species are known, and include *Nereisvirens*, *N. diversicolor*, *Harmothoeimbricata*, *Nephtyshombergii* and *Eulaliaviridis*.

**Adaptation strategies**

Adaptation is here defined as the ability of an organism to adjust in natural or human system in response to actual or expected climate change or their effects (Akinrotimi&Edun, 2013). In this direction, the following adaptation strategies have been reported for each of the communities considered in this context. For these animals, the synchronous timing of reproduction which is very crucial and tightly controlled, not only within the individuals, but also across the population has been developed as a biological mechanism (Garwood and Olive 1982; Baduini et al.,2001; Lawrence and Soame, 2004). There is also a strategy to release eggs and developed larvae during periods of abundant food supply (Olive et al., 1990). An explanation to the first strategy is based on the fact that temperature and photoperiod both influence the gametogenic process in the nereids (Rees, 1997; Last, 1997; Lawrence &Soame, 2004). These authors are of the view that low temperature (7 – 12$^0$C) will encourage oocytes growth in nereids, while high temperatures will inhibit growth of the oocytes. Short photoperiod (Light – Dark (L:D) 8: 16h) will also promote oocyte growth, while long days (L:D (16 – 8h) will inhibit it (Last, 1999; Lawrence and Soam, 2004; Baduihi*et al.,*2001). Therefore, bearing in the mind that these benthos die after release of gametes (ie development and release of gametes occurs once in a lifetime in nereids) for these groups of benthos in particular to maintain their population and ecological functions, the synchronization of the reproductive cycle has been developed as an adaptive strategy (Lawrence and Soame, 2004).

The third adaptation strategy has been that of producing few larger eggs and greater number of smaller eggs as temperature rises, with attendant longer photoperiods. Large egg sizes of nereids were reported to still remain viable under increased temperatures (Baduini et al.,2001) in South-Eastern Bering Sea during the Summer of 1997, while Clark (1988) reported that small-sized nereid eggs under the influence of rising temperature and longer photoperiod were still alive and viable in Humber estuary, Northeast England. This suggested the importance of benthos to be able to adapt to climate change by developing few larger eggs and greater number of small-sized eggs through a synchronized reproductive cycle, based on temperature and photoperiod effects. The eggs of Flounder fish have also been carefully studied by Dam and Baumann (2017) in relation to their adaptive strategies in Rhode Island to exhibit the strategy of reproducing few larger eggs and large number of small-sized eggs.

**Fish community**

As climate change continues to exacerbate existing ecological conditions in the aquatic ecosystem, it poses significant and long-term risks to fisheries community in relation to survival, growth, distribution, reproduction and the subsequent recruitment into the standing stock of the fish population (Ayub, 2010; Garcia and Rosenberg, 2010; Hlohowskyjl et al .,1996). Dwindled fish population due to the impact of climate change has been variously reported in the sub-Saharan waters (Mohammed and Uraguchi, 2013; Nye, 2010; Feidi, 2019; Olaoye*et al*., 2010) and other parts of the world (Harley*etal*., 2006, Scavia et al., 2002; Hughes et al., 2003; Hamilton et al., 2000).The effects of climate change have been and are being resisted by fish communities in the different aquatic ecosystems by the development of various adaptive strategies among which have been reported to include: Delayed reproduction (Lawrence and Soame, 2004; Ayub, 2010; Patrick, 2016; Olaoye et al., 2010), becoming larger than expected at maturity to enhance higher fecundities (Synder and Dingle, 1989), gene tinkering (Myelnikov (2019). Schult (2007) and Myelnikov (2019) maintain that genes can be turned up or down so that their functions become stronger or weaker given the prevailing climatic condition. In this basic genetical functioning, unlike evolution, the process of gene tinkering is extremely quick and can sometimes take place in just a matter of days. In tropical and sub-tropical estuarine waters, certain species have become better equipped to deal with rapid changes in climate than others particularly those that have a longer life span and lower reproductive rates. These have been observed in skates in the Southern Gulf of St. Lawrence, off the Labrador Peninsula by Myelnikov (2019).

**Discussion**

Natural climatic fluctuations, particularly those at medium (decadal) scale, have always affected arboreal, terrestrial and aquatic organism (Garcia and Rosenberg, 2010, Barange and Perry, 2009, IPCC, 2001, 2007, Bindoff et al.,2007). According to Christensen et *al.* (2007), warming in tropical and sub-tropical coastal waters is very likely going to be larger than the global annual mean warming throughout the region and in all seasons. The tropical regions according to Mohammed and Uraguchi (2013), will become more drier than the wetter tropics with a consequent decline in rainfall/rising water temperature known to threaten biodiversity (Abowei, 2010), and according to IPCC (2001, 2007; Urama and Ozor, 2010; Schallenberg et al.,2003), if water rises above the maximum tolerable threshold of a species, then its existence including other biological activities of the species are threatened. Urama and Ozor (2010) provide an example from the Labiden highlands in Cameroon where women have started hunting tadpoles and frogs because there are no fish in most of the Bangwa Rivers. According to Urama and Ozor (2010), even the number of tadpoles and frogs has significantly declined (partly) due to the warming rivers that have caused increased number of predator fish in an area they have never inhabited before.

Climate change can cause an increase or decrease in water salinity and this may happen in multiple ways (Mohammed and Uraguch, 2013), while tropical and subtropical coastal water including the oceans are increasingly becoming saltier, those closer to the poles are becoming fresher (Schallenberg et al. 2003; Mohammed and Uraguch, 2013). This highlights that tropical and subtropical and estuarine systems and oceans are very likely to suffer more from the potential impacts of increasing water salinity for example, relative to waters in higher latitudes (Schallenberg et al.,2003). Changes in water salinity (one of the many outcomes of global warming) have different effects depending on the tolerance level of the organisms and the nature of their ecosystem generally – whether freshwater, estuarine or marine. The salinity of some freshwater ecosystems have been predicted to increase as a results of anthropogenic climate change (IPCC, 2001). Such physical changes are known to have negative impact on the population of plankton, benthos and other aquatic species (Schallenberg et al.,2003).

One of the most important variables that determine the survival of organisms in estuarine ecosystems is salinity (Marshall and Elliot, 1998; Abowei, 2010). Salinity has a direct impact on the organism and can also indirectly destroy the habitats of the organisms, including their breeding and nursery grounds (Marshall and Elliot, 1998; Abowei, 2010; Mohammed and Uraguch, 2013). In a previous report, Schallenberg*et al.* (2003) noted that zooplankton communities of low-lying, coastal, tidal lake and wetlands are already adversely affected by small increases in salinity levels. It was concluded that such changes in zooplankton abundance ma further disturb the ecological functioning of the valuable, but vulnerable ecosystems.

According to Blaber (1997), all estuarine fish are euryhaline, this may or may not be true for all species of benthos, zooplankton and phytoplankton as the ability for an organism to cope with salinity fluctuations varies from species to species, hence, changes in salinity is likely to influence the distribution, survival and adaptation of the benthos, zooplankton, phytoplankton and fish in the tropical and sub-tropical estuarine ecosystems. Mohammed and Uraguch (2013),are of the view that even though salinity changes may not have a direct negative effect on estuarine species (fishes, plankton and benthos) per se, it is likely to have a negative impact on their habitat. This is informed by the report of IPCC (2007) that water salinity has contributed to the destruction of 60 percent of mangrove areas in Senegal. Parkins (2000) noted that each acre of mangrove forest destroyed for shrimp farming leads to an estimated 300kg loss in marine harvest in Senegal, and that change in water salinity had tremendous negative impact on fishery in the Senegalese region, threatening the livelihoods of many impoverished coastal communities.

Generally, climate change is already affecting the trends of some very important biological processes resulting in changes in primary production (Taucher and Oschlies, 2011; Mohammed and Uraguch, 2013). Inorder to adapt to the negative impacts of climate change, biological communities including the benthos, zooplankton and phytoplankton have developed different adaptive strategies to enable them survive, grow, reproduce and become distributed in their natural habitat therefore enhancing their continuous ecological functions in the ecosystem.

## Conclusion

When climate change is slow, species may have time to adapt to more suitable ecological conditions and locations and “invent” other biological and physiological processes that will (or likely to) promote their ecological roles in the ecosystem and their chose niche. But when climate change is relatively abrupt, many organisms are (or will be) unable to respond before conditions exceed their tolerance limits. Whole communities may be destroyed, and if the phenomenon is widespread, many species may become extinct as issues of climate change are unending.

When climate change is gradual, species may have time to adapt to more suitable locations and “invent” other biological and physiological processes that will (or likely to) promote their ecological roles in the ecosystem. But when climate change is relatively abrupt, many organisms are unable to respond before conditions exceed their tolerance limits. Whole communities may be destroyed, and if the climatic change is widespread, many species may become extinct.

## References

Abowei, J. F. N. (2010). Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. *Advance Journal of Food Science and Technology,* 2(1): 36-40.

Akinrotimi, O. A. and Edun, O. M. (2013).Impact of climate change on brackish water aquaculture development in the coastal areas of Niger Delta. Proceeding of 28th FISON Annual Conference, 25th – 30th November; 140-145.

Ayub, Z. (2010). Effect of temperature and rainfall as a component of climate change on fish and shrimp catch in Pakistan. The journal of Transdisciplinary environmental studies, 9(1): 1 – 9.

Baduini, c. L., Hyrenbach, K. J., Coyle, K. O., Pinchuk, A., Mendenhall, V. and Hunt, G. L. (2001). Mass Mortality of Short-tailed shear-waters in the South-Eastern Bering Sea during Summer 1997. Fisheries Oceanography, 10:117-130.

Barange, M. and Pery, R. I. (2009). Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. In: K. Cochraine; C. De Young; D. Soto and T. Bahr (eds). Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge. *FAO Fisheries and Aquaculture Technical Paper,* No. 530, Rome, FAO pp.7-106.

Barnet, T. P., Pierce, D. W., AchutaRao, K. M., Gleckler, P. J., Santer, B. D., Gregory, J. M. and Washington, W. M. (2005). Penetration of human-induced warming into the World's Oceans. Science, 309: 284-287.

Belkin, I. (2009). Rapid Warming of large Marine ecosystem. Progress in Oceanography, 81: 207-213.

Bindoft, N. L., Willebrand, J., Artale, V. (2007). Observation, oceanic climate change and sea level. In: *Climate change 2007*. *The Physical Science Basis.* Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. (Eds: S. Solomon; D. Qin; M. Manning; Z. Chen; M. Marquis, K. B., Averyt, M. Tigor. and H. L. Miller) Cambridge University Press, UK pp. 385-432.

Blabber, S. J. M. (2000).*Tropical Shrimp Farms.*Available at http://www.heureka.clara.net/shrimps.htm.Accessed 4th October, 2019.

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R., Kwon, K., Laprise, W. T., Magana, R., Reuda, V., Mearns, L., Menendez, C. G., Raisanen, J., Rinke, A., Sarr, A. and Whetton, P. (2007). Regional climate projections. In: *Climate Change 2007*: *The Physical Science Basics*. Contribution of workshop group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (S. Solomon; D. Qin; M. Manning; Z. Chen; M. Marquis, K. B., Averyt, M. Tigor. and H. L. Miller eds) Cambridge University Press, Cambridge, United Kingdom and New York.

Clark, S. (1988). A two phase photoperiodic response controlling the annual gametogenic cycle in HarmothoeImbricata (Polychaeta: Polynoide). *Invertebrate Reproduction*, 14: 245 – 246.

Dam, H. G. and Baumann, H. (2017). Climate Change, Zooplankton and Fisheries: Climate Change Impacts on Fisheries and Aquaculture: *A Global Analysis* (Chapter 25).

Daufresne, M., Lengfellnera, K. and *and Development*Sommer, U. (2009). Global warming benefits the small in aquatic ecosystem. *Proceedings of the National Academy of Science,* USA, 106: 12788 – 12793.

Deason, E. and Smayda, T. (1982). Ctenophore-zooplankton – phytoplankton interactions in Narragansett Bay, Rohode Island, USA, during 1972 – 1977. *Journal of Plankton Research,* 4: 203-217.

Doney, S. C., Fabry, V. F., Feely, R. A. and Kleyplas, J. A. (2009). Ocean accidification: the other CO2 problem. *Annual Review of Marine Science*, 1:169-192.

Donnelly, J. P. and Betness, M. D. (2001).Rapid shoreward of encroachment of salt marsh codgrass in response to accelerated sea-level rise.*Proceedings of the National Academy of Science,* 98: 14218-14223.

F. D. F. (2008) (Federal Department of Fisheries).Fisheries statistic of Nigeria, 47pp.

Feidi, I. (2019). Influence of climate change on fisheries resources in the Arab region.*GLOBEFISH-Information and Analysis on world Fish Trade*. 3p.

Garcia, S M and Rosenberg, A. A. (2010). Food security and marine capture fisheries: characteristics, trends, drivers and future perspective.

Garcia, S M and Rosenberg, A. A. (2010). Food security and marine capture fisheries: characteristics, trends, drivers and future perspectives. *Phil. Trans.R.SOC.B.*, 365: 2869 – 2880.

Garwood, P. R. and Olive, P. J. W. (1982).The influence of photoperiod on oocyte growth and its role in the control of the reproductive cycle of HarmothoeImbricata.*International Journal of Invertebrate Reproduction*, 5: 161 – 165.

Hamilton, L.; Lyster, P. and Otterstad, O. (2000).Social change, ecology and climate in the $20^{th}$ century, *Greenland. Climate change*, 47: 193 – 211.

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D. V. and Medina – Elizade, M. (2006).Global temperature change.*Proceedings of the National Academy of Science, USA*, 103: 14288 – 14293.

Harley, C. D. G.; Hughes, A. R.; Hutgren, K. M.; Miner, B. G.; Sorte, C. J. B.; Thornber, C. S.; Rodriguez, L. F. Tomanek and Williams, S. L. (2006). The impacts of climate change in coastal marine systems.*Ecology*, 9:228 – 241.

Hlohowskyjl, I. Brondy, M. S. and Lackey, R. T. (1996). Methods for assessing the vulnerability of African Fisheries resources to climate change. *Climate Research*, 6: 97 – 106.

Hofmann, G. E. and Todgham, A. E. (2010). Living in the now: Physiological mechanisms to tolerate a rapidly changing environment. *Annual Review of Physiology*, 72: 127-145.

Huertas, I. E., Rouco, M., Lopez – Rodas, V. and Costas, E. (2015). Warming will affect phytoplankton differently: evidence through a mechanistic approach. http://rspb.royalsocietypublishing.org

Hughes, T. P.; Bair, A. H.; Bellwood, D. R.; Card, M.; Connolly, S. R. and Folke, C. (2003). Climate change, human impacts and the resistance of coral reefs. *Science*, 301: 929 – 933.

IPCC (2001).Third report of the working group of the intergovernmental panel on climate change.Intergovernmental panel on climate change.Available at www.ipcc.ch.Accessed 4 October 2019.

IPCC (2007).*Climate change 2007. The Physical Science Basis.* Contribution of working group I to the Fourth Assessment report of the Intergovernmental Panel on Climate Change (Solomon, S. D., Qin, M., Manning, Z., Chen, M., Marquis, K. B., Averyt, M. T. and H. L. Miller (eds). Cambridge University Press, United Kingdom and New York, 969pp.

IPCC (2007). Climate change 2007: The Physical Science Basis. Contribution of working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.[Solomon, S. D; Qin; M. Manning; Z. Chen; M. Marquis; K. B. Averyt; M. Tignor and H. L. Miller (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, US, 996pp.

IPCC (2007).Inter-governmental Panel on climate change.Summary for Policymakers. In: Climate Change 2007: The physical science basis. Contribution of Working Group 1 to the Fourth Assessment of the Inter-governmental Panel on Climate Change (eds Solomon S., Qin D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L.) pp 235-336. Cambridge, U.K. Cambridge University Press.

Job, B. E.; Antai, E. E. Inyang-Etoh, A. P; Otogo, G. A. and Ezekiel H. S. (2015). Proximate composition and mineral contents of cultured and wild tilapia

1999. Swindon, UK: NERC.

Lawrence, A. J. and Soame, J. M. (2004). The effects of climate change on the reproduction (*Orechromisniloticus*) (Pisces: Cichlidae) (Linnaeus, 1758). *Pakistan Journal of Nutrition,* 14(4):195 – 200.

Last, K. S. (1999). How do ragworms tell the time? Worm clocks.NERC News spring of coastal invertebrates.*Ibis*, 146: 29-39.

Magnuson, J. J., Webster, K. E., Asseh, R. A., Bowser, C. J. and Dillon, P. J. (1997). Potential effects of climate changes on aquatic systems: Laurentian Great Lakes and Precambian Shield Region.*Hydrobiological Process,* 11: 825-871.

Marshall, S. and Elliot, M. (1998). Environmental influences on the fish assemblages of the Humber estuary, United Kingdom. *Estuarine, Coastal and Shelf Science,* 46(2): 175-184.

Marva, F., Lopez-Rodas, V., Rouco, M., Navarro, M., Toro, F. J., Costas, E. and Flores – Moya, A. (2010).Adaptation of green microalgae to the herbicides simazine and Diquat as result of preselective mutations.*Aquatic Toxicology,* 96: 130-134.

Mohammed, E. Y. and Uraguch, Z. B. (2013). Impacts of climate change on Fisheries: Implications for food security in sub-Saharan Africa. *Global Food Security.* Nova Science Publishers Incorporated, pp. 114-135.

Mohammed, E. Y. and Uraguchi, Z. B. (2013). Impacts of climate change on fisheries: Implications for food security in sub-Saharan Africa. In: Global Food Security (Munir A. Hanjra) (Ed.), FAO, Rome, 113-135pp.

Moran, X. A., Lopez – Urrutia, A., Calvo-Diaz, A. and Li, W. K. W. (2010).Increasing importance of small phytoplankton in a warmer ocean. Global Biological Change, 16: 1137 – 1144.

Muren, U., Berghund, J., Samuelsoon, K. and Anderson, A. (2005).Potential effects of elevated sea-water temperature on pelagic food webs.*Hydrobiologica* 545: 153-166.

Myelnikov, D. (2019). Tinkering with genes and embryos: the multiple invention of transgenic mice. *An International Journal of History and Technology*, 35(4):425-452

Nye, J. (2010). Climate Change and its effects on ecosystems, habitats and biota (pp 1-17). Marine: The Gill of Marine Council on the Marine Environment.

Olaoye, O. J.; Akintayo, I. A.; Udolisa, R. E. K. and Cole, A. O. (2010).Effect of rainfall pattern on fish production in Ogun State, Nigeria. *Proceedings of the Fisheries Society of Nigeria (FISON), ASCON,* Badagry, 25th- 29th of October, 2010: FSN - FM 0005.

Olive, P. J. W.; Clark, S. and Lawrence, A. (1990). Global warming and seasonal reproduction: perception and transduction of environmental information.*Advances in invertebrate reproduction,* 5: 265 – 270.

Parkis, K. (2000). Tropical shrimp farms.Available athttp://www.heureka.clara.net/gaia/shrimps.Htm accessed on 22nd September, 2019.

Patrick, A. E. S. (2016). Influence of rainfall and water level on inland fisheries production: A review. *Archives of Applied Science Research,* 8(6): 44-51.

Scavia, D.; Field, J. C.; Boesch, D. F.; Buddemeier, R. W.; Burkett, V and Cayan, D. R. (2002). Climate change impacts on U.S coastal and marine ecosystems. Estuaries, 25:149 – 164.

Schallenberg, M. C. and Burns, C. W. (2003). Consequences of climate induced salinity increases on zooplankton abundance and diversity in coastal lakes. *Marine Ecology Progress Series,* 251:181-189.

Schulte, P. M (2007). Responses to environmental stressors in an estuarine fish: Interacting stressors and the impact of local adaption. Journal of Thermal Biology, 32(3): 152 – 161.

Sniegowski, P. D. and Lenski, R. E. (1995). Mutation and adaptation: the directed mutation controversy in evolutionary perspective. Annual Review of Ecology and Evolutionary Systems, 26: 553-578.

Snyder, R. J. and Dingle, G. (1989).Adaptive, genetically-based difference in life history between estuary and fresh water three spine sticklebacks (*Gasterosteusaculeatus*). Canadian Journal of Zoology, 67(10):2448 – 2454.

Taucher, J. ad Oschlies, A. (2011). Can we predict the direction of marine primary production change under global warming? *Geophysical Research Letters*, 38 (L02603).

Urama, K. C. and Ozor, N. (2010). Impact of climate change on water resources in Africa: The role of adaptation. Available on http://www.ourplanet.com/climate.adaptation.Accessed 4th October, 2019.

# EFFECT OF CONSTANT DISAPPEARANCE OF LARGE PONDS ON FLOOD OCCURENCES IN THE ANCIENT CITY OF ZARIA, KADUNA STATE

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**Abstract**

*This paper aimed at examining the* effect of constant disappearance of large ponds on flood occurrences in the ancient city of Zaria, Kaduna state. *The study area has a total population of 1,020,277 based on 2021 population projection. The sample size of 204 was set out for this study. Therefore, total of 204 copies of questionnaire were purposively administered to respondents within the six selected wards of the study area with 100 copies representing 49% returned as response rate. The data collected were analyzed and presented using Likert scale, simple tables, percentages and Chi-square. Findings also showed that majority (93%) of the total respondents agreed that the current sizes of the remaining ponds are small, (less than 100by 100 feet). Result indicates that 86% of the respondents attested that water-borne diseases such as cholera, dysentery and typhoid are associated with flooding due to filling large ponds. Most respondents (93%) also revealed that the upgrade of buildings from mud to bricks has significant effect on flood risk reduction in the area. The paper concludes that ponds disappearance has significant impact on the rising cases of floods in the area. The paper recommends that there is need for adequate drainage channels that can drain the excess water out of the city without causing harm. There should be proper planning by government agencies such as KASUPDA on the erection of buildings and other infrastructural development near large ponds in the study area.*

**Keywords:** Effect, Large ponds, Flooding, Disappearance, Zaria

## Introduction

A pond is a natural or man-made inland body of standing water that is smaller than a lake and fed by rain water (Schlossberg and Tatiana, 2015). Ponds vary in sizes and shapes along with different characteristics, these features may arise from the origin of the ponds, either naturally formed ponds or man-made ponds (Okorie, 2010). Ponds can result from a wide range of natural processes, these includes depressions on the ground which collects and retains a sufficient amount of precipitation induced water and these depressions can be formed by a variety of geological and ecological events which includes. According to Jeb Aggrawal, Audrey and Edeleenbo (2012) man-made ponds are as a result of human activities that led to excavation of the ground for variety of purposes which include; building, aquaculture, road construction among others (Olabanji, 2019).

Recent studies found that ponds plays a vital role in reducing and mitigating the severity of floods in many cities in northern Nigeria, these had made the vitality of ponds and their significance to be highly considered (Sulaiman,2014).

Urban centers are usually attributed with floods, these floods could be coastal, or flash flood or the combination of both. Coastal flooding is caused by extreme tidal conditions that occurs because of high tidal wave levels, storm surge and wave actions on the adjoining coastal area. Fluvial floods occur when the discharge from rivers exceeds the capacity of the river channel to contain it, mostly due to high downpour of precipitation, while pluvial takes place when the rainfall exceeds the capacity of ground to absorb the water (Conelly, 2015).

Sand filling of ponds is the filling up of an existing pond with sand so as to reclaim the land for usage either for building construction, road construction, aesthetic use, infrastructural development, among others. This sand filling of ponds has led to the disappearance of ponds in many traditional cities in northern Nigeria paving way for pluvial and fluvial floods to prevail (Sulaiman, 2014). The following objectives were set out to:

1. determine factors for the constant disappearance of ponds due to floods in the area
2. characterize the current sizes of ponds in the area
3. assess the effects ponds disappearance on public health in the area.

**The Study Area**

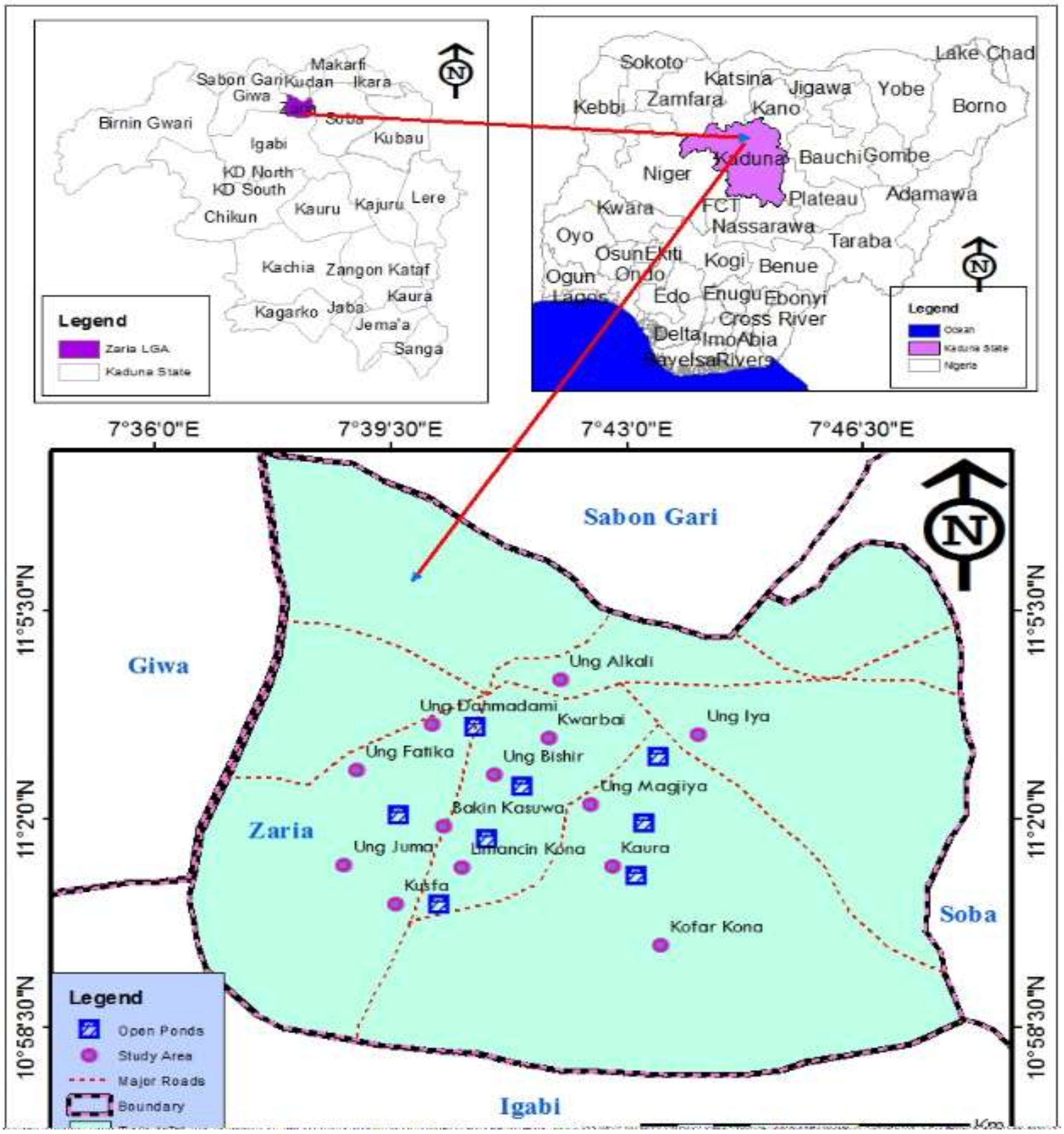
Zaria city is located on the North Central Plateau about 600m above sea level in the Northern Guinea Savannah. It is located between Latitudes 11º.02'20"N to 11º.07'23"N equator and Longitudes 7º.07'30"E and 7º.73'55"E Green which meantime. The town is at the distance of about 962km from the Atlantic Ocean. It is about 80km North East of Kaduna state capital and about 130km to Kano (Yusuf, Mustapha and Idris, 2010). The city is bordered to the East by Nagoyi layout, to the West by Kofar-Kuyambana, to the North by Tudun-wada and to the South by Kofar-Gayan (Kawu and Maikudi 2011) (See Figure 1).

The climate of Zaria city can be classified using the Koppen classification of climate as tropical wet and dry climate or continental type of climate. Rainfall is between 900mm-1200mm. Temperature is high in the months of March and April ranges between 30$^{o}$C to 37$^{o}$C and drastically reduces between 15$^{o}$C to 25$^{o}$C between December and February (Bashir, Umar and Sufiyan 2012).

The Major relief features found within the city wall are Madarkaci Hill, KwarbaiInselberg, Banzazzau Hill and the major man made relief feature of the city is the city wall called ‘’Ganuwa’’ in Hausa, which is about 28KM long (Odufuwa, 2012). The drainage pattern of Zaria City is dentric in nature, mostly shallow rivers or large water channels convey water out of the city. The major water channel that cuts across the city is known as Fadaman Sarki which flows south-wards through Kaura and Amaru settelmets which later drain to river Saye, a tributary to River Kaduna (Bashir, Umar and Sufiyan, 2012).

The Soil in Zaria is greatly influenced by climatic condition, nature of rocks and human activities. The parent material that forms the soil in the area is basically Granite rocks of igneous origin. The soil retains the properties of the granite rocks which is light in colour, moderate texture and high clay content. The major soil is tropical ferruginous type with ABCD horizons, moderate clay content, light in colour, pH value of 4 to 5 and high concentration of iron between C and D horizons. Mele (2015).The soil distinct characteristics favours the cultivation of Maize, Sugar cane, Tomatoes, cotton, guinea corn, Millet and Soya beans.

Zaria is classified under the guinea Savannah vegetation belt, also known as Savannah Woodland. It is made up tall grasses, scattered trees with umbrella shape, thick hard back, long tap roots and deciduous in nature. The dominant trees are shear butter, Locust Bean trees, SimCotton, Mango, Baobab and the dominant shrub is the Isobelina (doka). The vegetation in Zaria is greatly influenced by human activities (Suleiman, AbdulhamedMusa and Yelwa, 2019).




**F**

**ig.1:** Map of Zaria City showing the Study AreaExtracted from Google Map (2021).

**Materials and Methods**

The study area has a total population of 1,020,277 based on 2021 population projection. The sample size of 204 was set out for this study. Therefore, a total of 204 copies of questionnaire were purposively administered to respondents within the six selected wards of the study area with 100 copies representing 49% returned as response rate.

The population of this study is residents that lives close or are in the vicinity of the identified ponds, both existing and sand filled, in the study area of Zaria Local Government area. These would make the targeted population to be easily assessed. Respondents were selected from different pond sites within the city and they are the basis for the information used for this study.

The study area was divided into zones so as to ease the distribution of the questionnaire. The zones are the areas with high number of ponds in the study area which include: Kwarbai A, Kwarbai B, Kaura, Anguwan Juma, Anguwan Alkali, Limancin Kona, Kofar Gayan, Anguwan Bishar, Magajiya, Anguwan Fatika, AnguwanIya, Kofar Kuyambana and Kusfa all situated in Zaria city. The distribution of the questionnaire was divided into the zones; therefore, 100 questionnaires retrieved were divided into 12, making each area to have an equal 8 copies of questionnaire for the sake of convenience. The data collected were analyzed using simple descriptive analysis such as percentages, chars, histograms and ratios.

**Results and Discussions**

**Table 1:** Socioeconomic characteristics of Respondents

| Gender | Frequency | Percentage% |
|---|---|---|
| Male | 73 | 73 |
| Female | 27 | 27 |
| Total | 100 | 100 |
| Age | **Frequency** | **Percentages%** |
| <25 years | 20 | 20 |
| 25 – 40 years | 35 | 35 |
| 41 years and above | 45 | 45 |
| Total | 100 | 100 |
| Level of Education | **Frequency** | **Percentage** |
| Higher Institution | 25 | 25 |
| Secondary School | 30 | 30 |
| Primary | 27 | 27 |
| Tsangaya | 10 | 10 |
| Non Formal | 8 | 8 |
| Total | 100 | 100 |
| Status | **Frequency** | **Percentage** |
| Single | 32 | 32 |
| Married | 41 | 41 |
| Divorced | 18 | 18 |
| Widowed | 9 | 9 |
| Total | 100 | 100 |
| Occupation | **Frequency** | **Percentage** |
| Civil Servant | 36 | 36 |
| Business | 32 | 32 |
| Students | 27 | 27 |
| Others | 5 | 5 |
| Total | 100 | 100 |

**Source:** Field survey, 2020

**Table 2:** Sand Filling of Ponds for Economic Reasons

| Response | Frequency | Percentage |
|---|---|---|
| Strongly Agreed | 20 | 20 |
| Agreed | 34 | 34 |
| Disagree | 15 | 15 |
| Strongly Disagree | 10 | 10 |
| Undecided | 21 | 21 |
| Total | 100 | 100 |

**Source:** Field Survey, 2020

Table 2showed the response of the respondents regarding the reasons why the ponds were being filled up; the response is as follows; 54 people representing 54% of the respondents agreed that the main reason for the filling of the ponds with sand is basically for economic reason, 25 people representing 25% of the respondents disagreed that the reason for the filling of the ponds with sand is for economic reason and 21 people have not decided on whether the reason for the filling of the ponds is for economical.

**Table 3: Sand** Filling of Ponds for Political Reasons

| Response | Frequency | Percentage |
| --- | --- | --- |
| Strongly Agreed | **13** | **13** |
| Agreed | 15 | 15 |
| Disagree | 34 | 34 |
| Strongly Disagree | 27 | 27 |
| Undecided | 11 | 11 |
| Total | 100 | 100 |

Source: Field Survey, 2020

Table 3 showed the response of the respondents regarding the reasons why the ponds were being filled up; the response is as follows; 28 people representing 28% of the respondents agreed that the reason for the sand filling of the ponds is political, 61 people representing 61% of the respondents disagreed that the reason for the sand filling of the ponds is for political issues while 11 people representing 11% of the respondents have not decided whether the sand filling of the ponds is for Political reasons.

**Table 4:** Sand filling of ponds for aesthetic reasons

| Response | Frequency | Percentage |
| --- | --- | --- |
| Strongly Agreed | **37** | **37** |
| Agreed | 49 | 49 |
| Disagree | 9 | 9 |
| Strongly Disagree | 3 | 3 |
| Undecided | 2 | 2 |
| Total | 100 | 100 |

Source: field Survey, 2020

Table 4 showed the response of the respondents regarding the reasons why the ponds were being filled up; the response is as follows; 86 people representing about 86% of the respondents agreed that the ponds are being filled up with sand for aesthetic reasons, 12 people representing about 12% of the respondents disagreed that the reason behind the sand filling of the pods is for aesthetic reasons.

**Table 5:** Thecurrent sizes of the remaining ponds very large (over 100/100 ft)

| Response | Frequency | Percentage |
| --- | --- | --- |
| Strongly Agreed | 3 | 3 |
| Agreed | 4 | 4 |
| Disagree | 30 | 30 |
| Strongly Disagree | 46 | 46 |
| Undecided | 17 | 17 |
| Total | 100 | 100 |

**Source:** Field Survey, 2020

Table 5 showed the perception of the respondents regarding the current sizes of the remaining ponds in the study area. The response is a follows; 7 people representing 7% of the respondents agreed that the sizes not the remaining ponds is very large ( over 100/100 ft), 76 people representing 76% of the total response disagreed to that and 17 people have no decision on whether the sizes of the remaining ponds is over 100/100 feet. This signifies that the remaining ponds are not very large (over 100/100 ft).

**Table 6:** The current sizes of the remaining ponds arelarge (100/100 ft)

| Response | Frequency | Percentage |
|---|---|---|
| Strongly Agreed | 40 | 40 |
| Agreed | 32 | 32 |
| Disagree | 4 | 4 |
| Strongly Disagree | 10 | 10 |
| Undecided | 14 | 14 |
| Total | 100 | 100 |

**Source:** Field Survey, 2020

Table 6 showed the perception of the respondents regarding the current sizes of the remaining ponds in the study area. The response is as follows; 72 people agreed that the sizes of the remaining ponds is within the range of 100/100ft, 14 people disagreed and 14 were left with no choice whether the sizes of the remaining ponds is large (100/100ft). This shows that the sizes of the remaining ponds are relatively large (100/100ft).

**Table 7:** The current sizes of the remaining ponds aresmall (less than 100/100 ft)

| Response | Frequency | Percentage |
|---|---|---|
| Strongly Agreed | 62 | 62 |
| Agreed | 31 | 31 |
| Disagree | 2 | 2 |
| Strongly Disagree | 2 | 2 |
| Undecided | 3 | 3 |
| Total | 100 | 100 |

**Source:** Field Survey, 2020

Table 7showed the perception of the respondents regarding the current sizes of the remaining ponds in the study area. The response is as follows; 93 people representing about 93% of the total respondents agreed that the current sizes of the remaining ponds are small (less than 100/100ft), 4 people disagree that the current sizes of the remaining ponds is small and 3 people have not decided whether the current sizes of the remaining ponds is small. This signifies that the current sizes of majority of the ponds that are left is relatively small as urbanization is rapid in the study area and the excavation of vacant land is relatively absent.

**Table 8:** Waterborne disease like Cholera, Diarrhea, Typoid fever are associated with floods due to ponds disappearance

| Response | Frequency | Percentage |
|---|---|---|
| Strongly Agreed | 73 | 73 |
| Agreed | 13 | 13 |
| Disagree | 2 | 2 |
| Strongly Disagree | 2 | 2 |
| Undecided | 10 | 10 |
| Total | 100 | 100 |

**Source:** Field survey, 2020

Table 8 showed the response of the respondent regarding disease outbreaks due to flooding. The response is as follows; 86 people representing 86% of the respondents agreed that waterborne diseases are associated with environmental problems like flooding, 4 people disagreed to that and 10 people representing 10% of the respondents did not decide on whether waterborne diseases are associated with environmental problems like flooding. This signifies that waterborne diseases are highly associated with environmental problems like flooding in the study area.

## Conclusion and Recommendations

From the above findings, it could be concluded that ponds have a great significance in mitigating the detrimental impact of flooding in the study area. Although the ponds serves as water reservoirs, refuse dump sites, sand mining and also a means for aquaculture as fish rearing is practice in some of these ponds, but their absence could also mean a great development in the study area.

Based on the findings above, the study recommends the following:

1. There should be adequate drainage channels in areas where large ponds are filled up with sand so as to covey the excess water out of the city without causing harm.
2. The filling of large ponds with sand should not be frequent and should be done during the dry season by the governments and the immediate community.
3. There should be proper planning by government agencies like KASUPDA on the erection of buildings and other infrastructural developments near large ponds in the study area.
4. There should be proper refuse dumping and a substitute site for refuse disposal not in open large ponds in the study area

## References

Bashir, S.S, Umar, A.A and Sufyan M.B (2012) Effect of Maternal Literacy Status of Children Under 5 Years of Age in Babban-Dodo Community Zaria City, Northwest Nigeria Annals of Nigerian Medicine 6(2) Date of Retrieval 21st October, 2019.

Connelly, A, Gabalda, V, Garvin S Hunter, K, Kelly, D, Lawson, N.O.P And White I (2015) Testing Innovative Technologies to Manage Flood Risk." *Proceedings of the Institution of Civil Engineers Water Management*. 168(2) 6673.

Jeb, D.N. Aggrawal, S.P, Audrey T. And Edelenbos, J (2012) Flood Impact Mitigation and Resilience Enhancement INTRHOPEB Publication limited, Uk 87-94.

Kawu, A and Maikudi, M. (2011) Disaster Vulnerability and Resilience of Urban Residents: A Case of Rainstorm Disaster Risk Management in Zaria, Nigeria. *Business Journal of Environment And Earth Science*, 1(2) 162-173.

Mele, E. (2015) A Report Titled "Lessons From A 500 Year Record of Flood Elevetions, Association Of State Flood Plan Managers, Technical Report NO 7 Date of Retrieval 21st – 10 – 2020.

Odufuwa, B. (2012) Welcome to Zaria "An Inventory Archived at the Wayback Machine Bio-Technology Society of Nigeria at Ahmadu Bello University Zaria Date of Retrieval 21st – 10 -2020.

Okorie, O. (2010 ) Mapping of Flood Risk Zones in Ala River Basin Akure, Nigeria. *American Journal of Engineering and Applied Sciences. Retrieved January* 2019. DOI: 10.3844/ajeassp.2018.210.217

Olabanji, A. (2020) Flood Investigation and Adaptation Strategies through Best Management Practices in an Ungauged Basin in South-west Nigeria. *African Geographical Review Journal*, 40(2) 141-162.

Schlossberg, T. (2015) Climate Change in Every Day Sustainable Fishing, and Impacts of Coal Ash Ponds on Our Farmlands.

Sueliman, U.B. Abdulhamed, A. I, Musa, I. J and Yelwa, S.A (2019). “Decadal Analysis and Estimation of Temperature Changes in Northern Senatorial Zone of Kaduna State Nigeria FUDMA *Journal of Science (FJS),* 3, 509-518.

Sulaiman, L.(2014) “ Assessment Of Environmental Challenges Posed by Ponds in Katsina City, Northern Nigeria Sustainable Research And Innovation Conference At: Juja Kenya 86-93.

Yusuf, M, Mustapha, S, and Idris A (2017) The Effect Of Flooding on Farm Outputs Along River Kubanni, Zaria Kaduna State an Unpublished NCE Project Geography Department Federal College of Education Zaria.

# VULNERABILITY OF URBAN FRINGES TO FLUVIAL HAZARDS: A CASE STUDY OF ANATIGHA, ATIMBO AND LOWER SATELLITE TOWN ZONE B, CALABAR, CROSS RIVER STATE

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**Abstract**

*Fluvial hazards have become a reoccurring decimal posing serious risks for households and their livelihoods. The incidence of fluvial hazards in recent years has greatly challenged developments in the urban fringes of Calabar due to changing climatic conditions, unplanned urban fringes and ever increasing anthropogenic inputs. The paper examines the nature of fluvial hazards vulnerability of the study area. Primary and secondary data were utilized for this study. Questionnaires were administered to 200 heads of households. Results showed that 58.0 percent of the respondents had experienced fluvial hazard risks 55.0 percent were vulnerable to flooding, 25.0 Percent to erosion and 20.0 percent to subsidence. 58.0 percent attributed the extent of fluvial hazard to location and characteristics of neighbourhood building in the study area, while 81.0 percent attributed it to the throwaway refuse disposal method in the study area. 40.0 percent got help from family members/friends while 16.0. percent got help from no one. The study recommends that government agencies should institute coherent urban planning, emergency warning and response units, household/common unity level and adaptation policies/strategies.*

**Keywords:** Urban fringes, vulnerability, fluvial hazards, adaptation.

## Introduction

One of the most contentious environmental issues of recent years has been the influence of urban growth and climate change on the severity and frequency of fluvial hazards in the urban fringes of towns and cities the world over. This is perhaps caused by land cover removal, changes in vegetation types, poor urban planning, and increasing concentration of population in disaster and risk prone areas, thereby increasing the rate of population liable to the threat of extreme weather events especially flooding and other fluvial hazards.

The decision of many persons to establish in hazard prone areas exacerbate vulnerability especially in the absence of appropriate disaster risk reduction measures or robust disaster risk management frameworks. Many disasters take place in urban areas especially urban fringes, affecting thousands of people each year through loss of life, serious injury, loss of assets and livelihoods. Poorer groups are generally most vulnerable. International Federation of the Red Cross and Red Crescent Societies (IFRC) in the World Disasters Reports (IFRC, 2012, 2011) reveal that the number of people killed by fluvial hazards is still high and the number of people affected and associated economic losses have increased substantially since the 1990s.

It has been argued by scholars (Solecki, 2012; Adelekan, 2011; Olorunfemi, 2009, Olurunfemi and Raheem, 2007; Afesimama, 2008; Meshrotra *et al.,* 2009; Awoska *et al.,* 1993) that disasters are a function of the decisions people make about development, environment and management of disasters. This connotes that disasters can be avoided or reduced if the people modify their relationship with environment and plan future development with fluvial hazards occurrence in mind. This will also imply developing climate change awareness and adaptation measures among the people thus providing an opportunity to raise their awareness about potential fluvial hazards.

Adioye, Ayanlande and Babatimehin (2009) opined that fluvial hazards emanate from a combination of meteorological and hydrological extremes. In most cases, additional fluvial hazards are influenced by anthropogenic factors. Although fluvial hazards in built environment have been seen as a consequence of natural and man-made factors. Climatic factors tends to increase their diversity and accentuate fluvial hazards peaks (Nwachukwu *et al.,* 2018) studies by Bull Kamanga *et al.,* (2009) and Safferwaite *et al.,* (2007) noted that vulnerability of individuals, communities and towns to fluvial hazards is attributed to the interaction between an external threat or hazard and the internal characteristics of the system. Internal characteristics include socio-economic characteristics, living conditions and access to infrastructures among others. While vulnerability level can be determined by the location of the place or building, for example, close to flood plain, erosion site, along the coastline, windstorm path, water pathways and other insecured fluvial degrading environment. Most of these buildings or structures are established along fluvial courses or areas liable to fluvial erosion. The study critically x-rays the nature, causes of vulnerability of the people to fluvial hazards and coping strategies among residents as well as proffer adaptive measures to reduce the associated risks.

## Materials and methods

### Study area description

#### Location

Calabar Metropolis lies between longitudes $8^0$18’00’’E to $8^0$24’00’E and latitudes $4^0$54’00’’N to $5^0$04’00’N and. It is bounded by Calabar River, to west, Kwa River to the East, Odukpani L.G.A to the Northern flank, its creeks empty into the Atlantic Ocean in the south. The metropolis covers a land area of 406 square kilometers.(Fig. 1 is a map of the study area).

#### Brief history

Calabar is the capital city of Cross River State, south-south geographical zone of Nigeria. It comprises of Calabar Municipality and Calabar South Local Government Areas (LGAs). There are 22 wards in both LGAs, 10 in the later and 12 in the former. It is located in the southern senatorial district of the state as shown in figure 1.

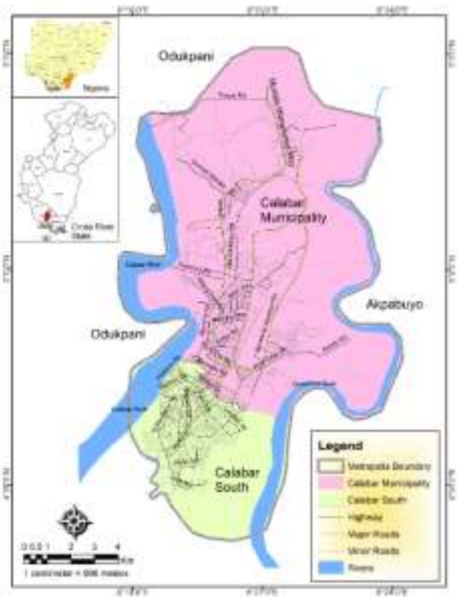


**Fig 1:** Map showing Calabar metropolis
**Source:** Office of Surveyor General CRS, 2017 modified by the Author, 2019

### Data collection and analysis

Both primary and secondary data were employed for the study. The study draws on a review of existing literature as well as reconnaissance survey and household interviews. A reconnaissance survey of the urban fringes of Calabar was first carried out in early February 2020 focusing on physical vulnerabilities within the study area. Purposive sampling method was adopted whereby 18 clusters were selected along floodplains and fairly hilly locations in the study area. The socio-economic characteristics were collected through the use of 200 questionnaires. Respondents were randomly chosen from households. Secondary data were obtained from published and government reports, periodicals, newspapers.

### Results and discussions

Vulnerability of individuals, communities to fluvial hazards is attributed to the interplay of climate change variables and internal characteristic of the place and level of anthropogenic activities of man. This section discusses the variables based on field survey, questionnaire and interviews.

### Socio-demographic characteristics of respondents

The sex distribution of respondents listed in table 1 indicates that 55 percent are males while the female constituted 45 percent. The findings show that Calabar city head of households are dominated by males. Majority of the respondents (44.5%) were married, with divorced/separated/widow 38.0 percent, single 17.5 percent respectively. The results further shows that 15.5 percent, 48.0 percent, 38.5 percent of the respondents are between the ages of below 30 years, 31-40 years, 41 and above. In like terms, 30.0%, 53.3% and 17.0% had primary education, secondary education and tertiary education respectively. The importance of educational qualification in promoting access to information cannot be overemphasized, besides it grossly affects their perceptions, management/coping strategies towards fluvial hazards in their respective environment.

Results on socioeconomics show that 66.0 percent of the respondents are engaged in business, farming (14.0%) and civil service (20.0%). This is in conformity with expectation that, the share of the population engaged in agriculture will be low in cities. In terms of earning, 50 percent of the respondents earn less than N50,000.00 annually, 30 percent between 51,000 – 200,000 while 20 percent between 201,000 and above respectively. The data depicts a low income of respondents thus making them vulnerable and inadequately endowed to prepare themselves and meet challenges posed by unexpected disasters in the study area.

**Table 1:** Socio-demographic characteristics of respondents

| Respondents | Frequency | Percentage |
|---|---|---|
| Sex | | |
| Male | 110 | 55 |
| Female | 90 | 45 |
| Total | 200 | 100 |
| Marital status | | |
| Single | 35 | 17.5 |
| Married | 89 | 44.5 |
| Divorced/Separated/widow | 76 | 38 |
| Total | 200 | 100 |
| Age | | |
| Below 30 years | 31 | 15.5 |
| 31-40 years | 96 | 48 |

| | | |
|---|---|---|
| 41 and above | 73 | 36.5 |
| Total | 200 | 100 |
| Educational status | | |
| Primary | 60 | 30 |
| Secondary | 106 | 53 |
| Tertiary | 34 | 17 |
| Total | 200 | 100 |
| Occupation | | |
| Business | 132 | 66 |
| Farming | 28 | 14 |
| Civil service | 40 | 20 |
| Total | 200 | 100 |
| Income | | |
| Less than 50,000 | 100 | 50 |
| 51,000 – 200,000 | 60 | 30 |
| 201,000 and above | 40 | 20 |
| Total | 200 | 100 |

**Source:** Authors' fieldwork

**Pattern and level of vulnerability**

Table 2 reveals that the 55 percent of the respondents have stayed in the study area for 5-10years, 15 percent (11-15 years) 10 percent (16-20 years) while 20 percent of the respondent had stayed in the study area for 21 years and above. The results above shows that a good number of the respondents are new settlers and are not well informed about the urban fringes characteristics, hence their vulnerability may affects their management and coping strategies for fluvial hazards in the immediate environment.

**Table 2:** Number of years stayed by the respondents in the study area

| No of years | Frequency | Percentage |
|---|---|---|
| 5-10 | | 55 |
| 11-15 | | 15 |
| 16-20 | | 10 |
| 21 and above | | 20 |
| Total | 200 | 100 |

**Source:** Authors fieldwork

**Neighbourhood characteristics of the study area**

Neighbourhood characteristics play a cardinal role in risk aversion and ability to withstand or cope with fluvial hazards. Location of building, appropriate age of building, state of access road, availability of drainage around the building and its environs, condition of the drainage, refuse disposal method constituted neighbourhood characteristics under review.

**Table 3:** Neighbourhood characteristics

| Neighbourhood characteristics | Frequency | Percentage |
|---|---|---|
| Location of building | | |
| Flat terrain | 28 | 14 |
| On flood plain | 116 | 58 |
| Hilly terrain | 16 | 8 |
| Sloppy terrain | 40 | 20 |
| Total | 200 | 100 |
| Approximate age of building | | |
| Below 5 years | 40 | 20 |
| 6-10 years | 44 | 22 |
| 11-15 years | 50 | 25 |
| 16-20 years | 30 | 15 |
| 21 and above | 36 | 18 |
| Total | 200 | 100 |
| State of access road | | |
| Untared not motorable | 47 | 39 |
| Untarred but motorable | 52 | 26 |
| Tarred and motorable | 45 | 22.5 |
| Tarred but not very accessible | 25 | 12.5 |
| Total | 200 | 100 |
| Availability of drainage around the building | | |
| Yes | 70 | 35 |
| No | 130 | 65 |
| Total | 200 | 100 |
| Condition of drainage | | |
| Blocked | 162 | 81 |
| Unblocked | 38 | 19 |
| Total | 200 | 100 |
| Refuse disposal method | | |
| Throw away culture | 80 | 40 |
| Burning/incineration | 60 | 30 |
| Composting | 46 | 23 |
| Landfilling | 14 | 7.0 |
| Total | 200 | 100 |
| Source of water | | |
| Stream/river | 24 | 120 |
| Well | 38 | 19 |
| Borehole | 102 | 51 |
| Pipeborne | 36 | 18 |
| Total | 200 | 100 |

**Source:** Authors fieldwork

Findings from table 3 reveals that majority of the buildings are located on floodplain (30.0%), 24.0 percent on flat terrain 15.0 percent very close to stream/river, 11.0 percent on hilly terrain and 20.0 percent on sloppy terrain respectively. Also the approximate age of buildings ranges from below 5 years (20.0%), 6-10 years (22.0%), 11-15 years (25.0%), 16-20 year (15.0%) and 21 years and above (18.0%). The results shows that above 33 percent of the buildings are not structurally sound and therefore are at risk of fluvial hazard because of their poor conditions in terms of accessibility of the terrain, most areas are linked by untarred roads and the only means of reaching these new areas is by footpaths (39.0%), about 26.0 percent of access roads are untarred but motorable, 22.5

percent tarred and motorable while 12.5 percent tarred but are in a state of disrepairs because of erosion, flooding, subsidence and poor earthwork during construction. The unavailability of good motorable link roads in some of the areas can hinder rescue operations during disaster periods thereby increasing vulnerability and mortality rates. Good drainage is a sine qua non to healthy living environment especially in areas liable to fluvial hazards. Field survey results reveals that 81.0 percent of the respondents opined that there is a drainage problem in the study area caused by the throw away method (40.0%) of refuse disposal in the study area. This method of disposal of refuse is responsible for the blockage of drainage channels and subsequently accentuating fluvial hazards and increasing the vulnerability index of the study area.

Majority of the respondents draw their source of drinking water from boreholes (51.0%), while the rest source water from streams/river (12.0%), well (19.0%) and pipe borne water (18.0%) respectively. Source of water can be a prelude to increased vulnerability to fluvial related illments and therefore increasing the prospensity to spend more on healthcare and less on developing infrastructures for defence against fluvial hazards and also reducing flexibility to adopt diversified approaches to building resilience and emergency preparedness of the individuals, communities and the city at large.

**Experience of fluvial hazards and sources of help**

The vulnerability of individuals/residents of urban fringes of Calabar depends on the quality of life. Poverty makes most urban fringe residents vulnerable to fluvial hazards such as flooding, erosion, subsidence etc. This findings corroborated the reports of Winchester and Szalachman (2009), Moor (2001), Hardo *et al.*, (2011) they maintained that the urban poor has no viable option than residing in vulnerable slum which greatly exposes them to the vagaries of fluvial and other environmental hazards. Results on table 4 shows that majority of the respondents have experienced fluvial hazards especially flooding and subsidence in the last 10-15 years (58%). About 30 percent and 17 percent of the respondents have experienced fluvial hazards in the last 5-9 years and 1-14 years respectively.

In terms of minimizing the impacts of fluvial hazards and coping strategies, the respondent resort to help from individuals, family members, NGOs, governments. About 18 percent got help from government, 26 percent from NGOs, 40 percent from individuals and family members while 16 percent got help from no one.

**Table 4:** Respondents experience of fluvial hazard and sources of help

| Items | No. of respondents | Percentage |
|---|---|---|
| Experience of fluvial hazards | | |
| 1-4 years | 34 | 17 |
| 5-9 years | 60 | 30 |
| 10-15 years | 106 | 53 |
| Total | 200 | 100 |
| Source of help | | |
| Individual/friend/members | 80 | 40 |
| Government | 36 | 18 |
| NGOs | 52 | 26 |
| No help | 32 | 16 |
| Total | 200 | 100 |

**Source:** Author's fieldwork

**Impact of urbanization on fluvial hazard risk in Calabar**

The degree of urbanization and fluvial hazard in Calabar has brought about impacts at both households and community level. Table 5 shows the impacts of urbanization on fluvial hazards.

Respondent identified several impact. The first impact identified by the respondents relates to drainage, power and road infrastructures these are considered community level impact. The damage to power infrastructure 35 percent is as a result of excessive flooding, 25.0 percent attributed to subsidence and 40 percent accounted by erosion.

**Table 5:** Impacts of urbanization on fluvial hazards risk in Calabar

| Impacts | No. of respondents | Percentage |
|---|---|---|
| Damage to power infrastructure | | |
| Flooding | 70 | 35 |
| Subsidence | 50 | 25 |
| Erosion | 80 | 40 |
| Total | 200 | 100 |
| Outbreak of diseases | | |
| Flooding | 75 | 75 |
| Subsidence | 8 | 4 |
| Erosion | 42 | 21 |
| Total | 200 | 100 |
| Displacement of homes | | |
| Flooding | 110 | 55 |
| Subsidence | 40 | 20 |
| Erosion | 50 | 25 |
| Total | 200 | 100 |
| Damage to buildings/properties | | |
| Flooding | 130 | 65 |
| Subsidence | 10 | 5 |
| Erosion | 60 | 30 |
| Total | 200 | 100 |
| Loss of lives/livelihood | | |
| Flooding | 100 | 50 |
| Subsidence | 40 | 20 |
| Erosion | 60 | 30 |
| Total | 200 | 100 |
| Development of slum settlements | | |
| Flooding | 120 | 60 |
| Subsidence | 30 | 15 |
| Erosion | 50 | 25 |
| Total | 200 | 100 |
| Traffic congestion | | |
| Flooding | 110 | 55 |
| Subsidence | 10 | 5 |
| Erosion | 80 | 40 |
| Total | 200 | 100 |
| Solid waste management challenges | | |
| Flooding | 142 | 71 |
| Subsidence | 18 | 9 |
| Erosion | 40 | 20 |
| Total | 200 | 100 |

**Source:** Authors fieldwork (2021)

In terms of damage to road infrastructure excessive flooding accounts for 60 percent subsidence (10%) while erosion 30 percent. Impact urbanization on fluvial hazards has its positive and negative impacts, its negative impacts includes outbreak of diseases, displacement of homes, damage to buildings and properties, loss of lives and livelihood, development of slum settlements, traffic congestion and solid waste management challenges. Flooding accounted for 75 percent of outbreak of diseases, subsidence (4%), erosion (21%). Flooding and erosion are key fluvial hazards leading to displacement of people from their homes (55% and 25%) while respondents opined that subsistence accounted for 20 percent. Likewise flooding and erosion has been adjudged by respondents as responsible for damage to buildings and properties (65% and 30%) and loss of lives/livelihoods (50% and 30%) while subsidence accounted for 20 percent. In terms of development of slum settlements (flooding 60%, subsidence 15%, erosion 25%), traffic congestion (flooding, 55%, subsidence 5%, erosion 40%) and solid waste management challenges (flooding 71%, subsidence 9%, erosion 20%).

**Respondents coping strategies**

The coping strategies abducted by respondents include social support system (a situation whereby the less vulnerable assist the more vulnerable members of the society), sales of livestocks and non-productive assets, loans, partial or phased out migration, charity, sand filling or failed portions and use of alternative routes, reconstruction of homes and damaged buildings, replacement/repairs of damaged household property, change of livelihood and diversification and relocation of livelihood activity, regular cleaning and sanitation activities, construction of storm proof defensive fence around building and construction of drainages around buildings and neighbourhoods. It is pertinent to note that the coping strategies adopted may with time not withstand future impacts in the city fringes. It therefore behooves that municipal government should strengthen their disaster risks preparedness by evolving an integrated, harmonized and multi-sectorial framework that will employ cross-cutting edge measures that will fit into the rapidly development and redevelopment of municipal urban city.

**Conclusion**

Fluvial hazards in a city is accentuated by rapid urbanization, and erratic government measures towards problems emanating from city expansion in the presence of climate change scenarios affecting humans, livelihoods and properties. Results from this study revealed that because of the position, soil type, rainfall regime of Calabar, the city fringes are still vulnerable to fluvial hazards which calls for appropriate measures to be taken by government and other stakeholders especially in priority to physical planning, proper synergy between private and public developers, flexibility, capacity to recognize and capacity to learn from past experiences as approaches geared towards vulnerability reduction.

**References**

Adelekan, I. O. (2009). Vulnerability for poor urban coastal communities to climate change in Lagos, Nigeria. Fifth Urban Research Symposium 2009.

Adeoye, N. O., Ajanlade, A. & Babatimehin, O. (2009). Climate change and menace of flood in Nigerian cities: Socio-economic implications. Advances in Natural and applied sciences.

Afesimama, E. A. (2008). Climate modeling as a tool of climate variability and change assessment. In challenges of climate change for Nigeria: A multi-disciplinary perspective. Eds. Akande, S. T. & Kumiyi, A. J., Nigerian Institute of Social and Economic Research (NISER) Ibadan, Nigeria. 1-32.

Bull-Kamangha, L., Diagne, K., Lavell, A., Leon, E., Lerise, F., McGregor, H., Maskrey, A., Meshack, M., Pelling, M., Reid, H., Satterhwaite, D., Songsore, J., Westgate, K. & Yitambe, A. (2003). From everyday hazards to disasters: The accumulation of risk in urban areas. *Environment and Urbanization*, 15(1), 193-203.

Hardoy, J., Gustavo, P. & Luz, B. (2011). Local disaster risk reduction in Latin American urban area. *Environment and Urbanization*, 23(2), 401-413.

IFRC (2011). World Disaster Report: 2011 International Federation of Red Cross and Red Crescent Societies, Geneva.

IFRC (2012). Summary for policy makers. In managing the risks of extreme events and disaster to advance climate change adaptation. Cambridge University Press, 1-19.

Moor, J. (2001). Cities at risk, in: Habitat Debate, 7, 4 (2001/12): 1.

Olorunfemi, F. B. (2007). Disaster incidence and management in Nigeria. *Research Review,* 24(2), 1-23.

Satterthwaite, D., Saleem, H., Mark, P., Reid, H. & Lankao, P. R. (2007). Adapting to climate change in urban areas the possibilities and constraints in low and middle-income nations. *Human Settlements Discussion Paper Series.*

Solecki, W. (2012). Urban environmental challenges and climate change action in York City. *Environmental and Urbanization,* 24(2), 557-573.

UN-Habitat (2004). Reducing urban risk and vulnerability. A thematic paper submitted for Discussion at the UN-HABITAT/UN-ISDR – Working meeting on vulnerability assessment and reducing urban risk, Madrid, 7 to 9th September, 2004.

United Nation Environment Programme UNEP (2007). Global Environmental outlook $GEO_4$: Environmental for Development, UNEP, Nairobi.

Winchester, L. & Szalachman, R. (2009). The urban poor's vulnerability to the impacts of climate change in Latin America and the Caribbean. A policy Agenda. Fifth urban Research Symposium 2009.

World Health Organization (1999). Overview of coping mechanisms. Emerging Health Training Programme for Africa; Panafrican Emerging Training Centre, Addis Aba.

**EFFECT OF CLIMATE VARIABILITY ON CASSAVA YIELD IN UYO AND IT'S ENVIRON, AKWA IBOM STATE, NIGERIA**

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**Abstract**

*This study examined the effect of climate variability on cassava yield in Uyo and it's environs, Akwa Ibom State, Nigeria. Data on annual climatic parameters (rainfall, temperature, sunshine and relative humidity) used for the study were obtained from University of Uyo Meteorological Station, Uyo, Akwa Ibom State. Data on cassava yield were obtained from Akwa Ibom State Agricultural Development Programme (AKADEP). Questionnaires were also administered to get data on this study. The method used for data analysis was both descriptive and inferential statistics. The descriptive statistic tools such as table, chart, percentage, trend analysis and standard deviation while inferential statistic tools such as multiple regression, multiple correlation and factor analysis were used for analysis of hypotheses. The results revealed a consistent fluctuation in the pattern of climatic variables of rainfall, sunshine, relative humidity and temperature in the area for the period of 2007-2016.Among the four climatic variables the result of the time series analysis showed that only rainfall had the highest increase of 503.67mm with significant change in pattern of rainfall for the period 2007-2016. The result further showed that there were variations in annual yield of cassava for the past 10years which was attributed to variations in climate. The least quantity of annual cassava yield for the period of 2007-2016 in the area was recorded in the year 2007 with 10,286 metric tons/hectare whereas 2016 was the year with the highest quantity of cassava yield with 26,718 metric tons/hectare. The regression model relating cassava yield to the climatic variables is Y=6722.91+0.89+0.26+0.48+0.19+e. The regression model summary had a coefficient of determination $R^2$ = 0.539 percent which indicated that about 54 percent of variation in cassava yield in the area was attributed to rainfall, sunshine, relative humidity and temperature. Rainfall and sunshine were the most important factors explaining cassava yield in the study area. The result of factor analysis indicated four factors of problems of adaptation accounted for 92.3 percent of total variance of 20 variables. The main adaptation strategies were employed by cassava farmers in response to climate variability. The study therefore strongly recommends training scheme for farmers on new and improved farming techniques that will help reduce the effect of climate variables on cassava yield in the study area.*

**Keywords**: Cassava yield, climate variability, rainfall, temperature, sunshine and relative humidity, Agriculture

## Introduction

Variations in climatic parameters such as temperature, sunshine, relative humidity and rainfall amount over the years have scientifically proven that there is variation in climate. The variability of these climate parameters have been a topical issue in a sustainable environment as the crop yield and production is very important to the economy and livelihood of the people of the world at large. It follows therefore that any change in climate may have effect in agricultural sector in particular and other socio-economic activities in general. Climate variability has generated discussions among stakeholders in agriculture and economic development experts recently. A favourable condition of climate may contribute in the improvement of cassava yield, while the fluctuations of climate variables can threaten cassava yield. The effect of these fluctuations is producing serious challenges to cassava yield in Nigeria as a whole and in Uyo and it's environ in particular.

Climate is defined as the composite of day-to-day weather condition of atmosphere of a place for a very long period of time say 35years (Ekpoh, 2009). Dinse (2011) sees climate variability as the way climate fluctuates yearly above or below a long-term average value variation in human and social environment usually affects land use patterns and has serious implications of varying magnitude for climate variability within which cassava grown.

Climate variability had constituted a serious global environmental threat. This phenomenon can cause severe weather, condition which might result in natural disaster. Of course, climate is constantly changing and the signal which indicates that the alterations are occurring can be evaluated over a range of temporal and spatial scales. We can consider climate to be an integration of complex weather conditions averaged over a significant area of the earth expressed in terms of both the mean of weather and properties such as temperature, radiation, atmospheric pressure, wind, humidity, rainfall and cloudiness amongst others and the distribution or range of variation of these properties usually calculated over a period of 30 years.

Presently, Uyo and its' environ seems to have a high degree of rainfall during the raining season, the yield of cassava seems not to be responding positively to the rate of rainfall. One would normally expect that the area with the unique rainfall pattern should be able to produce the quantity of cassava that is beyond the state consumption capacity, thereby presenting the need to transport them to other state in the country, but this appears not to be the case

Consequently, the yielding of cassava in Uyo and its' environ has not increased significantly in quantity and quality because the region experiences severe variability in its climate in terms of rainfall amount, temperature, and relative humidity. The fluctuations in these climatic parameters are believed to be of great concern to cassava yield

So many scholarly works have been done on the effect of climate variability on cassava yield. However, most of the previous studies on the effect of climatic factors on cassava yield placed much emphasis on temperature and rainfall, giving little attention or even neglecting other climatic elements that can exert considerable influence on cassava yield.Most of this works from their findings, showed a negative relationship between climate variability and cassava yield. Most works considered just one or few climatic variables and their effects on cassava yield. For instance, Alexander, Bakpo and Woke, (2015) only considered the effect of temporal variation of rainfall occurrence on tuber crop production in Niger Delta, South-South, Nigeria. It is based on this limitation that this study examines the effect of climate variability on cassava yield in Uyo and environs, Akwa Ibom State, Nigeria.

## Research Metholodogy

### Study area

The study area is Uyo and its environs. Specifically, the study area includes Uyo, Itu, Ibiono Ibom, and Nsit Ubium Local Government Area (Fig.1). It lies between Latitudes $4^0$53'00" and $5^0$10'00" N of the Equator, and Longitudes $7^0$51'00" and $8^0$54'00" E of the Greenwich Meridian. Uyo is bounded at North by Ikono Local Government Area, at the South by Eket Local Government Area, at the West by Abak and Okobo Local Government Areas Area at East.The study area covers a landmass of 2360km$^2$ (Google Maps, 2017).

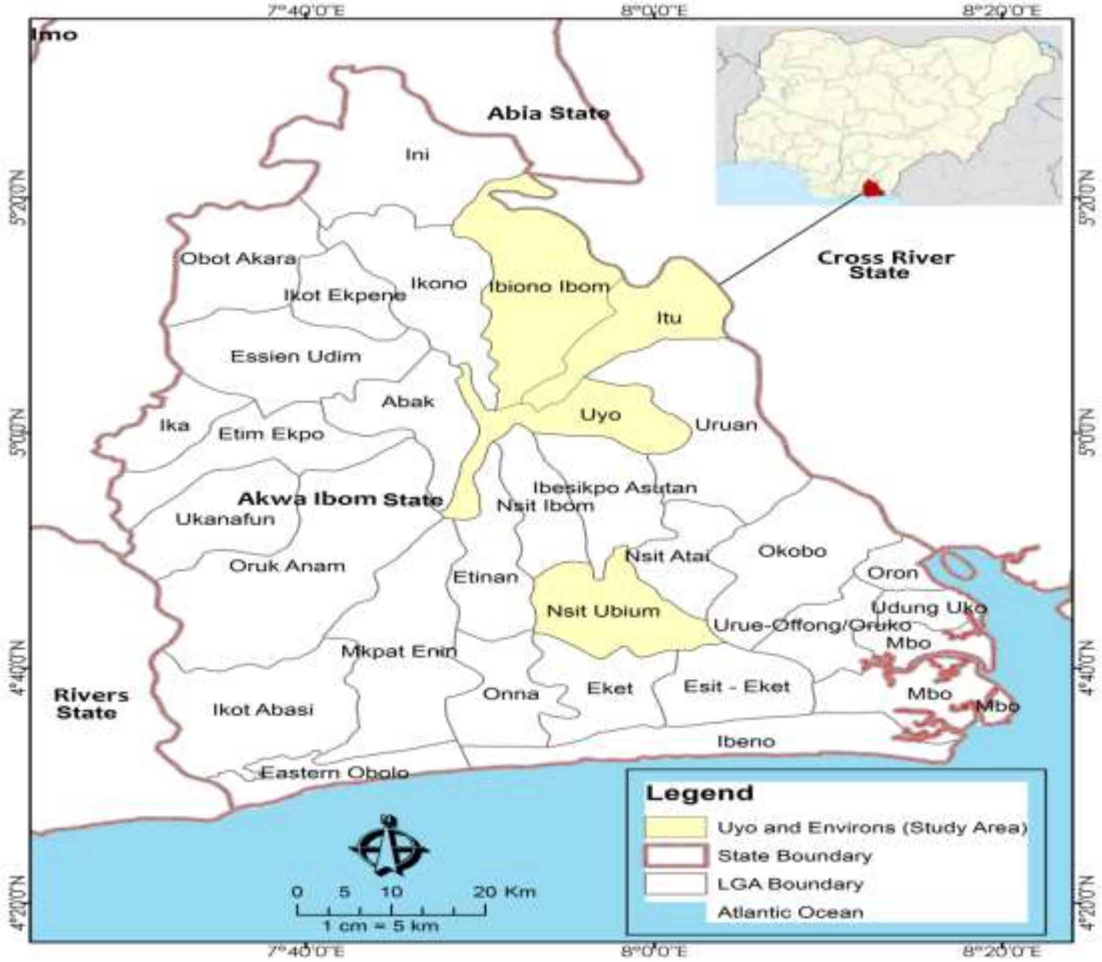


**Fig 1:** Map of Akwa Ibom State showing Uyo and it's environs (study area)
**Source:** Office of the State Surveyor General, Uyo, Akwa Ibom State

## Materials and Method of Data Collection

The major data for this study were obtained from University of Uyo Meteorological Station (NIMET), and Akwa Ibom State Agricultural Development Programme. The meteorological data include annual rainfall, temperature, sunshine and relative humidity the period of ten (10years).Data on cassava yield were obtained from Akwa Ibom State Agricultural Development Programme (AKADEP). Both descriptive and inferential statistics techniques were used for data interpretation. The descriptive statistic tools such as table, chart, percentage, trend analysis and standard deviation while inferential statistic tools such as multiple regression, multiple correlation and factor analysis were used for analysis of hypotheses. The mean of climatic data was calculated using the formular given by:

$$Y_o = a + bx + e$$

where

$Y_o$ = the dependent variables (annual rainfall amount, sunshine, relative humidity and temperature,)

x = the independent variables (time in years) (10years)

a = the y intercept i.e where the regression line touches the y-axis,

b = the regression co-efficient or slope (co-efficient of x) e =the residual or random error term

The multiple regression analysis equation was used to test for the relationship between climatic variables and cassava yield. It is given as;

$$Y = a + b_1X_1 + b_2 X_2+......+ b_n X_n + e$$

Where;
Y = estimated value of the dependent variable (cassava yield in metric tonnes).
a = Y intercept
$b_1$, b2 = the regression plane of the two independent variables.
$X_1X_2X_3 \ldots X_n$ = the independent variables (annual rainfall, temperature, sunshine and relative humidity).
$X_1$= Annual rainfall, $X_2$=Annual Temperature,$X_3$=Annual sunshine,$X_4$=relative humidity, e = error term

There is no significant effect in climatic variables (annual rainfall, temperature, sunshine and relative humidity) on cassava yield

**Sampling Technique**

A multi-stage sampling technique was used in choosing the required samples. In the first stage, the purposive sampling was used to select the four Local Government Areas who are cassava farming areas. The areas include Uyo, Ibiono, Nsit Ubium Local Government Area. The second stage was the identification of cassava household within the sample locations for atleast20years and above through purposive sampling technique. The third stage was used in selecting of four villages each from the 4-cassava farming Local Government Areas

**Technique for Data Analysis**

The data collected were analyzed using both descriptive and inferential statistics. Descriptive tools such as tables, percentages, trend analysis and standard deviation were used. While the inferential statistics such as multiple regression and multiple correlation were also used for the analysis. IBM SPSS version 20.0 software was used for the analysis

**Result and Discussion**

**Table 1**: Multiple effects of variations in climatic variables on cassava yield in Uyo and its environs for the period of 2007-2016

| S/N | YEAR | Temperature (ºC) | Rainfall( mm) | Sunshine (hour) | Relative humidity(%) | Cassava( metric tonnes) |
|---|---|---|---|---|---|---|
| 1 | 2007 | 27.6 | 3308.2 | 2.2 | 80.83 | 10,286 |
| 2 | 2008 | 27.8 | 2970.6 | 2.4 | 29.75 | 10,498 |
| 3 | 2009 | 27.9 | 1944.1 | 4.3 | 81.92 | 10,566 |
| 4 | 2010 | 28.0 | 2782.1 | 3.0 | 82.42 | 11,848 |
| 5 | 2011 | 27.2 | 2880.3 | 1.6 | 80.33 | 14,848 |
| 6 | 2012 | 25.8 | 3838.9 | 2.5 | 79.08 | 13,366 |
| 7 | 2013 | 25.9 | 2926.1 | 3.3 | 79.33 | 13,188 |
| 8 | 2014 | 26.3 | 3026.1 | 2.6 | 80.00 | 13,629 |
| 9 | 2015 | 26.4 | 2967.6 | 2.3 | 77.00 | 12,952 |
| 10 | 2016 | 27.2 | 3904.4 | 3.4 | 80.00 | 26,718 |

**Source:** Author's field work, 2019

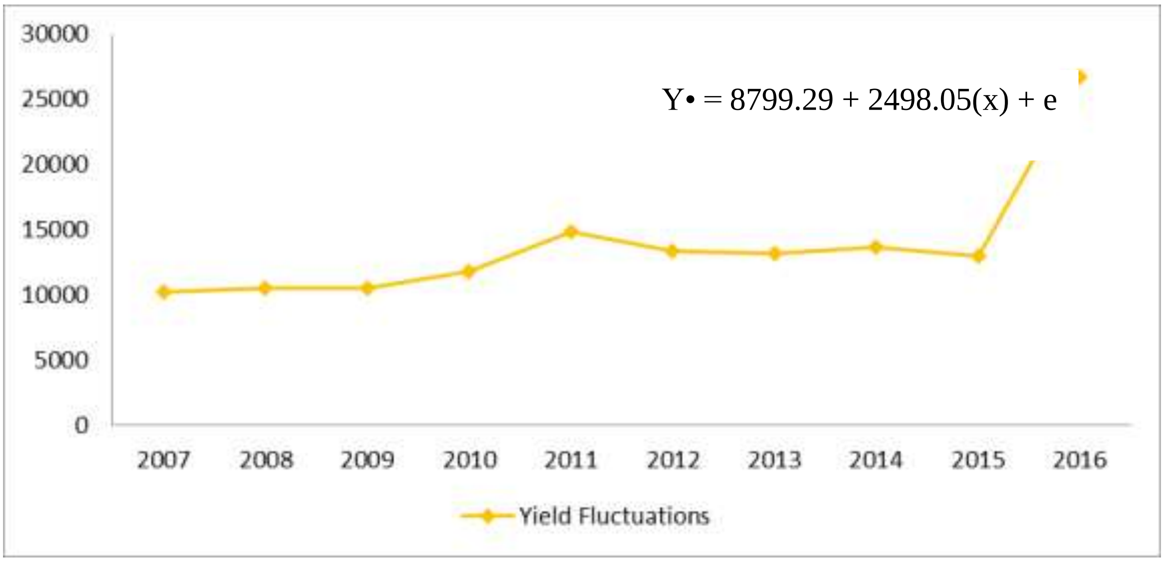


**Fig. 2:** Time series of Annual Cassava yield (metric tonnes/hectare) fluctuations in Uyo for the period of 2007-2016

**Source:** Author's analysis (2019)

The result in Table 1 as it relate to cassava in Uyo and it's environ revealed that in 2007 temperature was 27.2ºC, rainfall 3308.2mm, sunshine 2.1hr, relative humidity 80.8% and cassava yield was 10,286mt. In 2008, temperature was 27.8ºC, rainfall 2970.6mm, sunshine 2.hr, relative humidity 29.75% while cassava yield stood at 10,498mt. The year 2009 temperature was 27.9ºC, rainfall was 1944.1mm, sunshine was 4.3hr, relative humidity was 81.92% and cassava yield was 10,566mts. For 2010, temperature recorded was 28.0ºC, rainfall 2782.1mm, sunshine 3.0hr, relative humidity 82.42% and cassava yield was 11,848mts. For 2011, the recorded temperature level was 27.2ºc with rainfall amount of 2880.3mm, sunshine 1.6h, relative humidity 80.33 percent and cassava yield value of 14,833 metric tonnes. Furthermore, in 2016, the temperature level recorded was 27.2ºC, rainfall amount was 3904.4mm, sunshine 3.4h, relative humidity 80.00 percent with cassava yield value of 26,718 metric tonnes which is the last year in the series. The result showed that within the years under study, cassava had the highest yield value of 26,718mts in 2016. Year 2007 recorded the lowest cassava yield of 10,286mts. The results indicated that rainfall, temperature, sunshine and relative humidity contributed to cassava yield. It was also showed that cassava yield vary in relation to climate variables for the period under study. According to a report by Adejuwon and Agundimingha (2019), rainfall did not affect cassava yield rather temperature was significantly related to cassava yield. Reilly et al. (1996) agreed that if variability in temperature is high, crop yields are lower. Obafemi and Adebulu (2018) stated that variations in rainfall and temperature were found to have effect on cassava yield by 20%. This is in support of Timothy and Rasheed (2016) which reported that increase in climatic parameters cause a decrease in crop yield. This is also in agreement with Odjugo (2010) that climate change would impact negatively on agricultural production and food security. Orimoloye and Adegun (2017) reported that high rainfall and temperature may have a negative effect on cassava yield. Adewuyi et al. (2014) observed that rainfall and temperature were positively related to cassava yield and they were not significant statistically, while relative humidity and sunshine hour and time years had a negative relationship with cassava yield but they were not statistically significant. This also affirmed with the finding of David Boani (2017) on effect of climatic and non-climatic factors on cassava yields in Togo which reported that increasing within-lean-season rainfall variability and high lean-season mean temperature are detrimental to cassava yields, while increasing main-season rainfall and mean-temperature enhance cassava yields.

Table 2 showed the regression model summary with coefficients of multiple determination on the effect of climate variability on cassava yield.

The result from the model summary with coefficients of multiple determination $R^2$ was 0.539 or 53.9%. The results indicated that about 53% increased cassava yield in the study area for the period of 2007-2016 could be attributed to climate variability (rainfall, temperature, sunshine and relative humidity). The remaining factors outside the regression model summary might also be contributory factor to cassava yield in the study area. This result is in agreement with Nwaobiala and Nottide (2013) who affirmed that in all the four functional forms, the $R^2$ were statistically significant at 1.00% level of probability. The $R^2$ value of 0.5318 indicated a 53.18% variability of cassava output explained by the weather elements. The coefficient for temperature (99.32236) was positively signed and statistically significant at 5.00% level. This implies that 1.00% increase in temperature will lead to a 99% increase in cassava output from 1980-2011. This is in disagreement with a priori expectation. Eld, Phillip, Lindsay and Andrew (2006) affirmed that increase in temperature will speed up crop growth cycles, especially cassava which is a root crop that strive in extreme weather conditions. The coefficient for rain (0.2999875) was negatively signed and statistically significant at 10.00% level. This implies that 1.00% increase in rainfall will lead to a 0.29% decrease in cassava yield output. This is in disagreement with a priori expectation since rain which results to soil moisture encourages crop growth and development. This results is not surprising because cassava has attributed which thriving well even in extreme conditions of drought and soil such has been called the famine security crop (Awa & Tumanteh, 2001)

The ANOVA result in Table 3 reported significant F statistics (1.462,p<0.41), indicating that using the regression model is better than guessing the mean. The model summary shows a positive fit of R=73.4%, R-square=53.9% and Adjusted R=17.0% respectively.

The results revealed that, temperature, sunshine and relative humidity were not significant, indicating that these variables do not contribute much to the model. To determine the relative importance of the significant predictors, the standardized coefficients shows that, in cassava yield rainfall, temperature, sunshine and relative humidity were -0. 797, -0.257, -0.480 and -0.191 respectively. Rainfall actually contributes more to the model because it has a larger absolute standardized coefficient . Rainfall was statistically significant at (r=2.247, p ,< 0.1) This implies that there is a significant relationship between cassava yield and rainfall in Uyo and it’s environ.

**Table 2:** Model Summary[b]

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .734[a] | .539 | .170 | 4365.64792 |

a. Predictors: (Constant), Relative humidity, Sunshine, Rainfall, Temperature
b. Dependent Variable: Cassava yield

**Table 3:** ANOVA[b]

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 1.1158 | 4 | 2.787 | 1.462 | .041[a] |
| | Residual | 9.5297 | 5 | 1.906 | | |
| | Total | 2.0688 | 9 | | | |

a. Predictors: (Constant), Relativehumidity, Sunshine, Rainfall, Temperature
b. Dependent Variable: Cassavayield

**Table 4:** Coefficients[a]

| | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. | 95.0% Confidence Interval for B | | Correlations | | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Zero-order | Partial | Part | Tolerance | VIF |
| (Constant) | 6722.907 | 89150.666 | | -.075 | .943 | -235891.988 | 222446.175 | | | | | |
| Rainfall | 3688.678 | 3.066 | .797 | 2.247 | .075 | -.994 | 14.770 | .590 | .709 | .682 | .732 | 1.367 |
| Temper | 464.662 | 2580.360 | .257 | .568 | .595 | -5168.364 | 8097.687 | -.138 | .246 | .172 | .448 | 2.232 |
| Sunshine | 2982.993 | 2164.046 | .480 | 1.378 | .227 | -2579.864 | 8545.849 | .160 | .525 | .418 | .761 | 1.313 |
| Relative humidity | -603.186 | 1471.585 | -.191 | -.410 | .699 | -4386.015 | 3179.643 | -.143 | -.180 | -.124 | .426 | 2.347 |

a. Dependent Variable: Cassavayield

**Conclusion and Recommendation**

The study examined the effect of climate variability on cassava yield in Uyo and it's environ, Akwa Ibom State, Nigeria. The results showed that there were variations in climatic variables (rainfall, temperature, sunshine and relative humidity) for the period of 2007-2016 and cassava yield under study during the same period. From the result of analysis, it was concluded that climate variability had a 53.9% effect on the yield of cassava in the study area during ten(10)years of study. A project research also showed that some other factors affects the yield of cassava in Uyo and it's environ, non-climatic factors such as poor adaptation strategies, poor agricultural practices. The study therefore recommended training schemes for farmers on new and improved farming techniques that will help reduce the effect of climate variability on cassava yield.

**References**

Akwa Ibom State Agricultural Development Programme (AKADEP) (2012). Akwa Ibom State Agricultural Statistics. A working Document

Adewuyi, S. A.; B. Folorunso, L. O. Okoji& D. Akerede (2014). Effect of Climate Change on Food Crop Production and Vulnerability Assessment in Oyo State. *Journal of Economic and International Finance*, 7(1)18-24.

Adeguwon, JO; &Agundiminegha, YG (2019).Impact of climate variability on cassava yield in the Humid Forest Agro-ecological Zone of Nigeria. Department of Agriculture, Abeokuta, *Nigeria Journal Applied.Science. Environmental Management.* 23 (5), 903-908.

Awa, E. T. & Tumanteh, A. (2001). Cassava-based cropping systems and use of inputs in Different ecological zone of central Africa. *African Journal of root and Tuber Crops* 4(2): 45-49.

Eld, Phillip A. Lindsay, C & Andrew J. (2006). Livelihood adaptations to climate variability: Insights from farming households in Ghana. Regional environmental change 14 (4) 1615-1626.

Ekpoh, I. J. (2009). Climate, Society and Environment. University of Calabar. St. Paul Publications Company, Calabar. 2-3.

Dinse, K. (2011). Climate variability and climate change: what is the difference? Retrieved from: w.w.w.miiseagrantUmich. Edu/climate (Accessed /10/18).

David, B. D. (2017). Effect of climatic and non-climatic factors on cassava yields in Togo: Agricultural Policy Implications. Department of Economic and Technological Change, Center of Development Research, University of Bona, Born D-53113, Germany, Climate (2017). 5(2), 28.

Google Map, 2017.

Nwaobiala, C. U. & Nottidge, D.O.(2013).Effect of climatic variables on cassava farmers' production in Abia State, Nigeria. *Nigerian journal of Agriculture, Food and Environment,* 9 (4), 57-62.

Odjugo, P. A. (2010). Adaptation to Climate Change in Agricultural Sector in Semi-arid and Region of Nigeria. 2nd International conference: Climate, Sustainability and development in Semi-arid Regions August 16-20, 2010, Fortaleza-Cera Brazil.

Obafemi, O. O, &Adebolu, E.A. (2018). Effect of climate variability on the yield of scrops in Ondo State, Nigeria. Department of Environmental Engineering, Federal University of Tecnology, Akure, Ondo State, Nigeria. *International Journal of Water Resources and Environmental Engineering.* 10 (5),54-63.

Orimoloye, I. R. & Adigun, A. I. (2017). Response of cassava and maize yield to varying spatial scales of rainfall and temperature sceneries in Port Harcourt. *Research Journal of Environmental Sciences.*11: 137-142.

Reilley ,J.,Watson, R., Zinyowera, M.,Moss, R. &Dokken, D. (1996). Agriculture in a changing climate and investigation on its probable impacts on rice production at Sathkhira, Bangladesh, *Pakistan Journal of Meteorology* 6: 37-50.

Timothy, D. A. & Rasheed, A.B. (2016). Impact of Climate on the Yield of Major Tuber Crops in Kwara State, Nigeria. *Global Journal of Agricultural Sciences* 16:61-65.

# COMPARATIVE ANALYSIS OF EFFECTS OF CLIMATE CHANGE ON THREE NORTHERN AND THREE SOUTHERN STATES OF NIGERIA

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**Abstract**

*Climate change is a vital issue that has significant effects globally including Nigeria as a country located in the tropics. The landmass of Nigeria characterized it into different climatic seasons and variations from the North to the South with the later having higher rainfall while the former higher temperature. This study aimed at determining rainfall and temperature distribution between the North and South and to establish if there is any spatio-temporal variability of rainfall and temperature in the last 34 years in Nigeria. To achieve this aim, two hypotheses were formulated as follows: (i) the means of rainfall for the six different States did not show any significant difference, and (ii) the means of minimum temperature for the six different States did not reveal any significant difference. Climatic data from 1985 to 2019 was collected from a State in each of the six geo-political zones. The data was analyzed by using both qualitative and quantitative statistical methods such as sum, average, and ANOVA. The results revealed that the wettest year between 1985 and 2019 was 2019 with a rainfall amount of 2918.8mm. The temperature in the Northern States was high with maximum temperature of 35˚C - 37˚C. The means of both rainfall and minimum temperature for the six different states showed significant difference. The high amount of rainfall caused regular flooding in most cities in the South. However, because of the prolonged dry season in the north, the vegetation are scanty and patched and are easily entrained in slight amount of rainfall. It is recommended that further studies be conducted covering other States in each of the geo-political zones as to consolidate the findings of this result. The findings from this research will support in the decision making on issues relating to climate, vegetation, agriculture and the general human welfare in the country.*

**Keyword:** Climatic variability, geo-political zones, rainfall, temperature, Nigeria

## 1. Introduction

Severity of weather-related disasters are increasing and appears to have done so in a number of regions of the world and climate change has been finger-printed as the main factor responsible for these environmental devastations. Climate change, according to the Intergovernmental Panel on Climate Change (IPCC), is a change in global or regional climate patterns, in particular, a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels. In simple terms, Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (e.g. decades) (AMC, 2010; NRC 2010).

Climate change impacts the weather largely by putting the hydrological cycle into overdrive. With the burning of fossil fuels, greenhouse gases are introduced into the atmosphere, increasing the temperature and warming the planet (TCLP, 2020). The global average temperature is now 1.1°C higher than the beginning of last century which means it can hold 5-6 percent more moisture. UNEP's World Environment Situation Room includes regularly updated information about global temperature anomalies, and this report shows that January 2020 was the warmest January since records began, rising to 1.19°C above pre-industrial levels. With higher temperatures, we have more energy in the Earth's system. As temperatures around the globe rises, water from land and sea is evaporating faster, this results in more water evaporating into the atmosphere and formation of cloud. As air gets warmer, it holds more water vapour leading to more intense precipitation events and intensifying storms with adverse environmental consequences. (USGCRP, 2017)

Different types of flood and magnitude are recorded every year in Nigeria with those occurring along the River Niger and River Benue and their tributaries frequently causing disasters. Moreover, two thirds of Bayelsa State and half of Delta State are inundated by devastating floods for at least a quarter of each year (Obenade and Amangabara, 2015). Instances of flooding have increased in Nigeria and this has led to crop destruction and water contamination, which in turn spread diseases such as cholera and typhoid along with other water-borne diseases (Ogbonna *et. al*., 2008). In addition to the challenges above is the threat from rising sea-levels with a global average of 3.2mm rise in sea level rise. Nigeria with over 853 km (530mi) of coastline with extensive low-lying areas, are prone to flooding now than ever before and large numbers of people have become vulnerable to this threat and face being evacuated in the event of extreme flood either astronomical or meteorological. In the 2012 flood event, more than half a million were evacuated as internally displaced persons from the Nigeria Delta Region alone which was virtually submerged (Amangabara and Obenade, 2015). The most recent and extensive studies of sea-level rise predict that by 2100, there would be a 1400mm rise in sea-levels; this would displace about 30 million people and lead to the permanent loss and abandonment of about one fifth of the land, most notably in the Delta regions of the world.

In the northern part of the country, in addition to channel floods occasioned by intense precipitation the issue of desertification and drought occasioned by intense sunshine, increased temperature and dryness has been a challenge.

The aim of this study is to determine rainfall and temperature distribution pattern between the North and South and to establish a spatio-temporal variability of rainfall and temperature in the last 34 years and the implication on drought and flood. To achieve this aim, two hypotheses were formulated as follows: (i) the means of rainfall for the six different states did not show any significant difference, and (ii) the means of minimum temperature for the six different states did not reveal any significant difference.

## 2. Materials and Method

### 2.1. Study Area(s), Data Collection and Analysis

The study covered all the six geo-political zones of Nigeria were sampled with a State from each of the zones. FCT-Abuja for the North Central, Borno for the North East, Sokoto for North West, Imo for South East, Rivers for South-South, and Lagos for South West zone. On the basis of simple random sampling; one State was selected from each geo-political zone to reflect the temperature and vegetation zones of the country (This gives a representation of about 16.67% of the entire population). Usually the standard guide is 10%, provided the population size is not more than 1000. Mean annual air temperature from six (6) synoptic stations representing the six geopolitical zones of the country were collected for the years 1985 to 2019 from the Nigerian Meteorological Agency and were subjected to statistical analysis ( Time series and Analysis of variance)

Analysis of Variance (ANOVA) is helpful for testing three or more variables. However, it results in fewer type I errors and is appropriate for a range of issues. ANOVA groups differences by comparing the means of each group and includes spreading out the variance into diverse sources.


**Fig.1:** Study Area (Map of Nigeria showing the six geo-political zones)

## 3. Results and Discussion

**Table 1:** Descriptive Statistics for Rainfall

| | *Ikeja* | *Maiduguri* | *Owerri* | *Sokoto* | *Abuja* | *Port Harcourt* |
|---|---|---|---|---|---|---|
| Mean | 126.00 | 53.54 | 197.43 | 54.59 | 130.02 | 190.79 |
| Standard Error | 4.04 | 2.46 | 4.58 | 2.01 | 4.25 | 3.97 |
| Median | 129.47 | 51.34 | 197.49 | 54.65 | 126.78 | 189.49 |
| Standard Deviation | 23.93 | 14.55 | 27.09 | 11.88 | 25.15 | 23.50 |
| Sample Variance | 572.54 | 211.74 | 733.68 | 141.11 | 632.38 | 552.35 |
| Kurtosis | -0.19 | 0.18 | -0.33 | 3.30 | -0.66 | 0.91 |
| Skewness | -0.08 | 0.82 | -0.26 | 0.72 | 0.22 | 0.54 |
| Range | 99.22 | 58.97 | 106.44 | 64.46 | 101.70 | 113.80 |
| Minimum | 77.21 | 30.52 | 136.79 | 31.10 | 78.10 | 145.77 |
| Maximum | 176.43 | 89.49 | 243.23 | 95.56 | 179.80 | 259.57 |
| Sum | 4409.92 | 1873.87 | 6910.22 | 1910.67 | 4550.87 | 6677.80 |
| Count | 35 | 35 | 35 | 35 | 35 | 35 |

**Table 2:** Descriptive Statistics for Maximum Temperature

| | *Ikeja* | *Maiduguri* | *Owerri* | *Sokoto* | *Abuja* | *Port Harcourt* |
|---|---|---|---|---|---|---|
| Mean | 31.463 | 35.471 | 32.135 | 35.348 | 32.948 | 31.502 |
| Standard Error | 0.070 | 0.064 | 0.085 | 0.103 | 0.068 | 0.051 |
| Median | 31.366 | 35.621 | 31.995 | 35.375 | 33.043 | 31.504 |
| Standard Deviation | 0.413 | 0.379 | 0.504 | 0.609 | 0.401 | 0.299 |
| Sample Variance | 0.171 | 0.144 | 0.254 | 0.371 | 0.161 | 0.089 |
| Kurtosis | -0.447 | 1.192 | -0.576 | 0.623 | -0.354 | -0.544 |
| Skewness | 0.134 | -1.090 | 0.656 | 0.216 | -0.051 | 0.010 |
| Range | 1.693 | 1.683 | 1.808 | 2.900 | 1.738 | 1.179 |
| Minimum | 30.630 | 34.317 | 31.411 | 34.100 | 32.148 | 30.887 |
| Maximum | 32.323 | 35.999 | 33.219 | 37.000 | 33.885 | 32.065 |
| Sum | 1101.209 | 1241.475 | 1124.735 | 1237.167 | 1153.194 | 1102.585 |
| Count | 35 | 35 | 35 | 35 | 35 | 35 |

**Table 3:** Descriptive Statistics for Minimum Temperature

| | *Ikeja* | *Maiduguri* | *Owerri* | *Sokoto* | *Abuja* | *Port Harcourt* |
|---|---|---|---|---|---|---|
| Mean | 23.825 | 22.999 | 23.173 | 22.520 | 21.631 | 22.722 |
| Standard Error | 0.067 | 1.009 | 0.135 | 0.070 | 0.161 | 0.102 |
| Median | 23.867 | 20.425 | 23.350 | 22.500 | 21.452 | 22.760 |
| Standard Deviation | 0.397 | 5.968 | 0.798 | 0.414 | 0.952 | 0.605 |
| Sample Variance | 0.158 | 35.617 | 0.636 | 0.171 | 0.906 | 0.365 |
| Kurtosis | 0.017 | 1.318 | 0.459 | -0.606 | 0.942 | 15.538 |
| Skewness | -0.038 | 1.781 | -0.704 | -0.282 | 0.916 | -3.273 |
| Range | 1.716 | 16.808 | 3.538 | 1.608 | 4.033 | 3.682 |
| Minimum | 23.095 | 19.192 | 21.012 | 21.533 | 20.098 | 19.826 |
| Maximum | 24.811 | 35.999 | 24.551 | 23.142 | 24.131 | 23.508 |
| Sum | 833.867 | 804.979 | 811.059 | 788.185 | 757.073 | 795.282 |
| Count | 35 | 35 | 35 | 35 | 35 | 35 |

**Table 4:** Mean and Standard Deviation for Rainfall and Temperature Data

| | Rainfall | Maximum Temperature | Minimum Temperature |
|---|---|---|---|
| Ikeja | 126.00 ± 23.93 | 31.46 ± 0.41 | 23.82 ± 0.40 |
| Maiduguri | 53.54 ± 14.55 | 35.47 ± 0.38 | 23.00 ± 5.97 |
| Owerri | 197.43 ± 27.09 | 32.14 ± 0.50 | 23.17 ± 0.80 |
| Sokoto | 54.59 ± 11.88 | 35.35 ± 0.61 | 22.52 ± 0.41 |
| Abuja | 130.02 ± 25.15 | 32.95 ± 0.40 | 21.63 ± 0.95 |
| Port Harcourt | 190.79 ± 23.50 | 31.50 ± 0.30 | 22.72 ± 0.60 |

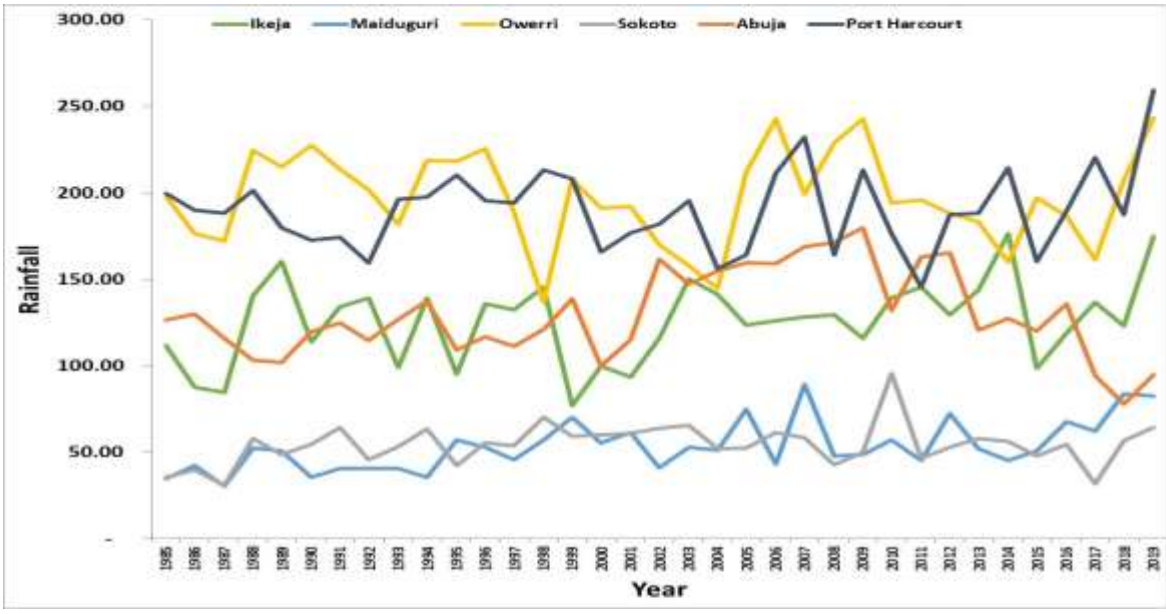


**Fig. 2:** Yearly Rainfall variation

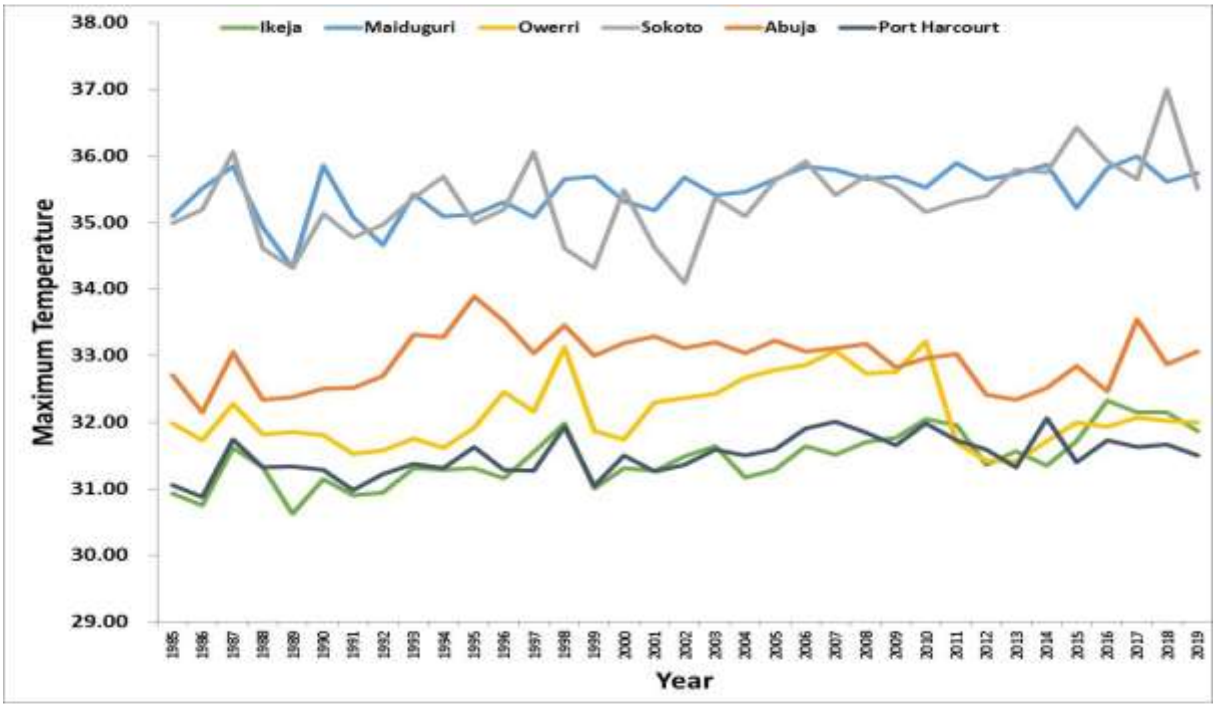


**Fig 3:** Maximum Temperature for Six States representing the six Geopolitical Zones

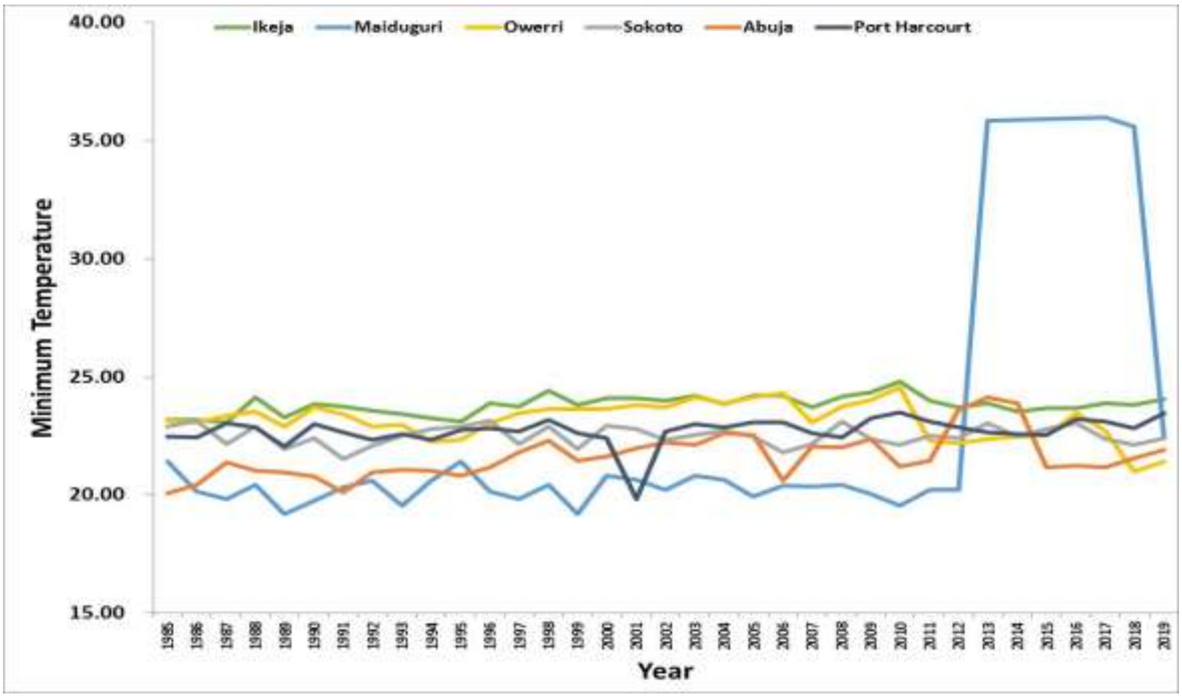


**Fig 4** Minimum Temperature for Six States representing the six Geopolitical Zones

**Table 5:** Analysis of Variance (ANOVA)

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Ikeja | 35 | 4,409.925 | 125.998 | 572.539 |
| Maiduguri | 35 | 1,873.867 | 53.539 | 211.744 |
| Owerri | 35 | 6,910.225 | 197.435 | 733.681 |
| Sokoto | 35 | 1,910.667 | 54.590 | 141.109 |
| Abuja | 35 | 4,550.867 | 130.025 | 632.377 |
| Port Harcourt | 35 | 6,677.800 | 190.794 | 552.353 |

**ANOVA**

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 688,281.467 | 5 | 137,656.293 | 290.434 | 0.000 | 2.258 |
| Within Groups | 96,689.303 | 204 | 473.967 | | | |
| Total | 784,970.770 | 209 | | | | |

There is a significant difference in the means of rainfall for the six different States. i.e. At least, one mean is different from the others. Since there is a significant difference in the means of rainfall, we compare the States pairwise in order to determine where the difference lies

Tukey multiple comparison procedure was used to compare the means pairwise (state by state) and separate the means into homogenous groups.

**Multiple Comparisons**

Dependent Variable: Rainfall

**Tukey HSD**

| (I) State | (J) State | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| Ikeja | Maiduguri | 72.459429* | 5.204202 | .000 | 57.48691 | 87.43194 |
| | Owerri | -71.436286* | 5.204202 | .000 | -86.40880 | -56.46377 |
| | Sokoto | 71.406571* | 5.204202 | .000 | 56.43406 | 86.37909 |
| | Abuja | -4.026857 | 5.204202 | .972 | -18.99937 | 10.94566 |
| | Port Harcourt | -64.796286* | 5.204202 | .000 | -79.76880 | -49.82377 |
| Maiduguri | Ikeja | -72.459429* | 5.204202 | .000 | -87.43194 | -57.48691 |
| | Owerri | -143.895714* | 5.204202 | .000 | -158.86823 | -128.92320 |
| | Sokoto | -1.052857 | 5.204202 | 1.000 | -16.02537 | 13.91966 |
| | Abuja | -76.486286* | 5.204202 | .000 | -91.45880 | -61.51377 |
| | Port Harcourt | -137.255714* | 5.204202 | .000 | -152.22823 | -122.28320 |
| Owerri | Ikeja | 71.436286* | 5.204202 | .000 | 56.46377 | 86.40880 |
| | Maiduguri | 143.895714* | 5.204202 | .000 | 128.92320 | 158.86823 |
| | Sokoto | 142.842857* | 5.204202 | .000 | 127.87034 | 157.81537 |
| | Abuja | 67.409429* | 5.204202 | .000 | 52.43691 | 82.38194 |
| | Port Harcourt | 6.640000 | 5.204202 | .798 | -8.33252 | 21.61252 |
| Sokoto | Ikeja | -71.406571* | 5.204202 | .000 | -86.37909 | -56.43406 |
| | Maiduguri | 1.052857 | 5.204202 | 1.000 | -13.91966 | 16.02537 |
| | Owerri | -142.842857* | 5.204202 | .000 | -157.81537 | -127.87034 |
| | Abuja | -75.433429* | 5.204202 | .000 | -90.40594 | -60.46091 |
| | Port Harcourt | -136.202857* | 5.204202 | .000 | -151.17537 | -121.23034 |
| Abuja | Ikeja | 4.026857 | 5.204202 | .972 | -10.94566 | 18.99937 |
| | Maiduguri | 76.486286* | 5.204202 | .000 | 61.51377 | 91.45880 |
| | Owerri | -67.409429* | 5.204202 | .000 | -82.38194 | -52.43691 |
| | Sokoto | 75.433429* | 5.204202 | .000 | 60.46091 | 90.40594 |
| | Port Harcourt | -60.769429* | 5.204202 | .000 | -75.74194 | -45.79691 |
| Port Harcourt | Ikeja | 64.796286* | 5.204202 | .000 | 49.82377 | 79.76880 |
| | Maiduguri | 137.255714* | 5.204202 | .000 | 122.28320 | 152.22823 |
| | Owerri | -6.640000 | 5.204202 | .798 | -21.61252 | 8.33252 |
| | Sokoto | 136.202857* | 5.204202 | .000 | 121.23034 | 151.17537 |
| | Abuja | 60.769429* | 5.204202 | .000 | 45.79691 | 75.74194 |

***.** The mean difference is significant at the 0.05 level.

**Analysis of Variance (ANOVA) For Minimum Temperature**

Hypothesis:

*$H_0$*: There is no significant difference in the means of minimum temperature for the six different states.

i.e. $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6$

*$H_1$*: There is a significant difference in the means of minimum temperature for the six different states.

i.e. At least, one mean is different from the others.

Find the Critical Value

d.f.N = degree of freedom number of groups = k – 1

d.f.D. = degree of freedom sample sum = N – k

where: k is number of groups = 6
N is sum of all samples = 6 x 35 = 210

d.f.N. = k – 1 = 6 – 1 = 5
d.f.D. = N – 6 = 210 - 5 = 205

From the F-distribution table, the critical value obtained at α = 0.05 is 2.258

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Ikeja | 35 | 833.867 | 23.825 | 0.158 |
| Maiduguri | 35 | 804.979 | 22.999 | 35.617 |
| Owerri | 35 | 811.059 | 23.173 | 0.636 |
| Sokoto | 35 | 788.185 | 22.520 | 0.171 |
| Abuja | 35 | 757.073 | 21.631 | 0.906 |
| Port Harcourt | 35 | 795.282 | 22.722 | 0.365 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 93.812 | 5 | 18.762 | 2.974 | 0.013 | 2.258 |
| Within Groups | 1,287.039 | 204 | 6.309 | | | |
| | | | | | | |
| Total | 1,380.851 | 209 | | | | |

Since F (= 2.974) is greater than the critical value (= 2.258), and also since the p-value (= 0.013) is less than α (= 0.05), we therefore do reject the null hypothesis; and summarise the result as follows:

*$H_1$*: There is a significant difference in the means of minimum temperature for the six different States.

i.e. At least, one mean is different from the others.

Since there is a significant difference in the means of minimum temperature, we need to compare the states pairwise in order to determine where the difference lies

**Multiple Comparisons With Tukey's HSD for Minimum Temperature**
Tukey multiple comparison procedure will compare the means pairwise (State by State) and separate the means into homogenous groups.

**Multiple Comparisons**

Dependent Variable: Minimum Temperature
**Tukey HSD**

| (I) State | (J) State | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| Ikeja | Maiduguri | .825429 | .600416 | .742 | -.90197 | 2.55283 |
| | Owerri | .652000 | .600416 | .887 | -1.07540 | 2.37940 |
| | Sokoto | 1.304857 | .600416 | .255 | -.42254 | 3.03226 |
| | Abuja | 2.194571* | .600416 | .004 | .46717 | 3.92197 |
| | Port Harcourt | 1.102571 | .600416 | .445 | -.62483 | 2.82997 |
| Maiduguri | Ikeja | -.825429 | .600416 | .742 | -2.55283 | .90197 |
| | Owerri | -.173429 | .600416 | 1.000 | -1.90083 | 1.55397 |
| | Sokoto | .479429 | .600416 | .968 | -1.24797 | 2.20683 |
| | Abuja | 1.369143 | .600416 | .207 | -.35826 | 3.09654 |
| | Port Harcourt | .277143 | .600416 | .997 | -1.45026 | 2.00454 |
| Owerri | Ikeja | -.652000 | .600416 | .887 | -2.37940 | 1.07540 |
| | Maiduguri | .173429 | .600416 | 1.000 | -1.55397 | 1.90083 |
| | Sokoto | .652857 | .600416 | .886 | -1.07454 | 2.38026 |
| | Abuja | 1.542571 | .600416 | .110 | -.18483 | 3.26997 |
| | Port Harcourt | .450571 | .600416 | .975 | -1.27683 | 2.17797 |
| Sokoto | Ikeja | -1.304857 | .600416 | .255 | -3.03226 | .42254 |
| | Maiduguri | -.479429 | .600416 | .968 | -2.20683 | 1.24797 |
| | Owerri | -.652857 | .600416 | .886 | -2.38026 | 1.07454 |
| | Abuja | .889714 | .600416 | .676 | -.83768 | 2.61711 |
| | Port Harcourt | -.202286 | .600416 | .999 | -1.92968 | 1.52511 |
| Abuja | Ikeja | -2.194571* | .600416 | .004 | -3.92197 | -.46717 |
| | Maiduguri | -1.369143 | .600416 | .207 | -3.09654 | .35826 |
| | Owerri | -1.542571 | .600416 | .110 | -3.26997 | .18483 |
| | Sokoto | -.889714 | .600416 | .676 | -2.61711 | .83768 |
| | Port Harcourt | -1.092000 | .600416 | .456 | -2.81940 | .63540 |
| Port Harcourt | Ikeja | -1.102571 | .600416 | .445 | -2.82997 | .62483 |
| | Maiduguri | -.277143 | .600416 | .997 | -2.00454 | 1.45026 |
| | Owerri | -.450571 | .600416 | .975 | -2.17797 | 1.27683 |
| | Sokoto | .202286 | .600416 | .999 | -1.52511 | 1.92968 |
| | Abuja | 1.092000 | .600416 | .456 | -.63540 | 2.81940 |

*. The mean difference is significant at the 0.05 level.

**Homogeneous Subsets**

Rainfall

Tukey HSD[a]

| State | N | Subset for alpha = 0.05 | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Maiduguri | 35 | 53.53857 | | |
| Sokoto | 35 | 54.59143 | | |
| Ikeja | 35 | | 125.99800 | |
| Abuja | 35 | | 130.02486 | |
| Port Harcourt | 35 | | | 190.79429 |
| Owerri | 35 | | | 197.43429 |
| Sig. | | 1.000 | .972 | .798 |

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 35.000.

**Homogeneous Subsets**

Minimum Temperature
Tukey HSD[a]

| State | N | Subset for alpha = 0.05 | |
|---|---|---|---|
| | | 1 | 2 |
| Abuja | 35 | 21.63057 | |
| Sokoto | 35 | 22.52029 | |
| Port Harcourt | 35 | 22.72257 | |
| Maiduguri | 35 | 22.99971 | |
| Owerri | 35 | | 23.17314 |
| Ikeja | 35 | | 23.82514 |
| Sig. | | .110 | .255 |

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 35.000.

The average rainfall in 35 years of study for Lagos is 126mm (Table 1). Minimum rainfall amount is 77.21 mm and maximum amount is 176.43 mm. Lagos recorded the highest rainfall of 2117.10 mm and 2,096.4 mm which occurred in 2014 and 2019 respectively. In terms of rainfall decades, 1985-1994 had 14,534.3mm. 1995-2004 had rainfall amount of 14,253.2 and 2005 – 2015 is 16,305.8 unarguably the rainiest decades in Lagos between 1985 and 2019. For Maiduguri (North East) the mean rainfall amount is 53.54mm. The least rainfall for 35 years in this region occurred in 1987 with 366.2mm of rainfall, 1990 with 429mm of rainfall, 1994 429.6mm of rainfall while the highest rainfall amount for the area occurred in 2007 ( 1,073.9mm), 2018(1004.3mm). 1985 – 1994 (48,521mm), 1995- 2004 (6,544mm) and 2005 – 2014 (6,921.2mm) of rainfall. The decades between 1985 and 1994 can be described as the driest period in the North east. Owerri, (South East) the mean rainfall is 197.49mm. Total amount of rainfall from 1985 to 1994 is 24,377.3mm. From 1995 to 2004 rainfall amount is 22,010.4mm while from 2005 to 2015 rainfall amount is 24,581.4mm. The wettest year between 1985 and 2019 is 2019 with a rainfall amount of 2918.8mm. Ten years earlier in 2009 the rainfall amount was 2916.7mm. 1998 had the least rainfall amount with 1641.5mm followed by 2004 with 1735.6mm. For other cities, rainfall amount for Sokoto showed that the mean 54.65, Abuja, 126.78 and Port Harcourt 189.49mm.

The temperature in the North are high with maximum temperature of 35˚C - 37˚C (Maiduguri and Sokoto respectively) and minimum temperature of 33˚C (Tables 2 and 3). Maiduguri and Sokoto approximately on the same latitude and in the same temperature zone - BSh (arid steppe hot type of climate & BWh arid steppe desert type of climate) has slight temperature variation, possibly the influence of Lake Chad the highest temperature in the South is in Owerri at 32 ˚C while Ikeja and Port Harcourt are at 31 ˚C. The SD (Table 4) for rainfall in the northern region - Maiduguri (North East) is 53.54 ± 14.55, Sokoto (North West) 54.59 ± 11.88. Abuja (North Central) 130.02 ± 25.15 The SD values for Maiduguri and Sokoto are Similar because they are in the arid Steppe hot climatic zone while Abuja is in the tropical savanna zone. A remarkable occurrence was observed that from 2012 to 2019 there was a spike in minimum temperature rising from 35˚C to about 37˚C (Fig. 4).

Results from Tukey HSD for rainfall shows that three homogenous groups were defined. The first group contains Maiduguri and Sokoto which have no significant difference in Rainfall, but this group is significantly different from the other groups. Ikeja and Abuja are contained in the second group and finally, Port Harcourt and Owerri are in the third group and rainfall is significantly different from the other groups.

For Temperature, results from Tukey HSD shows that two homogenous groups were defined. The first group contains Abuja, Sokoto, Port Harcourt, and Maiduguri which have no significant difference in minimum temperature with each other, but this group is significantly different from the other group containing Owerri and Ikeja. The results as presented above indicate rainfall variability as well as temperature variability across the country. Rainfall was highest in the coastal zone (Rivers and Lagos States). Borno and Sokoto States had the least rainfall. The ANOVA table clearly indicated the variability because Since F (= 290.434) is greater than the critical value (= 2.258), and also since the p-value (= 0.000) is less than $\alpha$ (= 0.05), In terms of atmospheric temperature, Sokoto and Borno spiked in both minimum and maximum temperature, this was expected. However it was also spotted that between 2012 and 2016 the temperature in Borno was consistently high either minimum or maximum. The implication is that increased temperature resulted in dryness of the soil causing patches leading to bare surfaces such that vegetation becomes unhealthy when the flood waters come infiltration is impeded which leads to flash flood. The intensive rainfall in the South leads to gully erosion in the South east and severe flooding in the coastal area

## Conclusion

Rainfall pattern between the north and the south differ very significantly. The high amount of rainfall results in constant flooding in most cities in the South. However, because of the extensive dry season in the north, the vegetation are scanty and patched and are easily entrained in slight amount of rainfall. When channel flow from upstream Niger Republic hits Nigeria, because of the loose soil due to less cohesiveness, the area experiences flash floods**.**

**References**

Amangabara, GT and Obenade, M (2015) Flood Vulnerability Assessment of Niger Delta States Relative to 2012 Flood Disaster in Nigeria. *American Journal of Environmental Protection*.Vol. 3, No. 3, DOI:10.12691/env-3-3-3 pp76-83

AMC (America's Climate Choices) (2010). Panel on Advancing the Science of Climate Change; National Research Council Advancing the Science of Climate Change. Washington, D.C.: The National Academies Press.

National Research Council (NRC). (2010). *Advancing the Science of Climate Change*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12782.

IPCC, 2012: glossary of items. In: Managing the risks of extreme events and disasters to advance climate change adaptation Field, C.B., V. Barros, T,F. Stocker, D.j. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G-k. Plattner, S.k. Allen, M,Tignor, and P.M. Midgley (eds.)]. A special Report of Working Groups 1 and 11 of the intergovernmental panel on climate change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp.555-564.

Obenade M and Amangabara, GT (2015). Climate Change and Population Displacement: Implications and strategies for the Niger Delta of Nigeria. Niger Delta Research Digest (NDRD) Vol. 9 (1) p 67-91

Ogbonna, D.N., Chilaka, S.N., Gobo, A.E. and Amangabara, G.T. (2008). Effect of waste disposal practices and perennial flooding in Port Harcourt Metropolis, *Journal of Research in Bioscience*, Vol. 4. No. 3 ISSN 1597-80IX pp 103-110.

The Climate Reality Project (2020). The Climate Crisis and Flooding: what you need to know. Retrieved from www.the climate reality project. January 2020

USGCRP (U.S. Global Change Research Program). (2017). Climate science special report: Fourth National Climate Assessment, volume I. Wuebbles, D.J., D.W. Fahey, K.A., Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.). https://science2017.globalchange.gov. doi:10.7930/J0J964J6.

Appendix 1

| S/N | Year | Ikeja | Maiduguri | Owerri | Sokoto | Abuja | Port Harcourt |
|---|---|---|---|---|---|---|---|
| 1 | 1985 | 111.65 | 34.66 | 198.02 | 35.55 | 126.78 | 199.64 |
| 2 | 1986 | 87.74 | 42.46 | 176.76 | 39.65 | 129.88 | 190.26 |
| 3 | 1987 | 84.60 | 30.52 | 172.50 | 31.10 | 115.98 | 188.44 |
| 4 | 1988 | 140.72 | 52.35 | 224.87 | 58.11 | 103.39 | 201.74 |
| 5 | 1989 | 160.58 | 50.86 | 215.12 | 48.84 | 102.27 | 180.02 |
| 6 | 1990 | 114.07 | 35.75 | 227.66 | 54.54 | 119.86 | 172.77 |
| 7 | 1991 | 134.17 | 40.51 | 213.76 | 64.29 | 124.97 | 174.53 |
| 8 | 1992 | 139.32 | 40.52 | 202.01 | 45.78 | 114.75 | 159.46 |
| 9 | 1993 | 99.03 | 40.92 | 181.90 | 53.52 | 126.89 | 196.65 |
| 10 | 1994 | 139.29 | 35.80 | 218.84 | 63.58 | 137.63 | 197.93 |
| 11 | 1995 | 95.11 | 57.02 | 218.52 | 42.51 | 109.24 | 210.25 |
| 12 | 1996 | 135.82 | 52.86 | 225.46 | 55.58 | 116.80 | 195.79 |
| 13 | 1997 | 132.46 | 45.78 | 189.37 | 53.82 | 111.36 | 194.15 |
| 14 | 1998 | 145.80 | 57.18 | 136.79 | 70.49 | 121.26 | 213.59 |
| 15 | 1999 | 77.21 | 70.22 | 208.04 | 59.33 | 138.99 | 208.18 |
| 16 | 2000 | 99.81 | 55.32 | 191.37 | 60.00 | 99.86 | 166.14 |
| 17 | 2001 | 93.77 | 61.47 | 192.02 | 60.97 | 115.25 | 176.95 |
| 18 | 2002 | 116.01 | 41.26 | 170.18 | 64.06 | 161.80 | 182.18 |
| 19 | 2003 | 150.19 | 52.87 | 157.81 | 65.85 | 147.54 | 195.80 |
| 20 | 2004 | 141.60 | 51.34 | 144.63 | 52.25 | 155.12 | 156.25 |
| 21 | 2005 | 123.66 | 75.09 | 212.12 | 52.72 | 159.56 | 164.46 |
| 22 | 2006 | 126.41 | 43.29 | 242.90 | 61.63 | 159.19 | 211.86 |
| 23 | 2007 | 128.32 | 89.49 | 199.41 | 58.65 | 168.90 | 232.57 |
| 24 | 2008 | 129.47 | 48.07 | 229.08 | 42.88 | 171.35 | 164.37 |
| 25 | 2009 | 116.10 | 48.55 | 243.06 | 50.11 | 179.80 | 213.54 |
| 26 | 2010 | 139.13 | 57.29 | 194.30 | 95.56 | 132.16 | 176.38 |
| 27 | 2011 | 145.67 | 45.28 | 195.98 | 46.48 | 163.12 | 145.77 |
| 28 | 2012 | 129.75 | 72.40 | 188.39 | 52.91 | 165.51 | 187.38 |
| 29 | 2013 | 143.89 | 52.01 | 183.33 | 57.92 | 120.61 | 188.30 |
| 30 | 2014 | 176.43 | 45.29 | 159.87 | 56.26 | 127.39 | 214.63 |
| 31 | 2015 | 98.55 | 50.85 | 197.49 | 47.76 | 120.28 | 160.56 |
| 32 | 2016 | 118.90 | 67.99 | 186.53 | 54.65 | 135.88 | 189.49 |
| 33 | 2017 | 136.95 | 62.45 | 161.53 | 31.99 | 94.38 | 220.78 |
| 34 | 2018 | 123.05 | 83.69 | 207.35 | 56.98 | 78.10 | 187.42 |
| 35 | 2019 | 174.70 | 82.44 | 243.23 | 64.38 | 95.02 | 259.57 |

# IMPACT OF URBAN FLOODING ON RESIDENTS OF CALABAR MUNICIPALITY, CROSS RIVER STATE

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**Abstract**

*Urban flood is a common phenomenon in coastal towns in Nigeria due to heavy rain and closeness to the sea. This year Nigeria Hydrological Services Agency had in their annual outlook of flood revealed that coastal flooding could be experienced in Cross River State. By this study investigated the problem of urban flood hazards in Calabar town as it is currently been experienced. The study was limited to areas that experienced street flooding and a sample of 205 was selected using Taro Yamane sample size table from a population of 420 households. 205 questionnaires were used to capture the menace of urban flood catastrophe and 200 responded. The result shows that lives and properties have been lost to flooding over the years; 67% of the respondent indicate that they have lost materials, 6% claims that lives have been lost while 27% claimed they lost nothing except inconveniences such as hindrance to movement, vehicle malfunctioning lateness to work etc. the study concluded that flooding in the area is as the result of heavy rainfall, poor drainage system, poor road design and improper waste management and recommendation by the residents include expansion and clearing of existing drainage system and proper waste disposal to enable proper runoff.*

**Keyword:** Flooding, Urban, Drainage System, Impact

## Introduction

Floods are among the most devastating natural disasters in the world, claiming more lives and causing more property damage than any other natural phenomena. In Nigeria, though not leading in terms of claiming lives, flood affects and displaces more people than any other disaster. It also causes more damage to properties. At least 20 per cent of the population is at risk from one form of flooding or another (Angela Etuonovbe 2011). The effects of flooding are felt by various 'receptors', including, people, buildings, infrastructure, agriculture, open recreational space and the natural world (Bariweni, Tawari & Abowei 2012).

Majority of Nigerian states are increasingly suffering from annual flooding during rainy seasons caused by increased precipitation linked to climate change (Aja & Olaore 2014). Floods are environmental hazards of meteorological phenomena, but most often in Nigeria, flood is induced by humans through poor planning practices, poor maintenance or unavailable drainage system and other poor infrastructure contributing to worsening the issue (Ebuzoeme, Ogechukwu 2015).

The Nigeria Hydrological Service Agency through Honorable Minister of Water Resource Engr. Suleiman H Adamu at the public presentation of the Annual outlook of flood 2021, revealed that 302 L.G.A's in 36 states of the federation including federal republic of Nigeria will experience moderate flood also States Contiguous to Rivers Niger and Benue are going to experience river flooding these includes; Kebbi, Niger, Kwara, Adamawa, Taraba, Benue, Nassarawa, Kogi, Anambra, Delta, Edo, Rivers and Bayelsa, while coastal flooding will be experienced by Cross River, Rivers, Bayelsa, Delta, Lagos and Ondo States. From the above report cross River was mentioned as one of the state that will be flooded as this study is justifiable also the strong coastal town in Cross River is Calabar and the Minister had pointed Cross River as one of the state that will experience coastal flooding. The impact of such flooding is high in urban centres which could be attributed to a number of other factors, aside precipitation and climate change.

Fig 1


Fig 2


**Fig 1 & 2:** Images of flood in the staudy area

**Study Area**

This research work was carried out in Calabar Municipality. Calabar Municipality is a local government area in Southern Senatorial District of Cross River State, Nigeria. It is bounded geographically by Odukpani Local Government Area in the North-East. Its Southern shores are bounded by the Calabar river and Calabar South Local Government Area. Calabar Municipality lies between latitudes 04° 15' and 5° N and longitudes 8° 25' E. with an area of 331.551 square kilometers (https://kekerete.tripod.com/CRSG/calmun.html).

Calabar Municipality is located in a coastal zone within the humid subtropical region and it is affected by weather systems originating from all sides. It experiences the full influence of the overhead sun throughout the year which provides abundant and constant insolation.

It has an equatorial type of climate. The annual temperature is moderately high, about 31-35°C and does not fluctuate greatly. The rainfall distribution shows that it is characterized by double rainfall maxima, which starts from the months of April to October, reaching its climax in the months of July and September, with a short dry period in August. The annual average rainfall is about 2000-3000mm.

Under Köppen's climate classification, Calabar features a tropical monsoon climate (Köppen: *Am*) with a lengthy wet season spanning ten months and a short dry season covering the remaining two months. The harmattan, which significantly influences weather in West Africa, is noticeably less pronounced in the city. Temperatures are relatively constant throughout the year, with average high temperatures usually ranging from 25 to 28 degrees Celsius. There is also little variance between daytime and nighttime temperature, as temperatures at night are typically only a few degrees lower than the daytime high temperature. Calabar averages just over 3,000 millimeters of precipitation annually.

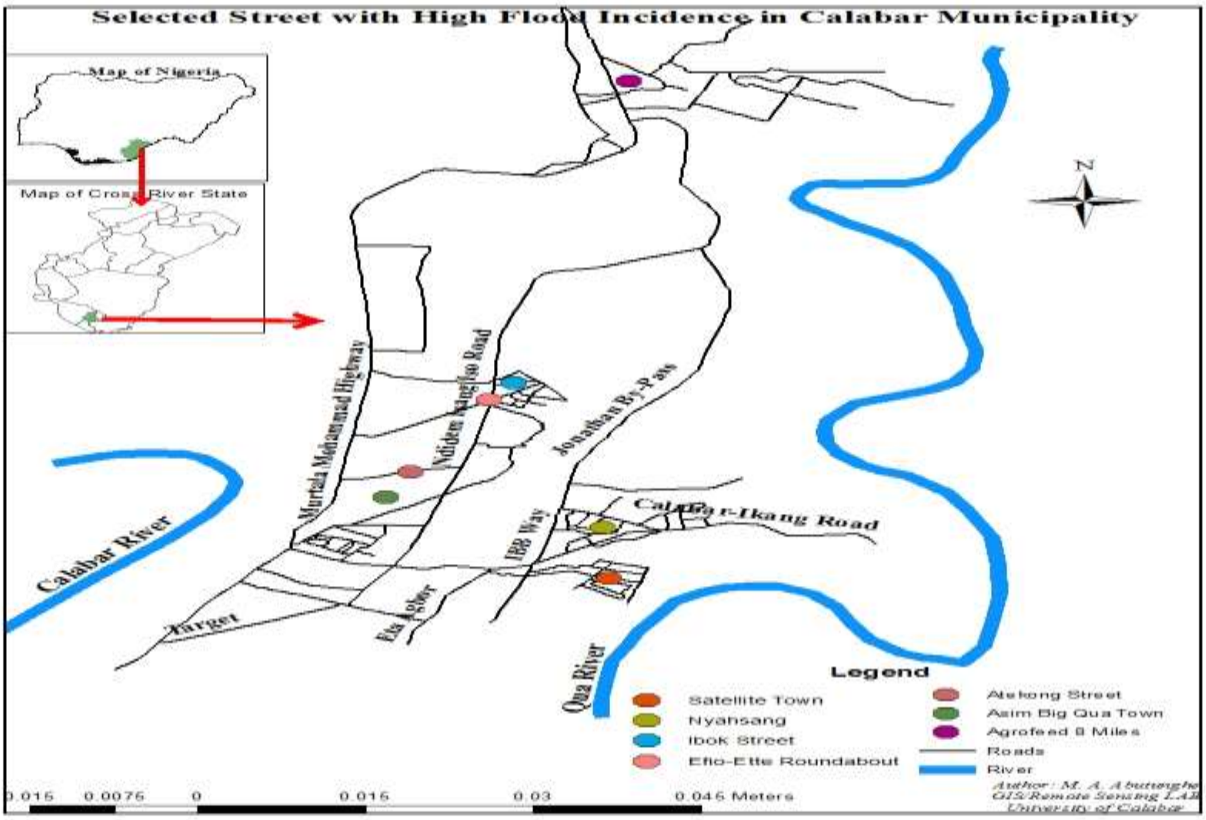


**Fig 3:** Map of Calabat Metropolis

**Aim of the Study**

The aim of this study is to determine the current impacts of flooding on residents of Calabar Municipality Local Government Area.

**Methods of study**

The flooded areas in Calabar Municipality were identified by State Emergency Management Agency (SEMA) Cross River State, Nigeria on a personal visit to them in their office to include; Satellite Town, Nyanasang, Big Qua Town, Atekong Street, Efio-Ete Junction, Ibok street, and 8 Miles by Agrofeed. A sample of 205 was selected from a population of 420 using Taro Yamane sample table, 205 questionnaires were administered to adults in these affected areas and 200 responded. The questionnaire captured years of staying in the study area, hindrances and effect of flooding to respondent and coping strategy and factors causing flooding. Each questionnaire was carefully checked to ensure it was properly filled. The results were presented in table and charts.

## Results and Discussion

**Table 1:** Years of staying in flooded area (n= 200)

| No of years | Frequency | Percentage |
|---|---|---|
| 1year- 10 years | 146 | 73.00% |
| 10 years – 20 years | 22 | 11.00% |
| 20 years- 30 years | 24 | 12.00% |
| 30 years-40 years | 8 | 4.00% |
| Total | 200 | 100.00% |

Table 1 shows how long the respondent had stayed in the flooded area. The longest stay is 1-10 years which is 73%, 10-20 years is 11%, 20-30 years is 12%, 30-40 which is 4%. From the data flooded areas do not have occupant staying for long because of the menace. Also, from the interview, the respondent that has the longest stay is because the houses or shops are their personal properties.

## Data on the Effect of Flooding (n= 200)

**Table 2:** Flood Causes Loss of Customers

| Loss of Customer | Frequency | Percentage |
|---|---|---|
| Yes | 130 | 65.00% |
| No | 58 | 29.00% |
| Not sure | 12 | 6.00% |
| Total | 200 | 100.00% |

**Table 3:** Flood delay daily activities

| Flood Delay daily activities | Frequency | Percentage |
|---|---|---|
| Yes | 174 | 87.00% |
| No | 20 | 10.00% |
| Not sure | 6 | 3.00% |
| Total | 200 | 100.00% |

**Table 4:** Flood prevent getting to work on time

| Prevent getting to work on time | Frequency | Percentage |
|---|---|---|
| Yes | 170 | 85.00% |
| No | 24 | 12.00% |
| Not sure | 6 | 3.00% |
| Total | 200 | 100.00% |

**Table 5:** Flood Causes vehicles malfunction

| Flood Causes Vehicle malfunction | Frequency | Percentage |
|---|---|---|
| Yes | 170 | 85.00% |
| No | 26 | 13.00% |
| No response | 4 | 2.00% |
| Total | 200 | 100.00% |

**Table 6:** Flooding Hinders from movement

| Flooding Hinders Movement | Frequency | percentage |
|---|---|---|
| yes | 174 | 87.00 % |
| No | 18 | 9.00 |
| Not sure | 8 | 4.00 |
| Total | 200 | 100.00% |

From table 2 to 6, over 80% of the respondent indicated that flooding act as hindrances to them in various ways; hinders them from movement, loss of customers and delay in daily activities for those doing business in such areas. Also, they responded that flooding is a serious hindrance to movement in flooded areas, they further revealed that it leads to vehicle malfunction. Flooding is a serious menace to the people living in those areas. The most affected residents are those staying in Ibok street, Big Qua and Agro Feed.

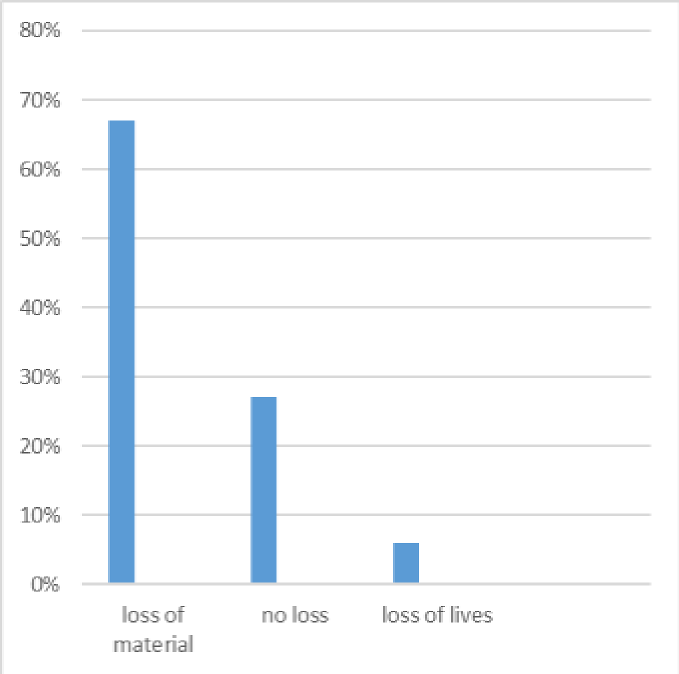


**Fig 4:** Chart showing loss of lives and properties to flood

The chart shows the frequency of respondent that had loss materials and lives to flood. 67% indicate that they had lost materials (household items, credentials etc), from the oral interview conducted some of the resident doing business had lost valuable business products to flood and fear for the outcome of the coming raining season. 34% said they have not experienced loss of material. 6% accept loss of live to flood in Calabar municipality.

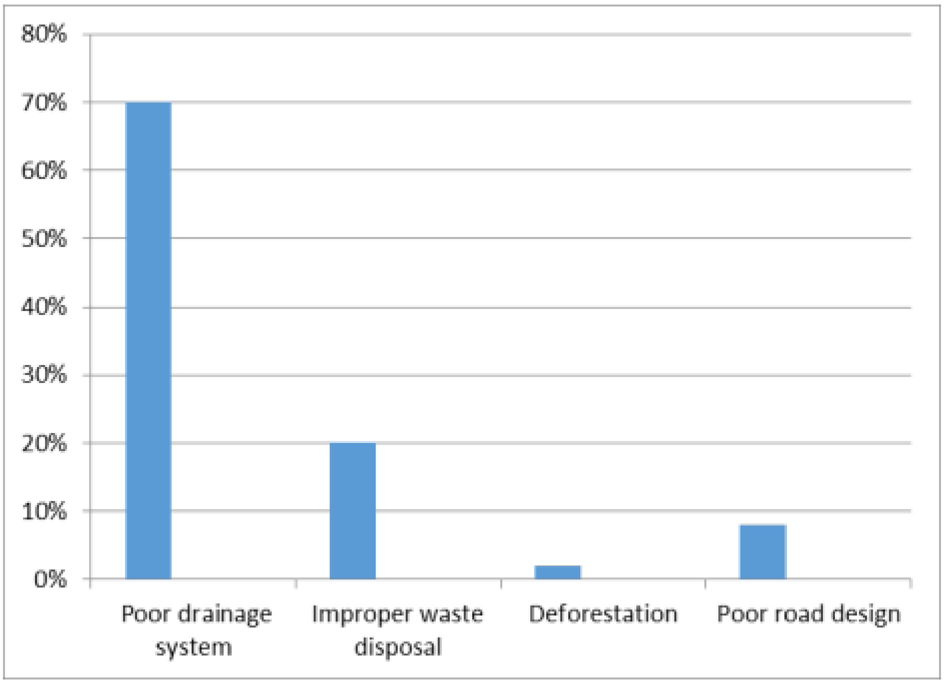


**Fig. 5:** Chart showing Factors responsible for flooding in Calabar Municipality

The above chart shows the factors responsible for flooding in Calabar Municipality. 70% of the respondent indicated that poor drainage system is the leading factor of flooding, 8% agreed that poor road design is another contributive factor to flooding and 20 agreed that improper waste disposal causes flooding.

**Fig. 6:** Showing poor drainage in Ibok street.

**Mitigation by Respondent**

The following are some of the mitigations caried by the residents of the study area to manage this flooding menace

1. Coating or building of fence.
2. Removing dirt and sand from gutter
3. Filling the surrounding with sandbags and fencing the compound
4. Building has wall pavement on gutters in front of house and shop to prevent flood.
5. Lifting the window level.
6. Building soak away to absorb excess water when it rains.

Fig 7

Fig 8


**Fig 7 & 8:** Showing mitigations by resident

## Conclusion and Recommendation

From the study it is concluded that there is serious impact of flooding in Calabar municipality and it possess effects on the lives, property and activities of the residents of the area. It can be ascertained that certain factors are responsible for this flooding in Calabar Municipality which are poor road design, improper waste disposal and poor drainage system been the leading factor of flooding in these areas. Some of the residents had tried personal remedies which had not really yielded the necessary result needed. It was also gathered that most of the resident had nowhere to go because the structures are their personal property. Sequel to the above findings and conclusion, the study recommends the following to better check this flood menace in the area:

1. Expansion of drainage system to avoid overflowing.
2. The current drainage system should be cleared on regular basis to allow free flow of water to prevent continuous floods
3. Sensitization of residents on the danger of indiscriminate disposal of waste should be carried out.
4. Waste bins should be properly sited and discharged when filled.

## References

Adaku Jane 2020. The impact of flooding on Nigeria's sustainable development goals (SDGs), Ecosystem Health and Sustainability, 6:1, 1791735, DOI: 10.1080/20964129.2020.1791735

Aja, G. N., and A. Y. Olaore. 2014. "The Impact of Flooding on the Social Determinants of Health in Nigeria: A Case for North-South Institutional Collaboration to Address Climate Issues." *Developing Country Studies* 4 (22): 6–12.

Angela Etuonovbe 2011. The Devastating Effect of Flooding in Nigeria. ts06j_etuonovbe_5002.

Ebuzoeme, Ogechukwu Divine-Favour. Evaluating the Effects of Flooding in Six Communities in Awka Anambra State of Nigeria. SSN 2224-3216 (Paper) ISSN 2225-0948 (Online) Vol.5, No.4, 2015.

Oladokun, V., and D. Proverbs. 2016. "Flood Risk Management in Nigeria: A Review of the Challenges and Opportunities." Flood Risk Management and Response 6(3): 485-497.

P.A. Bariweni, C.C. Tawari and J.F.N. Abowe. Some Environmental Effects of Flooding in the Niger Delta Region of Nigeria ISSN: 2049-8411; e-ISSN: 2049-842X © Maxwell Scientific Organization, 2012.

S Inah, E Okpa, E Nji, D Egbonyi, F Mboto. Flooding And Its Public Health Implications On Residents Of Calabar South, Cross River State, Nigeria. Vol.3, No.1, pp.1-13, September 2020 ISSN: Print: 2399-3464, Online: 2399-3472.

# CAUSES OF LOCALIZED ROAD FLOODING IN CALABAR SOUTH LOCAL GOVERNMENT AREA DURING RAINFALL

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**Abstract**
*This study assessed the causes of road flooding in Calabar South Local Government Area during rainfalls and offer recommendation for permanent solution to the menace. Questionnaires and field observations revealed that the major road flooding in the study area were localised at locations where the main water-collecting canal, popularly known as "big-gutter", in the study area is crossed by roads. The study reveals that the canal does not overflow its channel all through its course from where it enters Calabar South Local Government Area from Calabar Municipality, up to where it empties into the Great Qua River, behind the Cross River State University of Technology (CRUTECH), a distance of about 3.8km, except at locations crossed by roads. Analysis revealed that the overflow causing flooding at these locations is as a result of reduction in effective cross-sectional area where the water flow through the culvert under the roads. These reductions are basically from the design of the culverts. The canal is crossed at fifteen (15) locations within the study area. Out of these, twelve (12) locations are the usual flood location. Only three (3) of the crossed locations that are never flooded. These two locations have heights of the culverts higher than that of the canal, unlike the other twelve (12) locations where the heights of the culverts are lower than that of the channel, hence lower cross-sectional area, relative to that of the canal. Additional cause of the flooding at these locations is trapping of refuse/twigs which clogged the culvert and thereby add to the reduction in cross-sectional area of the water passage of the culvert. Tools such as measuring tape, GPS and questionnaires were used for data collection. Based on the findings of the study, it is recommended, amongst others, that the effective cross-sectional area of the culvert collecting water under the road should be reasonably (at least 1 meter) higher than the height of the gutter/canal. Slabs on roadside gutters should also be placed higher than the height of the gutters. Roads should be of hilly shapes where it cross such canal or big gutters to allow for the recommended relative height of the culverts. This work also provides a check-list for locations to avoid during heavy/long rainfall.*

**Keywords:** Causes, Localised, Road flooding, Rainfall, Canal and Culverts

## Introduction

Flooding and its attendant hazards due to climate change, especially high rainfall and rapid population growth has been receiving global attention (Peduzzi, Dao, Herold & Mouton 2011, Action Aid 2006). Flood refers to the overflowing of water from the water channels onto land areas that are usually dry (Olajuyigbe, 2012). Flooding is a regular event in many parts of Nigeria, resulting in destruction of lives and property worth billions of Naira (Eze, 2008; Emmanuel, Ojinmaka, Baywood & Gift, 2015). Flooding are of varying degrees of magnitude, impacts and damages. Flooding could be of Mega or Micro magnitude in extent and duration. Attentions are usually focused on the mega or macro magnitude flooding. Meanwhile, the micro or temporary flood deserves attention as well, as its impact is also negative on social, economic and health conditions, even though on relatively lower scale. Road flooding due to drainage overflow during rainfall is a classical example of micro flooding.

Road flooding due to drainage overflow during rainfall is a common occurrence on many roads in Nigeria. This has not received adequate attention, probably because its duration is relatively short.

It usually last for as long as the rain last in some locations. In some areas, it may take days for the water to recede or dry up completely. With the changing climatic conditions, it is likely to last longer. However, the damage within the short span of time is usually catastrophic. Causes of road flooding may vary from place to place. This study therefore is pertinent as it intends to identify causes of these localized flooding, proffer recommendation toward solving the menace in the study area and provide a guide for such road locations to be avoided during rainfall.

**Study Area**

Calabar South Local Government Area and Calabar Municipality jointly make up the Calabar Metropolis, which is the headquarters of Cross River State of Nigeria. Calabar South lies within longitude $8^0 15^1$ and $8^0 25^1$ East of the Greenwich Meridian and latitude $4^0 40^1$ and $5^0 05^1$ North of the Equator. Calabar South is of tropical climate with average annual temperature of $25.8^0$C/$78.5^0$F and annual average rainfall of 3306mm/13.02 inch. The climate is considered to be AM (short dry season) according to Koppen-Geiger climatic classification.

Precipitation is lowest in January with average of 50mm/2.0 inch and highest precipitation in July with average of 434mm/17.1 inch. Calabar South is generally a low land on an average of 64meters above sea level. It is a cosmopolitan urban area. It is bounded to the North by Calabar Municipality, to the South and East by the Great Qua River and to the West by the Calabar River.

It has a landmass of 264km$^2$ and a population of 191,630 according to 2006 census. Its postal code is 540 (Ewona and Udo, 2008). Wet season occur from April – October while dry season is from November to March.

**Methodology**

Questionnaires were distributed randomly across Calabar South Local Government Area to identify road locations usually flooded during rainfall. Among the questions on the questionnaires included:

i) Where in Calabar South Local Government Area usually have road flooding during rainfall?
ii) Does the road flooding stop movement of pedestrian?
iii) Does the road flooding stop vehicular movement?
iv) About how long does the flood usually last?

Global Positioning System (GPS) was used to ascertain the coordinates and elevations. Measuring tape was used to measure the heights and widths of the channels and that of the road underlain culverts, as well as the thickness, heights and spacing of the culvert-supporting cross-beams. Computation based on the measurements taken were made to calculate the cross-sectional areas of the respective canal and culvert – one meter apart. With the help of GIS (Geographical Information System), location/transect map was produced based on the coordinates and distances between successive locations.

The cross-sectional area (A) of the channel and culverts were calculated based on the formula:

A = base (width) x height for square and rectangular shape gutter/culvert

Or

A = $\pi r^2$ for circular cross-sectional culvert,

Where $\pi = \frac{22}{7}$ and r = radius of the culverts.

The number of cross-beams in respective culverts were counted.

Flood probability/vulnerability index of the channel is estimated mathematically as the difference in cross-sectional areas between the channel and the effective cross-sectional area of the culverts.

Flood probability/vulnerability index of culvert (FPI) was estimated based on the formula,

$A_d - (A_c - A_b)$

Where $A_d$ = Cross-sectional area of drain/channel

$A_c$ = Cross-sectional area of culvert
$A_b$ = Net cross-sectional area of pillar/beam.
$(A_c – A_b)$ = Effective cross-sectional area of culvert
$S_p$ = Spacing between pillars inside culverts
$H_d$ & $W_d$ = Height and Width respectively of drain
$H_c$ & $W_c$ = height and Width respectively of culvert.

**Table 1:** Data Analysis

| | Drain | | | Culvert | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Location | $H_d$ (m) | $W_d$ (m) | $A_d$ ($m^2$) | $H_c$ (m) | $W_c$ (m) | $A_c$ ($m^2$) | $S_p$ (m) | $A_b$ ($m^2$) | FPI | **Status** |
| A | 2.12 | 8.0 | 16.96 | 2.26 | 8.15 | 18.42 | 2.5 | 0.4 | -1.09 | NF |
| B | 2.1 | 4.65 | 9.77 | 2.4 | 5.45 | 13.08 | 2.14 | 1.6 | -1.71 | NF |
| C | 2.25 | 8.45 | 19.01 | 1.60 | 8.40 | 13.44 | 2.7 | 0.9 | +6.47 | F |
| D | 2.7 | 5.6 | 15.12 | 1.52 | 6.0 | 9.12 | 2.27 | 4.5 | +10.5 | F |
| E | 2.87 | 4.1 | 11.77 | 1.94 | 4.55 | 8.83 | 2.3 | 2.66 | +5.6 | F |
| F | 2.57 | 5.25 | 13.49 | 2.21 | 6.50 | 14.37 | 3.70 | 2.8 | +1.92 | F |
| G | 2.7 | 5.3 | 14.31 | 1.90 | 6.92 | 13.15 | 3.00 | 0.475 | +4.16 | F |
| H | 2.6 | 5.83 | 15.158 | 1.7 | 5.4 | 9.18 | 3.01 | 0.425 | +5.78 | F |
| I | 2.63 | 6.25 | 16.44 | 1.35 | 6.85 | 9.25 | 3.33 | 0.27 | +7.46 | F |
| J | 2.65 | 6.6 | 17.49 | 2.15 | 8.1 | 17.42 | 2.6 | 0.86 | +0.93 | F |
| K | 2.47 | 6.4 | 15.81 | 2.65 | 6.4 | 16.96 | - | - | -1.15 | NF |
| L | 4.3 | 9.3 | 39.99 | 4 circular holes of radius 1.325m | | 22.08 | Separating walls | | +17.91 | F |
| M | 2.35 | 8.5 | 19.98 | 3.0 | 7.6 | 22.8 | 1.4 | 1.5 | -1.32 | F |
| N | 2.05 | 9.1 | 18.66 | 2.1 | 8.75 | 18.38 | 2.63 | 0.89 | +2.91 | F |
| O | 2.05 | 10.2 | 20.91 | 2.35 | 10.65 | 25.03 | 1.3 | 1.41 | -2.71 | F |

NF – No flooding, F – flooded

The table above shows the summary of the field measurements of the various locations where the canal is crossed over by road, the calculated flood probability index (FPI) and flood status of the respective locations.

The calculated flood probability index (FPI) is an estimation of the probability or likelihood of the locations being flooded due mainly to the geometry of the channel and culverts. Positive FPI suggests flooding possibility. Negative FPI suggests no flooding.

## Result and Discussion

Field study and questionnaire noted that in spite of varying magnitudes of rainfall intensity, the big gutter has never over-flown its brims all through it course except at, almost, all the locations where the gutter is crossed-over by roads. The road-crossed locations where it does not overflow are those with negative flood probability index (FPI) as well as those close to the beginning of the gutter, where relatively fewer number of smaller gutters empty into it.

Locations B and K are not usually flooded due to negative flood probability index (FPI). Location A does not flood because of its usually lower volume/height of water in the channel.

The cross-sectional area of the culvert covered by the clogging increases proportionately with the number of the cross-beams as well as the spacing in between them

Other usually flooded locations, but with negative flood probability index (FPI), are so flooded due to massive clogging of the culverts as a result of trappings around the multiple and closely spaced cross-beams within the culverts, thereby significantly reducing the cross-sectional area available for the passage of water within the culvert.

Clogging is mainly responsible for flooding at location M and O, even though their flood probability index (FPI) is negative.

This study revealed that the overflow occasioning the flood is due to structures which reduce the cross-sectional area of the gutter at the points it meets the respective roads. These structures include the side pillars, overlying slabs/decking of the road, horizontal or vertical pipes within the channel as well as sediments and materials deposited/dumped previously or during the run-off.

The greatest of these structures are the pillars and slabs/decking of the culverts. The pillars usually narrow the width of the gutter while the slab/decking lowers the height of the channel. These reduce the cross-sectional area of the channel and ultimately reduce the volume capacity of the channel for the flowing water. This flooding occurs when the gutter is filled to the height of the channel and/or culvert. The water then splashes on the side pillars and the overlying slab/decking, thereby overflowing the roads.

The pillars and slab/decking are part of the road construction. Pipes are fixed/laid by agencies for conveyance of water. These structures also facilitate sedimentation, siltation and trapping of garbage, plastics, metallic objects etc. which eventually leads to blockage of the channel, occasioning flooding.

**Table 2:** Description of Locations crossed by roads over Main drain

| Location | D/L | Distance between locations | | Longitude (E) | Latitude (N) | Elevation |
|---|---|---|---|---|---|---|
| Barrack Road by Chronicle | A | | | 8.19.811 | 4.57.602 | 108.9 |
| Mary Slessor by Old Zoo | B | A – B | 235.41 | 8.19.762 | 4.57.484 | 125.0 |
| Goldie Street by Big Gutter | C | B – C | 369.47 | 8.19.676 | 4.57.303 | 116.6 |
| Target by Murray Street | D | C – D | 34.78 | 8.19.666 | 4.57.287 | 110.6 |
| Murray Street by Ibito Lane | E | D – E | 106.33 | 8.19.675 | 4.57.230 | 91.00 |
| Ibito Street by Elselfie | F | E – F | 229.92 | 8.19.654 | 4.57.107 | 110.5 |
| Nelson Mandela by Elselfie | G | F – G | 42.66 | 8.19.632 | 4.57.100 | 109.8 |
| Big Gutter by Webber Street | H | G – H | 230.25 | 8.19.591 | 4.56.982 | 92.0 |
| Anating Street by Atu Street | I | H – I | 182.55 | 8.19.587 | 4.56.883 | 82.8 |
| Mayne Avenue by Atakpa Street | J | I – J | 316.84 | 8.19.669 | 4.56.780 | 106 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ndon-Edet by Nyaraowo Street | K | J – K | 436.32 | 8.19.810 | 4.56.542 | 80 |
| Yellow-Duke Street by Big gutter | L | K – L | 487.04 | 8.19.945 | 4.56.315 | 57.2 |
| Palm Street Ext. by Big gutter | M | L – M | 161.15 | 8.19.929 | 4.56.229 | 61.6 |
| Big Gutter by Crutech Road | N | M – N | 631.18 | 8.19.962 | 4.55.888 | 45.8 |
| Big Gutter by Crutech 2nd | O | N – O | 362.18 | 8.20.109 | 4.55.758 | 42.9 |
| Total | (A – O) | | 3,826.10m (3.83km) | | | |

The table above (Table 1) gives the detailed description of the locations where the canal is crossed over by roads. It gives street names of the locations, designation of locations (D/L), distance between successive locations and elevations (in meters above sea level).

The big gutter (main drain) is crossed over by roads at fifteen (15) locations within the study area. Out of these fifteen (15) locations, twelve (12) locations are the locations of the major road flooding in Calabar South Local Government Area during rainfall.

Locations A, B, and K are the only three locations which do not flood during rainfall, out of the fifteen locations where the canal is crossed over by roads in the study area.

**Road and Drainage in Calabar South Local Government Area**

Calabar South Local Government Area has a network of well interconnected roads in the city. Except for the interior roads within the suburb of the town, most of the roads in the town are asphalted.

Most tarred roads have roadside gutter(s). These gutters are of varying sizes and are interconnected. The untarred roads have no gutters. These untarred roads empty their run-off water into the nearby gutters. The various gutters empty their water into another down the gradient. These gutters all discharge their contents into the main drain/canal referred to, popularly in the study area as “big gutter”, which transverses from Calabar Municipality, enters Calabar South Local Government Area at where it crosses the Barracks Road by the Nigerian Chronicle Newspaper Cooperation. It seemingly dissects Calabar South Local Government Area, collecting from other gutters along its route. It finally empties its contents into the Great Qua River as it passes through the back of Cross River State University of Technology (CRUTECH).

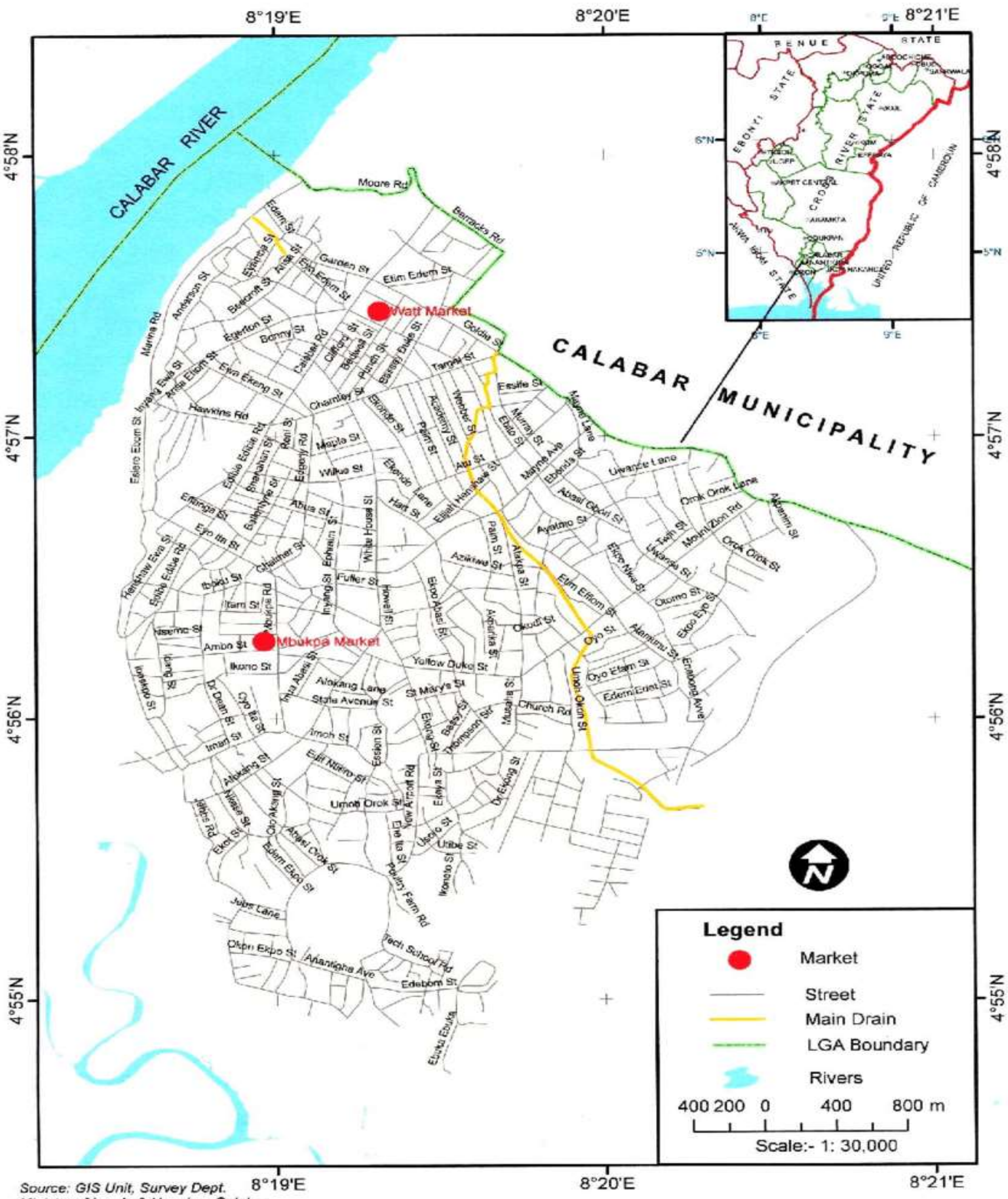
However, it is a recurrent decimal during rainy season, typically during rainfall with high intensity and/or duration to have disruption of human and vehicular traffic due to road flooding.

This flooding happens at typical locations where water overflows the channels/gutters. Depending on the intensity, duration and channel size, the flood duration which usually commence from about 30 minutes into the rain, may last for many hours, but hardly upto a full day. However, the floods usually completely recede and free the road, say one hour after the rain. This flood is usually with high volume and velocity that it sweeps off vehicles, properties and people, leading to loss of lives and properties. Many people, especially school children, have been victims of this hazard. This is a typical case of flash flood.

It also causes damages to building infrastructure in the neighbourhood of the flood. This relatively temporary flood also usually impact negatively on the sanitation and serenity of the environment as garbage from the channels are thrown out on the road and the surroundings.

Social and economic activities are haulted during the hours of this flooding. Apart from the health risk due to the environmental pollution and the direct fatality, it leads to more casualty as sick or accident patients cannot be rushed to hospital/medical centres due to blockage of movements.

The areas with these typical road flooding fall within the geosynclinic depression of the two main parallel ridges that extend in the North-South direction of the city, with one on the western side, while the other is on the opposite eastern side. The city is drained by the two rivers that sandwich the city. These are Great Qua River to the East and Calabar River to the West, which are tributaries of the main Cross River Estuary, which takes its course from the Cameroon (Eze, E.B, 2008). However, this study does not attribute the cause of road flooding to the geomorphology of the area.




Source: GIS Unit, Survey Dept. Ministry of Lands & Housing, Calabar

**Figure 1:** Map of Calabar South showing Street, Market and Main Drain

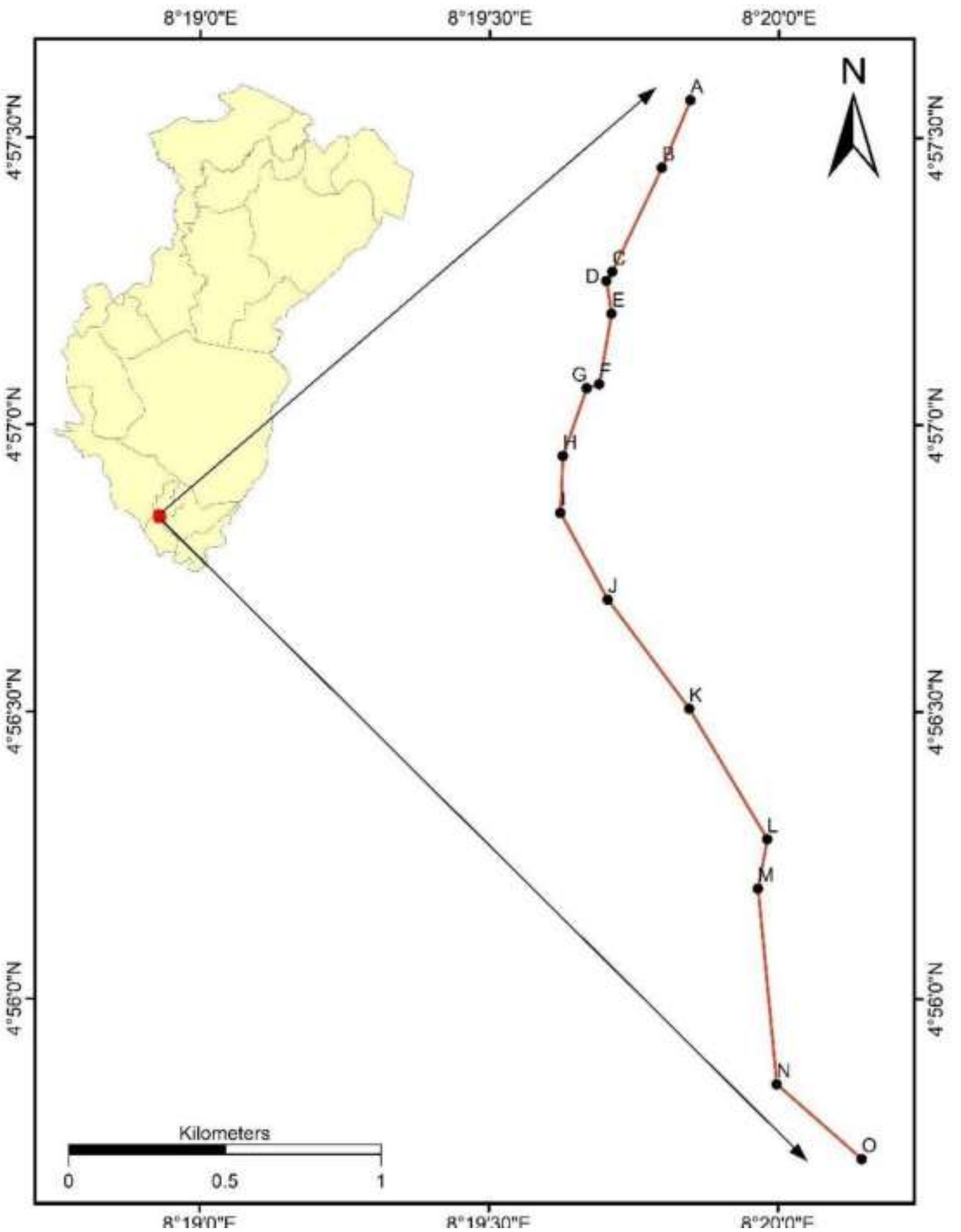



**Fig. 2:** Transect Map of Location (A – O) produced by the author using GIS

**Findings**

1. The study revealed that the cause of street flooding in Calabar South, is mostly as a result of reduction of the cross-sectional area, implying reduction in volume capacity, at the various point of gutter meeting the overlying slab of the road crossing.
2. Locations with such capacity reduction but not flooding are those ones upstream where the gutter are not filled to the brim (capacity). These are within the regions with lesser number of smaller gutters that empty into the main channel.
3. The further the canal downstream into Calabar South, the more the number of gutter that empty into it, the fuller its contents and the higher the velocity during rainfall.
4. Almost all such crossed locations in Calabar South have these geometrical reductions and are heavily flooded during heavy rainfall.
5. The distance of the big gutter, from the first culvert at Barrack Road, where it enters Calabar South Local Government Area, to the last culvert behind the Cross River State University of Technology (CRUTECH) is about 3.86km. The gutter continues beyond the last culvert down to the Great Qua River, behind CRUTECH, where it empties its content.
6. The study revealed that there is no other place where the gutter ever overflow its brims at any time, all through its course, within study area, except at the mentioned twelve (12) locations where it is crossed over by roads.
7. Clogging increases with increase in number of cross-beams, with close spacing, within the culverts, as well as decrease in the gradient of the floor of the channel. The velocity of the water decreases with decrease in the gradient of the floor of the channel. This increases sedimentation, deposition and trappings.
8. Apart from flooding at location of road-crossed over the gutter, other relatively minor flooding occur at certain locations on some roads in Calabar South. These happen typically where roadside gutters have been blocked due to trappings and siltation under and around slabs placed on the gutter at entrance to compounds/buildings. Factors causing this flooding are similar to that of culverts of the big gutter. Example of such location is Howel by Inyang in Calabar South.
9. Slabs on top of gutter or road-crossing on top of big gutters/canal can be likened to bridges across rivers. Rivers rarely or never overflow any bridge. Bridges are all constructed such that its elevation is far higher than the water surface. This does not allow for contact of the river water on the bridge, hence no overflow.
10. The lower the height and/or cross-sectional area of the culverts, relative to that of the canal, the higher the probability or vulnerability to road flooding.
11. The more the number of cross-beams within the culverts, the higher the tendency for clogging, hence the reduction of cross-sectional area of the culvert leading to road flooding.

12. As long as there is no hindrance to the flow of water in the canal by way of reduction in the cross-sectional area of its passage, the road or any other point will not be overflown until the end of the canal.
13. Channels will only overflow around/from the point of supply, if the supply is of greater volume than the capacity of the channel, otherwise, the flow will continue downstream without overflowing its brim/bank except and until it is hindered by blockage or reduction in cross-sectional area of the channel which would then result in overflow at/around the point of the hindrance.

**Conclusion**

This study focused on causes of localised road flooding in Calabar South Local Government Area during rainfall, which usually lead to interruption of business, sanitation problems, loss of lives and properties, amongst other hazards.

The major road flooding in Calabar South Local Government Area during rainfall occurs at locations where the main drain is crossed over by roads. The reduction of cross-sectional area of the road culverts, relative to the channel, is the primary factor responsible for this flood. Secondary cause of the flooding is logging of the gutter due to trappings of materials, which also leads to reduction of the cross-sectional area at the point of blockage.

Analysis shows that with proper dimensions of culverts, under the roads, the flooding of the road will cease or be avoided.

**Recommendation**

It is therefore, hereby recommended:

i) That culverts, under roads with possible high volume of water, should be constructed to be at least half a meter higher in height and of higher cross-sectional area than that of the channel.

ii) That bottom of slabs on roadside gutters should be at least six inches above the edges of the gutter to avoid trappings and blockage.

iii) That as much as possible, multiple cross-beams within the culvert should be avoided as this increases the tendency for trappings and clogging.

iv) That cross-beams within the culverts, if unavoidable, should be well spaced, at least 2.5 meters apart, to avoid trappings and clogging of the channels.

v) That the roads, at the locations of the culverts, should be hilly and not flattened, to allow for the relatively higher height of the culverts.

vi) That the culverts and gutters should be regularly disilted and cleared of any trappings and clogging to avoid hindrance to free flow of water that would occasion road flooding.

**References**

Action Aid (2006). Climate change, urban flooding and the rights of the urban poor in Africa: Key findings from six African cities. London: Action Aid International.

Emmanuel, U. A., Ojinnaka, O. C., Baywood, C. N. & Gift, U. A. (2015). Flood hazard analysis and damage assessment of 2012 flood in Anambra State using GIS and Remote sensing approach. *American Journal of Geographic Information System, 4 (1), 38 – 51*.

Eze, E. B. (2008). Topography and urban expansion as twin factors of street flooding in Municipality, Cross River State. In Bisong, F. E. (Ed.). Geography and the Millennium Development Goals: translating vision into reality in Nigeria. *ANG Conference Book of Proceedings (415 – 422).*

GIS Unit, Ministry of Land and Housing, Cross River State. Map showing roads and main drain (canal) in Calabar South Local Government area.

Olajuyigbe, E. A. (2012). Mapping and analysis of 2012 flood disaster in Edo State using geospatial technique. *Journal of Environmental Sciences, 6 (5), 32 – 44*.

Peduzzi, P., Dao, H., Herold, C. & Mouton, F. (2009). Assessing global exposure and vulnerability towards natural hazards: the disaster risk index, Natural. *Hazards Earth System Science, 9, 1149 – 1159,* doi: 10.5194/nhess-9-1149-2009.

**IMPACTS OF URBANIZATION ON THE HEADWATERS OF BONNY RIVER IN RELATION TO FLOODING IN PORTHARCOURT**

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**Abstract**

*Developing countries have been rapidly urbanizing over the last decades, resulting in majorEnvironmental impacts and increased vulnerability to natural disasters. The main aim of this study is to critically examine the effects of urban spread along the headwaters of bonny river in Port-Harcourt metrolopolis. Methodologically, various aspects of data acquisition systems such as the use of unmanned aerial vehicle and remotely sensed data were applied. The output was further used to map flood hazards, flood zones and damage potential of the study area. Priority areas and infrastructure at risk were identified by means of their location in flood zones and exposure to floods with high damage potential. In terms of the extent of change, this study revealed that urbanization and loss of agricultural land had been the dominant and intensive land use change along the headwaters of bonny river. Again, the study found that as much as about 20km2 of urban land lie under low risk. A number of districts selected for analysis indicated that there are more floodplain dwellers in the high-risk zone 1 area than medium risk zone 2 areas. Zoning is more effective in bare areas, and may be less effective where there are existing structures. It is projected to have a considerable impact on peak flow in a number of watersheds, which could have severe implications for flash flooding in some areas. Therefore to reduce flood risk where there are existing structures, this study suggests the need for the integration of structural and non-structural measures as well as relocation of flood channel dwellers to safer areas could also help reduce flood risk. The research was able to produce the flow extent map using elevation model. The research produced the flow direction of the study area which shows the channel direction of flow. It was observed that flood water flows from higher region to a lower region. This study was able to identify areas vulnerable to flooding using multi criteria approach. The study concludes that although the impact of urbanization is projected to be insignificant at the watershed scale. Priority infrastructures and areas of high flood risk within the study area is approximately 15.85km2 and 19.61km of road networks are at greater risk of flooding by means of their exposure to floods with the highest damage potential. Urbanization increased flood risk due to greater exposure of elements at risk in the flood plains to damaging floods which includes residential and commercial buildings, roads, schools, clinics and farmlands. It is recommended that the government and the private sectors should intensify advocacy for watershed conservation within the greater portharcourt city*

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**Keywords:** Urbanization, Headwaters, Flooding, Unmanned-Aerial-Vehiecle.

## Introduction

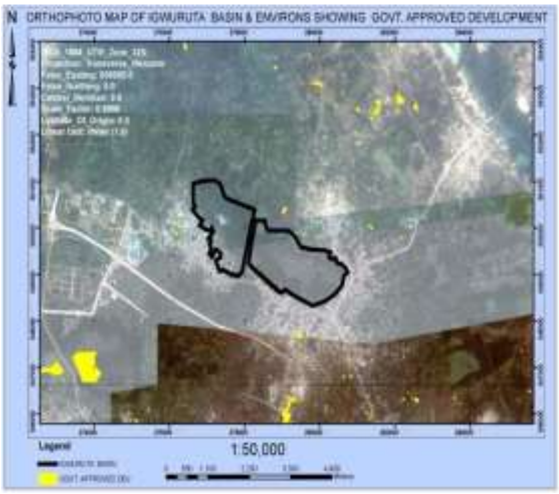
Cities in developing countries are growing at an unprecedented rate, resulting in profound and unintended environmental impacts. In particular, tropical cities in developing countries are increasingly at risk of flooding due to worsening natural and anthropogenic influences. These natural forces, includes intense precipitation, high tide and low topography. Moreover human influences due to urbanization that result in rapid land use changes and increased flood risk requires better management (Owei et al., 2010) Greater Portharcourt city of Rivers state is a rapidly growing city undergoing planned and unplanned expansion. Urban areas can be flooded by rivers, coastal floods, pluvial and groundwater floods, as well as artificial system failures, but often human factors such as urbanization aggravate floods.

**Statement of Research Problem**

Greater Port-Harcourt is a rapidly growing city within one of the most important and sensitive wetlands in the world (Abam, 2001). The city is the main economic capital of the Niger Delta widely known as the economic hub of Nigeria’s rich oil economy and at the same time the world’s third largest wetland. Demographically, it is confronted with high population influx resulting from economic and industrial activities in the area. Very little research has been conducted to investigate the flood impacts on the greater portharcourt city with respect to its rapid urbanization. The risk of flooding to flood plain dwellers of the greater portharcourt city has not been adequately investigated. It is against this backdrop therefore that this study is necessitated.

**Study Area**

Greater Port-Harcourt city includes the Port-Harcourt city and the surrounding areas laid out for, urban redevelopment expansion and modernization. It is an agglomeration or conurbation of the old Port Harcourt city and parts of other Local Government Areas originally made up of three LGAs that is: Port-Hrourt, Obio-Akpo and Okrika LGA's hence, in the urban plan, Greater Portharcourt city now includes eight LGAs such as Port-Harcourt, Obio-Akpor, Okrika, Oyigbo, Ogu-Bolo, Etche, Eleme and Ikwerre. The area of the entire Rivers State is about 11,077 sq km and the Greater Portharcourt city area span 1,900 sq km. Importantly, the watershed delineated for this study spans about 0.0156 sq km representing 0.30% of the entire area.




Map of the study Area showing the Watershed

**Aim and Objectives**

The aim of this research is to assess the potential flood risk to flood-plain dwellers in parts of Greater ort-Harcourt city of Rivers State in relation to urbanization.

The objectives are:

1. To identify major flood watersheds and natural water ways within the Greater Port-Harcourt city using orthophoto imagery of Rivers State.

2. To determine the flood causative factors and map flood hazard-prone areas within the study area.

3. To make recommendations on how to improve future planning from the outcome of this study.

**Materials and Methods**

**Data Acquisition**

This study used both primary and secondary data collection methods. In terms of primary data, Unmanned Aerial vehicle (drone) was deployed to the study area for data acquisition purposes.

Secondary data used for the study consist of:

1. Orthophoto Imageries from Rivers state survey department.
2. Greater Portharcourt city master plan from (GPHCDA)
3. Flood impacted household data from Rivers state Ministry of special duties.
4. Soil data from the FAO was used for determining hydrologic soil groups and runoff potential.
5. Observed daily rainfall data from the Nigerian Meteorological Agency (NIMET).

**Data Processing**

The background datasets such as Greater Port Harcourt city master plan and imagery of the study area were uploaded into ArcMap algorithm for thematic information extraction. The imagery was processed for geometric precision correction and ortho-rectification. Similarly, the imagery were filtered, registered and enhanced to produce second level images. Pre- assessment maps for the study area were produced based on the background data which gave us the preliminary details about the size, land use, economic activities and development encroachment within the watersheds.

The elevation data for the flood watersheds were processed using Pix4D image processing algorithm to generate 3-D surfaces, flood water flow pattern and direction as well as contour maps.

**Data Analysis**

Geographical analysis allows the study of real-world processes by developing and applying models. Such models illuminate underlying trends in the geographical data and thus make new information available. A GIS enhances this process by providing tools, which can be combined in meaningful sequences to develop new models.

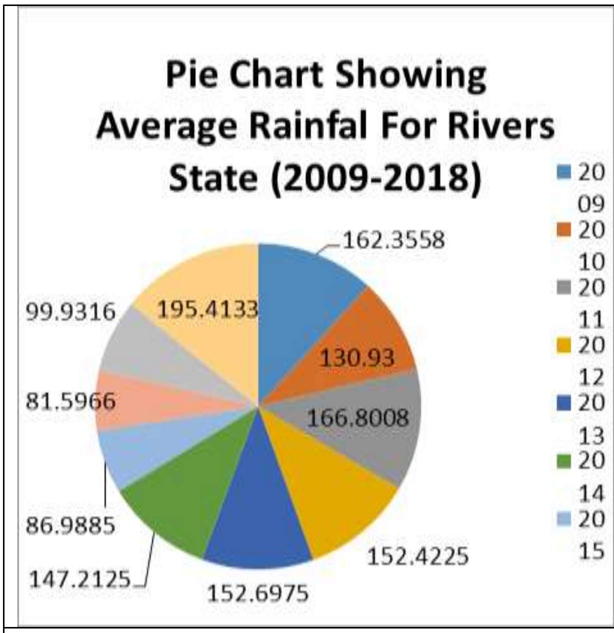
Flood impacted household data was used to determine the amount of people impacted by flooding and there spatial distribution. Soil data were used for determining hydrologic soil groups and runoff potential. Observed daily rainfall data was used to determine the amount of rainfall over the study area. The datasets were analyzed through qualitative and quantitative methods. Some of the analytical tools employed include; calculation of Areas and Distances, Proximity and Overlay Analysis. Vulnerability maps, Graphs and Tables were generated.

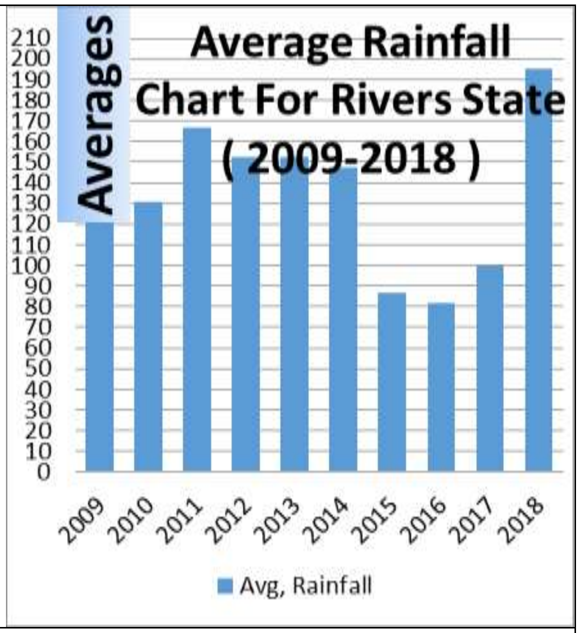
**Table 1:** Watershed Morphometry

| Watershed | Area (sqm) | Perimeter (m) | Average Elevation (m) | Road Segment (m) |
|---|---|---|---|---|
| A: Rukpokwu | 5,808,318 | 10,493 | 73 | 770 |
| B: Aluu | 3,414,130 | 7,665 | 49 | 87,366 |
| C: Igwuruta 1 | 2,690,218 | 7,379 | 58 | 31,332 |
| D: Igwuruta 2 | 1,975,118 | 7,429 | 50 | 118 |
| E: Ipo | 1,958,831 | 5,954 | 62 | 76,588 |
| Total size (sq km) | 15.85 sq km | | | 19. 61 km |

**Result Presentation**

Excessive rain, low soil permeability and high water table, the development during construction is likely to encourage runoff due to vegetation clearing since topsoil is vulnerable if devoid of Vegetation.

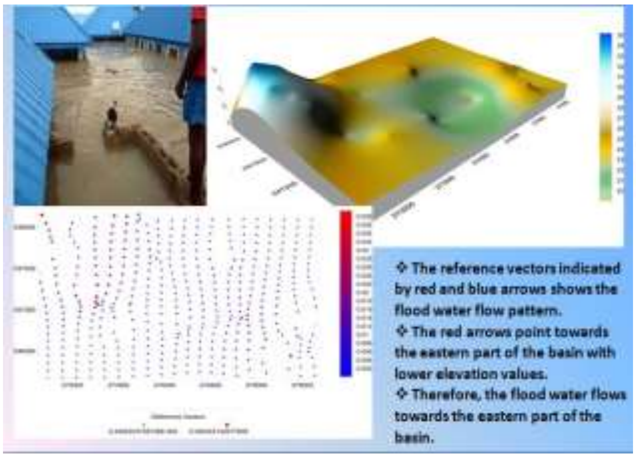


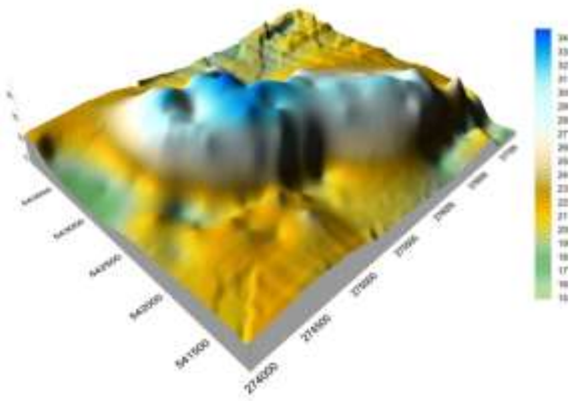
**Digital Elevation Analysis**

GIS can build three dimensional models, where the topography of a geographical location can be represented with an x, y, z data model known as Digital Elevation Model (DEM). The x and y dimensions of a DEM represent the horizontal plane, and z represent spot heights for the respective x, y coordinates.

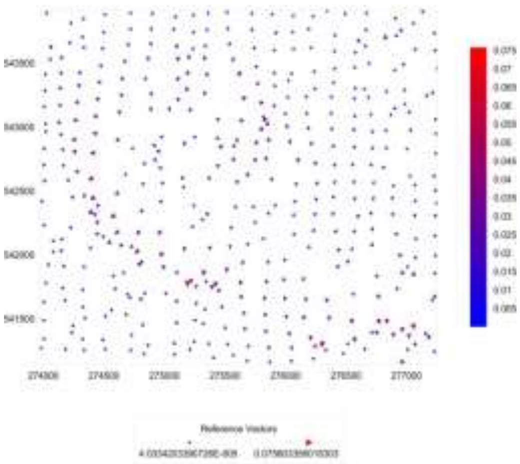
The data sets derived from a Digital Terrain Model were used to analyze surface configuration of the watershed. The visualization in three-dimensional form is shown below.



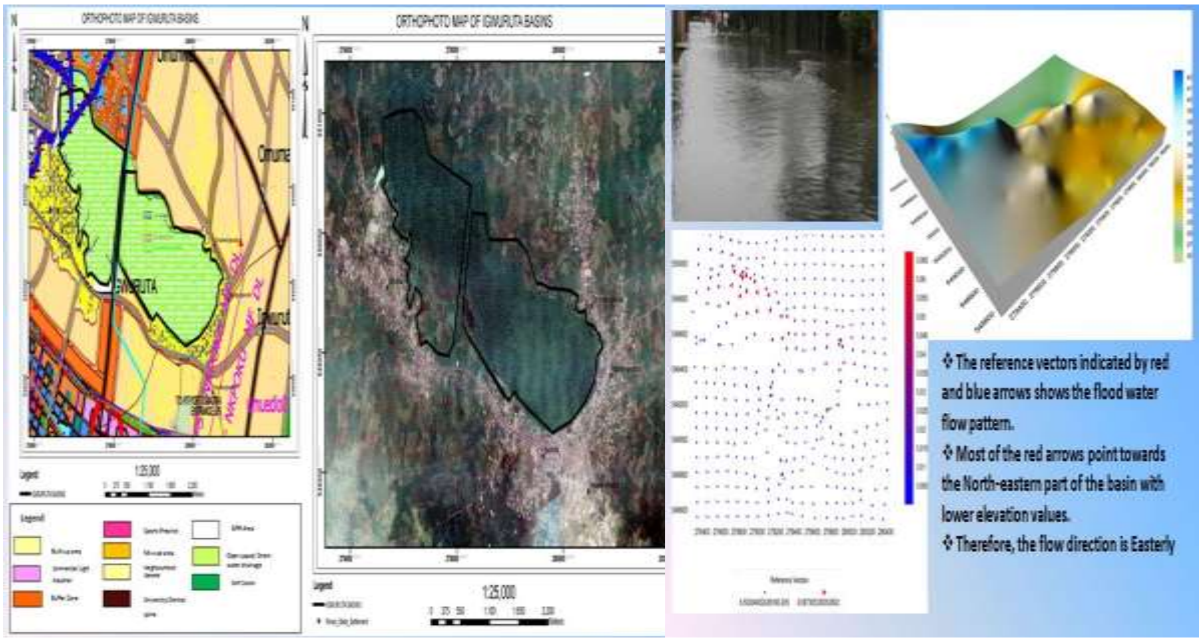

Digital Elevation Model of Aluu

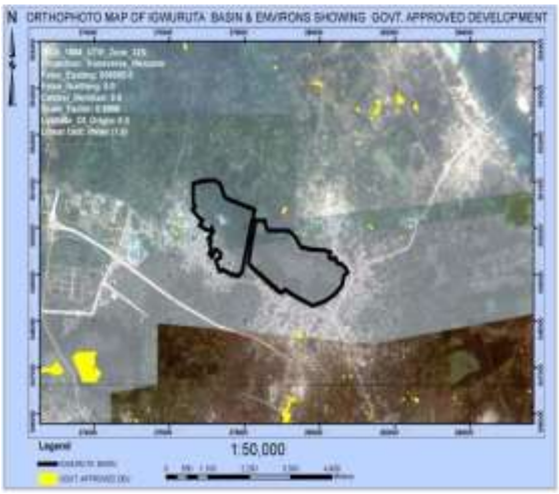


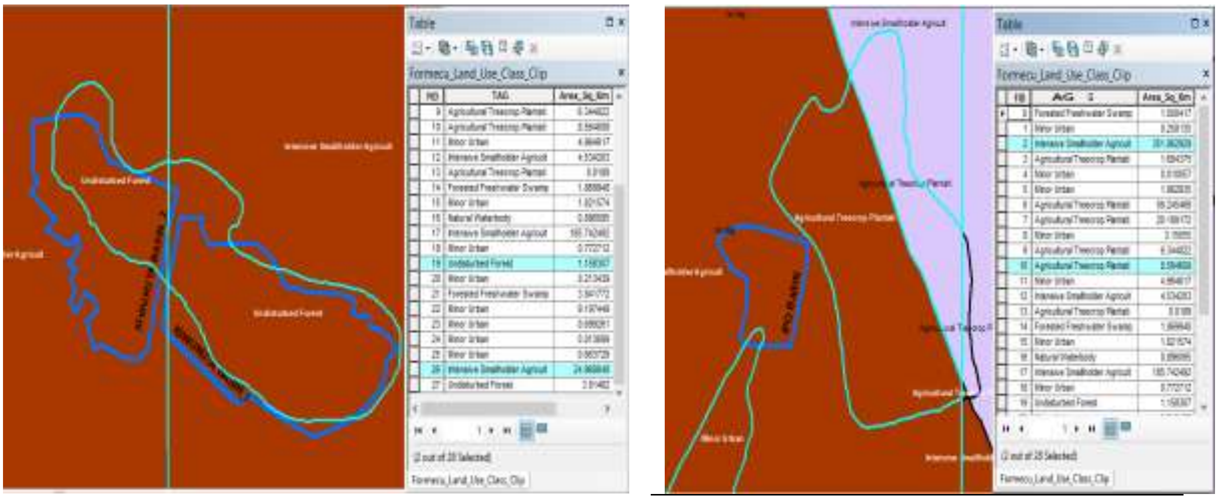
Digital Terrain Model of Rukpokwu



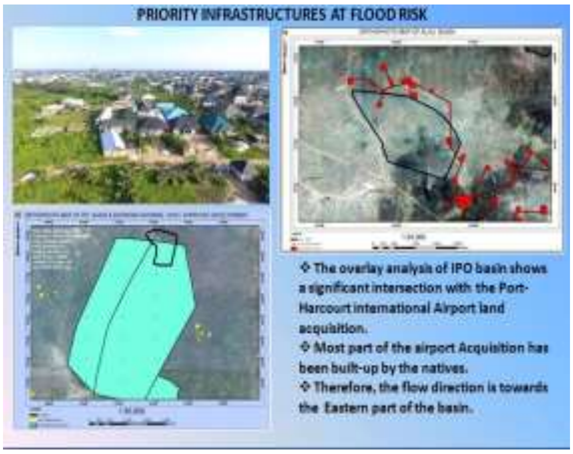

The reference vectors indicated by red and blue arrows show the flood water flow pattern. The red arrows point towards the eastern part of the watershed with lower elevation values. Therefore, the flood water flows towards the eastern part of the watershed.




Querry on the geospatial database showing the predominent agricultural land use type within the Igwuruta watershed.




Querry on the geospatial database showing the predominent agricultultural land use type within the IPO watershed.

**Impacts of Flooding in Greater Portharcourt City**

i. Property damage Loss of life: drowning, electrocution, etc.
ii. Property devaluation
iii. Damage to infrastructure
iv. Logistics challenges and man-hour losses
v. Refuse dispersion
vi. Pollution; especially of groundwater
vii. Diseases and epidemic risks
viii. Effects on businesses and livelihoods

**Recommendation and Conclusion**

Flooding in Greater Port Harcourt city is both natural and man-made and can be controlled by a combination of soft and hard engineering measures; the trend will be more frequent and severe if nothing is done now and there will drain on the city's economy and also displacement of wildlife such as snakes and other dangerous reptiles.

In view of the results obtained from this study**,** the following are recommended:

1. There should be an improved drainage capacities across greater portharcourt city
2. There is need for construction of large capacity canals to drain the northerly ponded areas
3. The government should ensure the Enforcement of the Greater Portharcourt master plan in respect to infrastructural development.
4. There should be intensive advocacy both from the government and private sectors on conservation of the flood watershed
5. Give allowance for the possibility of flooding during building and road construction.
6. Provision of early warning systems, risk and disaster mapping & other soft measures

**References**

Abam, T.K.S., 1999. Impact of dams on the hydrology of the Niger Delta. Bulletin of Engineering Geology and the Environment 57.

Abam, T.K.S., 2001. Regional Hydrological Research Perspectives in the Niger Delta. 46 1, 13 25.

Abbas, I.I., 2012. An Assessment of Land Use/Land Cover Changes in a Section of Niger Delta, Nigeria. Frontiers in Science 2, 137-143

Abd El-Kawy, O.R., Rød, J.K., Ismail, H.A., Suliman, A.S., 2011. Land use and land cover change detection in the western Nile delta of Egypt using remote sensing data. Applied Geography 31, 483-494.

Abon, C.C., David, C.P.C., Pellejera, N.E.B., 2011. Reconstructing the Tropical Storm

Ketsana flood event in Marikina River, Philippines. Hydrol. Earth Syst. Sci. 15, 1283-1289.

Ackerman, C.T., 2009. HEC-GeoRAS–GIS tools for support of HEC-RAS using ArcGIS, User's manual. US Army Corps of Engineers–Hydrologic Engineering Centre (HEC) 4.

Ackerman, C.T., Evans, T.A., Brunner, G.W., 2000. HEC-GeoRAS: linking GIS to hydraulic analysis using ARC/INFO and HEC-RAS. Hydrologic and Hydraulic Modelling Support with Geographic Information Systems. ESRI Press, New York.

Adekola, O., Mitchell, G., 2011. The Niger Delta wetlands: threats to ecosystem services, their importance to dependent communities and possible management measures. International Journal of Biodiversity Science, Ecosystem Services & Management.

Brabec, E., Schulte, S., Richards, P.L., 2002. Impervious surfaces and water quality: a review of current literature and its implications for watershed planning. Journal of planning literature 16, 499-514.

Brakensiek, D., Rawls, W., 1994. Soil containing rock fragments: effects on infiltration. Catena 23, 99-110.

Chow, V.T., 1956. Hydrologic studies of floods in the United States. International

Association of Hydrological Sciences 42, 134-170.

Chow, V.T., 1959. Open channel flow. MacGraw-Hill Book Co. Inc.: New York.

Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, R., Jones, R., Kolli, R.K., Kwon, W., Laprise, R., 2007. Regional climate projections. Climate Change, 2007: The Physical Science Basis. Contribution of Working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, University Press, Cambridge, Chapter 11, pp. 847-940.

Elenwo, E.I., Efe, S.I., 2014. Flood Problems in Port-Harcourt Metropolis, Nigeria. International Journal of Environmental Engineering and Natural Resources 1, 97-107.

El-Hames, A.S., 2012. An empirical method for peak discharge prediction in ungauged arid and semi-arid region catchments based on morphological parameters and SCS curve number.

Eludoyin, O., Wokocha, C., Ayolagha, G., 2011. GIS assessment of land use and land cover changes in OBIO/AKPOR LGA, Rivers State, Nigeria.

Eludoyin, O.S., Weli, V.E., 2012. Spatial Analysis of Flood Vulnerability Levels in Port- Harcourt Metropolis Using GIS. Journal of Earth Science and Engineering 2, 617.

Enaruvbe, G.O., Ige-Olumide, O., 2014. Geospatial analysis of land-use change processes in a densely populated coastal city: the case of Port-Harcourt, south-east Nigeria. Geocarto International 30, 441-456.

Galster, G., Hanson, R., Ratcliffe, M.R., Wolman, H., Coleman, S., Freihage, J., 2001. Wrestling sprawl to the ground: defining and measuring an elusive concept. Housing policy debate 12, 681-717.

Garg, V., Chaubey, I., Haggard, B., 2003. Impact of calibration watershed on runoff model accuracy. Transactions of the ASAE 46, 1347-1353.

# MODELING FLOOD EVENTS USING RAINFALL AND PEAK FLOWS OF RIVERS IN THE BENUE TROUGH, NIGERIA

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**Abstract**

*The frequency of flood events is more common than ever as a result of climate change coupled with human interference with the environment. Heavy amounts of rainfall experienced in the Benue trough have given rise to frequent reoccurrence of annual flooding affecting social, economic and environmental structures of the region. The study modelled flood events using rainfall information of the area and peak flows in rivers for proper planning in order to provide that needed satisfying environment. All functional rainfall stations and hydrological stations within the Trough were selected for rainfall and peak flow data. Several methods such as archival materials, field survey and observations were employed to obtain information on rainfall, water level and flood events in the study area between 1980 and 2014. Data were analysed using Time Series Analysis to examine rainfall events and peak flow. Flood events categorization was carried out using Honert and McAneney model. The study revealed that the maximum annual rainfall amounts is 1766.5mm in 1999 and the minimum amount is 793.1mm in 1982. The rainfall pattern shows that, all the stations in the upper Benue trough showed a decreasing trend while the stations in the lower Benue trough showed increasing rainfall trend. The results further showed three categories of flood events: major, moderate and minor flood events. The study concluded that in the upper Benue Trough, factors other than rainfall are the main cause of flooding in the area whereas, increased rainfall amount in the lower Benue trough will mean increased flood events and vulnerability. The study recommends that a resettlement programme be initiated for people living in flood prone areas as there is likelihood to experience major flood in every ten years or less.*

**Keywords:** Flood events, rainfall, peak flow, rivers, Benue trough

## Introduction

The frequency of flooding events and the associated risk in the Benue trough especially in urban areas is an increasingly important issue of concern in the region. The Benue trough has been seriously affected by flooding, especially in the last five decades. Floods have been recorded as most destructive natural disaster in areas that are susceptible to flooding. This natural disaster is a serious threat to the economic and social structures of affected areas in the region. Most of the areas in the region prone to flooding that have produced instance of widespread loss of human lives and significant damage to physical and social infrastructure, while undermining economic performance of the region (Serdeczney, Adams, Baarsch, Coumou, Robinson, Hare, Sxhaeffer, Perrette and Reinhardt, 2015). Increased flood problems in the Benue trough and other low lying areas of the country have disrupted socio-economic activities and in some cases displacement of persons in affected areas.

According to Adeoye, Ayanlade and Babatimehin (2009) flood brings misery to affected communities. They can cause loss of life and often cause a great disruption of socio-economic activities. Water can come into people's houses, drinking water and electricity supplies may break down, roads can be blocked, and people may not go to work, or even perform other activities. On the whole, undesirable disastrous effects may include damage to economic and social infrastructure, environmental modifications, fiscal and foreign sector imbalances, price increases, modification to demographic structures and changes in development priorities as the task of replacing lost or damaged assets results in the deferment of projects intended to overcome long-standing challenges. Deteriorating social well-being of affected people, especially among the poorest often times extend beyond the affected community through population migration, disease transmission, trade reductions or widespread environmental modifications (Warritty, Houston, Ball, Tavendale and Black, 2007).

Flood vulnerability in the areas within the Benue Trough is on the increase more so that flood generating mechanisms are beyond the control of the region. The drainage catchment area of river Benue extends to Cameroon and several man-made dams (Lake Nyosk and Lagdo dams) constructed by the Government of Cameroon. As a result of climate change leading to change in rainfall characteristics coupled with ageing of the dam facilities, excess rainfall will mean constant release of water from this dam to avoid collapse (Uyigue, 2006). In the recent times the flood of 1996, 2000, 2005, 2007, 2008, 2012, 2013, 2017, and 2019 in different parts of Benue trough with 2012 having the most devastating and widespread effects on communities in the area.

The process by which precipitation, which mainly occurs as rainfall, overwhelms soil infiltration capacity, and transforms into water surface run-off is still surrounded by much uncertainties in the region. Over the years, researchers in the field of environmental science have made significant progress in providing sufficient underpinnings for understanding flood events with regards to the changing precipitation pattern due to climate variations, increased run-off caused by rapid urbanisation and their impacts on settlement, health, livelihood, infrastructure (Ologunorisa and Tersoo, 2006; Mwepe, 2009; Ocheri and Okele, 2012; Tadesse, 2009; Oruonye, 2012; Shabu and Tyonum 2013; and Duru and Chibo, 2014, Hula, and Udoh, 2015). It is very important that a better understanding and modelling of the relationship between precipitation, surface runoff, and flood events is therefore imperative in tackling flood risks and other water-related problems in the region (Nkwunonwo, Whitworth & Baily, 2020).

## Materials and Methods

The study modelled flood event using rainfall amount and peak water discharge in the Benue trough, Nigeria. Rainfall amount records from six (6) weather stations namely: Ibi, Katsina-Ala, Makurdi, Jos, Lokoja and Yola were collected from Nigerian Meteorological Services (NIMETs). Peak flow records from hydrological stations in Umaisha, Gassol, Ibi, Lau, Makurdi, Katsina-Ala and Wuroboki on the river Benue and its tributaries system. This was collected from Nigeria Hydrological Services Agency (NIHSA). The rainfall and peak flow data were collected for the period of 1980 – 2014. Trend analysis was employed to examine the trend of rainfall events in the study area, while flood event modeling was carried out using Honert and McAneney, (2011) flood event modelling procedure.

## Study Area

The Benue trough, also called the Benue Valley or Benue Basin lies between Latitude $7^0$00'N to $12^0$00'N of the Equator and Longitude $5^0$00'E to $12^0$00'E of the Greenwich Meridian (Fig 1.1). It is located at the re-entrance in the West African Continental Margin. Its width is about 80-150kms and 800-1000kms long, and extends in a NE-SW direction from the northern limit of the Niger delta in the gulf of Guinea to the Southern boundary of Lake Chad basin in the interior of West African Precambrian Shield (Abaa, 2004).

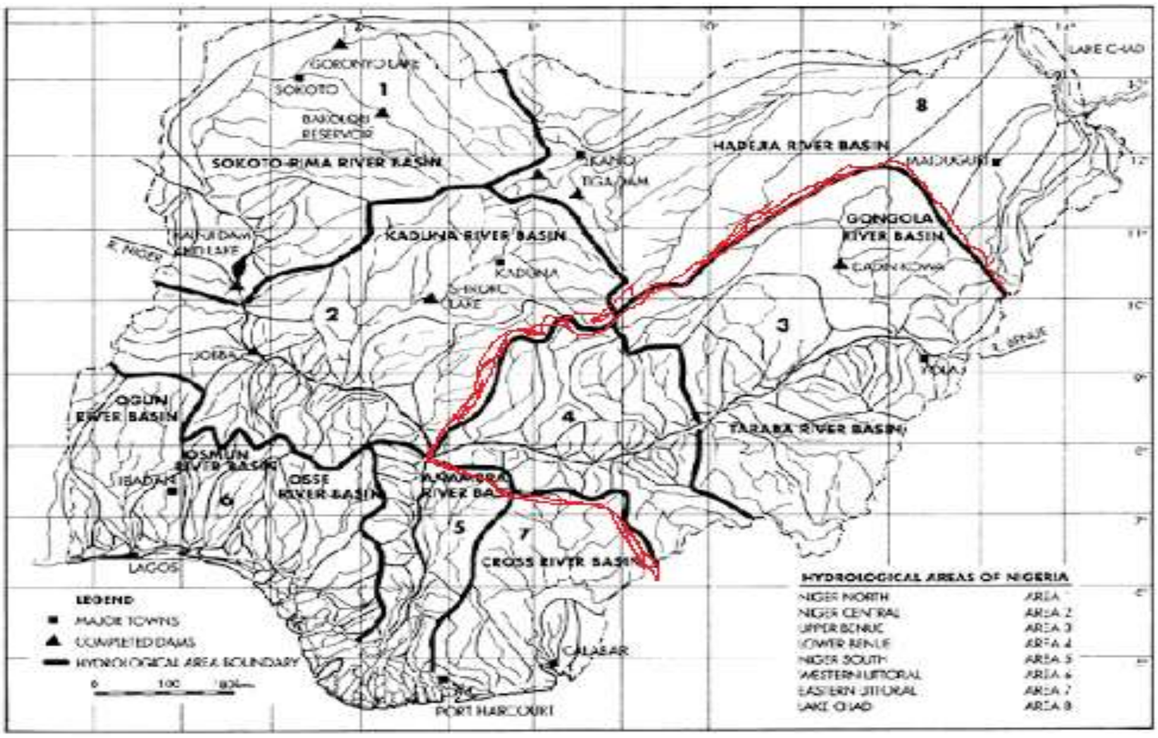


**Figure 1.1** No. 3 & 4 showing the Hydrological areas of the Benue trough

The Benue Trough is an elongated rifte depression in which the sediments reach well over 5000m thickness in some places and have been strongly folded. Probably by later adjustments along faults in the underlying basement. This area comprised two hydrological areas namely: the upper and lower Benue trough hydrological areas.

The River Benue is fed by rivers emanating both from the high central plateau and also from the Cameroon Mountains and Ogoja hills. The drainage pattern is mainly dendritic and the area is characterized by slightly undulating topography, this shows that the area is generally hilly. Surface drainage is generally good except near the banks of the major rivers where appreciable flood plains with swamp have developed. These extensive flood plains along the major rivers form suitable sites for dry season irrigated agriculture.

## Results and Discussion

### Rainfall Trends and Implications for Flooding in the Area

The heavy rainfall amounts experienced in the Benue Trough have given rise to frequent reoccurrence of annual flooding. Rainfall data for the study were collected from the metrological stations of Lokoja, Makurdi, Jos, Yola, Ibi and Katsina-Ala for a period of 34 years (1980 – 2014) from Nigerian Meteorological Services. Information on the rainfall amounts for the period is presented on Table 1.

**Table 1:** Rainfall amount in the Benue Trough for 34 years (mm)

| Year | Lokoja | Makurdi | Jos | Yola | Ibi | Katsina-Ala | Total |
|---|---|---|---|---|---|---|---|
| 1980 | 1061.6 | 1426.1 | 1108.5 | 1207.5 | 1232.5 | 1053.7 | 7089.9 |
| 1981 | 1135.3 | 1227.1 | 1272.8 | 892.1 | 1264.4 | 1413 | 7204.7 |
| 1982 | 793.1 | 951.1 | 1306.4 | 872.9 | 908.8 | 1287.8 | 6120.1 |
| 1983 | 853.4 | 930.3 | 1179.4 | 773 | 783.1 | 903.6 | 5422.8 |
| 1984 | 1148.2 | 1572.2 | 1155.9 | 695.3 | 1368.9 | 1077 | 7017.5 |
| 1985 | 950.8 | 1007.2 | 1160.8 | 802.8 | 1091.3 | 1470.5 | 6483.4 |
| 1986 | 1313.6 | 1207.7 | 1204.1 | 785.9 | 922.8 | 1293.8 | 6727.9 |
| 1987 | 1155.5 | 1207.7 | 1286.6 | 675.9 | 900 | 1083.8 | 6309.5 |
| 1988 | 1330.5 | 842.8 | 1226.9 | 1067.8 | 1048.5 | 1086.8 | 6603.3 |
| 1989 | 1519.5 | 1244.3 | 1211.5 | 860.8 | 1183.9 | 1527.2 | 7547.2 |
| 1990 | 1135.1 | 1120.9 | 1229.8 | 839.4 | 1111.8 | 1484.8 | 6921.8 |
| 1991 | 1492 | 927.5 | 1309 | 729.2 | 973.2 | 1191 | 6621.9 |
| 1992 | 981.8 | 972.7 | 1172.9 | 979.8 | 944.3 | 1068.4 | 6119.9 |
| 1993 | 994.9 | 1217.1 | 1124.9 | 878 | 1390.3 | 1165.4 | 6770.6 |
| 1994 | 1206.2 | 973.2 | 1271.9 | 777.2 | 1016.4 | 1193.9 | 6438.8 |
| 1995 | 1101.8 | 1119.6 | 856.7 | 893.6 | 1090.6 | 1464.4 | 6526.7 |
| 1996 | 1239.5 | 1702.6 | 1387.7 | 935.3 | 1373 | 1503.1 | 8141.2 |
| 1997 | 1334 | 1344.3 | 1355 | 997 | 815.9 | 1893.6 | 7739.8 |
| 1998 | 1030.6 | 1456.5 | 1095.7 | 1044.8 | 901 | 1216.4 | 6745 |
| 1999 | 1766.5 | 1615.5 | 1137.8 | 956.7 | 1111.8 | 1410.4 | 7998.7 |
| 2000 | 1008.3 | 1164 | 1158.9 | 937.9 | 895.4 | 1352.3 | 6516.8 |
| 2001 | 1003.3 | 1034.9 | 1247.8 | 777.7 | 1021.8 | 1046 | 6131.5 |
| 2002 | 1275.9 | 1311 | 1581.8 | 911.6 | 930 | 1451.2 | 7461.5 |
| 2003 | 918.3 | 745.1 | 1307.9 | 898.4 | 691.3 | 1492.5 | 6053.5 |
| 2004 | 1256 | 948.8 | 1209.8 | 894.5 | 814.5 | 1298 | 6421.6 |
| 2005 | 939.2 | 871.3 | 1202.4 | 618.2 | 877.4 | 1326.2 | 5834.7 |
| 2006 | 1671.8 | 1343 | 1256 | 1005.2 | 907 | 1275.9 | 7458.9 |
| 2007 | 1501.4 | 1339.9 | 1355.6 | 1081.5 | 952.4 | 1308.3 | 7539.1 |
| 2008 | 1176 | 1550.5 | 1304 | 495.8 | 1183.4 | 1674 | 7383.7 |
| 2009 | 1631.5 | 1402.5 | 1187.7 | 682.9 | 1569.1 | 1411.2 | 7884.9 |
| 2010 | 1057.6 | 1115.3 | 1432.6 | 814.5 | 1203.9 | 1121.7 | 6745.6 |
| 2011 | 931.5 | 1151 | 1184.8 | 575.5 | 986.1 | 1426.8 | 6255.7 |
| 2012 | 1343.3 | 1466.7 | 1468 | 930.7 | 1207.4 | 1497.4 | 7913.5 |
| 2013 | 1119.9 | 1287.8 | 1119.2 | 646.4 | 920.9 | 1436.6 | 6530.8 |
| 2014 | 1482 | 1121.5 | 1273.1 | 740.4 | 856.3 | 1623.6 | 7096.9 |
| Mean | 1195.99 | 1197.706 | 1238.397 | 847.8914 | 1041.411 | 1329.437 | 6850.84 |

**Source:** Nigerian Meteorological Services, 2015

From Table 1, the average rainfall amount for Lokoja is 1195.997mm, maximum and minimum annual rainfall amounts are 1766.5mm (in year 1998) and 793.1mm (in year 1982) respectively. Results show that the trend parameters for Lokoja station are clearly positive a clear reflection of general increase of rainfall amount over the 34 years (1980 – 2014) in the area (See Fig 2).

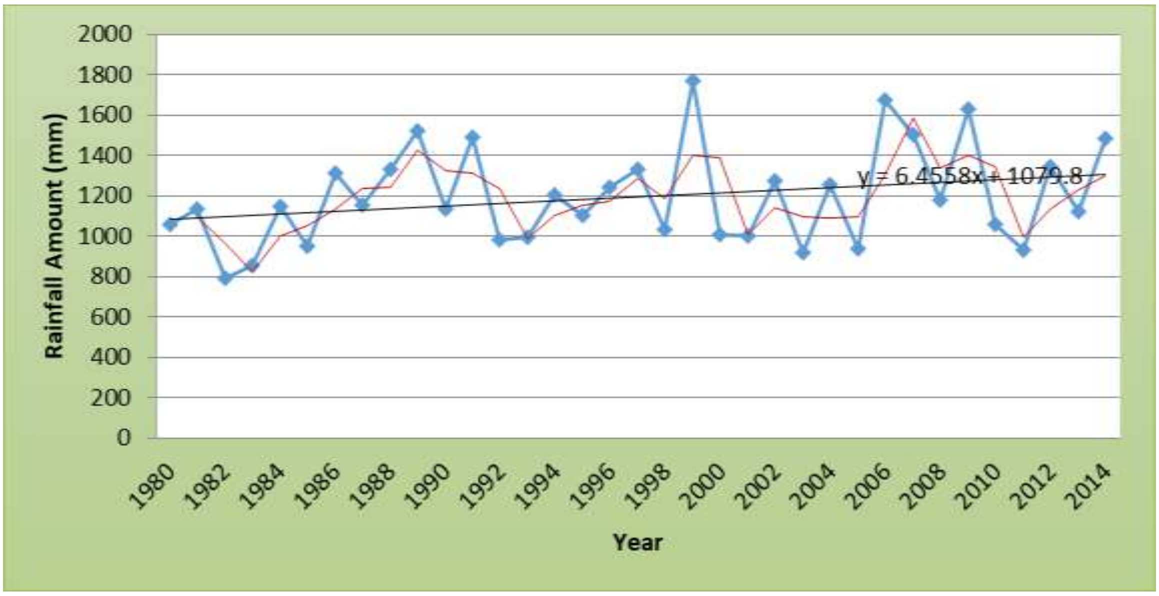


**Fig. 2:** Rainfall Trend in Lokoja (1980-2014)

Rainfall distribution of Makurdi as presented on Table 1 reveals a wide variability as shown in Figure 3. The highest rainfall amount for the period was recorded in 1996 (1702.6mm), while the lowest figure was recorded in 2003 (745.1mm). The rain increased generally in the 34years period (1980 – 2014) with a mean rainfall amount of 1197.71mm.

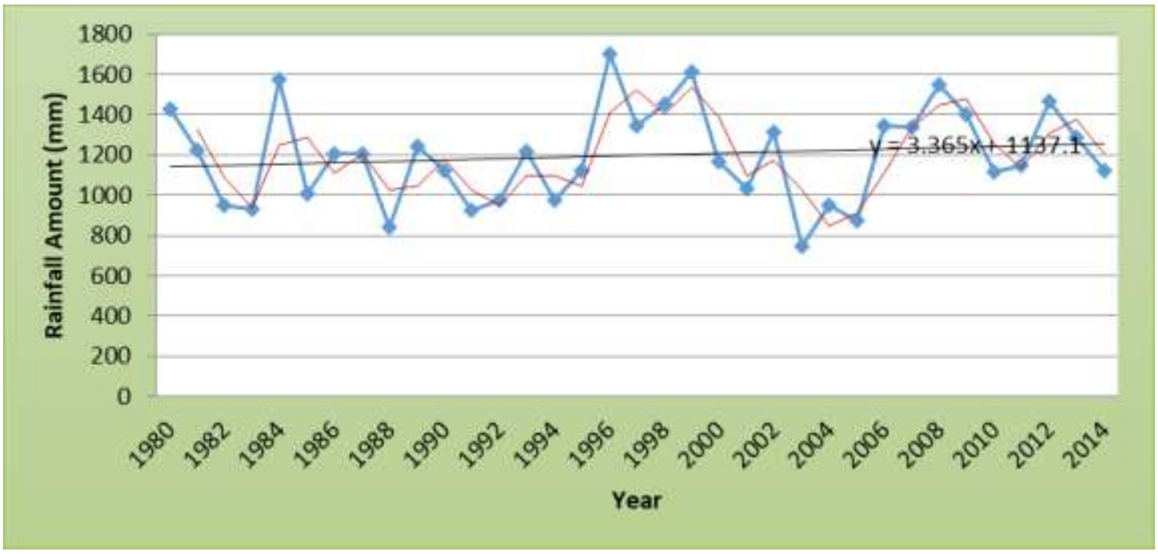


**Fig. 3:** Rainfall trend in Makurdi (1980-2014)

Rainfall distribution in Jos as presented on Figure 4 reveals a general increase in rainfall amount (positive constant 'a' of 3.098) with little variability. The highest rainfall amount for the period was recorded in 2002 (1581.8mm), while the lowest figure was recorded in 1995 (856.7mm). Average/mean rainfall amount in Jos station for the 34 years was 1238.39mm.

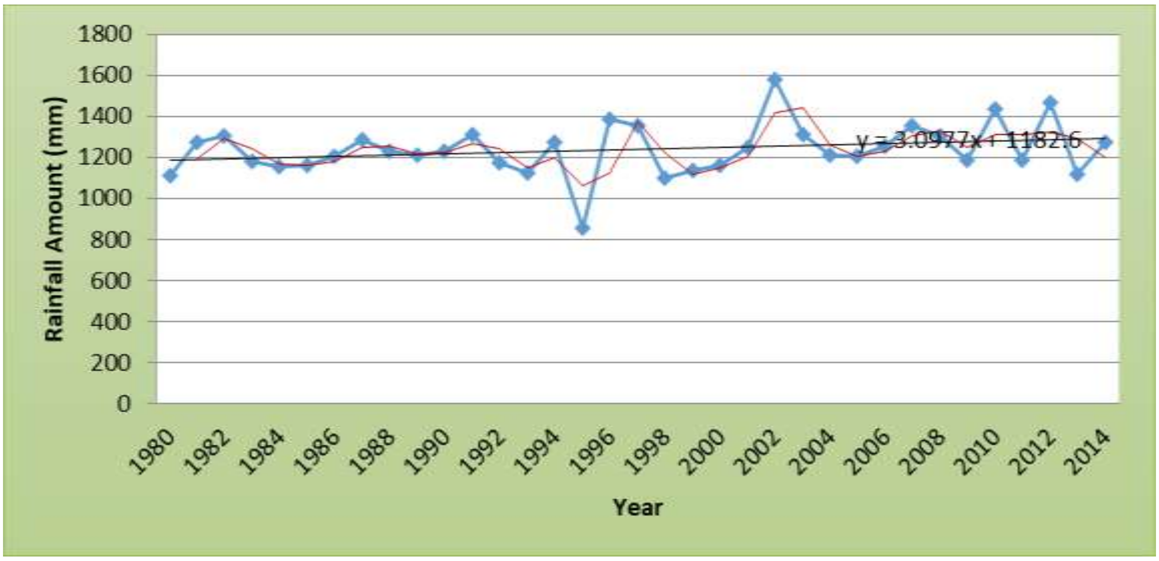


**Fig. 4:** Rainfall Trend in Jos (1980-2014)

Rainfall distribution in Katsina-Ala as presented on Figure 5 shows that, there is a significant increase in the rainfall trend over the 34 years period with a positive constant value of 8.107. The highest amount of rainfall over the period of time is 1893.6mm recorded in 1997, while the lowest figure was recorded in 1983 (903.6mm) with average rainfall amount of 1329.44mm for the 34 years period. All the four stations: Lokoja, Makurdi, Jos and Katsina-Ala are located within the lower Benue Trough. The implication of these high amounts of annual rainfall values recorded is that increase rainfall amount trend will mean increase flood events and vulnerability. This agrees with Ayoade (1998), Babatolu (1997), Jimoh (2000), Oriole (2000), Ali (2005), Ologunorisa and Tersoo (2006) who identified heavy rainfall as the principal factor in most flood events.

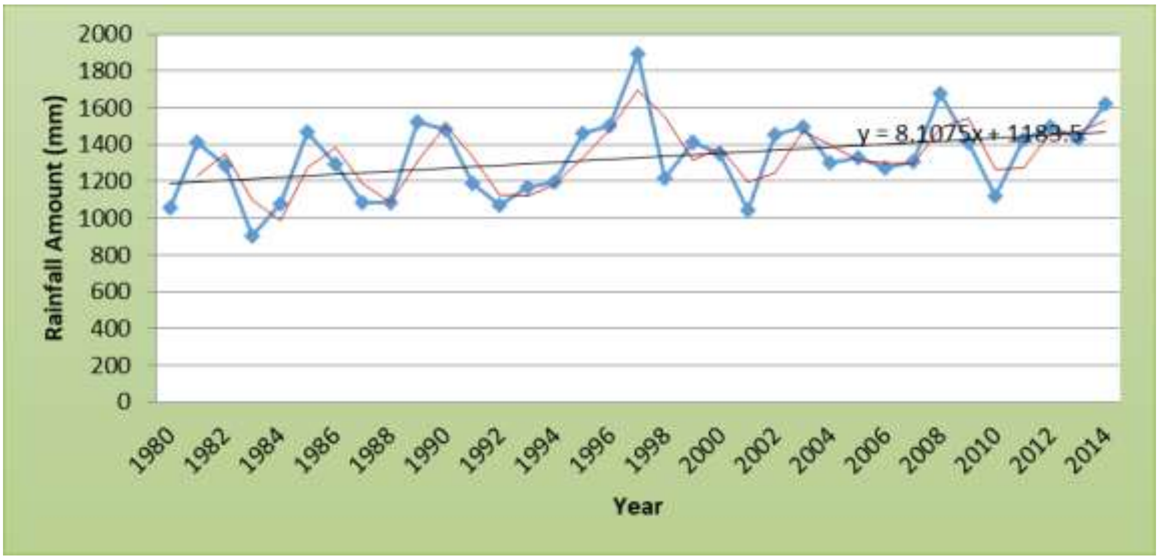


**Fig. 5:** Rainfall Trend in Katsina-Ala (1980-2014)

Rainfall distribution in Ibi as presented on Figure 6 shows a decreasing trend (a=-2.08) over the 34years period. The highest amount of rainfall was recorded in 2009 (1569.1mm), while the lowest amount of rainfall was recorded in 2003 (691.3mm). Average rainfall amount between 1980 and 2014 is 1329.44mm with high level of variability.

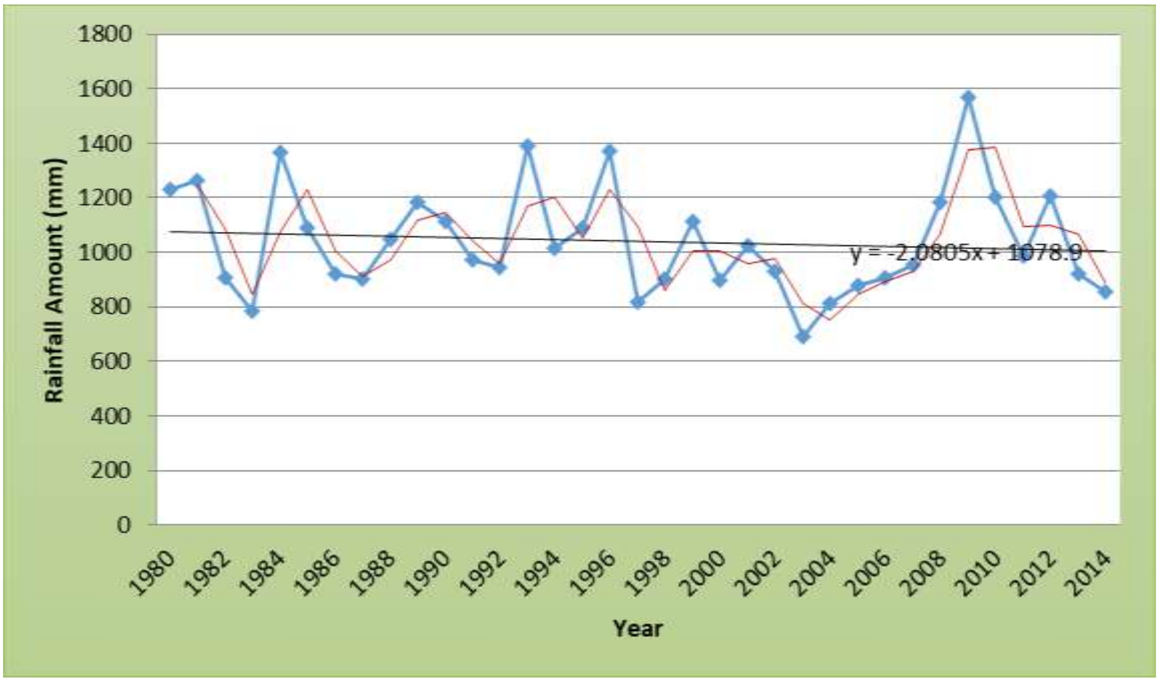


**Fig. 6:** Rainfall Trend in Ibi (1980-2014)

Rainfall distribution in Yola station in upper Benue trough as presented on figure 7 also showed a significant decreasing trend (a = -3.90) in annual rainfall amount over the 34years period. The highest annual amount of rainfall was recorded in 1980 (1207.5mm), while the lowest annual rainfall amount was recorded in 2008 (495.8mm) with average annual rainfall amount of 847.89mm for the 34 years period.

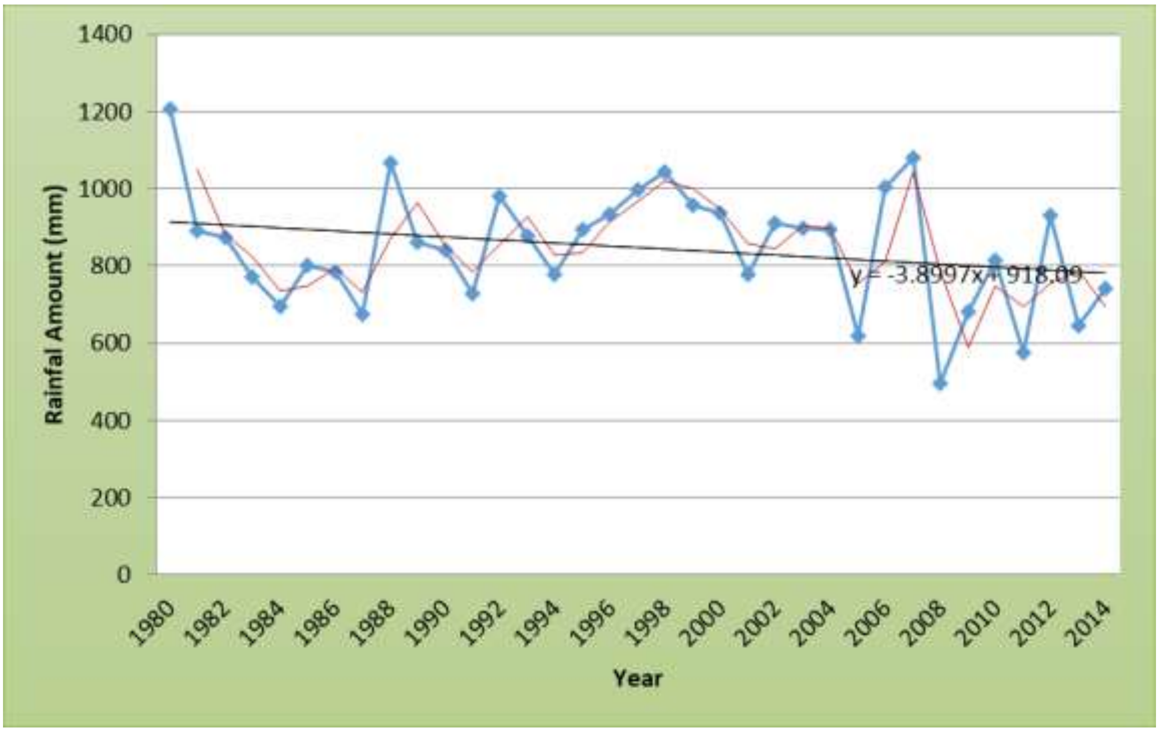


**Fig. 7:** Rainfall Trend in Yola, Adamawa State (1980-2014)

Rainfall pattern in upper Benue trough indicates a decreasing trend over the 34years period. The implication of this rainfall distribution in the area is that factors (deforestation, excess water from dam e.g Lagdo dam in Cameroon, Urbanization, landuse and other human activities) other than rainfall are gradually becoming the main factors contributing to incidence of flooding in the region.

**Water Level in Rivers and Implications for flooding in the area**

Riverine floodplains range from narrow, confined channels (as in steep river valleys in hilly and mountainous areas) to wide, flat areas (as in much of the Middle course and in many coastal areas). In the steep narrow valleys, flooding usually occurs quickly and is of short duration, but is likely to be rapid and deep. In relatively flat floodplains, areas may remain inundated for days or even weeks, but floodwaters are typically slow-moving and shallow. Flooding in large rivers usually results from large-scale weather systems generating prolonged rainfall over wide areas. These same weather systems may cause flooding in hundreds of smaller basins that drain into the major river system. The streams and small rivers are also susceptible to flooding from more localized weather systems that cause intense rainfall over only a small area. In parts of the Benue trough, annual floods result from heavy rainfall and the extent of flooding is dependent upon volume of water in rivers (Ayoade, 1998).

Water levels in rivers of the Benue Trough can fluctuate for a short-term (seasonal) or long-term (yearly basis). Periods of heavy rainfall, for example, can cause high water levels for short periods of time and annual fluctuations are phenomenon that can cause high water and subsequent flooding problems lasting for long period of time (PDNA, 2013). Information on peak water level in the area is presented on Table 2.

**Table 2:** Peak Water Level in Benue Trough (m)

| Year | Gassol | Ibi | Lau | Makurdi | K/Ala | Wuroboki | Umaisha |
|---|---|---|---|---|---|---|---|
| 1980 | MV | 8.89 | 8.25 | 10.13 | 1.43 | 1.26 | 9.61 |
| 1981 | MV | 8.69 | 7.55 | 10.27 | 5.07 | 2.3 | 9.69 |
| 1982 | MV | 7.72 | 6.98 | 9.34 | 5.41 | 4.16 | 8.13 |
| 1983 | MV | 6.36 | MV | 8.94 | 5.15 | 4.39 | 8.4 |
| 1984 | MV | 5.88 | MV | 8.67 | 5.83 | 4.41 | 7.92 |
| 1985 | MV | 8.28 | MV | 9.8 | 6.4 | 5.1 | 9.37 |
| 1986 | MV | 7.28 | MV | 9.3 | 6.19 | 5.0 | 8.79 |
| 1987 | 5.18 | 7.85 | 6.98 | 9.37 | 5.92 | 5.3 | 8.67 |
| 1988 | 4.68 | 8.86 | 8.74 | 10.09 | 2.22 | 5.49 | 9.41 |
| 1989 | 4.99 | 9.03 | 4.96 | 10.54 | 4.2 | 5.82 | 9.49 |
| 1990 | 4.05 | 7.78 | 5.12 | 10.22 | 3.83 | 5.61 | 9.19 |
| 1991 | 4.12 | 8.17 | 8.91 | 10.17 | 2.78 | 6.2 | 9.25 |
| 1992 | 3.43 | 8.21 | 6.55 | 7.1 | 3.15 | 6.74 | 9.12 |
| 1993 | 3.5 | 8.67 | MV | 6.59 | 3.03 | 5.04 | 8.3 |
| 1994 | 4.39 | 8.88 | 9.54 | 10.98 | 3.47 | 4.84 | 8.7 |
| 1995 | 4.55 | 9.04 | 7.64 | 10.95 | 3.44 | 4.8 | 9.1 |
| 1996 | 2.22 | 8.87 | MV | 4.95 | 6.1 | 4.25 | 9.5 |
| 1997 | 2.94 | 7.33 | MV | 9.67 | 3.88 | 4.8 | 9.25 |
| 1998 | 2.82 | 8.12 | MV | 10.98 | 3.77 | 4.72 | 8.9 |
| 1999 | 5.38 | 9.41 | 7.64 | 10.87 | 3.78 | 4.9 | 8.3 |
| 2000 | 5.18 | 8.71 | 8.24 | 10.41 | 5.67 | 4.98 | 8.7 |
| 2001 | 2.8 | 9.23 | MV | 9.53 | 2.6 | 5.41 | 9.2 |
| 2002 | 2.79 | 9 | MV | 8.97 | 3 | 5.8 | 9.7 |
| 2003 | 3.5 | 7.18 | MV | 8.5 | 3.31 | 5.3 | 8.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2004 | 4 | 7.23 | MV | 8.89 | 3.8 | 5.9 | 7.6 |
| 2005 | 4.2 | 7.56 | MV | 9.2 | 3.4 | 6.0 | 8.2 |
| 2006 | 4.36 | 8.1 | MV | 10.7 | 3.68 | 6.03 | 8.1 |
| 2007 | 3.9 | 8.73 | MV | 10.43 | 4.1 | 4.13 | 8.7 |
| 2008 | 4.22 | 9.97 | MV | 10.27 | 5.2 | 3.26 | 8.8 |
| 2009 | 4.5 | 8.73 | MV | 10.49 | 5.6 | 3.97 | 8.6 |
| 2010 | 4.79 | 7.57 | MV | 9.33 | 5.92 | 3.97 | 9.2 |
| 2011 | 5.07 | 8.12 | MV | 9.34 | 5.91 | 4.2 | 9.69 |
| 2012 | 5.14 | 11.09 | MV | 12.58 | 5.35 | 5.52 | 11.12 |
| 2013 | 5.02 | 8.9 | MV | 10.02 | 5.21 | 4.3 | 9.71 |
| 2014 | MV | MV | MV | 10.94 | MV | MV | MV |

**Source:** Nigeria Hydrological Services Agency (NIHSA), 2014
*MV – Missing Value

Information on Table 2, shows that between 1980 and 2014, peak water level at Gassol varied between 2.22m and 5.38m. The maximum peak water level occurred in 1999 while the minimum peak level occurred in 1996. Peak water level for this period indicated that six (6) major flood events took place in the area (i.e 1987, 1989, 1999, 2010, 2011 and 2012). Thirteen (13) moderate flood events occurred while six (6) minor flood events in the area (see Figure 8). The high peak level observed in 2012 was as a result of inflow from Lagdo dam in Cameroun into river Benue in July and subsequent months.

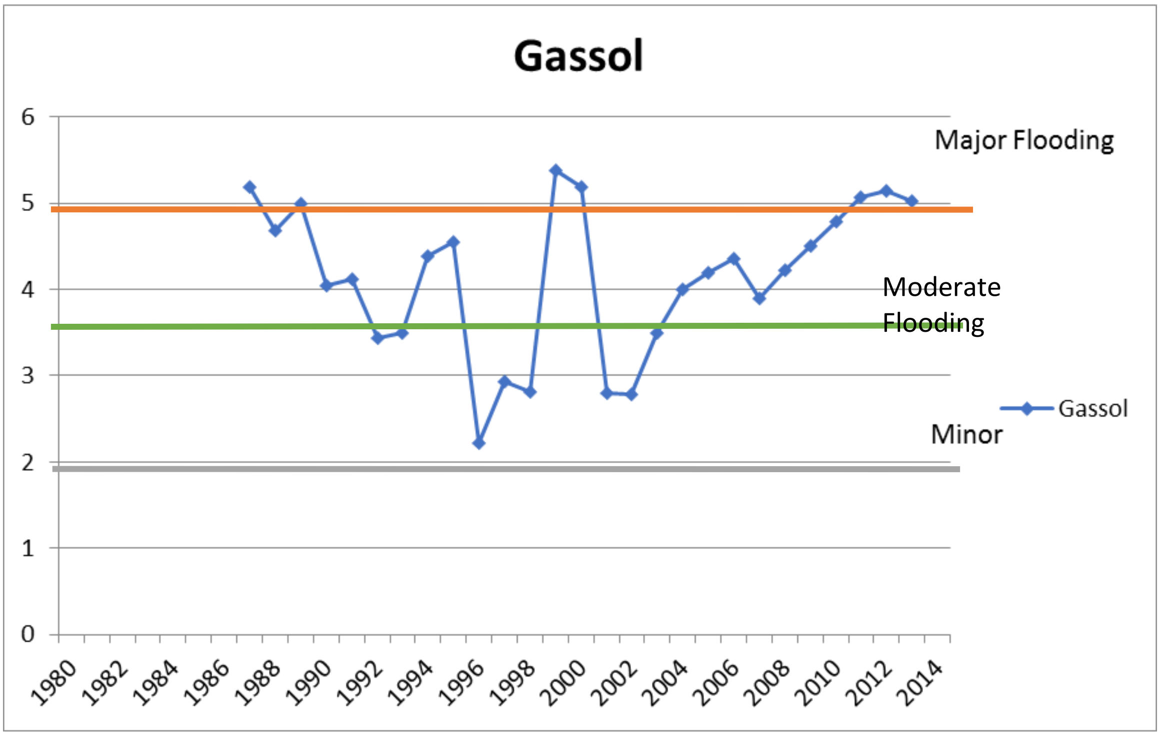


**Fig. 8:** Water Peak Level at Gassol on River Benue (Modelled after Honert and McAneney, 2011).

Peak water level at Ibi gauging station shows that between 1980 and 2014, water stage height varied between 5.88m and 11.88m. The maximum peak water level occurred in 2012 while the minimum peak level occurred in 1984. Peak water level for this period indicated that four (4) major flood events took place in the area (i.e 1999, 2001, 2008 and 2012). Twenty-eight (28) moderate flood events occurred and two (2) minor flood events in the area (see Figure 9). The high peak level observed in July, August and September, 2012 led to River Benue overflowing its bank and submerging arable land, crops and settlements in both upper and lower Benue Trough and it was as a result of inflow from Lagdo dam in Cameroun into river Benue in July and subsequent months.

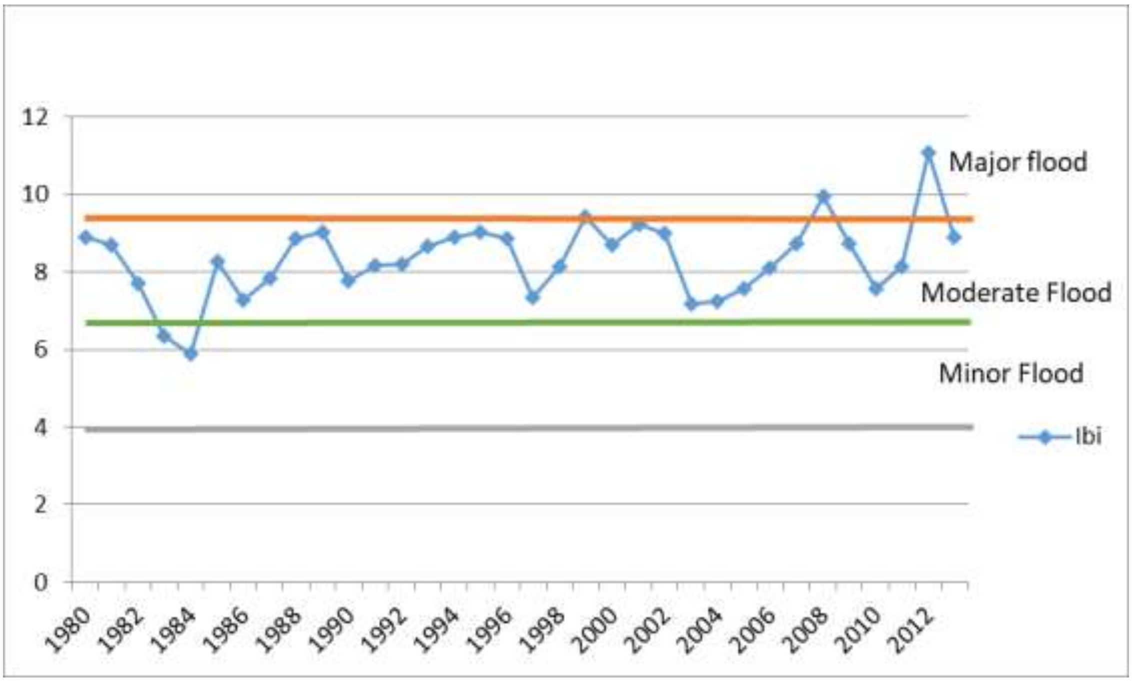


**Fig. 9:** Water Peak Level at Ibi on River Benue (Modelled after Honert and McAneney, 2011)

Peak water level at Makurdi gauging station shows minimum and maximum peak water stage height of 4.95m and 12.58m respectively for the period of 1980 to 2014 (Figure 10). The maximum peak water level occurred in 2012 while the minimum peak level occurred in 1996. Peak water level between 1980 and 2014 indicated that thirteen (13) major flood events occurred in the area. Eighteen (18) moderate flood events occurred and three (3) minor flood events in the area. The high peak level observed in July, August and September, 2012 led to River Benue overflowing its bank and submerging arable land, crops and settlement in upper and lower Benue Trough and it was as a result of inflow from Lagdo dam in Cameroun into river Benue in July and subsequent month.

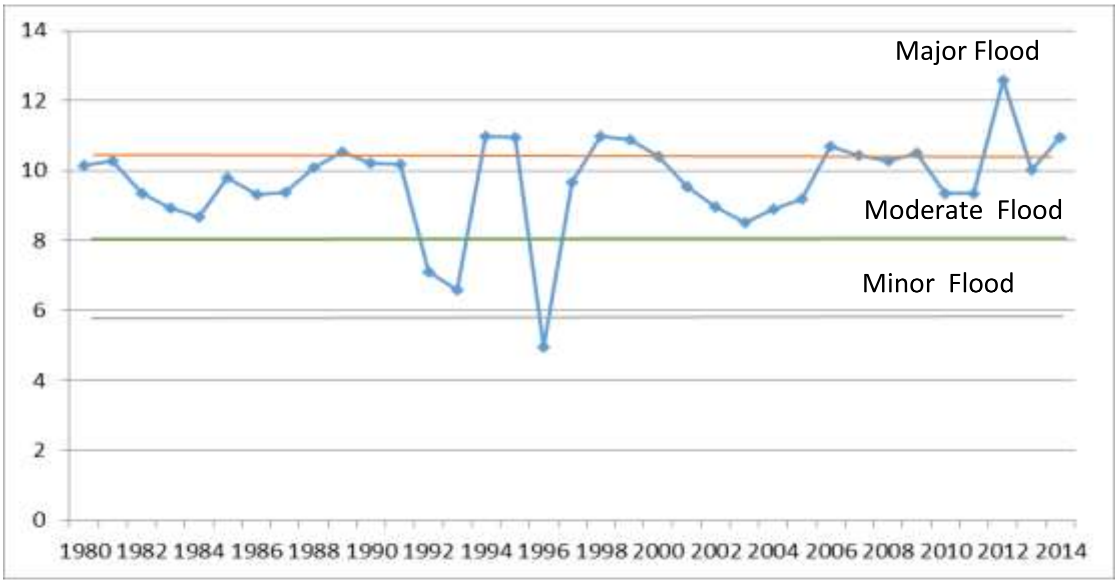


**Fig. 10:** Water Peak Level at Makurdi on River Benue (Modelled after Honert and McAneney, 2011)

Information on Table 2 shows that between 1980 and 2014, peak water level at Katsina-Ala gauging station varied between 1.43m and 6.4m. The maximum peak water level occurred in 1985 while the minimum peak level occurred in 1980. Peak water level for this period indicated that ten (10) major flood events occurred in the area. Six (6) moderate flood events occurred, thirteen (13) minor flood events, while four (4) years did not experience flood at all in the area (see Figure 11). The inflow water from Lagdo dam in Cameroun into river Benue in July and subsequent months did not influence water level in Katisna-Ala River a tributary to river Benue.

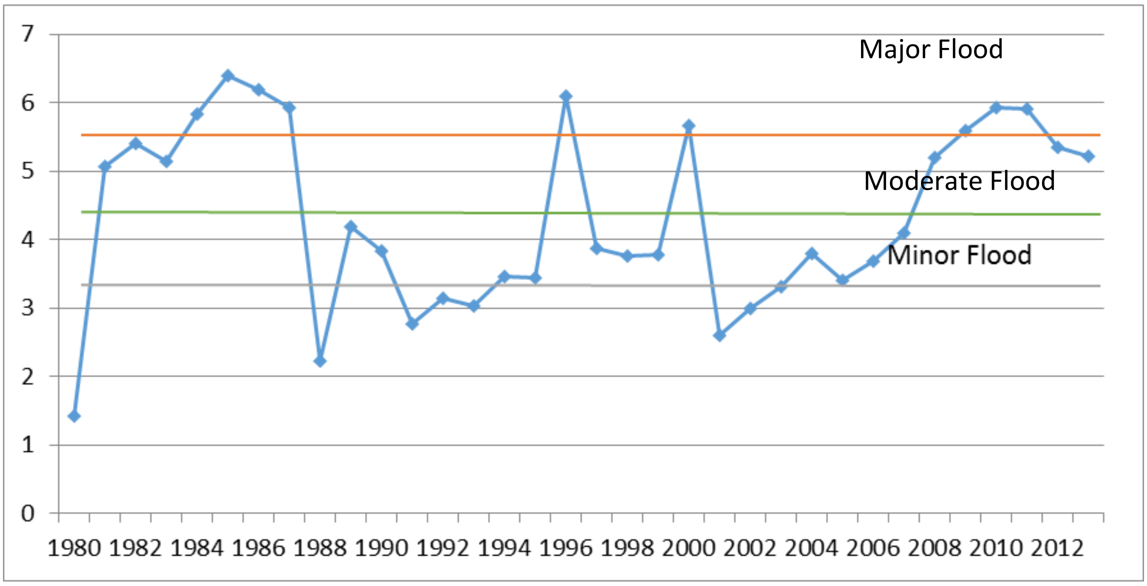


**Fig. 11:** Water Peak Level at Katsina-Ala on River Katsina-Ala (Modelled after Honert and McAneney, 2011)

Peak water level at Wuroboki gauging station varies between 1.26m and 6.74m (Figure 12). The maximum peak water level occurred in 1992 while the minimum peak level occurred in 1980. Peak water level between 1980 and 2014 indicated that five (5) major flood events occurred in the area. Eleven (11) moderate flood events occurred and thirteen (13) minor flood events in the area while three years had no flood event at all.

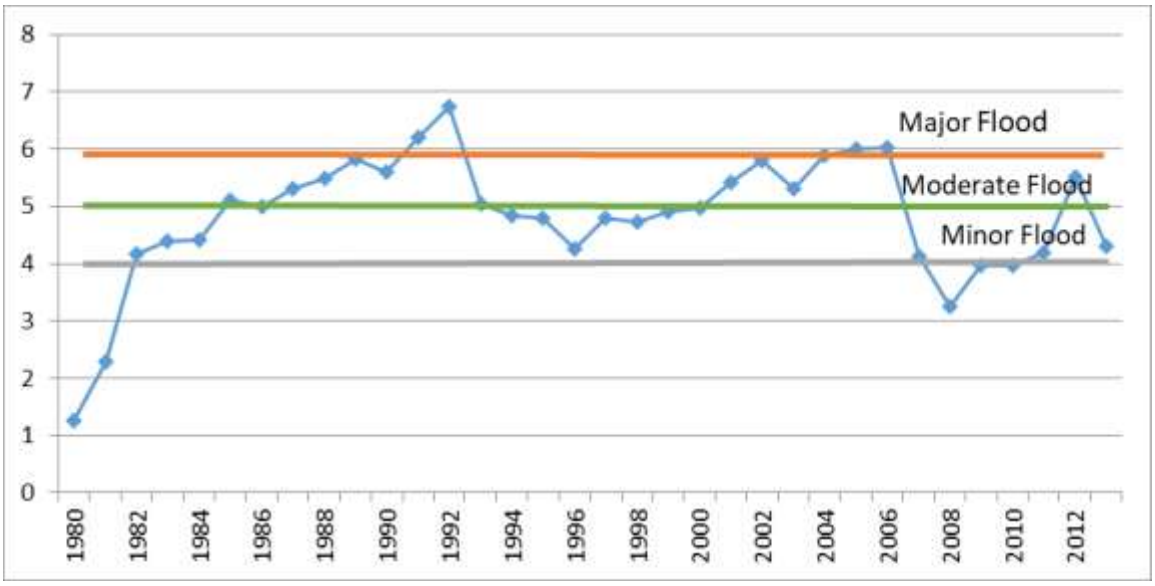


**Fig. 12:** Water Peak Level at Wuroboki on River Benue (Modeled after Honert and McAneney, 2011)

Peak water level at Umaisha gauging station on River Benue varied between 7.6m and 11.12m (Figure 13). The maximum peak water level occurred in 2012 while the minimum peak level occurred in 2004. Peak water level between1980 and 2014 indicated that eight (8) major flood events occurred in the area. Twenty-three (23) moderate flood events occurred and one (1) minor flood events in the area. The high peak level observed in July, August and September, 2012 led to River Benue overflowing its bank and submerging arable land, crops and settlement in upper and lower Benue trough and it was as a result of inflow from Lagdo dam in Cameroun into river Benue in July and subsequent months (PDNA, 2013).

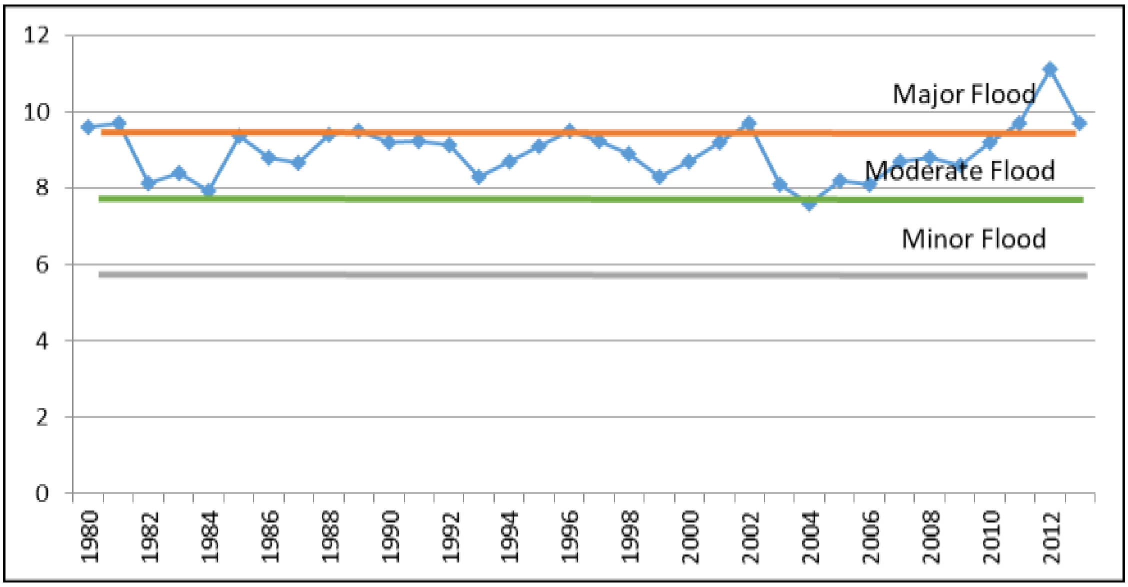


**Fig. 13:** Water Peak Level at Umaisha on River Benue (Modeled after Honert and McAneney, 2011)

## Conclusion and recommendation

The study concluded that in the upper Hydrological area of the Benue Trough, factors other than rainfall are the main cause of flooding in the area whereas, increased rainfall amount in the lower hydrological area of Benue trough will mean increased flood events, vulnerability and impact. The study recommends that a resettlement programme be initiated for people living in flood prone areas as there is likelihood to experience major flood in every ten years or less.

## References

Abaa, S. I. (2004). Origin of the Benue Trough and its Economic Significance to Nigeria. *2nd inaurgural Lecture of Benue State University, Makurdi*.

Adeoye, N.O., Ayanlade, A. and Babatimehin,O. (2009). Climate Change and Menace of Floods in Nigerian Cities: Socio-economic Implications. *Advances in Natural and Applied Sciences, 3(3)*, 369-377.

Ali, P.I.O (2005). Flood Damage Assessment in Makurdi Town, Unpublished M.Sc. Thesis, Department of Geography, Benue State University, Makurdi.

Ayoade, J. O (1988). *Tropical Hydrology and Water Resources*, London: Macmillan Publishers,

Babatola, J. S (1997). The June 24th 1995 Flood in Ondo Antecedent and Incident, *Ife Research Publication in Geography* 6, 125-136.

Duru, P. N. and C. N. Chibo. (2014). Flooding in Imo State Nigeria: The Socio-Economic Implication for Sustainable Development. *Humanities and Social Sciences Letters, 2(3)* , 129-140.

Honert, R. C. and McAneney, J. (2011). The 2011 Barisbane Floods: Causes, Impacts and Implications; water, 3, 1149-1173. www.mdpi.com/journal/water

Hula, M. A. and Udoh, J. C. (2015) An Assessment of the impact of Flood Events in Makurdi, Nigeria*, Civil and Environmental Research 7, 10, 53-60*

Jimoh, H. I. (2000). Man-Environment Interactions, *Contemporary Issues in Environmental Studies Edited by* Jimoh, H. I. and Ifabiyi, I. P, Haytee Press and Publishing Co. LTD. Ilorin-Kwara State.

Mwape, Y. P. (2009) *An Impact of Floods on the Socio-economic Livelihood of people: A Case Study of Sikamzwa Community in Kazungula district of Zambia.*

Nigeria Hydrological Services Agency (NIHSA) (2014). *Peak Water Levels,* The Nigeria Hidrological Services Agency, Federal Ministry of Water Resources.

Ocheri, M. I. and E. Okele. (2012). Social Impact and People's Perception of Flooding in Makurdi Town, Nigeria. *Special Publication of the Nigerian Association of Hydrological Sciences* , 97-105.

Ologunorisa, E. T and Tersoo, T. (2006). The Changing Rainfall Pattern and its Implication for flood Frequency in Makurdi, Northern Nigeria. *Journal of Applied Science and Environmental Management, vol. 10, no. 3*

Oriola, E. O (2000). Flooding and Flood Management in Jimoh, H. I (ed) Contemporary Issues on Environmental Studies, Ibadan.

Oruonye, E. D. (2012). Socio-Economic Impact Assessment of Flash Flood in Jalingo Metropolis, Taraba. *International Journal of Environmental Sciences Vol. 1 No. 3* , 135-140.

PDNA, (2013). Nigeria Post-Disaster Needs Assessment 2012 Floods, A Report by the Federal Government of Nigeria with Technical Support from the World Bank, EU, UN, and other Partners.

Serdeczney, O., Adams, S., Baarsch, F., Coumon, D., Robinson, A., Hare, W., Shaeffer, M. and Reinhardt, J. (2015). Climate Change Impacts in Sub-Saharan Africa: from Physical Changes to their Social Repercussions, *Regional Environmental Change,* Vol. 15, No. 8

Tadesse, A. (2009). The Dynamics of Resettlement with reference to the Ethiopian Experience, *Kimmage Development Studies Centre*.

Uyigue, E. (2006). Dams arev Unrenewable: A Discussion Paper, Community Research and Development Centre, Nigeria pp1-19.

Warritty, A., Houston, D., Ball, T., Tavendale, A. and Black, A. (2007). Exploraing the Social Impacts of Flood Risks and Flooding in Scoteland, *Scotish Executive Social Research* pp1-157

Shabu, T. and Tyonum E. T, (2013). Residents Coping Measures in Flood Prone Areas of Makurdi Town, Benue State. *Applied Ecology and Environmental Sciences, Vol. 1, No. 6*, 120-125.

# ASSESSMENT OF DROUGHT VULNERABILITY IN NORTHERN NIGERIA

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**Abstract**

*Drought is one of the most devastating hazards and widespread natural menace. Several studies have employed precipitation-based indices for drought appraisal in different geographical locations. In this study, the standardized precipitation evapotranspiration index (SPEI) was applied to assess the severity of drought in some parts of northern Nigeria (Bauchi and Gombe substations). The SPEI was calculated from fifteen-year precipitation and temperature data at 3- and 6-month time scale. It was observed that mild drought has been ever present in the area of study at short- and long-term accumulation periods. The year 2019 was observed to be the driest year. The study concludes that SPEI-3 and SPEI-6 showed the ability to quantify drought.*

Keyword: SPEI, Drought, Evapotranspiration, Northern Nigeria

## 1. Introduction

Drought is one of the most costly and widespread hazards which cut across all hydro-climatological region and at any time of the year (Wilhite et al., 2000) bearing with it, severe societal consequences that span various sectors of the economy. While much of the other hazardous phenomena like flood, pollution and earthquake are distinct events, drought is a creeping phenomenon as it is more gradual, slowly affecting an area and tightening its grip (Mishra and Desai, 2005). It gradually increases in severity and tend to persist over a long period of time even after it has stopped (Yue *et al.* 2018).
Mishra and Desai (2005) opines that the multidimensional and multifaceted nature of drought makes it difficult to arrive at a unique definition of drought, however, based on the nature of water deficit, studies from Zulfiqar *et al.* (1992), Okorie (2003), Sepulcre-Canto *et al.* (2012), Abaje et al (2013), and Achugbu and Anugwo (2016) amongst others, broadly classifies droughts into four: (a) meteorological drought which is defined as a shortage or lack of precipitation, (b) the agricultural drought which is related to the period of inadequate water to meet crop water requirement (c) hydrological drought occurs when the water reserves available in surface and ground water sources fall below a locally significant threshold and (d) socio-economic drought which is related to failure of water resources systems to meet the water demands and therefore, associating droughts with supply of and demand for an economic good, in this case, water. In all these categories, drought can be said to occur as a result of significant rainfall deficit or lack of it for a fairly long period of time resulting to hydrological imbalances and affects the land productive system (Eze, 2018).
Drought has been identified as an integral part of Sudano-Sahel ecological zone (SSEZ) of Africa in which Northern Nigeria is part of since the 1960s (Adeniyi and Uzoma, 2016; Chibueze, 2016). The result of this menace according to Eze (2018) includes but not limited to impoverished household, livestock mortality, low crop yield and increased desertification. Consequently, the situation is being worsened by increase in human population, overgrazing, over-cultivation and high poverty rate (Abaje et al, 2013).

However, studies on the evaluation of drought impact have been undertaken in Northern Nigeria (Adeaga, 2011; Abaje*et al.*, 2013; Chibueze, 2016; Achugbu and Anugwo, 2016; Adeniyi and Uzoma, 2016; Achugbu and Balogun, 2017). The studies concentrated on the use of precipitation-based drought indices like standardized precipitation index (SPI) and drought severity index (DSI), hence, taking only account of precipitation as the only parameter for assessment. According to Narendra *et al.* (2019) precipitation-based indices give a wrong conceptualization of drought because it is based on the assumption that droughts are controlled by the temporal variability in precipitation only while other variables like temperature, evapotranspiration ($E_T$) and relative humidity remain stationary. Therefore, a key limitation for the precipitation-based index is that it cannot be used to evaluate future climatic scenario since parameters like temperature and evaporation are negligible. The standardized precipitation evapotranspiration index (SPEI) developed by Vicente-Serrano et al (2010)is considered as an alternative to SPI because it takes into account variability in temperature for the calculation of potential evapotranspiration (PET). The SPEI combines the effect of PET with multi-temporal nature of SPI (Potopova, et al., 2015).

Therefore, the seasonal and inter-annual climatic variability in rainfall and temperature in this present global warming scenario calls for a suitable technique for drought assessment based on relevant data (Abaje et al., 2013). Against this background, the research seeks to assess the temporal variability of droughts in some parts of Northern Nigeria using standardized precipitation evapotranspiration Index (SPEI).

## 2. Methodology

The Sudan-Sahel ecological zone (SSEZ) in northern Nigeria lies between the latitude 10º N-14.00ºN and longitude 2.73º E-14ºE (Adeniyi and Uzoma, 2016).It extends from the Sokoto plains in the west to the Chad Basins in the east. Ferruginous tropical soils which are heavily weathered and markedly laterized covers more than half of the region (Oladipo, 1993; FRN, 2000).

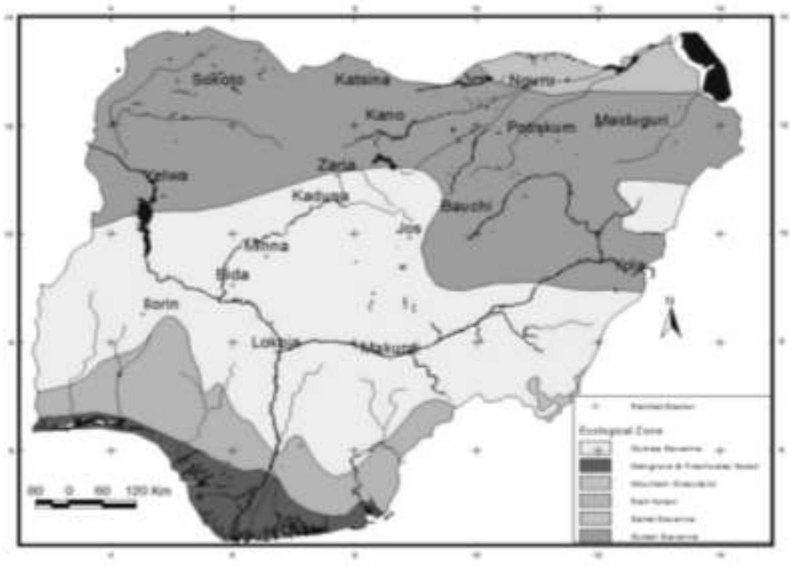


**Figure 1**: Map of Nigeria showing the study area. Source: Adeaga (2011)

The vegetation is the Savanna type consisting of Sudan and Sahel with the density of trees and other plants decreasing as one move northwards (Abaje, 2007). The region's climate is dominated by two distinct seasons; dry season with northeast winds (October–April) and wet season (May-September) with strong southwest winds (Achugbu and Balogun, 2018). The average annual rainfall ranges between 300mm to 1500mm with peaks in July and August (Olatunde, 2013). For the purpose of this study, analysis of drought is narrowed down to two selected stations within the zone: Bauchi and Gombe, which are located in the north Eastern part of Nigeria. Fifteen years monthly precipitation, relative humidity and maximum and minimum temperature data has been collected for the study area from 2006 to 2020. Variations in the annual precipitation for fifteen years from 1950 to 2019 are shown in Figure 2 and Figure 3.

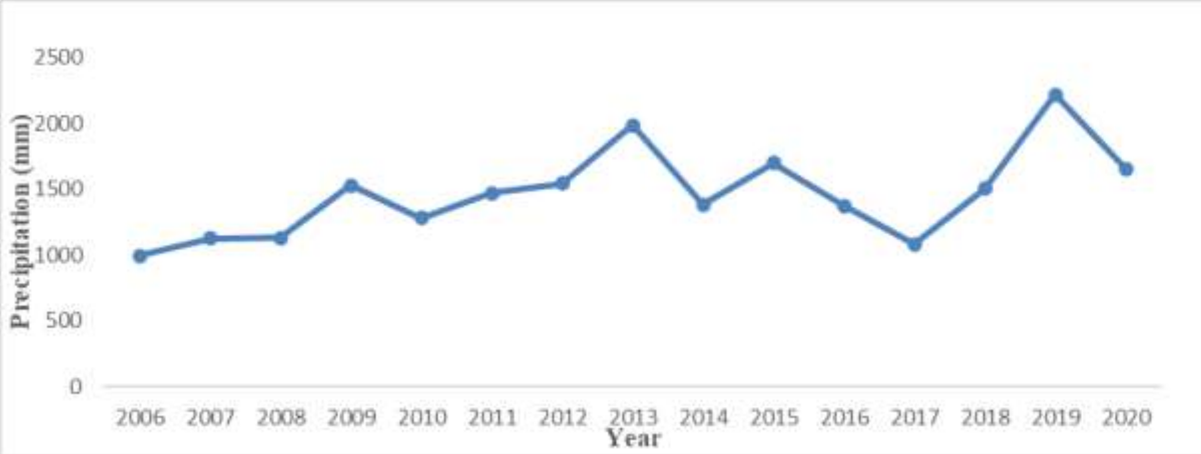


**Figure 2**: Annual Precipitation (mm) from 2006 to 2020 for Bauchi Station

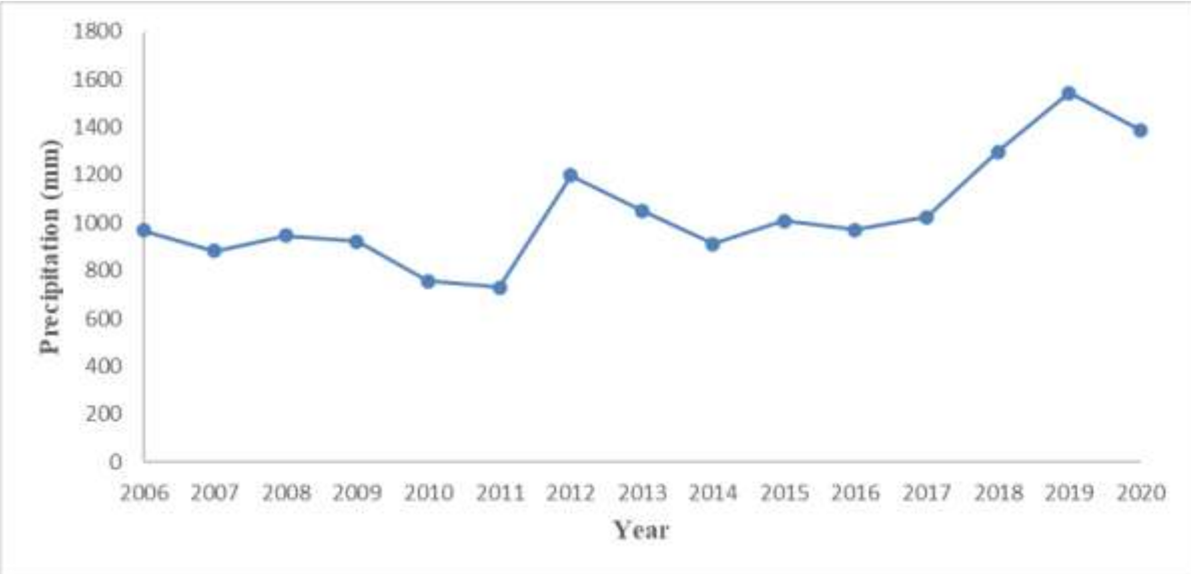


**Figure 3**: Annual Precipitation (mm) from 2006 to 2020 for Gombe Station

### 2.1 Standardized Precipitation Evapotranspiration Index (SPEI)

In this study, the SPEI was used to evaluate the drought events based on simple climatic water balance, that is, the difference between precipitation and potential evapotranspiration for each day. In line with Vicente-Serrano *et al.* (2010), the calculated daily $D_i$ were aggregated at different time scales of 3 and 6 month following the same procedure as SPI.

$$D_i = P_i - PET_i \qquad (1)$$

Where, $D_i$ is the difference between precipitation and potential evapotranspiration, $P_i$ is the daily precipitation, and $PET_i$ is the daily potential evapotranspiration.

The three-parameter log-logistic distribution was used to standardize the D series to get the SPEI. The log-logistic probability density function was used to fit the sequence as follows:

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1}\left[1+\left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right]^{-2} \qquad (2)$$

where α, β and γ are scale, shape and origin parameters of the Log-logistic distribution respectively, for the D values in the range (γ> D<∞).

Thus, the probability distribution function of the D series, according to the log-logistic distribution, is given by:

$$F(x) = \left[1 + \left(\frac{\alpha}{x-y}\right)^{\beta}\right]^{-1} \quad (3)$$

The SPEI was then obtained as a standardized value of F(x) using the classical approximation of Abramowitz and Stegun (1965) as given by Vicente-Serrano *et al.* (2010);

$$\text{SPEI} = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3}, \quad (4)$$

where, W = $\sqrt{-2\ln(P)}$ for $P \leq 0.5$, and P is the probability of exceeding a determined D value and P = 1 – F(x); when P > 0.5, P = 1 – P. the constants are $C_0$ = 2.515517, $C_1$= 0.802853, $C_2$ = 0.010328, $d_1$ =1.432788, $d_2$ =0.189269 and $d_3$ =0.001308

For ease of computation and elimination of error, all calculations were done using Microsoft Excel

**Table 1:** Standardized Precipitation Evapotranspiration Index Drought classification

| SPI numerical range | Drought Conditions |
|---|---|
| Greater than 2.0 | Extremely wet |
| 1.5 - 1.99 | Very wet |
| 1.0 - 1.49 | Moderately wet |
| -0.99 to 0.99 | Near normal |
| -1.00 to -1.49 | Moderately dry |
| -1.50 to -1.99 | Very dry |
| Less than -2.0 | Extremely dry |

**Source:** Faye et al. (2019)

### 2.2 Estimation of Potential Evapotranspiration (PET)

The PET in this study was estimated on temperature based empirical model developed by Duru (1984); the Blaney-Morin Nigeria (BMN). Blaney Morin Nigeria (BMN) takes into account the wide variability of relative humidity in Nigeria and the role it plays in evapotranspiration process(Idike, 2005). The PET estimate was obtained using the following formula:

$$\text{PET} = \text{Ƥ}\frac{(0.45t+8)(H-R^{m})}{100} \quad (5)$$

where, PET = Potential evapotranspiration (mm/day), Ƥ = ratio of maximum sunshine hours for the period of interest to the annual maximum, t = average temperature (◦C), R = relative humidity (%), H and m are empirical constants given as 520 and 1.31 respectively.

## 3. Results and Discussion

Tables 2 to 4 present the results of SPEI-3 and SPEI-6 for Bauchi and SPEI-3 and SPEI-6 for Gombe. From the tables, the drought months investigated are June to November as these are months which fall within the rainy season in Nigeria. The temporal variability of droughts was analysed for both 3-month and 6-month timescales.A higher negative value of SPEI suggests more severe drought, and persitence of negative value in the consecutive year for a given time scale depicts the persistence of drought. In this study, the SPEI diagrams (Figures 4 to 7) for drought months under investigation have been presented to show the pattern and trends in the years of study.

Thedrought analysis based on SPEI-3 in Bauchi indicates anear normal condition through the study period (2006 to 2020) (see table 2). This is illustrated in Figure 4 in which the month of Junewitnessed 7 consective years of mild drought between 2008 and 2014, July month also reveals 13 mild drought years except in 2012 and 2013 in which moderate droughts were observed. The result also showed severe drought years in August; 2013 and 2019. SPEI-3 September potrays 3 mild droughts, 10 moderately drought and 2 severe drought (2013 and 2019) were observed. Twelve drought years were observed in August and September more than other months.

Analysis of the variations of droughts years as illustrated in Figure 7 depictthe spatial extent of SPEI as it reveals similarity between droughts events in both sub-stations (Gombe and Bauchi). Twelve mild wet years and 3 mild droughts years were observed in June. August years reveals mild and moderates droughts at the beginning of the first six and at the end of the last three years of the study period. SPEI-6 of September showed that the last three consecutive years were moderately dry while 2006 to 2012 were are slightly dry.

Generally, the results from this work shows that both the temporal variations of rainfall and temperature of Bauchi and Gombe are characteristically similar. a findings in this work agrees with the judegment of Abaje et al (2012a)

**Table 2:** SPEI-3 for Bauchi Sub-station

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | | | 1.0217 | 0.8607 | 0.19 | -0.1883 | -0.6968 | -0.827 | -0.7578 | -0.371 | 0.04 | 0.643 |
| 2007 | 0.83 | 0.833 | 0.8472 | 0.7126 | 0.63 | 0.1103 | -0.3706 | -1.145 | -1.1914 | -0.858 | 0.096 | 0.814 |
| 2008 | 0.826 | 0.833 | 0.8504 | 0.8118 | 0.44 | -0.3813 | -0.7686 | -1.176 | -0.8303 | -0.538 | 0.36 | 0.621 |
| 2009 | 0.84 | 0.845 | 0.8597 | 0.1465 | 0.03 | -0.4429 | -0.5485 | -1.01 | -1.1326 | -1.089 | -0.47 | 0.085 |
| 2010 | 0.837 | 0.843 | 0.8582 | 0.6522 | 0.32 | -0.132 | -0.7308 | -0.607 | -1.0325 | -0.786 | -0.781 | 0.179 |
| 2011 | 0.834 | 0.835 | 0.8509 | 0.8358 | 0.47 | -0.0726 | -0.3488 | -1.184 | -1.3647 | -1.291 | -0.422 | 0.338 |
| 2012 | 0.828 | 0.829 | 0.8419 | 0.7653 | 0.06 | -0.2082 | -1.0883 | -1.205 | -1.3961 | -0.826 | -0.309 | 0.765 |
| 2013 | 0.827 | 0.829 | 0.8437 | 0.7045 | 0.42 | -0.3702 | -1.2167 | -1.703 | -1.5853 | -1.189 | 0.08 | 0.314 |
| 2014 | 0.844 | 0.748 | 0.7375 | 0.3537 | 0.04 | -0.4636 | -0.916 | -1.147 | -1.1264 | -0.653 | 0.002 | 0.778 |
| 2015 | 0.839 | 0.837 | 0.7562 | 0.7587 | 0.69 | 0.1933 | -0.8211 | -1.485 | -1.6135 | -1.249 | -0.257 | 0.596 |
| 2016 | 0.842 | 0.842 | 0.7934 | 0.6671 | 0.17 | -0.1483 | -0.7591 | -1.171 | -1.2683 | -0.901 | -0.038 | 0.829 |
| 2017 | 0.84 | 0.841 | 0.8529 | 0.8602 | 0.45 | 0.0661 | -0.4165 | -0.966 | -0.9671 | -0.798 | 0.11 | 0.511 |
| 2018 | 0.838 | 0.841 | 0.8499 | 0.8377 | 0.22 | -0.3339 | -0.7711 | -1.326 | -1.2762 | -1.097 | 0.021 | 0.551 |
| 2019 | 0.84 | 0.839 | 0.8576 | 0.5173 | 0.14 | -0.442 | -1.0974 | -1.603 | -1.5938 | -1.464 | -0.692 | -0.1 |
| 2020 | 0.836 | 0.836 | 0.752 | 0.7405 | 0.36 | -0.1139 | -0.8767 | -1.352 | -1.4525 | -1.161 | -0.374 | 0.509 |

**Table 3:** SPEI-6 for Bauchi Sub-station

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | | | | | | 0.2952 | 0.0039 | -0.2948 | -0.46138 | -0.50179 | -0.343 | -0.105 |
| 2007 | 0.0248 | 0.451 | 0.7814 | 0.8071 | 0.768 | 0.4975 | -0.012 | -0.459 | -0.62355 | -0.60141 | -0.587 | -0.466 |
| 2008 | -0.144 | 0.4838 | 0.8646 | 0.8524 | 0.6745 | 0.0238 | -0.069 | -0.5294 | -0.58847 | -0.62149 | -0.549 | -0.173 |
| 2009 | -0.1 | 0.6356 | 0.7758 | 0.5155 | 0.3044 | -0.02 | -0.103 | -0.5634 | -0.81587 | -0.82615 | -0.742 | -0.578 |
| 2010 | -0.359 | -0.0458 | 0.4871 | 0.7814 | 0.6116 | 0.2045 | -0.081 | -0.0858 | -0.63255 | -0.726 | -0.662 | -0.467 |
| 2011 | -0.078 | -0.0742 | 0.5381 | 0.8673 | 0.6868 | 0.3897 | 0.0433 | -0.5317 | -0.82472 | -0.90129 | -0.845 | -0.734 |
| 2012 | -0.565 | -0.0138 | 0.6223 | 0.8313 | 0.4594 | 0.1463 | -0.374 | -0.6491 | -0.94564 | -0.94505 | -0.822 | -0.687 |
| 2013 | -0.115 | 0.07 | 0.8384 | 0.8022 | 0.6598 | 0.03 | -0.513 | -1.072 | -1.15059 | -1.19727 | -1.163 | -0.963 |
| 2014 | -0.457 | 0.3034 | 0.565 | 0.6314 | 0.2793 | -0.073 | -0.319 | -0.6671 | -0.81913 | -0.76202 | -0.613 | -0.408 |
| 2015 | 0.0361 | 0.4298 | 0.8043 | 0.8334 | 0.7998 | 0.5077 | -0.129 | -0.7952 | -1.01245 | -1.04395 | -1.035 | -0.949 |
| 2016 | -0.519 | 0.1115 | 0.7342 | 0.7906 | 0.5319 | 0.1712 | -0.1 | -0.589 | -0.82229 | -0.80409 | -0.71 | -0.542 |
| 2017 | -0.18 | 0.2618 | 0.8729 | 0.8812 | 0.6828 | 0.3333 | 0.0002 | -0.3354 | -0.51682 | -0.58367 | -0.502 | -0.322 |
| 2018 | -0.088 | 0.3567 | 0.716 | 0.8699 | 0.5546 | 0.0588 | -0.065 | -0.7227 | -0.88534 | -0.92545 | -0.824 | -0.604 |
| 2019 | -0.366 | 0.2995 | 0.7398 | 0.7151 | 0.5127 | -0.02 | -0.439 | -1.0101 | -1.17647 | -1.29984 | -1.254 | -1.095 |
| 2020 | -0.749 | 0.0022 | 0.1874 | 0.8235 | 0.6313 | 0.1798 | -0.183 | -0.7175 | -0.96973 | -1.01254 | -0.957 | -0.791 |

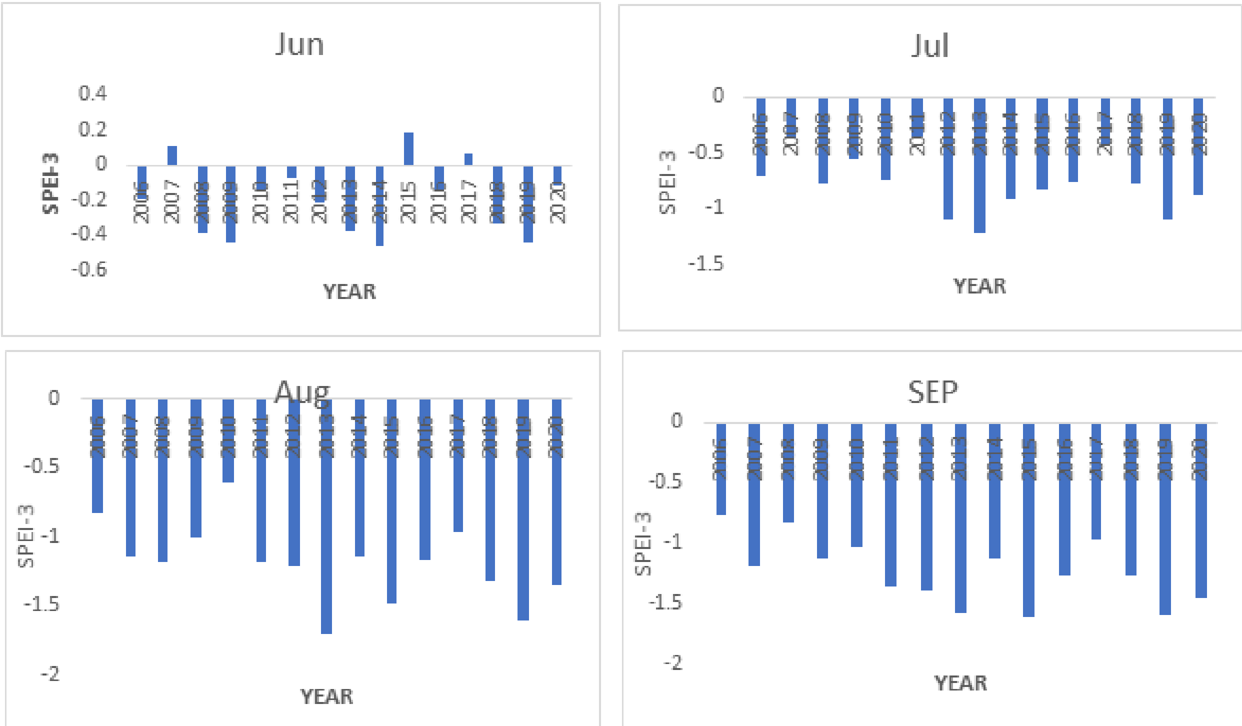


**Figure 4:** BAUCHISPEI-3 diagram for Jun, Jul, Aug, Sep

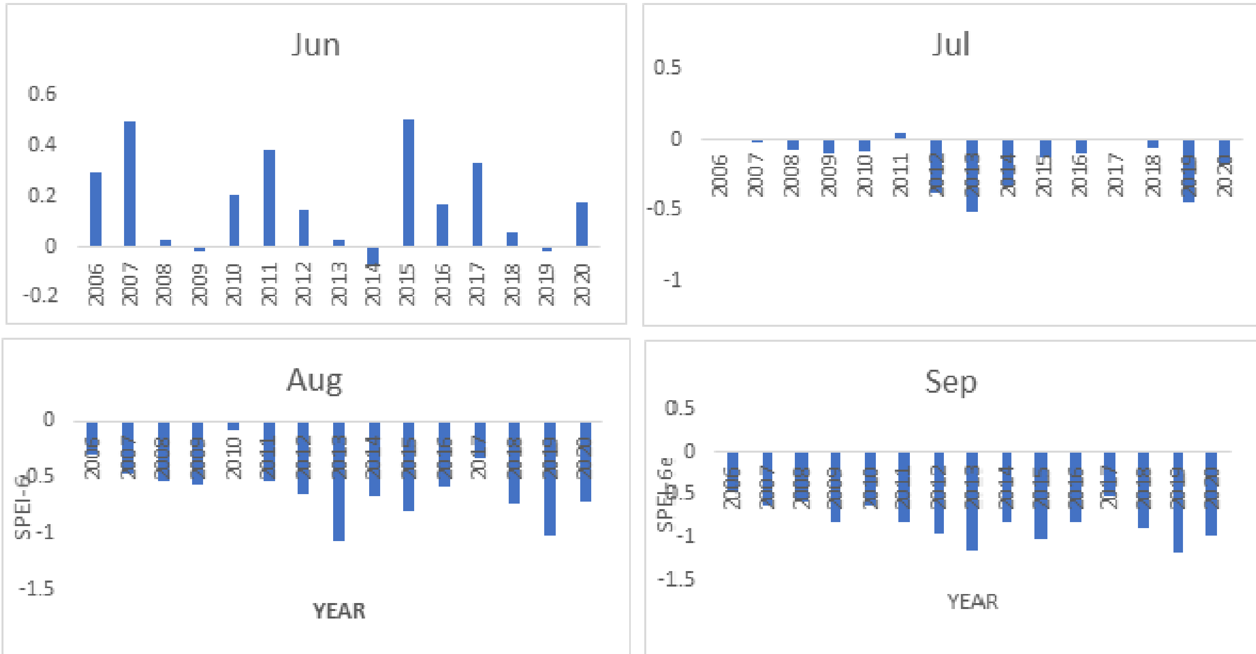


**Fig. 5:** BAUCHISPEI-6 diagram for Jun, Jul, Aug, Sep

The SPEI-3 for Gombe stations demostrates that Gombe suffered from 32 droughts episodes. Table 4 depicts January through to June and subsequently November to December as normal months. The drought analysis based on 3-months time scale for SPEI-3 (June) points to 10 mild drought years and 5 mild wet years. SPEI-3 (July) demostrate 11 mild droughts, 3 moderate droughts and 1 severe drought in 2019. In this study, SPEI-3 reflects the similar spatio-temporal characteristics in Gombe as well as Bauchi (Figure 4 and 6) as the drought severity levels observed in both sub-stations have occurrence of frequent mild drought conditions, occasional moderate droughts as well as flashes of severe drought in the August and November months. This by implication means both states are prone insufficent rainfall which can be a danger to agricultural development. This findings agree with Achugbu and Balogun (2017)

The multiscalar nature of SPEI like the SPI could also be asscoaited with seasonal to medium term trends in precipiatation as impacts stream flows, reservoir levels (WMO, 2012). Figure 5 shows that Bauchi experienced 12 years of mild wet and 3 years of mild droughts episodes (see SPEI-6 June). Like SPEI-3, the SPEI-6 (July) shows persistence of mild drought in 13 years. A glance at SPEI-6 August shows negative values. Although, the values are not extreme case of drought severity but the continued negative value indicate a likelihood of crop stress resulting from inadequte water to meet soil moisture. The mild drought years were further revealed in Figure 5 which reveals 7 consective years of mild drought (2006 to 2012) but 12 drought years in total for SPEI-6 September. Moderate droughts were also observed in between years ( 2013, 2015 and 2019).

**Table 4**: SPEI-3 for Gombe sub-station

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | | | 1.082 | 0.922 | 0.477 | 0.052 | -0.621 | -0.986 | -1.275 | -1.0116 | -0.46 | 0.6142 |
| 2007 | 0.8782 | 0.883 | 0.9 | 0.752 | 0.3877 | -0.0089 | -0.7734 | -1.172 | -1.179 | -0.621 | 0.089 | 0.855 |
| 2008 | 0.8579 | 0.883 | 0.901 | 0.741 | 0.0522 | -0.1911 | -0.4684 | -0.939 | -1.089 | -1.0223 | -0.2 | 0.4363 |
| 2009 | 0.8861 | 0.89 | 0.908 | 0.689 | -0.0896 | -0.3812 | -0.7224 | -0.892 | -0.92 | -0.763 | -0.1 | 0.3653 |
| 2010 | 0.8831 | 0.891 | 0.899 | 0.59 | 0.3816 | 0.044 | -0.4176 | -0.805 | -0.752 | -0.5837 | 0.028 | 0.2284 |
| 2011 | 0.8847 | 0.884 | 0.906 | 0.613 | 0.4621 | 0.0354 | -0.2828 | -0.845 | -0.918 | -0.627 | -0.06 | 0.5203 |
| 2012 | 0.8858 | 0.887 | 0.902 | 0.835 | 0.4375 | -0.3186 | -1.1076 | -1.519 | -1.467 | -0.996 | 0.01 | 0.6922 |
| 2013 | 0.8812 | 0.885 | 0.872 | 0.723 | 0.5112 | 0.0971 | -0.3397 | -1.433 | -1.374 | -1.2632 | 0.058 | 0.5017 |
| 2014 | 0.8833 | 0.885 | 0.902 | 0.716 | 0.0308 | -0.1309 | -0.7131 | -0.781 | -1.142 | -0.7576 | -0.33 | 0.7053 |
| 2015 | 0.8818 | 0.889 | 0.85 | 0.858 | 0.6432 | 0.0658 | -0.3828 | -1 | -1.299 | -1.206 | -0.63 | 0.2277 |
| 2016 | 0.8849 | 0.886 | 0.788 | 0.284 | 0.0847 | -0.4843 | -0.6 | -1.085 | -1.067 | -0.8301 | -0.07 | 0.8261 |
| 2017 | 0.8854 | 0.885 | 0.898 | 0.685 | 0.0591 | -0.5291 | -1.0101 | -1.052 | -1.125 | -0.6905 | -0.11 | 0.6946 |
| 2018 | 0.8821 | 0.886 | 0.9 | 0.903 | 0.0963 | -0.1066 | -0.7833 | -1.313 | -1.648 | -1.4187 | -0.63 | 0.7355 |
| 2019 | 0.8824 | 0.883 | 0.895 | 0.831 | 0.2101 | -0.9542 | -1.5044 | -1.675 | -1.326 | -1.1157 | -0.52 | -0.101 |
| 2020 | 0.8796 | 0.879 | 0.705 | 0.519 | 0.0282 | -0.5451 | -1.2729 | -1.458 | -1.538 | -1.0743 | -0.4 | 0.5038 |

**Table 5:**SPEI-6 for Gombe sub-station

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | | | | | | 0.497 | 0.113 | -0.321 | -0.756 | -0.808 | -0.723 | -0.549 |
| 2007 | -0.23 | -0.006 | 0.7898 | 0.847 | 0.667 | 0.312 | -0.06 | -0.509 | -0.696 | -0.668 | -0.592 | -0.399 |
| 2008 | 0.094 | 0.5032 | 0.9068 | 0.833 | 0.482 | 0.1928 | -0.06 | -0.414 | -0.69 | -0.75 | -0.586 | -0.422 |
| 2009 | -0.24 | 0.1826 | 0.7031 | 0.82 | 0.401 | 0.0621 | -0.04 | -0.427 | -0.647 | -0.714 | -0.514 | -0.299 |
| 2010 | -0.01 | 0.2524 | 0.6618 | 0.77 | 0.667 | 0.3451 | -0.07 | -0.202 | -0.364 | -0.462 | -0.407 | -0.212 |
| 2011 | -0.1 | 0.3297 | 0.5909 | 0.783 | 0.706 | 0.4816 | 0.026 | -0.208 | -0.404 | -0.423 | -0.383 | -0.251 |
| 2012 | 0.098 | 0.4156 | 0.7436 | 0.89 | 0.694 | 0.1049 | -0.33 | -0.83 | -1.024 | -1.042 | -0.978 | -0.725 |
| 2013 | -0.22 | 0.3185 | 0.8158 | 0.835 | 0.732 | 0.3676 | 0.027 | -0.728 | -0.827 | -0.871 | -0.832 | -0.671 |
| 2014 | -0.48 | 0.486 | 0.734 | 0.832 | 0.47 | 0.2335 | -0.02 | -0.303 | -0.708 | -0.706 | -0.537 | -0.399 |
| 2015 | -0.01 | 0.0926 | 0.812 | 0.899 | 0.799 | 0.4764 | 0.044 | -0.287 | -0.708 | -0.843 | -0.805 | -0.665 |
| 2016 | -0.42 | 0.0957 | 0.5408 | 0.612 | 0.365 | -0.054 | -0.08 | -0.592 | -0.786 | -0.69 | -0.568 | -0.299 |
| 2017 | -0.07 | 0.4104 | 0.8919 | 0.818 | 0.349 | -0.052 | -0.28 | -0.575 | -0.843 | -0.839 | -0.633 | -0.387 |
| 2018 | 0.046 | 0.2428 | 0.8295 | 0.921 | 0.509 | 0.2488 | -0.03 | -0.712 | -1.123 | -1.143 | -1.012 | -0.91 |
| 2019 | -0.64 | 0.0917 | 0.8473 | 0.887 | 0.571 | -0.177 | -0.74 | -1.033 | -1.152 | -1.335 | -1.253 | -0.843 |
| 2020 | -0.33 | -0.052 | 0.1792 | 0.733 | 0.327 | 0.1031 | -0.57 | -0.919 | -1.149 | -1.175 | -1.042 | -0.836 |

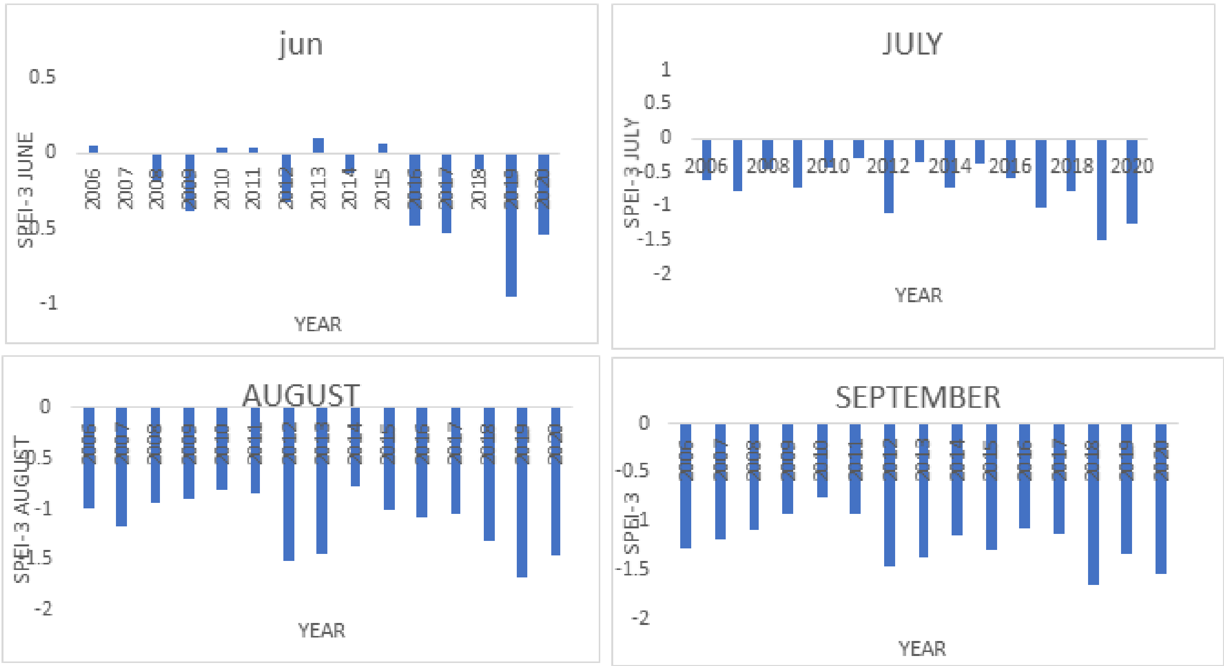


**Fig. 6:** GOMBESPEI-3 diagram for JUN, JUL, AUG, SEP

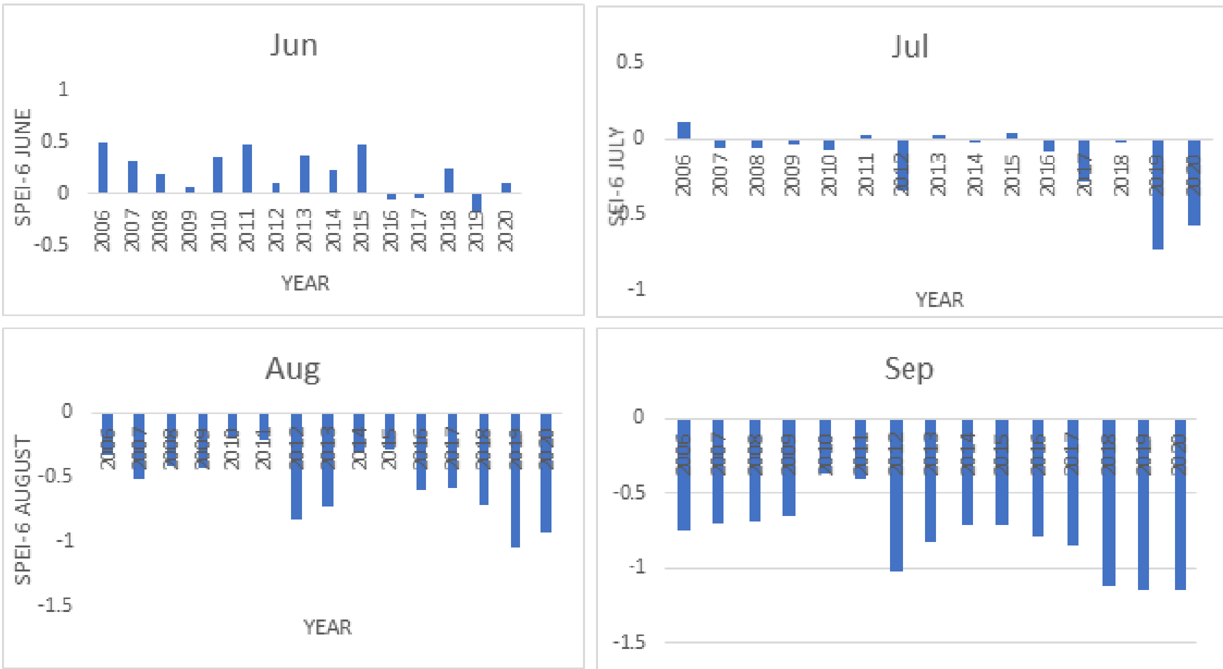


**Fig. 7:** GOMBESPEI-6 diagram for JUN, JUL, AUG, SEP

## 4. Conclusion

This study was undertaken to evaluate the severity of droughtsin some selected parts of northern Nigeria which fallswithin the Sudan-Sahelbelt.Temporal variability of both meteorological and agricultural droughts at seasonal scale were also investigated and results showed that mild droughts were the most dominant drought category in the area of study with constant presence. The years 2012, 2013, 2015 and 2019 qualified as the most drought prone years by SPEI-3 and SPEI-6. However there was no record of extreme drought conditions except flashes of severe droughts which was observed in 2019 that also happened to be the driest year. The study furtrher showeda similar temporal variation of both stations under study as the drought spatio-temporal characteristics have a similar trend. It can be concluded that better judegement of the drought ocurrence and its impact on agriculture and water resources can be obtained using both the SPEI-3 and SPEI-6.

**References**

Abaje, I.B. (2007). Introduction to Soils and Vegetation. Kafanchan: Personal Touch Productions

Abaje, I.B., Ati, O.F. and Iguisi, E.O. (2012a). Changing Climatic Scenarios and Strategies for Drought Adaptation and Mitigation in the Sudano-Sahelian Ecological Zone of Nigeria. In: M.A. Iliya and I.M. Dankani, eds. Climate Change and Sustainable Development in Nigeria. Ibadan: Crown F. Publishers. Ch.5

Abaje, I.B., Ati, O.F., Iguisi, E.O., and Jidauna, G.G. (2013). Droughts in the Sudano-Sahelian Ecological Zone of Nigeria: Implications for Agriculture and Water Resources Development. *Global Journal of Human Social Science* 13 (2): 12–23.

Abramowitz, M., and I. A. Stegun, 1965: Handbook of Mathematical Functions, with Formulas, Graphs, and Mathematical Tables. Dover Publications, 1046 pp.

Achugbu, I.C. and Anugwo, S.C (2016). Drought trend analysis in Kano using standardized precipitation index. FUOYE Journal of Engineering and Technology. Vol.1, issue 1

Achugbu, I.C. and Balogun, I.A. (2018). Spatial-Temporal characteristics of drought in Northern Nigeria. Global Journal of Pure and Applied sciences. Vol.24, pg 81-89.

Adeaga, O. (2011). Drought risks and impact on water resources in part of Northern Nigeria: Hydro-climatology: Variability and Change (Proceedings of symposium J-H02 held during IUGG2011 in Melbourne, Australia, July 2011) (IAHS Publ. 344, 2011).

Adeniyi, M.O., and Uzoma, E.K. (2016). Assessment of severity of drought in some Northern Nigerian states using Drought Severity Index ($DSI_5$). Ghana Journal of science, Technology and Development. Vol.4, Issue 2.

Chibueze, N. (2016). Historical Analysis of the Economic Effect of Drought on Tropical Forest Management in Northern Nigeria. J Pol Sci Pub Aff 4: 214. doi:10.4172/2332-0761.1000214

Duru, J.O. (1984). Blaney-Morin Nigeria. Evapotranspiration Model. Journal of Hydrology, Vol. 70, pp. 71-83.

Eze, J.N. (2018). Drought occurrences and its implications on the households in Yobe state, Nigeria. Geoenviron Disasters 5, 18 https://doi.org/10.1186/s40677-018-0111-7

Faye, C., Grippa., & Wood, S. (2019). Use of the standardized precipitation and evapotranspiration index (SPEI) from 1950 to 2018 to determine drought trends in the Senegalese territory. Climate Change, 2019, 5(20), 327-341.

Idike, F.I. (2005). Blaney-Morin-Nigeria (BMN) evapotranspiration model (A technical Note). Niger. J. Technol. 24(2):101-104

Mishra, A. K. and Desai, V.R. (2005). Drought forecasting using stochastic models. Retrieved from https://www.researchgate.net/publication/226230747

Narendra, D., Swapnil, V., Pulak, G., Shweta, M., Nivedita, T., Balasubramanian, R. and Chattopadhyay, N. (2018). Drought monitoring over India using multi-scalar standardized precipitation evapotranspiration index. Journal of Indian Institute of Tropical Meteorology (IITM)

Okorie, F.C. (2003). Studies on Drought in the Sub-Saharan Region of Nigeria Using Satellite Remote Sensing and Precipitation Data.

Sepulcre-Canto, G., Horion, S., Singleton, A., Carrao, H., and Vogt, J. (2012). Development of a Combined Drought Indicator to detect agricultural drought in Europe. Natural Hazards Earth System Sciences, 12, 3519–3531

Potopova, V., Stepanek P., Mozny M., Turkott L., Soukup J. (2015). Performance of the standardized precipitation evapotranspiration index at various lags for agricultural drought risk assessment in the Czech Republic. Agr. Forest Meteor., 202, 26-28

Vicente-Serrano, S. M., Beguería, S. and López-Moreno, J. I., (2010). A multi-scalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index, Journal of Climate, 23, 7, 1696-1718

Wilhite, D. A., Hayes, M. J. & Svoboda, M. D. (2000) Drought monitoring and assessment: status and trends in the United States. In: Drought and Drought Mitigation in Europe (ed. by J. V. Vogt & F. Somma), 149–160. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Yue, Y., S. Shen, and Q. Wang. 2018. Trend and variability in droughts in Northeast China based on the reconnaissance drought index. *Water* 10 (318): 1–17.

Zulfiqar, A., Ijaz, H., and Muhammed, F. (2019). Annual characterization of regional hydrological drought using auxiliary information under global warming scenario. Journal of Natural Hazard and Earth System Sciences. Retrieved from http://doi.org/10.5194/nhess-2018-373

# SUB-THEME 6:

# WATER SECURITY AND GOVERNANCE

# HYDRAULIC MODEL APPLICATION OF HARDY CROSS PIPE NETWORK ANALYSIS FOR IMO STATE WATER AND SEWERAGE CORPORATION (ISWSC)

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**Abstract**

Water modeling is becoming an increasingly important part of hydraulic engineering. One application of hydraulic modeling is pipe network analysis, using programmed algorithms and computer softwares of HydraulicCAD, WaterCAD V8i, WaterGEMS V8i and EPANET that can repeatedly solve continuity and energy equations, thus reducing the amount of time required to analyze a closed conduit system. These hydraulic models remained valuable tools for water systems development. The Hardy Cross method as the pioneer systematic network analysis which permits the computation of rates of flow through a network and resulting head losses until acceptable hydraulic balance is achieved. Simultaneous loop flow technique connection in each pipe was considered to calculate head losses, node pressures, losses due to pipe fittings, e.g, valves, pipe boards, elbows, etc, using the equivalent length of pipe method. The water works of ISWSC was adopted as a case study. The network has sixteen fixed grade nodes (16NF) and twenty four pipes (NP24) which are connected to form nine loops (9NL) and nine paths for pseudo (9PS-L) geometric data for the network analysis in order to simplify the network/demands at the nodes computations in all pipe heads. This study is with 10,000 iterative and analytically generated average value from pipe diameter d (m), length l (m), Weisbach resistance r, pipe flow rate Q($m^3/s$), headloss $h_l$ (m), flow component $2h_l/Q$ ($ms^{-2}$), friction factor f and self cleansing velocity, $V_{cl}$ (m/s) as 1.46, 354.17, 2366.52, 0.25, 158.7, 258.97, 0.0242 and $\geq$ 0.6 respectively using the Darcy-Weisbach methodology. This model is recommended for hydraulic model simulation in our water corporation.

**Keywords**: Pseudo geometric data, iterative values, hydraulic balance and hydraulic model simulation.

## Introduction

Water supply is the provision of water by public utilities, commercial organizations, community endeavors, or by individuals, usually via a system of pumps and pipes, through water (aquifers) surface water (lakes and rivers) conservation and the sea desalination. Treated water flows either by gravity or pumped reservoirs, which can be elevated in water towers, (Ingeduld and Zdenek, 2006).

Water modeling is becoming an increasingly important part of hydraulic engineering. One application of hydraulic modeling is pipe network analysis, using programmed algorithms and computer softwares of HydraulicCAD, WaterCAD V8i, WaterGEMS V8i and EPANET that can repeatedly solve continuity and energy equations, thus reducing the amount of time required to analyze a closed conduit system. These hydraulic models remained valuable tools for water systems development.

Pipe network analysis is an important hydraulic exercise in the design and management of water distribution systems. A number of methods of pipe network analysis have been developed over the years and formed the basis for analyzing flow and pressure in pipe networks, (Lee, 1983).

The Hardy Cross method is the pioneer systematic network analysis which permits the computation of rates of flow through a network and the resulting head losses in the system (Cross, 1936). It is a relaxation method by which corrections are applied to assumed flows or assumed heads until acceptable hydraulic balance of the system is achieved. It is a single path method in which, for the loop variation of the method, the head loss function is linearized.

The Hardy Cross method is an iterative method for determining the flow in pipenetwork systems where the inputs and outputs are known, but the flow inside the network is unknown. Efforts have been made in the past to implement the method using different programming technique and adaptation of the moment distribution method for determination of moments in indeterminate structures. (Ernest and Horage, 2000; Fox, 2005; Jeppson, 2010; Lopes, 2013; Coulson and Richardson, 2015).

**Water Transmission and Distribution**

Water transmission is usually achieved through canals, aqueducts, tunnels and pipelines. Though investigations carried out on African waters reviewed significant contamination of their waters (Egborge and Fagade, 1999). Undoubtedly, wastewaters from industries and residential areas discharged into another environment without suitable treatment could disturb the ecological balance of such an environment, Okpala, 1980; Botkin and Kelly, 1998; Onyenechere, 2011; Mohapatra et al., 2012).

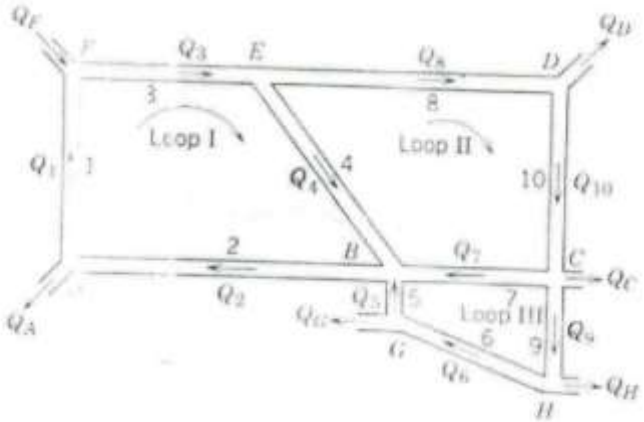


**Figure 1.1:** Pipe network distribution system

Consider the pipe network distribution system in Figure 1.1, using capital letters for A-H for pipe junctions, 1-10 for individual pipes while I-III are donated for closed circuits. Flows are assumed to be clockwise around each loop. Pipes 1, 3, 4 and 2 comprise loop 1, Pipes 2, 8, 10, 7 comprise loop 2, Pipe 4 is common to both loops. Solution to any network problem must satisfy continuity and energy principles throughout the network. Bernouli principle requires that at any junction only one EGL is possible and any head loss around any single loop must bezero. Applying this to each loop and junction results in a series of simultaneous method of Equations (1.1 - 1.6) assuming that pipe sizes, length, hydrauliccharacteristics, inflows and outflows, and elevations are known.

$$\sum_{A} Q = -Q_A + Q_2 - Q_1 = 0 \quad (1.1)$$

$$\sum_{F} Q = Q_1 + Q_F - Q_3 = 0 \quad (1.2)$$

$$\sum_{E} Q = Q_3 - Q_4 - Q_8 = 0 \quad (1.3)$$

$$\sum_{B} Q = -Q_2 + Q_4 + Q_7 + Q_5 = 0 \quad (1.4)$$

$$\sum_{I} h_l = r_1 Q_1^n + r_3 Q_3^n + r_4 Q_4^n + r_2 Q_2^n = 0 \quad (1.5)$$

The solution is by trial and error with reasonable set of guesses, $\sum_{i=0}^{10} Qi$, that satisfied continuity equation and then iterate, until head loss is satisfied.For a pipe that is only in one loop then,

$$Q_i = Q_n \pm \Delta_L \quad (1.6)$$

where ($\pm$) depends on the directions for each assumed Qi.

## Methodology

Applying Hardy Cross multiple distribution system in ISWSC supply system, thevarious size pipes, geometric orientations, hydraulic characteristics, pumps, valves fittings, etc were considered. Applying Equations (1.1 – 1.6) in formulating the model using iterative solution method which involves repeated acceptable tolerance values.

Although, Newton-Raphson method is also considered for solving the network problems based on computational procedure, takes into account loops of common pipes, yet the application of hydraulic simulation method covers both hardy cross and Newton-Raphson methods, (WaterCAD-Spec, 2015; Elsheikh et al. 2018; Wood, 2019).

HhydraulicCAD, WaterCAD V8i, WaterGEMS V8i and EPANET used as the hydraulic modelling softwares generated the iterative model simulation values, Table 3.1, with Darcy-Weisbach Methodology in Equations (2.1 and 2.2).

$$h_l = rQ^2 \quad (2.1)$$

$$r = \frac{8fl}{\pi^2 g D^5} \quad (2.2)$$

Where; $r$ = Weisbach resistance, $f$ = Weisbach friction factor (0.0242), $l$ = pipe length (m), $g$ = gravitational constant (9.81 ms$^{-2}$), $D$ = pipe diameter (m), $\pi$ = pie factor (3.142), $Q$ = flow rate discharge (m$^3$/s) and $h_l$ = headloss (m).



The network, Figure 2.1, has sixteen fixed grade nodes *(NF=16)*, and twenty four pipes (NP=24) which are connected to form nine loops *(NL=9)* and nine path (or pseudo loop) *(NF-l=9)*. The geometric data for the network is shown in Table 3.1. In order to simplify the network/demands at the nodes, pumps and pressure reducing valves were not included. This enabled an exact solution for flows in all pipes and heads at the nodes to be determined analytically.

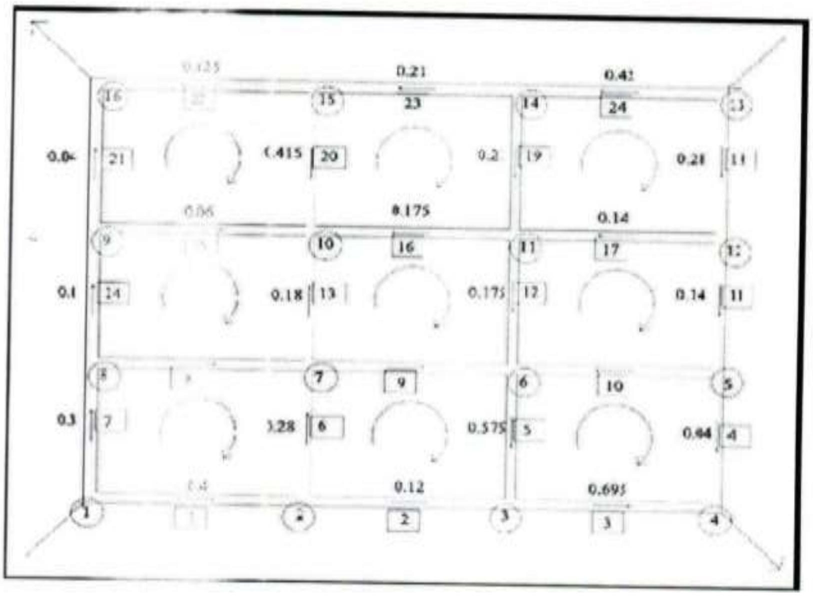

**Figure 2.1:** Network analysis with pipe length, discharge, nodes with loops

**Results and Conclusion**

**Result**

The results from simultaneous loop flow model technique simulations with applied hydraulic modeling softwares observed with Darcy-Weisbach method, Equations (2.1 and 2.2) for the 24 pipes iterative model application is shown in Table 3.1.

**Table 3:1:** Iterative model simulation values

| **Pipe** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|
| $D$ **(m)** | 0.30 | 0.15 | 0.30 | 0.30 | 0.20 | 0.20 | 0.30 | 0.60 |
| $l$ **(m)** | 700 | 300 | 400 | 350 | 350 | 200 | 300 | 500 |
| $r$ | 576 | 7901 | 329.22 | 288.06 | 2787.5 | 1250 | 246.91 | 38.58 |
| $Q$**(m$^3$/s)** | 0.40 | 0.12 | 0.695 | 0.04 | 0.575 | 0.28 | 0.30 | 0.20 |
| $h_l$**(m)** | 92.18 | 113.77 | 159.02 | 0.46 | 723.24 | 98.00 | 22.22 | 1.54 |
| $2h_l/Q$ **(m$^2$/s)** | 460.9 | 1.896 | 457 | 23 | 2.512 | 700 | 148 | 15 |
| **Pipe** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***D*** **(m)** | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.30 | 0.30 | 0.15 |
| ***l*** **(m)** | 200 | 200 | 200 | 200 | 200 | 350 | 800 | 200 |
| ***r*** | 5207.5 | 5267.5 | 5267.5 | 5267.5 | 5267.5 | 288.06 | 658.43 | 5267.49 |
| ***Q*** **($m^3$/s)** | 0.10 | 0.14 | 0.175 | 0.175 | 0.18 | 0.10 | 0.06 | 0.175 |
| $h_l$ **(m)** | 253.12 | 52.67 | 161.32 | 161.32 | 170.67 | 2.88 | 2.37 | 161.32 |
| $2h_l/Q$ **($m^2$/s)** | 1.687 | 1.2053 | 1.844 | 1.844 | 1.896 | 58 | 79 | 1.855 |
| **Pipe** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| ***D*** **(m)** | 0.15 | 0.15 | 0.15 | 0.30 | 0.30 | 0.30 | 0.15 | 030 |
| ***l*** **(m)** | 200 | 300 | 200 | 350 | 500 | 600 | 300 | 600 |
| ***r*** | 5267.49 | 7901.23 | 5267.49 | 288.06 | 411.52 | 493.83 | 7901.23 | 493.83 |
| ***Q*** **($m^3$/s)** | 0.11 | 0.28 | 0.21 | 0.415 | 0.04 | 0.625 | 0.21 | 0.42 |
| $h_l$ **(m)** | 103.34 | 619.15 | 232.30 | 49.61 | 0.66 | 192.90 | 348.44 | 87.11 |
| $2h_l/Q$ **($m^2$/s)** | 737 | 3.425 | 2212 | 239 | 33 | 617 | 3.318 | 415 |

## Conclusion

It has been established from this study that Hardy Cross and Newton-Raphson methods have been modified using HydraulicCAD, WaterCAD V8i, WaterGEMS V8i and EPANET for solving complex pipe network problems. Geometric and pseudo geometric orientations generated fom the softwares resulted to more reliable model simulated values. The Weisbach resistance, gravitational constant and friction factor involved in the model techniques as pseudo factors helped in the generated twenty four (24) complex pipes iterative models with minimum error. From Table 3.1, the twenty four (24) pipeline network analysis showed average values of $D = 1.46m$, $l = 354.17\ m$, $r = 2366.52$, $Q = 0.25m^2/s$, $h_l = 158.73m^2/s$ and $2h_l/Q = 258.97$. The study recommends that more than 10,000 iterations be applied in more than 24 network pipes for ISWSC and many other cities.

## References


Botkin, D. B. and Kelly, E. A. (1998). Environmental Science; Earth as a living Plant. 2nd edn. John Wiley and Sons USA: pp. 420-424.

Coulson, J. M. and Richardson, T. F. (2015). Chemical Engineering, 1. 6th ed. Butterworth Heinemann, Oxford. pp. 62-142.

Cross, H. (1936). Analysis of Flow in Networks of Conduits or Conductors, Univ. Bull. pp. 286.

Egborge, A. B. M. and Fagade, S. O. (1999): Notes on the Hydrobiology of the Wikki Warm Spring, Yankari Game Reserve, Nigeria. Pol. ArchHydobiol. 23: pp. 313-322.

Elsheikh, M. A., Salem, H. I., Rashwan, I.M. and El-Samadoni, M. M. (2018). Hydraulic Modelling of Water Supply Distribution for Improving its Quality, Sustain. Environ. Res., 23(6), pp. 403-411.

Ernest, F. B. and Horage, W. (2000). Hand book of Hydraulic Engineering Problems, 6th ed. McGrawHill, New York. pp. 6-60. 1976.

Fox, J. A. (2005) Hydraulic Analysis of Unsteady Flow in Pipe Networks, the Macmillan PressLtd, London and Basingstoke.

http://hydraulicd.com as Retrieved on August 21, 2014.

Ingeduld, P. and Zdenek, S. (2006). Modeling intermittent water supply systems with EPANET, 8th annual WD symposium EPACincinnati.

Jeppson, R. W. (2010). Analysis of Flow in Pipe Networks, Ann Arbor Science Publishers, INC., Ann Arbor, Michigan.



Lee, M. F. (1983). Pipe Network Analysis. Project report, University of Florida, USA, 1983.

Lopes, A. M. G. (2013). Implementation of Hardy-Cross Method for the Solution of Piping Networks. ADAI-Departamento de Engenharia Meca" dade de Coimbra, 3030 Coimbra, Portugal. 2003.

Mohapatra, S., Kamble, S., Sargaonkar, A. and Labhasetwar, P. K. (2012). Efficiency Study of a Pilot Water Distribution System Using EPANET *), Conference CSIR-NEERI.*

Onyenechere, C. F. (2011). Water and Sanitation Service Provision in Owerri City, Nigeria.

Okpala, D. C. E. (1980). Water Supply Constraints on Nigeria's Economic Development: The Example of Anambra State. Third World Planning Review, 2 (2), 170-186.

Wood, D. J. (2019) Algorithms for pipe network analysis and their reliability. University of Kentucky, Water Resources Research Institute Research Report 7, 1981.

WaterCAD-Spec/www.bentley.com, Retrieved on January 6, 2015. www.bentley.com/WaterGEMS-Spec as Retrieved on January 24, 2015.

# IMPACT OF UPSTREAM WATER ABSTRACTION ON RESERVOIR STORAGE, YIELD AND OPERATING RULES

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**Abstract**

*Water managers often struggle to manage the limited resource in the face of hydrological and infrastructural constraints without incorporating the impact of human behaviour. For example, the co-evolutionary dynamics between reservoir performance and upstream human activities relating to water abstraction are still not well-understood. Conventional reservoir yield analysis entails assessing the system's yield potential under hydrological and physical constraints for a given operating rule which can fail to assess the actual dynamics of the system, as the impacts due to unlawful human activities are not realistically and quantitatively incorporated. It is only recently that socio-hydrology; the study of the co-evolutionary dynamics of human-water systems that aims for more human-centred water governance has been formalized. This study employed the concept of socio-hydrology to coupled and simulated reservoir water balance model with hypothetical reservoir upstream water abstraction to assess the impact of such illegal activities on reservoir storage, yield and operating rules via simulation-optimization modelling using three scenarios; conventional reservoir analysis, high and low users' compliance ($UC_1$ and $UC_2$). A trigonometric function was used to parsimoniously definereservoiroperatingrulecurvesusing the Shuffled Complex Evolution (SCE-UA) optimization method. The coupled model was applied to Eland River Water Management Area, South Africa. The storage trajectories revealed how water was massively abstracted at reservoir upstream in $UC_1$ than $UC_2$ and conventional scenarios.The yields obtained from the optimized operating rules in conventional, $UC_1$ and $UC_2$ scenarios were 49.4, 42.9 and 48.1% of the total runoff into the reservoirs with the corresponding yield reductions of 0.0, 2.6 and 13.2% respectively. This revealed how human behaviour can affect reservoir storage, operating rules and yield which stressed the need to incorporate the impact of reservoir upstream water abstractions while developing operating rules.*

**Keywords*:*** Operating rules, Reservoir storage, Reservoir upstream, Water abstraction, Yield

## Introduction

Water management tasks are increasingly becoming challenging due to hydrological uncertainties, infrastructural constraints, demand dynamics and a notable decrease in human ethical practices. Previously, water management has been regarded as effective if it guarantees a reliable and cost-effective water supply. However, sustainable water management needs to incorporate the dynamics of the changing societal norms and values as these can significantly impact management performance (Shanono, 2020). For example, the causes and effects of water users' unlawful activities relating to water abstractions (*the ethics of water use*) are usually not explicitly incorporated (Groenfeldt, 2013;Shanono, 2021). In many countries, efforts for preventing unlawful water use in the form of proposals have been incorporated in their water management strategies (Beumer *et al*., 2011), however, their implementation remains elusive. The quantitative integration of the effects of human behaviour into water management analysis as explained in the concept of socio-hydrology (Sivapalan *et al*., 2012) could lead to more effective water governance. Thus, scenarios that quantitative integrate the impact of human behaviour can guide the development of more effective water policies (Walker *et al*., 2001).

The concept of Integrated Water Resources Management is known to promote sustainable water management (Hooper, 2006). However, it does not incorporate the impacts due to the co-evolutionary dynamics and interactions between human and water systems (Montanari *et al.*, 2013). The task of reservoir analysts involves predicting future challenges due to hydrological and demand uncertainties and proposing alternative solutions to attain a balance between water availability and demand(Loucks *et al.*, 2005). This has been the practice and the concept of socio-hydrology intend to change such business-as-usual by incorporating the impact of inevitable human behaviour such as water abstraction at reservoir upstream (van Oel *et al*., 2008;Shanono et al., 2019;Shanono, 2021). Such water abstraction at reservoir upstream can have significant negative impacts on the water management performance.

Several studies have reported how human activities adversely affected water system performance, and these can be grouped into; i) unlawful use, ii) wastage, iii) discharging untreated wastewater and chemicals into watercourses and iv) collusion incidences (Plummer & Cross, 2006; Hermann-friede *et al*., 2014;Shanono et al., 2015;Shanono et al., 2020). Although these incidences have been reported and documented, their incorporation into reservoir system analysis remains elusive. This study seeks to integrate the hydrological, physical and human behaviour in the reservoir yield analysis model (reservoir water-balance). Section 2 describes the conceptualization of the reservoir socio-hydrological model while the results and conclusions are in sections 3 and 4.

**Reservoir Operation Socio-Hydrological Model**

Decision making relating to reservoir operation would be expected to improve if the causes and effects of changing human behaviour are explored, well-understood and realistically incorporated into reservoir operational analysis. One of the causes of changing human behaviour is the perception of risk which has been considered as an inherent part of decision-making (Williams & Noyes, 2007). According to Kinzig et al. (2013), the perceived level of risk by a given society can interrupt and change that society's established norms. Drought for example can escalate water use by irrigators due to perceived threat to crop yield and hence, their wellbeing (Firoz et al., 2017). The low reservoir storage commonly experienced in drought periods are made worse by large abstractions upstream of reservoirs (van Oel et al., 2008). Therefore, the reservoir operation socio-hydrological simulation model is based on the causal relationships of the following perceptions: i) reservoir hydrological state affect users' wellbeing and hence, their propensity to compliant/unlawful activities relating to water abstractions, ii) unauthorized water abstraction affects the performance of the reservoir system, iii) the effects on reservoir performance prompt commensurate corrective activity by the water managers and iv) the corrective activity affects the reservoir hydrological state which in turn affects the users' wellbeing and propensity to compliant/unlawful activities. The state variables in the modelling are the hydrological state, users' wellbeing, users' compliance and management actions.

Since droughts are usually inter-decadal multi-annual events, a year is an appropriate time step for the hydrologic state of a reservoir system and is adopted here. In drought periods, reservoir storage declines, the users' perceived risk rises, thereby increasing their propensity to unlawful water abstractions. The main hydro-climatic variables known to affect storage are inflows, rainfall and evaporation. The normalised annual values of rainfall, temperature and storage are therefore used to indicate the annual hydrological state. The annual rainfall, temperature and storage are normalised using feature scaling normalisation to range between -1 and +1 and the hydrological state is then obtained as a weighted average of the three normalized variables. The weighting recognizes that increasing temperature has an adverse effect on the hydrological state and its normalized value is therefore subtracted. The values of the weights ($w_P$, $w_S$ and $w_T$) could be set based on the climatic conditions and their likely impacts on the water demand, and the location vulnerable to unlawful abstraction in relation to the reservoirs and other factors.

The occurrence of unlawful water abstraction is considered to depend on the level of water users' compliance (UC). The UC is modelled as a normalised stochastic variable that ranges from 0 to 1 and unlawful water abstraction occurs if the UC falls below a set threshold ($\varphi$) within this range. The intention of individuals and therefore the level of compliance to set rules has been found to depend on the level of perceived risk (RP) (Williams & Noyes, 2007) and this dependence is included in the modelling. The RP is considered to be negligible for zero or positive hydrological states (HS). For negative HS, the RP is considered to depend on the severity of water shortage as quantified by the hydrological state, the users' wellbeing and the management competence and was modelled as a function of these variables. In order to obtain a normalized quantification of UC and its dependence on RP logistics functions (Komarek & Moore, 2005) are used. Two basic forms of logistics functions (Eqn. 1 and 2) are used to obtain convex and concave relationships between UC and RP as shown in Figure 1. By varying the logistics model shape parameter (τ), the desired relationship between RP and UC can be obtained. Parameter τ therefore indirectly account for the ability to activate virtues on compliance. The convex relationship (observed from the origin) is applicable for users whose tendency to withdraw water unlawfully is highly vulnerable to the risk perception while the concave relationship would apply for users who have much higher abilities to act virtuously and not abstract water illegally even when faced with high levels of risk perception.

$$UC_1 = 2\left(\frac{1}{1+e^{\tau RP}}\right) \qquad (1)$$

$$UC_2 = 1 - 2\left[\left(\frac{1}{1+e^{\tau(1-RP)}}\right) - \left(\frac{1}{1+e^{\tau}}\right)\right] \qquad (2)$$

Where: $UC_1$and $UC_2$= low and high levels of users' compliance, *RP* = risk perception, $\tau$= virtue activation parameter.

Threshold$\varphi$,is a decision boundary between the possibilities for compliant and unlawful activities relating to water abstraction as expressed in Eqn. 3.

$$If\begin{cases} UC_i \geq \varphi; Unlawfulwaterabstraction(UI_i)doesnotoccur \\ UC_i < \varphi; \quad Unlawfulwaterabstraction(UI_i)occurs \end{cases} \qquad (3)$$

Where; $UC_i$ = user compliance and $\varphi$ is the threshold.

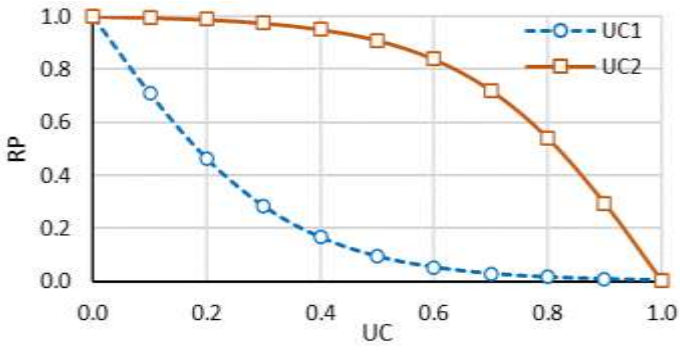


**Fig. 1:** Compliance-risk perception relationships for various virtue activation characteristics of $\tau = 7$, obtained from Eqn. 1 and 2

The model was applied to a hypothetical but realistic reservoir system using a 90-year monthly historic hydrologic dataset and configuration of the Elands River reservoir system (Rust de Winter, and Mkhombo dams) in South Africa.Eqn. 4 shows reservoir mass balance incorporating the effects of unlawfulabstractions upstream of the dams and used to assess the impact of humans by comparing the differences between the reservoir storages, yields and operating rules when upstream water abstraction was included, and when it was not. The system was simulated using the commonly used operating rules that maintain high storage states in the upstream reservoirs. The monthly allocated supply from each reservoir and the regulated supply from the upstream to the downstream reservoir depended on the monthly demand (set to vary to reflect the monthly variation in irrigation water demand), the month of the year, total storage state, and storage of each reservoir. The reservoir operation was based on four restriction zones, within which supply allocations of 100, 80, 50 and 30% of the monthly demand could be made. 3 scenarios were used during the simulation; conventional reservoir analysis, high UC ($UC_1$) and low UC ($UC_2$).

$$S_{i,j+1,k} = S_{i,j,k} + \left(1 - UI_{u,i,j,k}\right)Q_{i,j,k} - R_{i,j,k} - NE_{i,j,k} - SP_{i,j,k} \quad (4)$$

$$0 \leq S_{i,j,k} \leq C_k$$

Where: $S_{i,j,k}$ and $S_{i,j+1,k}$, = storage of reservoir $k$ at month $j$ and $j+1$ of year $i$ respectively. $Q_{i,j,k}$ = natural inflow to reservoir $k$ in month $j$ of year $i$; $R_{i,j,k}$ = allocated supply to demand from reservoir $k$ in month $j$ of year $i$. $UI_{u,i,j,k}$ = proportions of upstream inflows unlawfully abstracted in month $j$ of year $i$ at the upstream and downstream of reservoir $k$ respectively. $NE_{i,j,k}$ and $SP_{i,j,k}$= net evaporation losses and spills of reservoir $k$ in the month $j$ of year $i$. $C_k$ is the capacity of reservoir $k$.

The reservoir operation rule curves were optimized using trigonometric function and Shuffled Complex Evolution (SCE-UA) optimization method that maximizes reservoir yield. The SCE-UA (Duan *et al*., 1992,1994) is a population-based evolutionary, and heuristic global optimisation method that combines deterministic and stochastic search approaches. The system yield as a performance indicator was computed and maximized as the percentage of the ratio of the total delivered supply to the total runoff as in Eqn. 5.

$$maximize\, Y = \frac{\sum_{i=1}^{T}\sum_{j=1}^{12}\sum_{k=1}^{N} R_{i,j,k}^{a}}{TR} X100 \quad (5)$$

Where: $Y$ = system yield, $R_{i,j,k}^{a}$ = allocated supply from the reservoir $k$in the month $j$ of year $i$. $TR$ = total runoff into the reservoirs for the entire simulation period; $N$ and $T$ is the number of reservoirs and years of simulation respectively.

## Results and Discussions

### Impact of upstream water abstractions on reservoir storage

Figure 2 shows 90-year trajectories of the total annual storage for the conventional reservoir analysis, low and high UC scenarios ($UC_1$ and $UC_2$). The storage showed how water was massively abstracted at reservoir upstream in $UC_1$ compared to the $UC_2$ scenario. However, the effect of upstream water abstraction is more manifested in years with low storages. Thus, massive water abstraction was found to correspond with the drought years due to an increased water users' perceived risk. Thus, upstream water abstractionsare more likely to occur during a poor hydrological state thereby reducing the reservoir storage. For that reason, the model revealed how a change in climatic variables and hydrological processes can significantly affect water users' behaviour due to perceived threat to loss of crop yield, income and hence, quality of life.

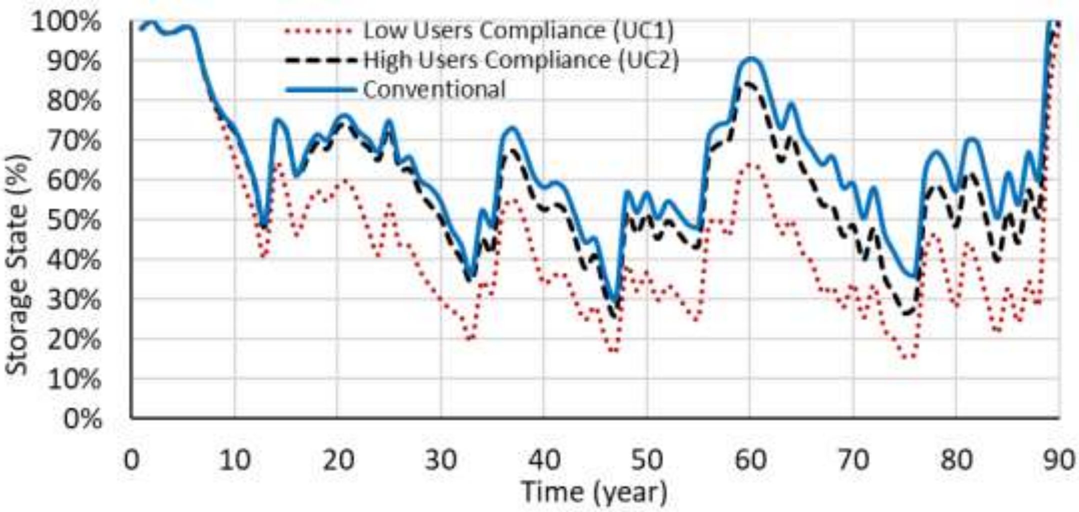


**Fig. 2:** Total annual storage trajectories for conventional, $UC_1$ and $UC_2$ scenarios

### Impact of upstream water abstractions on reservoir yield

The yield was optimized using Eqn. 5 and the yields achieved from $UC_1$ and $UC_2$ scenarios were found to be less than the yield obtained from the conventional scenario and by default assumes perfect human behaviour. Table 1 and figure 3 show the optimized yield and yield reduction as a result of upstream abstractions. The optimized yield for conventional, $UC_1$ and $UC_2$ scenarios were 49.4, 42.9 and 48.1% with the corresponding yield reductions of 0.0, 2.6 and 13.2% respectively. The yield reduction of 13.2% in $UC_2$ approximates the obtained annual water-scarcity probabilityof10% as a result of upstream water abstractions (VanOel*et al*., 2008).

Table 1: Optimized yield and yield reduction for the 3 scenarios

| **Scenarios** | **Optimize Yield (%)** |
|---|---|
| Conventional | 49.4 |
| High Compliance (UC1) | 42.9 |

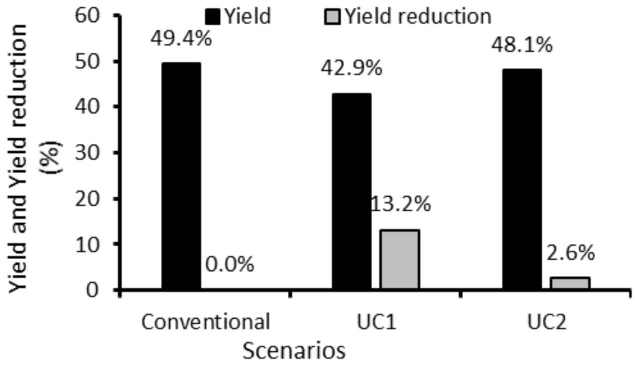


Figure 3: Optimized yield and yield reduction for the 3 scenarios

**Impact of human behaviour on reservoir operating rules**

Figure 4 presents the optimised operating rule curves for Rust de Winter and Mkhombo dams obtained from the optimisation runs that gave the best objective function (yield) for conventional and $UC_2$ scenarios. For Rust de Winter dam, the upper rule curve at the beginning of the water year were 0.55 and 0.62 for conventional and UC2 scenarios. The relatively higher value of 0.62 in $UC_2$, is attributed to unlawful abstractions upstream which reduces the storage. Thus, when the storage decreases, the operating rule curves will rise, and subsequently increase the possibility of implementing supply restrictions. The curves also continue to rise progressively with the highest minimum storage level to supply 100% of 0.78 and 0.95 for conventional and $UC_2$ scenarios respectively. Thus, the yield is expected to be higher in the conventional scenario when compared to the $UC_2$ scenario. Another example is, 50% of the monthly allocation will be released in the $5^{th}$ month at a storage state of 0.50 for conventional scenario whereas only 30% of the monthly distribution will be released in the $5^{th}$ month at the same storage state (0.50) for $UC_2$ scenario. Similar operating rule cures were also obtained for the Mkhombo dam. Hence, reservoir operating rules developed without incorporating the impact of upstream abstractions could lead to unexpected system failure. This revealed how human behaviour can negatively affect reservoir operating rule curves and the yield performance which highlighted the need to incorporate the impact of upstream water abstractions while developing reservoir operating rules.

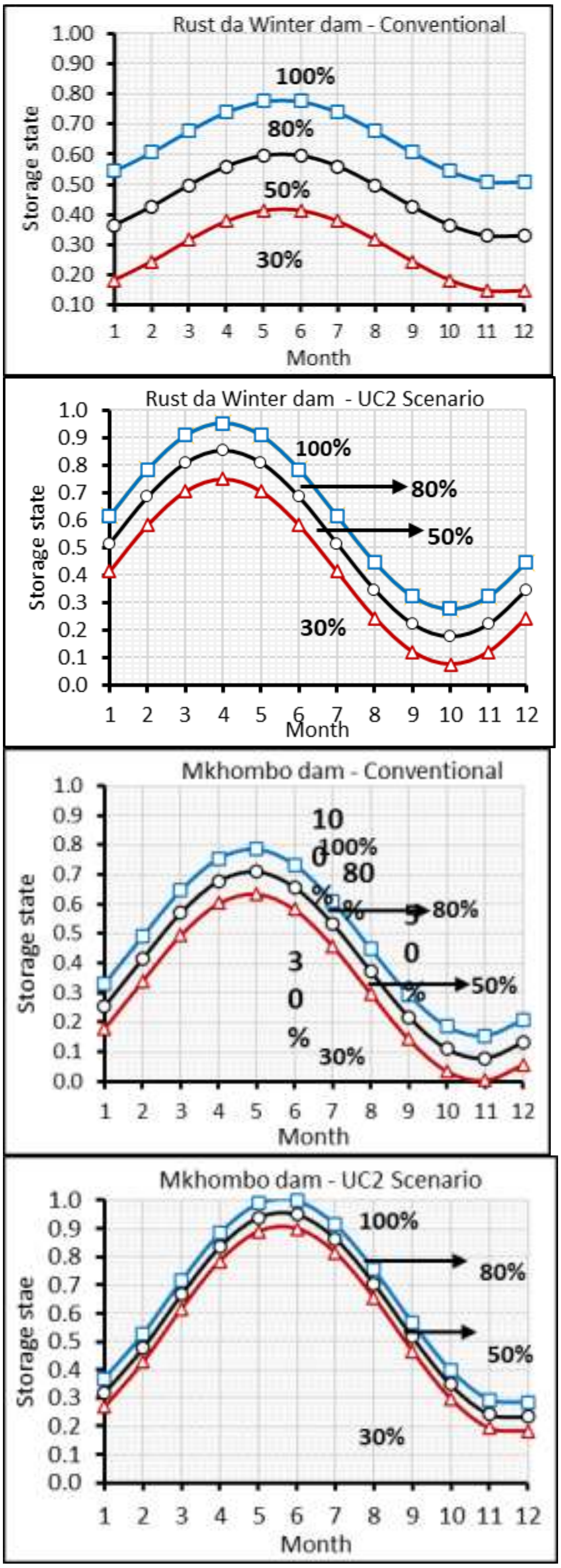


**Fig 4:** Optimised trigonometric rule curves for scenario 0 and 9 for reservoir 1 and 2

**Conclusions**

The study develops a reservoir operation simulation-optimization socio-hydrological model that couples and dynamically co-evolves reservoir water balance model and water users' propensity to water abstraction at reservoir upstream using 3 scenarios (conventional, high and low UC). A trigonometric function was used to parsimoniously definereservoiroperatingrulecurvesusing the Shuffled Complex Evolution (SCE-UA) optimization method. The storage trajectories showed how water was massively abstracted at reservoir upstream in $UC_1$ compared to $UC_2$ and conventional scenarios. However, the effect of unlawful water abstraction upstream of reservoirs is relatively more manifested in years with low storages. The optimized yield for conventional, $UC_1$ and $UC_2$ scenarios were 49.4, 42.9 and 48.1% with the corresponding yield reductions of 0.0, 2.6 and 13.2% respectively. The spaces between the optimized rule curves found to reduce in the $UC_2$ scenario when compared to the conventional scenario which also increases the probability of changing the level of supply restriction. Such discrepancies between the rule curves for conventional and $UC_2$ scenarios could be the reason for higher yields in conventional (49.4%) than $UC_2$ (48.1%) with a yield reduction of 13.2%. Hence, reservoir operating rules developed without incorporating the impact of upstream abstractions could lead to unexpected system failure. This revealed how human behaviour can negatively affect reservoir storage, operating rules and yield performance which highlighted the need to incorporate the impact of upstream water abstractions while developing reservoir operating rules.

## References


Beumer, J., Van Veelen, M., Mallory, S., Timm, D., & Levin, M. (2011). *Development of a Reconciliation Strategy for the Olifants River Water Supply System*. *Water Quality Report No. P WMA 04/B50/00/8310/14*. Retrieved from http://www.dwaf.gov.za/Projects/OlifantsRecon/Documents/Main Reports/ORRS Final Reconciliation Strategy Report.pdf

Cardwell, H. E., Cole, R. A., Cartwright, L. A., & Martin, L. A. (2006). Integrated Water Resources Management: Definitions and Conceptual Musings. *Journal of Contemporary Water Research & Education*, *135*, 8–18. https://doi.org/10.1111/j.1936-704X.2006.mp135001002.x

Duan, Q., Sorooshian, S., & Gupta, V. (1992). Effective and Efficient Global Optimization for Conceptual Rainfall-Runoff Models. *Water Resources Research Research*, *28*(4), 1015–1031. Retrieved from https://pdfs.semanticscholar.org/2d8f/234f0ae930e8cd01e849412acc3bcc5c7038.pdf

Duan, Q., Sorooshian, S., & Gupta, V. K. (1994). Optimal use of the SCE-UA global optimization method for calibrating watershed models. *Journal of Hydrology*, *158*(3–4), 265–284. https://doi.org/10.1016/0022-1694(94)90057-4

DWA. (2011). Development of a Reconciliation Strategy for Olifants River Water Supply System. *OLIFANTS RECONCILIATION STRATEGY (ORS) NEWS*, 2. Retrieved from http://www.dwa.gov.za/Projects/OlifantsRecon/Documents/Newsletters/Newsletter 3.pdf

Firoz, A. B. M., Nauditt, A., Fink, M., & Ribbe, L. (2017). Quantifying human impacts on hydrological drought using a combined modelling approach in a tropical river basin in Central Vietnam. *Hydrology and Earth System Sciences Discussion*, *86*, 1–33.

Groenfeldt, D. (2010). Viewpoint – The Next Nexus? Environmental Ethics, Water Policies, and Climate Change. *Water Alternatives*, *3*(3), 575–586. Retrieved from http://www.water-alternatives.org/index.php/allabs/117-a3-3-7/file

Groenfeldt, D. (2013). *Water Ethics: A values approach to solving the water crisis* (First Edit). Routledge.

Hermann-friede, J., Kropac, M., Achermann, S., Heeb, J., & Feuerstein, L. (2014). *Integrity Management Toolbox for Water Service Providers: Manual for Facilitators - Water Integrity Network (WIN)*. Retrieved from www.waterintegritynetwork.net

Hooper, B. P. (2006). *Key Performance Indicators of River Basin Organizations - Visiting Scholar Program Institute for Water Resources (IWR) US Army Corps of Engineers.* Retrieved from www.iwr.usace.army.mil

Kinzig, A. P., Ehrlich, P. R., Alston, L. E. E. J., Arrow, K., Barrett, S., Timothy, G., … Saari, D.

(2013). Social Norms and Global Environmental Chaiienges : Tiie Complex interaction of Beiiaviors , Vaiues , and Poiicy. *BioScience*, *63*(3), 164–175. https://doi.org/10.1525/bio.20n.63.3.5

Komarek, P., & Moore, A. W. (2005). *Making logistic regression a core data mining tool: A practical investigation of accuracy, speed, and simplicity.School of Computer Science at Research Showcase - Carnegie Mellon University*. https://doi.org/10.1109/ICDM.2005.90

Loucks, D. P., van Beek, E., Stedinger, J. R., Dijkman, J. P. M., & Villars, M. T. (2005). *Water Resources Systems Planning and Management and Applications: An Introduction to Methods, Models and Applications*. *Water* (Vol. 51). UNESCO. https://doi.org/92-3-103998-9

Montanari, A., Young, G., Savenije, H. H. G., Hughes, D., Wagener, T., Ren, L. L., & Belyaev, V. (2013). " Panta Rhei — Everything Flows ": Change in hydrology and society — The IAHS Scientific Decade 2013 – 2022. *Hydrological Sciences Journal*, *58*(6), 1256–1275. https://doi.org/10.1080/02626667.2013.809088

Plummer, J., & Cross, P. (2006). *Tackling Corruption in the Water and Sanitation Sector in Africa: Starting the Dialogue*. *Water and Sanitation Program (WSP)*. Retrieved from http://www2.wsp.org/UserFiles/file/712200782528_Tackling_Corruption_in_the_Water_and_Sanitation_Sector_in_Africa.pdf

Shanono, N. J. (2020). Applying the concept of socio-hydrology to assess the impact of human behaviour on water management sectors: A review. *Bayero J.of Eng & Tech*, *15*(2), 105–116. Retrieved from https://www.bayerojet.com/wp-%0Acontent/uploads/journal/published_paper/volume-15/issue-2/bjet_Dtl5F0Qb.pdf

Shanono, N. J. (2021). Co-evolutionary Dynamics ofHuman Behaviour and Water Resource Systems Performance: A Socio-Hydrological Framework. *Academia Letters*, *1191*, 1–6. https://doi.org/https://doi.org/10.20935/AL1191

Shanono, N. J., Bello, M. M., Zakari, M. D., Ibrahim, A., Nasidi, N. M., Usman, I. M. T., & Maina, M. M. (2020). Stakeholders Conflict and Infrastructural Decay in Nigerian Irrigation Schemes: A Review. *Nigeria Journal of Engineering Science and Technology Research*, *6*(1), 78–90. Retrieved from http://www.njestr.com.ng/view.php?_folder&_yr=2020&_vl=6&_ish=1

Shanono, N. J., Nasidi, N. M., Maina, M. M., Bello, M. M., Ibrahim, A., Umar, S. I., … Putra, U. (2019). Socio-hydrological study of water users' perceptions on the management of irrigation schemes at tomas irrigation project, Kano, Nigeria. *Nig J. Eng, Sci & TECH*, *5*(2), 139–145. Retrieved from http://www.njestr.com.ng/view.php?_folder&_yr=2020&_vl=6&_ish=1

Shanono, N. J., Sabo, A. A., Nasidi, N. M., Zakari, M. D., Mohammed, M., Isma'il, H., & Halilu, A. G. (2015). Hydraulic Infrastructures and Institutional Assessment of Watari Irrigation Project, Kano. *Bayero J.of Eng & Tech*, *10*(2), 44–51. Retrieved from https://www.bayerojet.com/wp-%0Acontent/uploads/journal/published_paper/volume-10/issue-2/bjet_OK3Hjei6.pdf

Sivapalan, M., Savenije, H. H. G., & Blöschl, G. (2012). Socio-hydrology: A new science of people and water. *Hydrological Processes*, *26*(8), 1270–1276. https://doi.org/10.1002/hyp.8426

van Oel, P. R., Krol, M. S., Hoekstra, A. Y., & de Araújo, J. C. (2008). The impact of upstream water abstractions on reservoir yield: The case of the Orós Reservoir in Brazil. *Hydrological Sciences Journal*, *53*(4), 857–867. https://doi.org/10.1623/hysj.53.4.857

Walker, W. E., Rahman, S. A., & Cave, J. (2001). Adaptive policies, policy analysis, and policy-making. *European Journal of Operational Research*, *128*(2), 282–289. https://doi.org/10.1016/S0377-2217(00)00071-0

Williams, D. J., & Noyes, J. M. (2007). Theoretical Issues in Ergonomics Science How does our perception of risk influence decision-making? Implications for the design of risk information. *Theoretical Issues in Ergonomics Science*, *8*(1), 1–35. https://doi.org/10.1080/14639220500484419

# BARRIERS TO SOLVING WATER PROBLEMS IN CROSS RIVER STATE OF NIGERIA

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**Abstract**

*The need for water has always been ranked among the most fundamental needs of the human society ever since man first inhabited the earth. This status-quo has remained unbroken even within the context of contemporary civilization where man himself in his intrinsic characteristics coupled with his activities tailored towards a meaningful lifestyle as well as natural challenges have phenomenally bastardized water supply thereby making it a severe problem of cosmic dimension. This paper using documentary sources, interviews and personal observations as a basis for descriptive analysis identifies ill-defined agreements, inadequate knowledge, technological handicaps, socio-economic and political constraints as bottle necks in the noble attempts at solving water problem in Cross River State of Nigeria. On the other hand, the paper postulates well spelt out agreements, a good background knowledge, improvement in technology and social or cultural innovations, greater funding and radical overhaul of the political machinery as possible strategies for minimizing the barriers that have for long bedeviled attempts towards addressing issues and concerns surrounding water supply in Cross River State.*

**Keywords:** Water, Barrier, problem, behavioural environment, cognitive dissonance

## Introduction

Throughout the human history, water has always ranked among the top priorities in the chain of basic necessities for survival of all life forms ranging from plant communities in all their ramifications of primitive algae through creeping plants and the higher order plant communities to the animal kingdom including man. This is evidenced in the phenomenal situation of ancient settlements along water courses like the Tigris, Hwang ho and the Nile valley in Africa. In deserts, oases were choice sites for settlement development. In plants communities for example, the range of tolerance which expresses the ability of plants species to withstand forces of stress and disturbance in an ecological niche is substantially factored by rainfall, (Chapman & Reiss, 1995; Peterson, Soberon & Pearson, 2011). On the other hand, the humans beginning right from their physical body, is largely composed of water and also needs it in reasonable quantity to enable the body carry out its bio-chemical routines involving food intake, cyclic metabolic activities and transportation of food nutrients to the complexity of blood streams.

Furthermore, the cyclic movement of water in its naturality which promotes environmental quality requires pre-existing water to propel the process. For instance, on a hot sunny day, water particles move upwards in gaseous form from ponds, streams, lakes, oceans and seas as well as from the ground in the form of evaporation while at the same time doing so from plants bodies as transpiration. These go up, condense and fall back as rainfall which is again absorbed by the ground, plants and water bodies thereby setting the stage for yet a repeat of the same process (Wright & Boorse, 2011). The foregoing are only brief expressions to support the indispensable role of water in the overall articulation of both the abiotic and biotic attributes of the environment.

Contemporary civilization by the human society has over the last couple of decades impacted adversely on the numerous avenues for steady water supply for use in domestic and in industrial activity as well as agriculture. For instance, through agriculture, substantial portions of forest lands have been cleared which offsets the delicate balance in the cyclic channel of water thereby reducing forested lands to semi-desert. In the same vein, urbanization and industrialization has predicated lots of pollutants in our precious water reserves including water-sheds (Norton, 2008).

To address above issues and concerns, lots of noble attempts have been instituted which are however yielding little or no fruits, according to World Bank (2002), poor environmental management practices like deforestation through agricultural production depletes water resources in the long run thereby gradually reducing crop yield and impacting negatively on the part of rural localities in terms of income. Additionally, series of world summits on the environment have held in Rio De Jainero, Brazil, (2000), Johannesburg (South Africa) September 2002 among many more featuring on forestry and water resources management (Oyeshola, 2008). In Nigeria, the phenomenal establishment of the river basin development authorities: the Sokoto and Lake Chad Basin in 1973 and eventually increasing the number to eleven (11) in 1976 with a backing law by the military government of Gen. Obasanjo represents spectacular landmarks in concerted efforts to boost water resources and harness same for sustainable food production. Within barely ten (10) years of their establishment, they simply became white elephants – a status quo they have maintained till date, (Oguntoyinbo, Areola & Filani, 1976).

Cross river state government over the years has been confronted with the challenge of sustainable waste supply scheme and a state wide coverage of safe water provision which is still inadequate at the moment. To add to that is the organization requirement needed for commercial and effective public and private sector partnership in water supply schemes in the areas of operation, maintenance and revenue generation. To overcome these challenges, the government has centered it policy thrust on access to safe drinking water for all and eradication of the scourge of water borne diseases. The state government intends to achieve these objectives through the provision of safe drinking water all over the state, bringing environmental and water pollution under control in all the communities and then foster private sector participation in environmental management and by so doing, government will invest in water supply and rehabilitation of existing dams for domestic and industrial use through partnership with private sector and other donor agencies of water supply schemes. Maintain existing water supply schemes, embark on capacity building for rural communities to enable them maintain and sustain the schemes and to monitor progress and prepare reports.

Government has established the Cross River State Rural Water Supply and Sanitation Agency (RUWATSSA) which alongside other agencies like UNICEF, UNDP, EU, World Bank, ADB and NGOs are responsible for providing water in the rural areas under the mini hand pomp water schemes and borehole provision. All Local Government Council Headquarters, urban and semi-urban centers are served through urban and semi-water supply schemes. These schemes combined have made it possible for government to supply or provide safe water for Cross Riverians- an effort complemented by private water developers who currently account for a small percent of the water demand in the state.

Providing a permanent solution to water problem can be determined by a number of factors. Prominent among them is the behavioural environment in which an individual is operating and the forces of cognitive dissonance in operation. These two factors influence the decisions and actions of individual and groups.

It is against the background of such persistent failures of vital investment opportunities across Africa, Nigeria and Cross River State in particular that this paper undertakes to investigate the barriers that constitute bottlenecks in the noble attempts of solving water related problems in Cross River State of Nigeria with the view to making appropriate suggestions that shall serve as lasting solutions.

## Method of Study

### Cross River State

A state located in the South South geopolitical zone of Nigeria and created in 1976 is located within longitudes $7^0 57'34.848''$E and $9^0 28'9.156''$E and latitudes $4^0 41'47.618''$N and $6^0 53'50.881''$N**.** Bounded in the north by Benue State to the south by the Atlantic ocean, to the east by the Republic of Cameroon and to the west by Ebonyi, Abia and Akwa Ibom States. With a landmass of 20,156 square kilometers and a projected population of 4,221,852 and a growth rate of 3.2%, the state play host to 18 local government areas. English and French are the major foreign languages spoken in the state while Efik, Ejagham, Bekwarra, Bette and Mbembe are the major indigenous languages.

Cross River State is endowed with huge volume of both surface and underground water and it is from these water resources that the state derived its name. The great River Cross that originates from the Mamfe region of Cameroon and emptied its water into the Atlantic Ocean is a major river and identity in the state. Other rivers of no less importance include Rivers Aloma, Aya, Qua, Calabar and Afi.

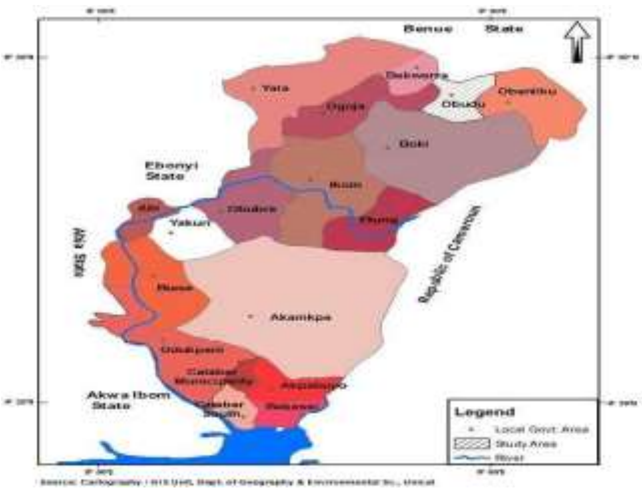


**Fig 1:** Map of Cross River State

### Types of Data

Data needed for this study include the major barriers to solving water problem in Cross River State and the solutions.

### Sources of Data

The information for this study were obtained from key informants from Cross River Water Board Limited (CRSWBL), Cross River Basin Authority (CRBDA), Cross River State Rural Water Supply and Sanitation Agency (RUWATSSA), politicians and citizens of cross River State. These sources of information were chosen because they were directly involve in water supply and demand management.

### Method of Data Collection

The main method of data collection for this work is the key informant interview where some heads and members of boards and agencies directly involve in water supply and management were selected and interviewed. Here such question as "is water really a problem in Cross River State?" are there agreement, knowledge, technological, economic, social and political barriers to solving water problem in the state? To what extent has water shortages bastardized socio-economic development? What Cross River State Government and well-meaning individuals do to overcome challenges of water shortages in the state? Other methods are physical observation and assessment of the scenario on ground and documentary evidences. The information were analysed and presented descriptively.

## Results and Discussion

### Barriers to Effective Management of Water Problem in Cross River State

From a descriptive analysis of data obtained from selected key informants, this paper considers a chronicle of barriers as constituting bottleneck in the process of resolving water problems in Cross River State of Nigeria as follows:

### Agreement Affiliated Barriers

Qualitative analysis of responses to question asked on whether water is really a problem in Cross River State revealed three categories of respondents; those who accepted that there is problem in the water sector, those who accepted the problem but considered it insignificant and those who deny the problem. These three categories of views on water issues can be a huge barrier to finding solution to water problem in Cross River State. Variation in agreement was due to inadequate information and the uncertainty surrounding water supply situation as well as individual behavioural environment. These categories of persons will act differently when they find themselves in the seat of administration of water resources in the state. The phenomenal failure to reach agreement on water related issues has result is acute shortage of water supply in many parts of Cross River State.

### Barriers of knowledge

Knowledge refers to facts, actualities, skills and information about phenomena acquired through experience or educational training, (Thinghan, 2011). Without the basic facts and information surrounding an issue of interest, the development planning process is bound to crumble even after takeoff. It is no exaggeration to state categorically that most rural and urban boreholes in Cross River State have been sunk without geo-physical Survey which would have exposed the nature of underlying rocks in terms of porosity and permeability which translates to water retention capacity, (Jordan and Grotzinger 2008). There is virtually little or no comprehensive research covering the entire state on the nature of demand and supply of safe drinking water.

### Technological Handicaps

This group of barriers are defined strictly in terms of the ability to or level at which advanced technological apparatus are employed in the process of addressing water problems. Meanwhile, low level of technology has bedeviled the entire Nigerian State in her quest for improved lifestyle. According to Aboyade (1976, 2003), gross shortfalls in technological innovations have kept Nigeria backward and impacted adversely on economic development. The inability of Cross River State Government to maintain stability in electricity supply which is central to water supply is directly linked to this barrier. Of sad note too is the fact that lots of boreholes in Calabar metropolis alone are out of use due mainly to technological constraints.

### Economic Barriers

These are shortfalls of financial affiliations which make it difficult to execute projects to the expected standards or initiate projects in the first place. This explains why a lot of Cross River State territory is grossly lagging behind in terms of water availability.

**Social Constraints**

This involves personal social attitudes towards the development of water supply. Traditional and cultural values and beliefs all go a long way in affecting the extent to which water problems can be addressed. Whereas some cultural beliefs favour natural water that runs in a stream as against bore holes, other may not. Meanwhile stream water fluctuates and drops in volume during dry season. Thus defendants of such sources of water are bound to suffer water shortages seasonally. Social vices targeted at water installations such as vandalisation and stealing of water supply equipment were reported. This can be a nightmare to policy implementation.

**Political Barriers**

Man is basically a political animal and politics is all about ideas, decisions and their implementations, (Dahl 1984). Dirty politics revolves around personal and selfish interest. It is no overstatement that Cross River State has been rocked by dirty politics in which political top shots tend to compromise standard in consideration of personal interest. This has led to unfortunate situations on non-execution of some water projects or a general lack of water supply schemes in some localities of Cross River State and or the collapse of some water projects due to politics of personal aggrandizement.

**Conclusion**

This paper has explicitly identified some ills or barriers to amicable solutions to a multi-plicity of water problems. The problems are of numerous affiliations and go a long way in adversely affecting the entire Cross River State of Nigeria and until they are amicably resolved, water supply shall continue to remain ineffective thereby impacting negatively on general socio-economic development in the state.

**Suggestions**

Cross River State goes by the appellation of “the people’s paradise. Water scarcity in most part of the state is phenomenally bastardizing this noble identity. The following measures are therefore put forward in attempts at addressing the issues and concerns raised in the paper.

- ✓ Public awareness for proper definition of water related problem
- ✓ Careful outline of agreed issues in water supply and demand.
- ✓ Good background history/knowledge of what is required for effective supply management.
- ✓ Radical improvements in indigenous and conventional technology
- ✓ A boost in project funding by Govt. & other stake holders.
- ✓ Social re-orientation involving development of sound and progressive attitudes.
- ✓ Radical reforms in the political machinery.
- ✓ Harsh punitive measures for corruption- eg. Long prison terms without options of fine

**References**

1. Aboyade, O. (2003) development burden and benefits: reflections in Nigeria development process. Edited by Olopoema. Ibadan: development policy centre.

2. Aboyede, O. (1976). Issues in the development of tropical Africa. 2nd edition, Ibadan University press.

3. Chapman J. L., Reiss M.J. (1995). ecology: principles and application low priced edition. Cambridge, Cambridge university press.

4. Dahl, R. A. (1984). Modern Political Analysis, 4th Ed. New York, Prentice-Hall.

5 Ebong, M. O. & Animashaun, I. A. (2009).A planning perspective in rural settlement. Calabar: Wusen Publishers.

6. Jhingan, M. L. (2011). The economics of development and planning. 40th edition, New Delhi, Vrinda Publications ltd.

7. Norton, W. (2008). Economic Geography. 2nd Edition, Princetown: Princetown University Press.

8. Oyeshola, D. (2008). Sustainable Development in Nigeria: issues and challenges. Ibadan, Daily Graphics Nigeria ltd.

9. Oguntoyinbo, J.S., Areola, O., Filani, M.O. (1983). A geography of Nigerian development. 2nd edition. Ibadan, Heinemann Educational Books Ltd.

10. Peterson, A.T, Soberon, J, Pearson, R. G. (2011). Species environment relationship, ecological Niche and Geographic Distribution, Prince town, prince town university press.

11. Wright R.T., Bourse, D. F. (2011). Environmental science: towards a sustainable future. New Jersey, Pearson Educ. Inc.

12. World bank (2002). Linking poverty reduction with environmental management, policy challenges and opportunities. Washington D.C: author

# ANALYSIS OF FLOOD INCIDENCE, RISK AND MANAGEMENT IN PARTS OF LAGOS, NIGERIA

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**Abstract**

*Flooding poses significant environmental, health and socio-economic impacts on the human population. The present study examined flood incidence, risk, and management in parts of Lagos, Nigeria. A well-structured questionnaire was administered to 400 respondents to obtain information on flood incidence, risk, and management in the study area using random sampling. Descriptive statistics and cartographic techniques were employed for data analysis. The result revealed that the majority of the respondents live in a rented room and parlor built with concrete and wooden materials. The increasing rate of flooding incidence is attributed to; nature of the terrain, poor maintenance of storm drains, rainfall intensity, and indiscriminate waste dump into storm drainage. Major flood risks include; poor sanitation, water contamination/waterborne diseases, and mental stress. Major flood management measures are; clearance of drains,environmental sanitation,public awareness, and training/education.The study concluded that non-compliance with regulatory laws contributes to flooding in the study area. The study contributes to knowledge by identifying flood risks. The study has potential policy implications for planning and interventions in areas vulnerable to flooding. Monitoring of construction activities, enforcement of building codes, awareness campaigns, and early warning flood technology were proffered for sustainable flood management and control strategies in the area.*

**Keywords:** Cartographic technique,Lagos-Nigeria, flood incidence, flood management, flood risk

## Introduction

The menace of flooding in Lagos, Nigeria has greatly impacted the socio-economic activities of the residents in several ways. Flooding poses a significant source of health and environmental challenges. Previous studies noted that flooding is caused due to several factors such as; population growth, urbanization, decayed infrastructure, lack of proper planning, poor land use management and indiscriminate solid waste disposal, poor urban governance, climate change phenomenon among others (Adeloye and Rustum 2011; Oludare et al. 2012; Adelekan 2013; Ajibade et al. 2014; Agbonkhese et al. 2014; Shiru et al. 2015; Nkwunonwo et al. 2015). Other scholars have attributed the causes of flooding to heavy and prolonged rainfall, river bank overflow, nature of the topography, land use and land cover modifications, tidal influence and frequent incursion from the Atlantic into the lowlands, and poor drainage system (Odunuga 2008; Aderogba et al. 2012; and Ologunorisa, 2009). In addition, poor perception about flooding among the local communities, and non-adherence to flood warning, cultural/ ethnic affinity, and weak institutional framework also contribute to the frequent occurrence of flooding in developing countries (Ayoade and Akintola 1980; Oriola 2000; Odunuga et al. 2012; Unaegbu and Baker 2014; Ibrahim and Abdullahi 2016; Nkwunonwo, 2016; Oladokun and Proverbs, 2016; and Olanrewaju et al. 2019). Various scholars have employed different techniques in explaining flood occurrence, risks, and management. For example, the use of descriptive and multivariate statistical methods, vulnerability mapping, and modeling. Despite the relevance of these techniques, there exists scanty literature on a social survey that employed the applications of cartographic method to map the incidence, risks, and management of flooding. This study, therefore, seeks to analyze flood incidence, risk, and management in parts of Lagos metropolis. The study offers the public and relevant stakeholders a better and easier understanding of flooding issues spatially without much difficulty. The study contributes to knowledge by employing cartographic techniques to establish the risks of flooding in the area. The study has potential policy implications for planning and interventions in areas vulnerable to flooding for sustainable flood managementstrategies in the area.

## Methodology

The study area lies on Long $3^0$ 20' 00''E and $3^0$ 50' 00'' E to Lat $6^0$ 26' 30'' N and $6^0$ 37' 0'' N. A major environmental challenge in the region is fluvial flooding due to the low-lying nature of the state (Odunuga et al. 2012; Kaoje and Ishaku 2017). It is bounded by Epe Local Government Areas (LGAs) in the East and the North by Ogun state, while the Atlantic Ocean and Ajeromi-Ifelodun/Ikeja LGAs form the southern and western boundaries respectively.

### Data collection, administration of survey questionnaire

Four settlements namely Ijora, Majidun, Isheri, and Lagos were randomly selected from Apapa, Ikorodu, Kosofe, and Lagos Local Government Areas (LGAs) respectively. The research design employed a structured questionnaire to analyze the causes of flooding, risk, and management in parts of Lagos metroplois based on Tunstall et al. (1997), and Sefton and Sharp (2007) approaches to flood risk analysis. The research questions focused on three main sections. Section one describes the socioeconomic and demographic attributes of respondents. Section two elicits information on the respondent's perception and the causes of flooding, and risks while section three examined flood management measures. To ensure a representative sample for the study, a random sampling method was adopted using face-to-face interview (Adelekan 2010; Otomofa et al. 2015; Odafivwotu 2019) to obtain information from 100 respondents across each settlements making a total of 400 respondents (representing 0.39%) of the entire population of 1,018,759(NPC 2006). Only adults were considered for the survey exercise. The 400 respondents were considered adequate for the study based on Yamane (1973) and Israel (1992) formula for determining sample size from a given population as indicated in equation 1.

$$n = N / 1 + N(e)^2 \qquad \text{Eq.1}$$

Where:
*n*= the sample size, *N*= the finite population, *e* = level of significance (or limit of tolerable error) (0.05), 1= unity (a constant).

Data were analyzed using descriptive statistics. On ethical consideration, respondents were assured of their anonymity and confidentiality of the survey. They were also assured of the right to decline the researcher's information at any time without justification during the interview process.

**Results**

The result of the socio-demographic attributes of respondents is presented in Table 1.

Table 1: Socio-demographic attributes of respondents

| | | Settlements | | | | |
|---|---|---|---|---|---|---|
| Variable | options | Majidun | Isheri | Ijora | Lagos | Total |
| Gender | Male | 61(61.0) | 68(68.0) | 55(55.0) | 63(63.0) | 247(61.8) |
| | Female | 39(39.0) | 32(32.0) | 45(45.0) | 37(37.0) | 153(38.3) |
| Education | No formal education | 3(3.0) | 6(6.0) | 5(5.0) | 5(5.0) | 19(4.8) |
| | Primary | 25(25.0) | 22(22.0) | 7(7.0) | 12(12.0) | 66(16.5) |
| | Secondary | 42(42.0) | 41(41.0) | 58(58.0) | 57(57.0) | 198(49.5) |
| | Tertiary | 30(30.0) | 31(31.0) | 30(30.0) | 26(26.0) | 117(29.2) |
| Ethnicity | Foreigner | 1(1.0) | 0(0.0) | 14(14.0) | 17(17.0) | 32(8.0) |
| | Hausa | 7(7.0) | 14(14.0) | 2(2.0) | 4(4.0) | 27(6.8) |
| | Igbo | 9(9.0) | 24(24.0) | 18(18.0) | 45(45.0) | 96(24.0) |
| | Yoruba | 83(83.0) | 62(62.0) | 66(66.0) | 34(34.0) | 245(61.2) |
| Dwelling type | Single room | 1(1.0) | 1(1.0) | 24(24.0) | 37(37.0) | 63(15.8) |
| | Room and parlor | 53(53.0) | 38(38.0) | 46(46.0) | 39(39.0) | 176(44.0) |
| | Flat | 42(42.0) | 52(52.0) | 28(28.0) | 22(22.0) | 144(36.0) |
| | Duplex | 4(4.0) | 9(9.0) | 2(2.0) | 2(2.0) | 17(4.3) |
| Ownership | No | 77(77.0) | 83(83.0) | 18(18.0) | 17(17.0) | 195(48.8) |
| | Yes | 23(23.0) | 17(17.0) | 82(82.0) | 83(83.0) | 205(51.3) |
| Purpose/Use | Religious | 0(0.0) | 1(1.0) | 4(4.0) | 4(4.0) | 9(2.2) |
| | Commercial | 9(9.0) | 0(0.0) | 29(29.0) | 25(25.0) | 63(15.8) |
| | Mixed | 9(9.0) | 35(35.0) | 40(40.0) | 39(39.0) | 123(30.8) |
| | Residential | 82(82.0) | 64(64.0) | 27(27.0) | 32(32.0) | 205(51.2) |

**Awareness and impacts of flooding in the study area**

Respondents' level of awareness about flooding shows that a greater proportion representing 98 percent are well informed about flooding issues in the study area. Their level of perception is also reflected across the various settlements with more than 95 percent of the respondents well acquainted about flooding incidence. Respondents' experience of flooding shows that about, 87.3 percent have experienced various forms of flooding in the study area. The disparity across the locations shows a similar pattern with Isheri having the highest proportion of 94 percent. Despite the negative impacts of flooding experienced by the residents in the area, 29.4, 29.0, 27.8 and 13.9 percent of the respondents are reluctant to relocate to safer areas due to personal/family issues, nearness to the place of work, cheaper cost of accommodation, and cultural affinity respectively. Across the settlements, the majority of the respondents from Majidun and Isheri representing 53.8 and 40.5 percent claimed accommodation challenges while 37.7 and 34.0 percent attributed their unwillingness to relocate due to nearness to the place of work / personal/family, and cultural affinity at Ijora and Lagos respectively.

**Causes and risks of flooding in the study area**

The result of the causes of flooding in the study area indicates seven main causes namely; nature of the terrain (NOT), poor maintenance of storm drainage (PMSD), rainfall intensity (RI), stagnant water (SW), dumping of waste into storm drainage (DWSD), construction on storm drainage (CSD), and high water level (HWL)/ meteorological characteristic (METC). Across the geographical locations, Isheri has the highest percentage for all the variables except for PMSD which recorded the highest proportion at Lagos with 93.8%. The mean value varied from 3.11 to 4.04 with SD of 0.78 to 2.8. Rainfall intensity and land use recorded the highest and lowest mean value respectively. The Chi-Square test indicates that all the variables are significant at $p<0.05$.

The result of the flood risks in the study area shows eight major flood risks namely; sanitation problem (SP), breeding ground for mosquito (BGM), waterborne disease (WBD), pollution of water body (PW), hindrance to mobility (HM), loss of property (LOP), disruption of public facility(DPF), and emotional and psychological stress (EPS). The test statistic shows that all the variables are significant at $p<0.05$ except for contamination of drinking water (CODM).

**Flood management measures in the study area**

The result of the descriptive statistics shows seven significant flood management measures namely; clearance of blocked drains, construction of drainage, periodic environmental sanitation, public awareness program, training and education, land use planning law and enforcement, and policies and laws to curtail flooding in the study area.The variations over the locations indicate that Isheri recorded the highest mean value which ranged from 1.88 to 3.13, with a SD of 0.84 to 1.16. The variable with the highest and lowest mean value is clearance of blocked drains and construction of grass and bush cover respectively. The test statistics show that there is a significant difference between the variables at $p< 0.05$.

## Discussion

The dominance of the male gender interviewed in the study area is an indication of the active role of the male gender in securing the family, property, and the immediate environment during flood hazards. This result corroborates with the findings of (Jonkman and Vrijling 2008). The observed high proportion of temporary structure at Majidun is indicative of the nature of the terrain that is usually vulnerable to flooding. This result confirms the findings of (Sharma and Joshi 2008 and Chacowry 2014). Homeownership revealed that half of the respondents own a house with the highest from. This result agrees with the findings of (Ibrahim and Abdullahi 2016). The low compliance of setbacks regarding building and the road can be attributed to the poor layout design which has severe implications for planning purposes.

Knowledge about flooding issues by the residents plays a vital role in empowering residents against the flooding menace. The present result corroborates the findings of (Bhaduri 2013; Fabiyi and Oloukoi 2013). The impact of flooding is significant. The result agrees with the findings of (Shankman et al. 2006; Rosenzweig et al. 2007; Adelekan 2010). In most of these settlements, the storm drains have collapsed completely and residents have turned it into dumping sites. Thus, posing severe public health challenges such as water-borne diseases (e.g. malaria, dengue, diarrhea, typhoid, and fever) and environmental problems e.g. contamination of water supply sources poor sanitation among others. The result corroborate the findings of (Hashizume et al. 2008; Ologunorisa 2009; Ajibade et al. 2014 and Olanrewaju et al. 2019).Structural and non-structural measures of flood management, awareness/education and training measures will help to empower and prepare the people to take precautionary steps against flood menace. This result matches the findings of (Thieken et al. 2007; Parker et al. 2009 and Edelenbos et al. 2017).

## Conclusion

The present study examined flood incidence, risk, and management in parts of Lagos, Nigeria. The result shows that the major causes of flooding in the area include; nature of the terrain, poor maintenance of storm drainage, rainfall intensity, stagnant water, dumping of waste into storm drainage, construction on storm drainage, and high water level/ meteorological characteristic. The significant flooding risks suffered by the residents are; sanitation problems, a breeding ground for mosquitoes, waterborne disease, pollution of water body, a hindrance to mobility, loss of property, disruption of public facility, and Emotional and psychological stress. The significant flood management measures are; clearance of blocked drains,construction of drainage, periodic environmental sanitation,public awareness program,training and education,land use planning law and enforcement, and policies and laws. The study has potential policy implications for information dissemination, planning, and interventions in areas vulnerable to flooding. The study suggested monitoring of construction activities, enforcement of building codes in consonance with layout design. Awareness campaigns, regular sanitation, and deployment of early warning flood technology.The study concluded that Governments' response to flood management measures in the area will require attitudinal change by the populace and cooperation with the relevant agencies for sustainable flood mitigation and control strategies.

**References**


Adelekan O (2010) Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environment and Urbanization 22 (2):433-450.

Adelekan IO (2013) Private Sector Investment Decision in Building and Construction: Increasing, Managing and Transferring Risks:Case Study of Lagos, Nigeria, The United Nations Office for Disaster Risk Reduction, Global Assessment Report on Disaster Risk Reduction, 1–9.

Adeloye AJ, Rustum R (2011) Lagos (Nigeria) flooding and influence of urban planning, Urban Design and Planning 164, 175– 187.

Aderogba K, Martins OM, Oderinde S, Afelumo T (2012) Challenges of poor drainage systems and floods in Lagos metropolis, Nigeria, International Journal of Social Science and Education 2, 412–427.

Agbonkhese O, Agbonkhese EG, Aka EO, Joe-Abaya J, Ocholi M, Adekunle A(2014) Flood menace in Nigeria: Impacts, remedial and management strategies. Civil and Environmental Research 6 (4):32-40

Ajibade I, Armah FA, Kuuire VZ, Luginaah I, McBean G,Tenkorang EY (2014) Assessing the bio-psychosocial correlates of flood impacts in coastal areas of Lagos, Nigeria. J. Environ. Plann. Man 58, 445–463, doi:10.1080/09640568.2013.861811

Ayoade JO, Akintola FO (1980) Public perception of flood hazard in two Nigerian cities, Environ. Int. 4, 277–280.

Bhaduri A (2013) Impact of climate change on life & livelihood of Dalits: An exploratory study from disaster risk reduction lens. NCDHR & SPWD, New Delhi.

Chacowry A (2014). Community recovery and resilience building in the aftermath of flood hazards in the small island developing state of Mauritius (Doctoral dissertation, University of Gloucestershire).

Edelenbos J, Van Buuren A, Roth D, Winnubst M (2017) Stakeholder initiatives in flood risk management: exploring the role and impact of bottom-up initiatives in three ‘Room for the River’ projects in the Netherlands, Journal of Environmental Planning and Management, 60 (1): 47-66, DOI: 10.1080/09640568.2016.1140025

Fabiyi OO, Oloukoi J (2013) Indigenous knowledge system and local adaptation strategies to flooding in Coastal Rural Communities of Nigeria. Journal of Indigenous Social Development 2(1): 1–19

Hashizume M, Wagatsuma Y, Faruque, AS, Hayashi T, Hunter PR, Armstrong B, Sack DA (2008) Factors determining vulnerability to diarrhoea during and after severe floods in Bangladesh. Journal of Water and Health 6(3): 323-332.

Ibrahim AH, Abdullahi SZ (2016) Flood menace in Kaduna Metropolis: impacts, remedial and management strategies. Science World Journal11(2): 16-22.

Israel GD (1992) Sampling the evidence of extension program impact. Paper presented at the Program Evaluationand Organisational Development (PEOD-5), Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Jonkman SN,Vrijling JK (2008) Loss of Life due to Floods. Journal of Flood Risk Management 1(1): 43-56.

Nkwunonwo UC, Whitworth M, Baily B (2016) A review and critical analysis of the efforts towards urban flood risk management in the Lagos region of Nigeria. Nat. Hazards Earth Syst. Sci. 16(2): 349–369.

NPC (National Population Census), (2006) Details of the breakdown of the national and state provisional population totals. Official Gazette 96 (2): 1–42, Federal Republic of Nigeria, Abuja.

Odunuga SS (2008) Urban Land Use Change and the Flooding Patterns in Ashimowu Watershed, Lagos, Nigeria (Doctoral dissertation, School of Postgraduate Studies University of Lagos.).

Odunuga S, Oyebande L, Omojola AS (2012) Socio-economic indicators and public perceptions on urban flooding in Lagos Nigeria. Hydrology for disaster management', Nigerian Association of Hydrological Sciences 82–96.

Oladokun VO, Proverbs D (2016) Flood risk management in Nigeria: A review of the challenges and opportunities', International Journal of Safety and Security Engineering 6(3): 485-497.doi: 10.2495/SAFE-V6-N3-485-497

Olanrewaju CC, Chitakira M, Olanrewaju OA, Louw E (2019) Impacts of flood disasters in Nigeria: A critical evaluation of health implications and management. Jàmbá: Journal of Disaster Risk Studies 11(1): 1-9.

Ologunorisa TE (2009) Strategies for Mitigation of Flood Risk in the Niger Delta, Nigeria. J. Appl. Sci. Environ. Manage. 13(2): 17- 22.

Oludare HA, Bashir OO, Olusegun HA (2012) Building capabilities for flood disaster and hazard preparedness and risk reduction in Nigeria: Need for spatial planning and land management. Journal of Sustainable Development in Africa 14(1): 45-58

Oriola EO (2000) Flood and flood management. In: Jimoh, H.I.J. (Ed) Contemporary issues on environmental management, Haytee Press, Ibadan 100-109.

Otomofa JO, Okafor BN, Obienusi EA (2015) Evaluation of the Impacts of flooding on Socio-Economic Activities in Oleh, Isoko South Local Government Area, Delta State. Journal of Environment and Earth Science 5(18): 155-171.

Sharma A, Joshi M (2008) Indigenous knowledge and modern science give environment friendly shelter solution in flood affected Desert Region of India. Indigenous Knowledge for Disaster Risk Reduction, pp.9-13.

Shiru MS, Johnson LM, Ujih OU, AbdulAzeez OT (2015). Managing Flood in Ilorin, Nigeria: Structural and Non Structural Measures Asian Journal of Applied 3(5): 507

Thieken AH, Kreibich H, Müller M, Merz B (2007) Coping with floods: preparedness, response and recovery of flood-affected residents in Germany in 2002. Hydrological Sciences Journal 52(5): 1016-1037.

Tunstall S, Tapsell S, Wills J (1997) Public perceptions of flood risk, rivers and flood defence. In Proceedings of the 32nd MAFF Conference of Rivers and Coastal Engineers. Ministry of Agriculture, Fisheries and Food, Keele University (pp. 2-4).

Unaegbu EU, Baker K (2014) Assessing community perception and attitude towards flooding in the Lower Benue River Basin, Nigeria. J Earth Sci Clim Change 5: 206. doi:10.4172/2157-7617.1000206

Yamane T (1973) Statistics: An introductory analysis, (3rd ed), New York, Harper and Row.

# RAINFALL-RUNOFF RELATIONSHIP FOR URBAN FLOOD MANAGEMENT IN PORT HARCOURT CITY

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***Abstract***
*The catchment basin that approximates the Greater Port Harcourt area is largely drained by the Bonny River system. The area is characterised by a bi-modal rainfall regime which induces high runoff and a common phenomenon associated with the runoff is flooding. Runoff is one of the most vital hydrologic components essential for water resource management. This study analyses the rainfall-runoff capacity of Port Harcourt and its implications to urban management. The average monthly rainfall and temperature data for 39 years (1979-2018) used in the study were sourced from Nigeria Meteorological Agency. The US SCS-CN model and the Khosla's technique that incorporates both rainfall and temperature data were also utilised in the study and a correlation of the two outputs executed using Pearson's Product Moment Correlation Coefficient. Results from the analysis showed that the average minimum and maximum runoff depth for the entire area were 0.1 mm and 754 mm. For the period under review, January and December had the least average monthly runoff depth for Port Harcourt at 14.2 mm and 15 mm, respectively; while July and September had the highest at 330 mm and 327 mm. Average annual estimated runoff depth for the area was minimum in 2011 at 127.8 mm and maximum in 2007 at 220 mm. There was a high positive correlation between the two methods used for this study indicating 0.99 with standard deviations and coefficient of variations of 20.83 and 21.13; 11.98 % and 11.93 % for the SCS-CN and Khosla's techniques, respectively. The estimated runoff depth for the area showed that average runoff values between 0 – 99 mm constituted about 33 % while values >99 mm constituted about 67 %. The implication of this study is that Port Harcourt will always be prone to intermittent flooding especially during intense storm if efforts are not made by Policy Makers to effect sustainable urban plan that mitigates flooding.*

**Keywords**: Port Harcourt, Rainfall, Runoff, Flooding, Urban management

## Introduction

Rainfall-to-runoff is a vital source of water refill for rivers, lakes and oceans around the globe (Karamage *et al.*, 2018). Port Harcourt, a coastal domain, approximately 60 km from the Atlantic Ocean with a bi-modal high rainfall regime experiences this significant rainfall-runoff relationship that enhances flooding. Runoff is a characteristic of the environment's trend noticed within metropolis. Runoff is that part of rainfall which appears on the surface as a flow collected from a drainage basin or catchment, that appears at an outlet of the basin and it can either be perennial or intermittent (Abam, 2004, Kumari *et al.*, 2019). In an urban area such as Port Harcourt, the larger coverage of pavement, buildings and compressed soils inhibits infiltration of rainfall when compared to a bare surface. Runoff is principally generated by the intensity and duration of rainfall, and other important instigating factors such as soil types, suitability of drainage channels and the extent of impervious surface stretches and dimensions across a catchment area. Estimating and predicting water runoff in mostly ungauged water catchment areas or basins is an essential practical application to the design of drainage infrastructure, flood defenses and for climate impact analysis (Bloschl et al., 2013). Urban runoff is of vital environmental concern since water resources management are among the most significant resources in an urban area. This study characterizes runoff in Port Harcourt and its implication on flooding using the mentioned environmental variables.

**Materials and Methods**

To establish the relationship between rainfall, air temperature and runoff depth in the study area, monthly rainfall and temperature data from 1979-2018 was sourced from the Nigerian Meteorological Agency, Abuja. Two methods were adopted to predict the average runoff for the study area and results were analysed statistically and presented in graphical outputs.

**The Soil Curve Number Model for Rainfall–Runoff Relationship**

An empirical approach to forecasting runoff from rainfall is the Curve Number (CN) approach developed by the United States Department of Agriculture, Soil Conservation Service in 1969 (Davie, 2008; Subramanya, 2008). The fundamental equation of the CN method is shown in equation 1.

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$ ………….. equation 1

where Q is the surface runoff (mm); Pis the rainfall total (mm); $I_a$is the initial abstractions i.e. all losses before runoff commences, e.g. surface storage, rainfall interception (mm); and S is the retention parameter (mm) defined in equation 2:

$$S = 25.4\frac{1000}{CN} - 10$$ ………… equation 2

where CNrepresents the curve in relation to soil category, land use type and variations in antecedent soil water content. The curve number which has a range of between 0-100 shows a CN of 100 relating to the total amount of rainfall converted as surface runoff due to an impermeable terrain, while 0 relates to an infinitely permeable terrain. The initial abstraction term (*Ia*) can be estimated using equation 3:

$$I_a = 0.2S$$ ………………equation 3

This reduces equation 3 to the form shown in equation 4:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$ ……………equation 4

In the CN methodology, the hydrological soil classification is adopted based on group A-D i.e. terrain with high-very low infiltration rates. The Port Harcourt basin was classified in group D for a nearly developed urban environment with CN of 93 at 72 percent impervious surface. The most significant advantage of the CN model is the analysis of land use change in relation to soil characteristics and land cover. The soil type in Port Harcourt is approximately 70 % and above dominated by the Benin formation (Greater Port Harcourt Development, 2009).

**The Khosla Model for Rainfall-Runoff Relationship**

Another method used in this study is the Khosla formula (Praveen Kruma, *et al.*, 2016) which have been used by researchers to analyze rainfall, runoff and temperature data given by:

$$R_m = P_m - L_m$$ ……………equation 5

and

$$L_m = 0.48T_m \; for \; T_m > 4.5^oC$$ ……………...equation 6

Where $R_m$ is monthly runoff in mm and $R_m \geq 0$, $P_m$ is monthly rainfall in mm, $L_m$ is monthly losses in mm and $T_m$ is monthly temperature of the catchment area in $^oC$.

$$\text{Annual runoff } (R_a) = \Sigma R_{im\text{-}12} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ equation 7}$$

**Results and Discussions**

Results from the study predictions showed that the minimum and maximum range of runoff depth for the entire area were 0.1 mm to <800 mm. For the period under review, January and December had the least average monthly runoff depth for Port Harcourt of <20 mm while July and September had the highest value of ranges between 330 to <350 mm. Analysis from the SCS-CN model showed that average annual estimated runoff depth for the area was minimum in 2011 at 127.8 mm and maximum in 2007 at 220 mm. There was a high positive correlation between the two methods used for this study indicating 0.99 with standard deviations and coefficient of variations of 20.83 and 21.13; 11.98 % and 11.93 % for the SCS-CN and Khosla's techniques, respectively. The estimated runoff depth for the area showed that average runoff values between 0 – 99 mm constituted about 33 % while values >99 mm constituted about 67 %. This indicates a higher runoff values capable of inducing enormous floods within the study area with inadequate drainage basins. The estimated runoff coefficient for the area which is the ratio of the average monthly predicted runoff to that of rainfall ranged from 0.6-1. Table 1 shows the statistical summary of results from the methods used in this study. A Global comparative runoff study conducted by Karamage *et al.,* (2018) from analysis of Global runoff data revealed that average annual runoff for the coastal areas of West Africa ranged from 50-400 mm. The predicted runoff values for Port Harcourt in this study is within this range.

It is noted that Port Harcourt metropolis is nothing near a positive control balance between the natural hydrological pattern and the city's developmental characteristics (Greater Port Harcourt Development, 2009, Nwankwoala and Jibril, 2019). The inadequate state of the drainage systems in the city with its corresponding growth and development rate is increasing the capacity of the city's dimension in discharging runoff water effectively. According to Ligtenberg (2017), increased urbanization with high rainfall intensity will increase surface runoff due to slower infiltration rate.

**Table 1:** Statistical summary of the estimated average runoff values

| Statistical Parameters | SCS-CN model | Khosla model |
|---|---|---|
| Mean | 173.795 | 177.125 |
| Standard error | 3.292805 | 3.340528 |
| Standard deviation | 20.82553 | 21.12735 |
| Sample variance | 433.7025 | 446.365 |
| Coefficient of variation | 11.98 | 11.93 |
| Range | 92.1 | 93.8 |
| Ave. annual minimum | 127.8 | 130.2 |
| Ave. annual maximum | 219.9 | 224 |
| Ave. monthly minimum | 14.2 mm (January) | 7.1 mm (January) |
| Ave. monthly maximum | 330 mm (July) | 338 mm (July) |
| Correlation with mean monthly rainfall ($R^2$) | 0.9995 | 1 |
| Regression equation | $Y = 0.9664x - 11.908$ | $Y = 1.00057x - 16.128$ |

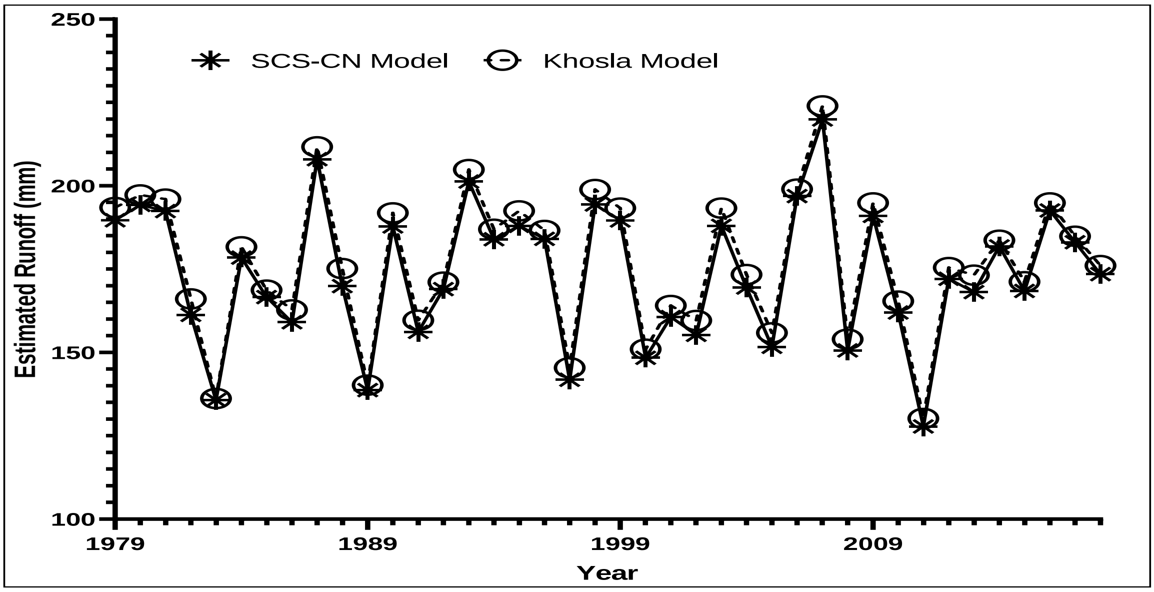


**Fig. 1:** Mean Trends of Estimated Runoff in Port Harcourt using the US SCS-CN and Khosla Models

Over the years, the unplanned metropolitan development circle in Port Harcourt with resultant terrain alterations has negatively impacted the surface hydrological permutations for the area. So, flooding arises when surface runoff water is stagnated and unable to navigate quickly to the city's discharge points.

## Conclusion

In this study, two runoff prediction techniques were utilised to estimate the average runoff depth for Port Harcourt basin. Findings from the study showed that the minimum and maximum range of runoff depth for the entire area were 0.1 mm and <800 mm with July and January being the average maximum (300 to <340 mm) and minimum (>20 mm) runoff depths. As runoff becomes increasingly noticeable in Port Harcourt, flooding will be increasingly unavoidable. it is expected that Policy Makers will efficiently manage and improve on quality delivery of the incapable drainage systems available in the metropolis.

## References

Abam, T.K.S. (2004). Geohydrology with Applications to Environmental Management. Charismatic Graphics: Aba.

Bloschl, G., Sivipalan, M., Wagener, T., Viglione, A. and Savenije, H. (2013). Runoff Prediction in Ungauged Basins: Synthesis across Processes, Places and Scales. First Edition. Cambridge University Press: Cambridge.

Davie, T. (2008). Fundamentals of Hydrology; 3rd Edition. Taylor & Francis: New York

Greater Port Harcourt Development (2009). The Greater Port Harcourt City Development Master Plan. Stormwater Master Plan, Volume 3. Government of Rivers State, Nigeria.

Karamage, F., Liu, Y., Fan, X., Justine, M. F., Wu, G., Liu, Y., Zhou, H. and Wang, R. (2018). Spatial Relationship between Precipitation and Runoff in Africa. Hydrol. Earth Syst. Sci. Discuss., 1-27.

Kumari, R., Mayoor, M., Mahapatra, S., Parhi, P.K. and Singh, H.P. (2019). Estimation of Rainfall-Runoff Relationship and Correlation of Runoff with Infiltration Capacity and

Temperature over East Singhbhum District of Jharkhand. *International Journal of Engineering and Advanced Technology (IJEAT)*, 9(2), 461-466.

Ligtenberg, J. (2017). Runoff changes due to urbanization: A review. UMEA University, The Netherland.

Nwankwoala, H.O. and Jibril, T. (2019). Flood Height Measurement and Analysis in Parts of Obio/Akpor Local Government Area, Port Harcourt Metropolis, Nigeria. *Engineering Management Research*, 8(2), 1-10.

Praveen Kumar B.J., Pradeep, H., Lokesh. A., Akarshraj K.H., Surendra H.J. and Avinash S.D. (2016). Estimation of Runoff using Empirical Equations and Fuzzy Logic method: A case study.*International Journal of Scientific & Engineering Research*, 7(5) 28-37.

Subramanya, K. (2008). Engineering Hydrology; 3rd Edition. Tata McGraw-Hill: New Delhi.

**MANAGING URBAN FLOODING THROUGH PHYSICAL PLANNING INTERVENTIONS IN MAKURDI TOWN, NIGERIA**

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**Abstract**

*Incidences of urban flooding are increasingly becoming frequent, devastating and costly to manage in the face of rapid urbanisation in Nigerian cities like Makurdi. The current and projected levels of urban flooding and its accompanying impacts are and will be exacerbated by climate change. The combined effects of urbanisation and climate change give urgency to the need to focus on urban flood management. Thus, this paper analysed the current state of the Idye drainage basin in Makurdi town and examined specific physical planning interventions that can be applied to sustainably manage urban flooding in Makurdi town. Data were collected through observation and interviews with residents and staff of Benue State Urban Development Board. Google images of the Idye drainage basin for the years 2005 and 2020 were analysed and compared to see the extent of land use change. The study found that though the Makurdi master plan (which is currently obsolete) designated the Idye drainage basin as a green area, buildings have emerged in the area; contributing to the intensity of flooding in Makurdi town. However, many of the buildings have been constructed without planning permission from the Benue State Urban Development Board. In spite of the conversion of the area into a built-up area, inadequate provisions have been made for drainage channels to discharge the excess surface run-off. Physical planning interventions that could be applied are the creation of detention/retention basins which are large tracts of open space that hold the excess run-off, introduction of alternative less intensive land uses such as recreational uses or well landscaped open spaces that add aesthetic value to Makurdi town. The study recommends the preparation of flood risk maps for urban areas to assist in making evidence-based decisions in sustainable flood management.*

**Keywords:** Urban flooding, Development control, Drainage basin, Makurdi

## Introduction

Research suggests that the global trend of urbanisation and climate change will influence the scale and impact of flood events now and in the coming years (Jha, Lamond, Bloch et al., 2011). This implies that flood events may increase in the future as a result of climate change, steady increase of human population, as well as increasing growth of the built-up environment (United Nations International Strategy for Disaster Reduction, 2004). A significant percentage of the extant literature on the causes of urban flooding in developing countries reviewed by Asiedu (2020) identified heavy rainfall, urbanisation, inadequate drains or poor maintenance of drains, poor waste management, unplanned urban growth, failure of infrastructure, storm surge, development on flood plains and climate change as the causes of urban flooding (Asiedu, 2020). The correlation between urbanisation and flooding has also been confirmed by Zhang, Villarini and Smith (2018) in their study in Houston, USA where they reported that the probability of extreme flood events caused by hurricane Harvey increased by about 21 times in 2017 because of urbanisation. Similarly, Singh and Upmanyu (2019) reported that the Chennai international airport in India which is built on the riverine flood plains led to massive flooding in 2015. With the growing evidence of the singular and combined influence of urbanisation and climate change on flooding, the focus will be on low-and middle-income developing countries in Asia and Africa like Nigeria; where the prognosis suggests that poor physical planning and extreme weather events will leave urban populations vulnerable to floods.

Already, analysts suggest that Africa is fast transitioning into an urban continent. It is estimated that more than half of the population in Africa will live in urban areas by the year 2050 (Bello-Schunemann and Aucoin, 2016; Teye, 2018). Data presented by the World Bank suggests that the urban growth rate for Nigeria in 2019 was 4.2%. With the high urbanisation rates, urban centres are witnessing intensive physical development in terms of building construction to accommodate the increasing urban population (Falade, 2003). The intensive physical development occasioned by urbanisation has increased impervious surfaces and by extension surface run-off on one hand; and led to the encroachment on marginal urban lands, including floodplains on the other. The consequence of this is the rising incidences of flooding witnessed in many states of Nigeria. Infact, the 2021 annual flood outlook released by the Nigerian Meteorological Agency presents gloomy predictions for some States and cities in the country. The forecasts show that river flooding is expected in fourteen states of Nigeria, including Benue State; while on the account of poor drainage facilities which is a product of poor urban planning, flash and urban flooding are expected in cities like Lagos, Port-Harcourt, Yola, Kaduna, Maiduguri, Ibadan, Sokoto and Makurdi.

Makurdi town has witnessed significant growth since it became the capital of Benue State in 1976. The city grew from a population of 151,515 in 1991 to 300,377 in 2006 (National Population Commission, 2006). In recent times, Makurdi has grown exponentially as a result of the influx of displaced persons from rural communities affected by conflicts in Benue and other neighbouring States. This has triggered rapid development and expansion of the built-up spaces, increasing building density in the older neighbourhoods and further encroachment on marginal lands in virtually all directions of the town. Additionally, flood occurrence has become an annual seasonal event impacting lives, properties and the environment as a whole. Concern over the incidents of flooding, especially in urban areas, has attracted several studies focusing on different aspects like Akintola (1978); Akintola (1982); Omiunu (1981); Odemerho (1983); Rashid (1982); Ayoade and Akintola (1980); Babatolu (1997); Oriola (2000); Ologunorisa (2004); Ali (2005) and Ologunorisa and Tor (2006). Thus, in view of the links between urban growth and poor physical planning to flood risks, it is imperative to examine the ways in which urban planning measures can be applied to mitigate flood occurrence in vulnerable cities like Makurdi. This paper therefore, aims to analyse the current state of the Idye drainage basin in Makurdi town and examine specific physical planning interventions that can be applied to sustainably manage urban flooding in Makurdi town. The Idye drainage basin was initially designated as an open space in the now obsolete master plan of Makurdi town. Figure 1 shows the location of the Idye drainage and adjoining neighbourhoods in Makurdi town.

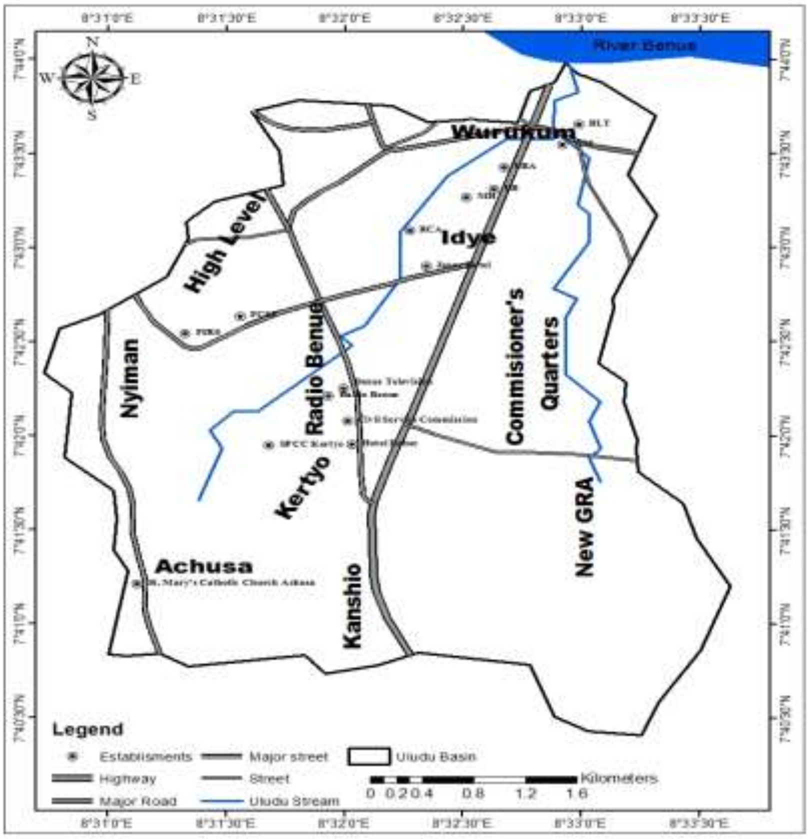


**Fig. 1:** Idye Drainage Basin and Adjoining Residential Areas in Makurdi Town

**Methodology**

The study collected data on the conditions of the Idye drainage basin through observations, interviews and the application of Geographic Information System (GIS) to analyse the changes in land use and land cover in the area for the years 2005 and 2020. The observations involved examining the drainage channels in the area, waste disposal and the level of physical development. The interviews with officials of the Planning Agency focused on lapses in development control and potential ways in which physical planning measures can be applied in curbing flooding and managing floodplains in a sustainable way. The land-use/land cover change were analysed, computed and presented in maps and a table. The interviews were analysed descriptively. Photographs were also presented to show the current condition of the Idye drainage basin.

**Findings and Discussions**

The Idye drainage basin is a wetland ecosystem characterized by poorly drained mineral soils and by plant life dominated by grasses. Since the area consists of sediments deposited by the stream water, the lands are poorly drained and the area is often waterlogged. Sediments deposited by the stream provide fertile grounds for fibrous-rooted grasses which bind the mud together and further hinder water flow. Though there is an uncompleted drainage channel which was constructed as part of the ecological funds released to Benue State and managed by the Ministry of Water Resources and Environment, flooding in the area and its environs has continued unabated. The condition of the constructed concrete drainage channel and the natural channel is further worsened by solid wastes which contribute to the clogging of the channels as shown in Plate 1.

**Plate 1:** Wastes disposed in the Natural drainage channel

The Idye drainage channel evacuates excessive surface water that cannot infiltrate into the ground during intense rainfall and discharges same into the River Benue. However, with the absence of drains in some parts of the Idye basin and the poor maintenance of the concrete and natural drainage channels, the excess surface flow usually inundates the area leading to flooding. In addition, the effectiveness of the existing concrete drainage channel to evacuate water is affected by the design of the channel - its alignment, size and gradient.The constructed concrete drain in the Idye drainage basin is 8 metres wide, the depth is 2 metres while the length is 3,619 metres. The size of the drainage has proven to be inadequate in evacuating large volumes of water especially during the raining season. This leads to flooding in the area (Plate 2a, 2b) and other adjoining neighbourhoods.

Com

**Plates 2a, 2b:** Flooded Houses and Access Route in the Idye Drainage Basin Physical Development in the Idye Drainage Basin

Uncontrolled development is currently occurring in the Idye basin as a result of the increase in population and accompanying demand for housing in Makurdi town. Though the master plan of Makurdi town which is now obsolete designated the area as a green area, it was observed that buildings have been constructed and occupied and are still under construction in the area. A total of 74 buildings were sited in very close proximity (7 metres) to the constructed concrete drainage channel in the area while other completed and uncompleted buildings were also seen in other parts of the drainage basin. Interviews with the residents revealed that their decision to build in the area was due to unavailability of land and poverty. Staff of the Urban Development Board also revealed that majority of the residents purchased the land from older settlers and built without obtaining planning permission from the Board. However, there are obvious lapses in development control since the buildings have not been demolished or the residents relocated or evicted. The absence or weak enforcement of development control measures have emboldened developers as more buildings are springing up in the area. The progressive land use change and growth of built environment on unsuitable urban places or areas liable to flood plays a significant role in the increasing flood frequency in Makurdi.

An analysis of the land use/land cover change for the Idye drainage basin area using Geographic Information Sytem (GIS) shows that while the built-up area covered 866 (39%) out of the total 2,250 hectares in the year 2005, it increased to 969 (43%) hectares in the year 2020 (Figure 2). On the other hand, vegetation cover decreased from 1,055 hectares (47%) in 2005 to 739 hectares (33%) in the year 2020 (Table 1). The results suggest that the area is gradually been taken over by physical development; a situation that could contribute to worsening incidences of flooding in the area and its environs.

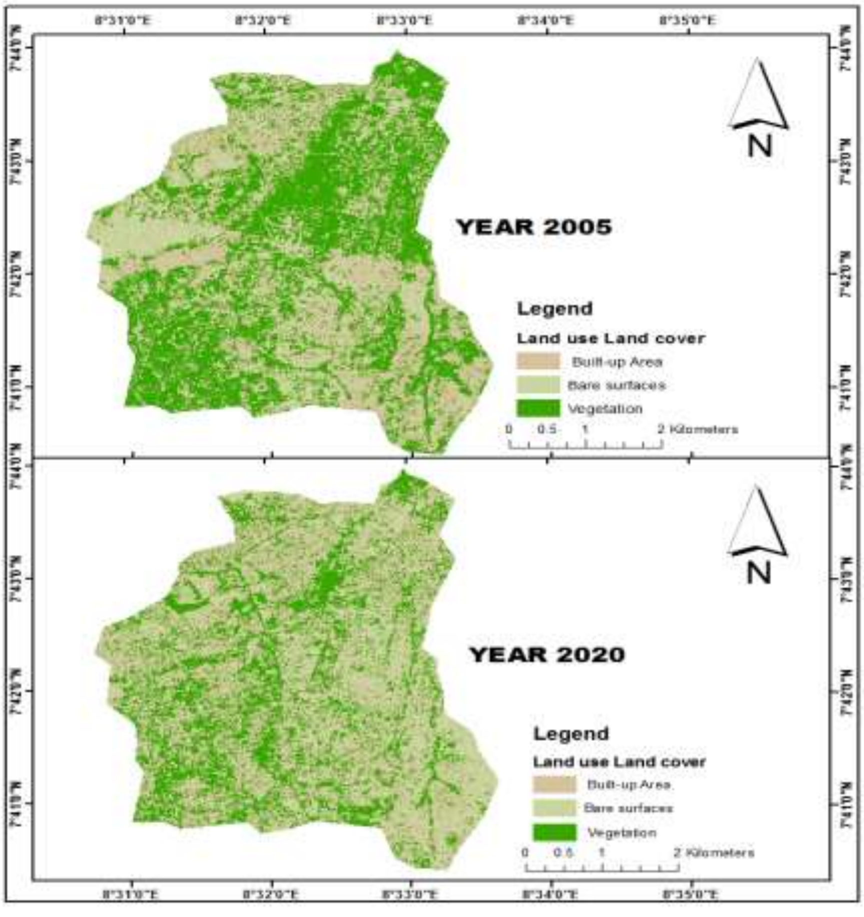


**Fig. 2:** Idye Drainage Basin showing Land Use/Land Cover changes in 2005 & 2020

**Table 1:** Analysis of Land Use/Land Cover in Idye Drainage Basin (2005 & 2020)

| | Year | | | |
|---|---|---|---|---|
| LULC Type | Area in Hectares | | | |
| | 2005 | % | 2020 | % |
| Vegetation | 1055.88 | 46.92 | 739.75 | 32.87 |
| Built-up Area | 866.88 | 38.52 | 969.42 | 43.08 |
| Bare surfaces | 327.59 | 14.56 | 541.24 | 24.05 |
| Total | 2250 | | 2250 | |

**Source:** GIS Laboratory Analysis

## Managing Urban Flooding through Urban Planning Interventions

Flood occurrences could be managed effectively through physical planning interventions like the provision of flood mitigation infrastructure. The creation of detention/retention basins which are large tracts of open space that hold the excess run-off are an often overlooked form of flood mitigation infrastructure. In addition, alternative less intensive land uses such as recreational uses or well landscaped open spaces that add aesthetic value to Makurdi town could be introduced. Recreational land uses are suitable for floodplains because they are not greatly affected by flooding and they do not trigger flood events; especially because such land use may not require intensive physical development and constructions. In addition, zoning by-laws and building permits can be used to control development and direct urban growth in ways in which floodplains remain protected fragile ecosystem. Planning agencies in Makurdi like the Urban Development Board do not have either flood risk maps or flood risk reduction strategies; inspite of the noticeable impacts of urbanisation on incidences of flooding. A comprehensive approach that involves the development of flood risk maps and flood mitigation measures will enable land use planners to prevent or manage incidences of flooding more effectively and sustainably.

## Conclusion

The study has shown that weak development control and the neglect of urban planning has significantly contributed to the incidences of flooding in the Idye drainage basin and its environs in Makurdi town. The study reveals some of the unintended but often inevitable consequences of unplanned urbanisation. The paper further highlights the importance of flood risk plans that provide information of areas at risk by defining flood risk zones to give input to spatial planning and support the processes of prioritizing, justifying and targeting investments in order to manage and reduce the risk to people, property and the environment (Kötter, 2003).

## References

Ali, P.I.O. (2005). Flood damage assessment in Makurdi town. Unpublished M.Sc Dissertation, Department of Geography, Benue State University, Makurdi-Nigeria.

Asiedu, J. B. (2020). Reviewing the Argument on Floods in Urban Areas: A Look at the Causes. *Theoretical and Empirical Researches in Urban Management,* Vol. 15, No. 1, 24-41.

Ayoade, J.O. (1988). *Tropical Hydrology and Water Resources*. Ibadan: MacMillian Publishers.

Ayoade, J.O. and Akintola, F. (1980): Public perception of flood hazards in two Nigerian cities. *Environmental International*, Vol.4, 277-280.

Babatolu, J.S. (1997). The June 24th 1995 Flood in Ondo: Antecedent and Incident. Ife: Research Publications in Geography, Vol. 6, 125-136.

Bello-Schunemann, J. and Aucoin, C. (2016). "African Urban Futures". African Futures Paper 20, Institute for Security Studies.

Federal Ministry of Environment/UNDP (2012). Automated web-based Early Warning System (EWS) launched in Abuja. Perspective". Enugu EL DEMAK Publications.

Jha, A., Lamond, J., Bloch, R., Bhattacharya, N., Lopez, A., Papachristodoulou, N., Bird, A., Proverbs, D., Davies, J. and Barker, R. (2011). Five Feet High and Rising: Cities and Flooding in the 21st Century. Policy Research Working Paper 5648. The World Bank, East Asia and Pacific Region – Transport, Energy and Urban Sustainable Development Unit.

Jha, A. K., Bloch, R. and Lamond, J. (2012). Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. World Bank and GFDRR

Nirupama, N. and Simonovic, S. P. (2007). Increase of Flood Risk due to Urbanisation: A Canadian Example. *Natural Hazards,* 40:25-41. DOI:10.1007/s11069-006-0003-0

Odemerho, F. O., (2004). Benin City: "A Case Study of Urban Flood Problem".

Ologunorisa, E.T. (2004). An assessment of flood vulnerability zones in the Niger Delta, Nigeria. *International Journal of Environmental Studies*, Vol.61, 31-38.

Ologunorisa, E.T. and Tor, T (2006). The changing rainfall pattern and its implication for flood frequency in Makurdi, Northern Nigeria. *Journal of Applied Science and Environmental Management*, Vol. 10(3) 97-102.

Oriola, E.O. (2000). "Flood and flood management" in Jimoh, H.I.J. (ed), Contemporary issues on environmental Management. Ibadan: Haytee Press, 100-109.

Singh, M. and Upmanyu, V. (2019). "Urban Flooding: The Case of Drowning Cities and Rising Vulnerability". DownToEarth www.downtoearth,org,in

Teye, J. (2018). Urbanisation and Migration in Africa. Paper presented at the Expert Group Meeting, United Nations Headquarters in New York, 1-2 November

UNEP (2006). Gathering Storm: The Humanitarian Impact of Climate Change.

UNISDR (2004). "Towards Sustainable Development in Africa" – Report on the Status of Disaster Risk Management and Disaster Risk Assessment in Africa. UNISDR, African Union, NEPAD and African Development Bank

Zhang, W., Villarini, G. and Smith, J. A. (2018). Urbanization exacerbated the rainfall and flooding caused by hurricane Harvey in Houston. *Nature*, 563, 384-388.

**RESIDENTS' COPING MEASURES IN FLOOD PRONE AREAS OF HADEJIA –JAMAARE RIVER BASIN, JIGAWA STATE, NIGERIA**

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**Abstract**
*The study investigated flood hazard events and examined residents' coping strategies in flood prone areas of Hadejia-jamaare river basin (HJRB), Jigawa State. Data were obtained through field work using a combination of semi structured interview and field observation. The data obtained were analyzed using statistical tools including frequency distribution, simple percentages, graphs and charts. Findings from the study revealed that flood is the most common environmental disaster in the study area associated with tragedies and causes serious damages to socioeconomic and environment. The finding also revealed that heavy rainfall, inadequate drainage facilities and mismanagement of water reservoir (mainly dams) are the major causes of flood disaster in the area. Moreover, other infestation of water channels, topography, vegetation and soils of the area also have significance influence on flood disaster in the most of the affected areas. The flood disaster causes both environmental and socioeconomic damages to a great extent. The residents' coping measures in the flood prone areas of Hadejia Jama'are River Basin to the menace of flood disaster in the study area, however the study revealed that the residents used to build embankments along the river banks that may prevent water outflow. Disaster management agencies also provide relief and rehabilitation support for the victims whenever the flood disaster happened. Thus, these efforts are inadequate in addressing the risk and menace of flood disaster inthe flood prone areas of Hadejia Jamaare River Basin. There is the need for the policy makers to strengthen efforts towards providing feasible solution to threat of flooding and its attendant disaster in the study area through precautionary and preventive measures. Recommendations were given for implementation by relevant authorities.*

**Keywords***:* flood disaster, residents, measures, and Hadejia

## Introduction

It is basically a fact that at one point in time, societies and communities are often faced with certain disaster, either naturally or artificially induced that can cause serious damages (Usman and Adnan, 2017). A disaster is any potentially damaging phenomena induced by physical or human activity that may cause loss of life, injury, property damages, socioeconomic disruption and/or environmental degradation (Rose, et al. (2014)). Among all other forms of natural disasters, flood has the highest frequency of occurrences, coverage and impacts. Across the globe, flood has posed serious disaster to human lives and properties (United Nations Environmental Program (2003)). Flood occur when ponds, lakes, riverbeds, soils and vegetation cannot contain all the water received (Bariweni, P.A Tawari, C.C and Abowei, J.F.N. 2012). The 2012 unprecedented flood disaster experienced in Nigeria was considered the most devastating flood disaster in the five decades. The disaster affected about 27 states of the federation (including Jigawa state) causing death of over 400 persons and displacing about 2 million people from their homes in the affected areas (Nigeria Hydrological Science Agency, 2013). The risk and damages caused by flood disasters in terms of loss of life, properties, displacement of people and disruption of socioeconomic activities as well as loss of valuable agricultural land due to the attendant inundation of floodplain from flood can never be overemphasized (Sani, 2008). Several areas along the major and minor river channels (floodplain) of Hadejia Jamaare River Basin are affected by flood every year. Thus, this paper focuses at finding out the flood hazards events and residents' coping measures in flood prone areas of Hadjia Jamaare River Basin Jigawa State to line with the flood appropriately its positive elements and mitigate the adverse effects associated with the flood disaster.

**Objectives of the Study**

The study aimed at investigating the flood hazards events and residents coping measures in flood prone areas of Hadejia-Jamaare River Basin, Jigawa State.
The achieved objectives are to:

1) Identify the causes of flood disaster in the study area
2) Assess the frequency of flood disaster in the study area
3) Assess the residents' coping measures of flood disaster in the study area

**Research Methodology**

**The Study Area**

Hadejia Jamaare RiverBasin is part of the Lake Chad basin Hydrological Area identified as HA-VIII by the Nigerian Hydrological Service Agency, situated in the Sudono Sahelian zone of Northern Nigeria. The area lies within (lat12$^0$ 26"N and long 10$^0$ 04"E) and has a total drainage area of 25,900km$^2$ (Usman A.A. Sunday, G.Y and Alkali, A.N. 2016). The area boarded by Katsina state to the west, Kaduna and Plateau states to the south and Yobe state to the east and Niger republic to the North.supply (Chiroma, M.J. Yahaya, D.K. and Abba J.G. 2010).

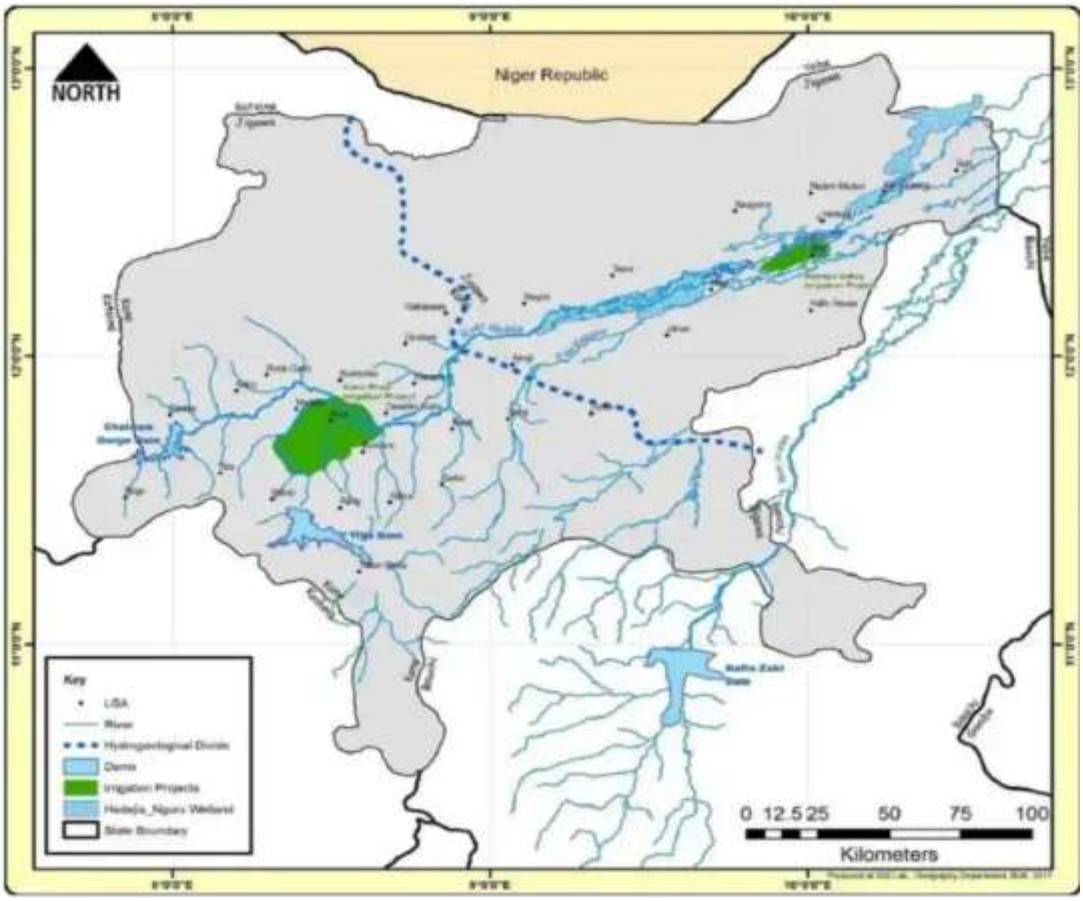


**Fig. 1:** Map of study area showing the catchment area of Hadejia Jamaare River Basin
**Source:** GIS Lab. Bayero University Kano Produced from Goggle Earth (2017).

Politically, the catchment area of the Hadejia Jamaare River Basin comprises the whole of Kano and Jigawa and two-third of Bauchi state and it considered as the largest floodplain in Northern Nigeria (Hadejia Jamaare River Basin Developmet Authority, 2014). Economically, over 15 million people are supported by the basin through agriculture, fishing, livestock keeping and water

## Materials and Method

The data for the study were obtained through field work using a combination of semi structured interview and field observation to elicit the required information. Hundred (100) copies of questionnaires were purposively selected using systematic multi-stage sampling techniques. The data obtained were presented and analyzed using statistical tools including frequency distribution, simple percentages, graphs and charts.

## Results and Discussion

**Table 1:** Most Common Environmental Disaster in Hadejia Jamaare River Basin

| Environmental Disaster | No of Respondents | Percent (%) |
|---|---|---|
| Flood | 75 | 75.0 |
| Erosion | 15 | 15.0 |
| Desertification | 07 | 7.0 |
| Drought | 03 | 3.0 |
| Total | 100 | 100.0 |

**Source:** Field Survey 2021

### Most Common Environmental Disaster in Hadejia Jamaare River Basin

The table 1. A significant number of respondents 75% revealed that flood is the most common identified environmental disaster in the study area, while Seven (7) percent indicated that desertification is also among the main common disaster. Therefore, Three (3) percent of the respondents identified drought and henceforth the study revealed that erosion is the second common environmental disaster which is mainly gully in Hadejia Jamaare River Basin as it was revealed by the 15% of the respondents.

**Table 2:** Frequency of Flood Occurrences in Hadejia Jamaare River Basin

| Environmental Disaster | No of Respondents | Percent (%) |
|---|---|---|
| Annually/Regularly | 75 | 75.0 |
| Periodically | 25 | 25.0 |
| Total | 100 | 100.0 |

**Source:** Field Survey, 2021

### Frequency of Flood Occurrences in Hadejia Jamaare River Basin

The table 2 Shows the frequency of flood occurrence inHadejia Jamaare River Basin. From the analysis 75% of the respondents indicated that the flood occurs regularly, while 25% indicated that the flood occurrence is periodic.

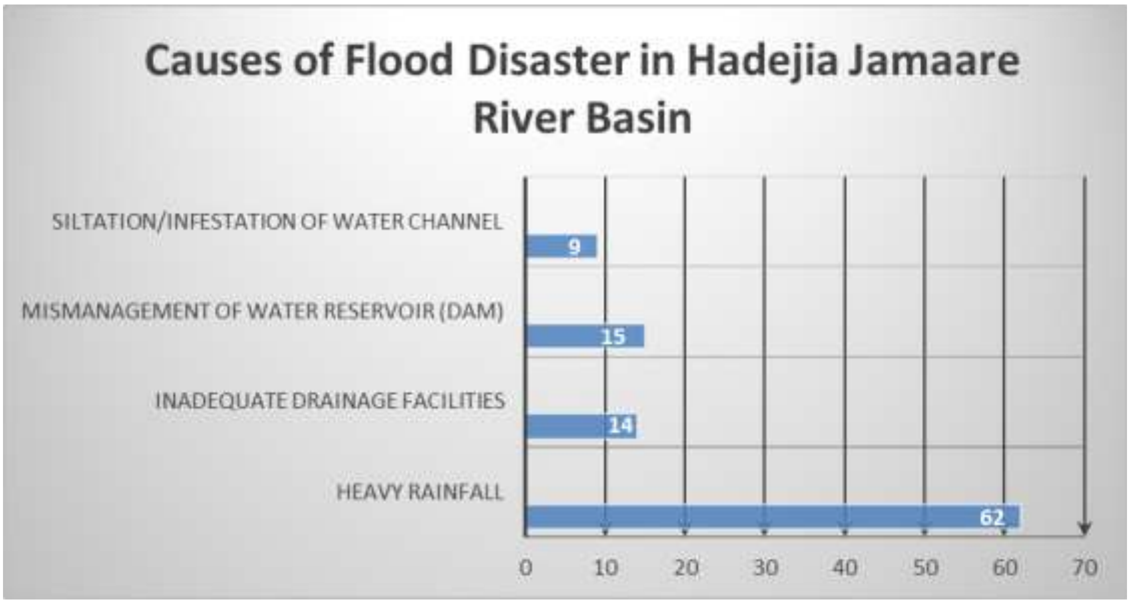


**Fig. 2:** Causes of Flood Disaster in the Study Area
**Source:** Field Survey 2021

**Causes of Flood Disaster in Hadejia Jamaare River Basin**

On the causes of flood disaster in Hadejia Jamaare River Basin, figure 2. Shows that 62% of the respondents believed that flood occurs as a result of the heavy rainfalls while 14% revealed that it occurs due to inadequate drainage facilities and 15% indicated that it occurs as result of mismanagement of dams and Nine (9) percent revealed that infestation of water channel contribute to flood disaster in Hadejia Jamaare River Basin.

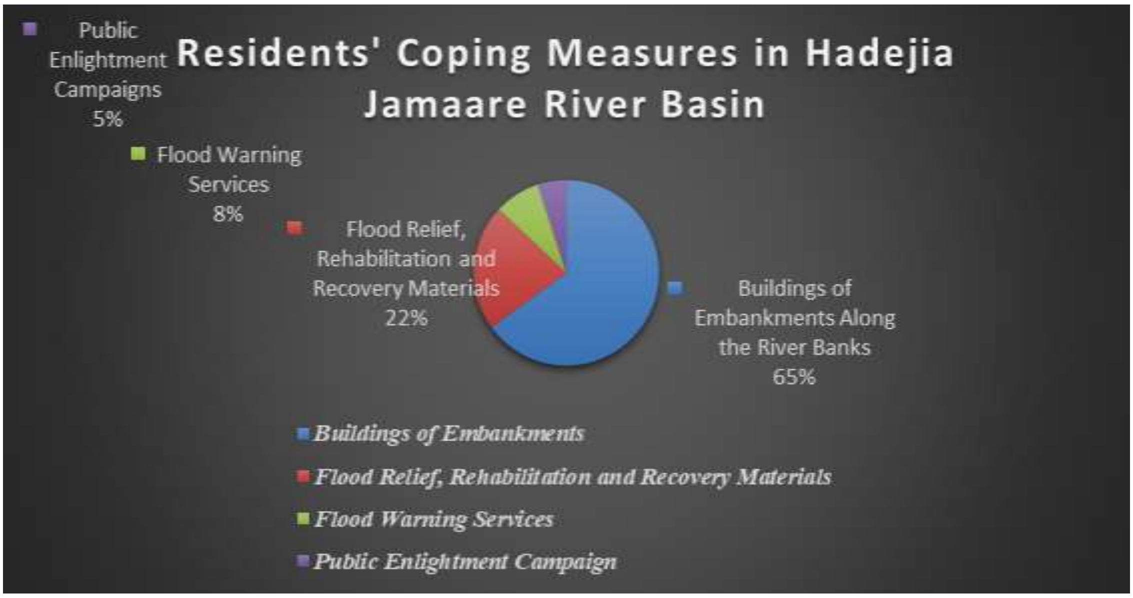


**Figure 3:** Residents’ coping Measures
**Source:** Field Survey, 2021

### Residents' Coping Measures in Hadejia Jamaare River Basin

From the analysis, figure 3. Shows how the residents used to cope with flood disaster in the flood prone areas of Hadejia Jamaare River Basin. From the respondents 65% indicated that buildings of embankments are the significant measure against the flood disaster, while 22% revealed that relief and rehabilitation support for the victims after the disaster occurred is the main measure they use to tackle the disaster. Therefore, Eight (8) percent lamented that flood warning services is the main measure they used to consider and Five (5) percent indicated that public enlightenment campaigns are used to do on the risk and menace of flood disaster in Hadejia Jamaare River Basin.

### Discussion

The study revealed that Hadejia Jamaare river basin is constantly been ravaged by riverine and urban floods. Floods are flash floods in nature, characterized by intense and high velocity flow of water occurring suddenly as a result of short-term heavy and above normal rainfalls (Usman and Adnan, 2017). Long durations received around the months of August and October, and failure of surface reservoirs and dams' upstream also resulted to floods. Normal rainfalls also causes urban floods in the study area as a results of dumping of refuse in water channels and surface drains by the residents.

Generally, the flood disaster is very destructive and devastating in nature, it lasts for days and causes serious damages to human life and properties. The flood water usually submerged farmlands, houses, roads, schools, market places and causes lots of damages to socioeconomic and environmental features. From the study some of the respondents believed that flood is not beneficial to residents living in the flood prone areas of HJRB. Nevertheless, significant percentage of the respondents indicated that flood bring about some benefits. There is possibility of fishing in the flood water and when the water drained the soil used to become fertile and favorable for farming among others. This means that flood disaster has both positive and negative impacts, thus the findings revealed that flood often bring about more negative impacts than the positive impacts. Based on the findings, the severity of flood disaster in HJRB of Jigawa State were categorized into three (3) risk areas namely: areas with high risk of flood, areas with moderate risk of flood and areas with low risk of flood.

Disaster Management Organization are making efforts in responding to the menace of flood disaster in Hadejia Jamaare River Basin. However, according to the study revealed that the efforts made by the disaster management agencies is ineffective in addressing the risk and menace of flood disaster in the study area, this is because their interventions are skewed. The efforts of the disaster management agencies is lopsided because they only provide relief and rehabilitation support for the victims.

### Conclusion of the Study

Flood disaster is the most frequent occurring environmental disaster in Hadejia Jamaare River Basin, although the flood disaster in the study area is a flash flood mainly caused by heavy rainfall and rainfall cannot be stopped, risk and menace of flood disaster can be mitigated. It is hopeful that suggested precautionary and preventive measures will mitigate the future occurrences, risk, adverse effects and menace of flood disaster in the study area. The flood also enables people in the flood prone areas live with the flood at appropriate its positive impacts.

### Recommendations

Due to the effects of flood there is need to look for ways to mitigate it, some arrangements must be developed and evaluated to deal with the problems. From the study the following recommendations are made to tackle the problem of flood and for further studies:

1) The government should provide a proper operation and maintenance of hydraulic structure, through controlled released of water from existing dams and reservoir upstream to minimize the risk of overflow and eventual flood disaster in the flood prone areas of Hadejia Jamaare River Basin.
2) Disaster Management Organization and Civil Societies need to implement Developmental projects in flood prone areas of Hadejia Jamaare River Basin and should be critically analyzed based on the effective factors causing flood in order to mitigate the hazards and afforestation should also be encouraged in areas liable to flood.
3) Residents in flood prone areas of Hadejia Jamaare River Basin should avoid erecting buildings along the waterways and strongly advised to stay away from river bank and channel, especially when rainy season is at its peak to minimize the risk of been submerged.

**References**

Bariweni, P.A Tawari, C.C and Abowei, J.F.N. (2012). Some environmental effects of flooding in Niger Delta Region of Nigeria. International Journal of Fisheries and Aquatic Sciences, Vol. 1 (I), pp. 35-46

Chiroma, M.J. Yahaya, D.K. and Abba J.G. (2010), water management issues in the Hadejia – jamaare Komadugu Yobe Basin (HJKYB). DFID-JWL and state holders experience in information sharing, reaching consensus and physical interaction

Federal Government of Nigeria (2013), Nigeria Post Disaster Need Assessment (PDNA), Areport of the federal government of Nigeria with Technical support from the European Union, United Nations, World Bank and other partners.

Goggle earth™ (2017) offline map encyclopedia

Hadejia Jamaare River Basin Development Authority, (2014). Water for development, A Biannial Newletter of Hadejia-Jamaare River Basin Development Authority (HJRBDA) Maiden action.

Jigawa State Emergency Management Agency (SEMA), 2010. Report of the council committee on the 2012 flood disaster, unpublished.

Nigeria Hydrological Service Agency (NHSA), (2013). 2013 Annual flood outlook for Nigeria.

Umar F.I. and Adnan A. (2017). Flood risk assessment in part of Hadejia-Jamaare River Basin (HJRB) of Jigawa state, MSc. Thesis, Bayero University Kano.

Usman A.A. Sunday, G.Y and Alkali, A.N. (2016). Flood frequency analysis at Hdejia River in Hadejia-Jamaare River Basin, Nigeria Journal of civil environmental research , vol. 8 (9), pp. 124-139

Rose, et al. (2014). Flood hazard assessment of river Dep. Floodplains in North Central. International Journal of Water resources and environmental engineering, vol. 6 (2), pp 67-72

Sani Yahaya, (2008). Multi criteria analysis for flood vulnerable areas in Hadejia Jamaare River Basin, Nigeria. ASPRS 2008 Annual Conference, Portland, Oregon. April 28 – May 2, 2008.

United Nations Environmental Program (UNEP), (2003). Global Environmental Outlook 3. London: Earthscan Publications.

## A REVIEW ON DROUGHT ONSET AND DEMISE

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**Abstract**
*The characteristics of drought, which is a global phenomenon, is known to be complex, with no universally accepted single definition. Lots of studies bordering on the assessment or vulnerability of drought had been carried out but studies on drought onset and demise is still nascent and/or not well developed or known as other aspect of drought. This paper is aimed at reviewing some key studies on drought onset and demise, noting the main findings (directly replicable and/or modified for adoption) and research gaps, for further studies and advancement in drought studies, for eventual global benefits. Since not much is published concerning research works in this area in northern Nigeria, well-known for being devastated by the recurrent events of drought, it is hoped that interest will be spurred for concerted or intentional efforts in this regard.*

**Keywords:** Climate, Climatic, Demise, Drought, Onset, Precipitation

## Introduction

The global phenomenon called drought (different from all other natural disasters) with its impacts is ever evolving, yet none of its several definitions have been universally accepted, owing to its nature or characteristics, which are complex, multifaceted and hydro-climatical-variable dependent (Wilhite & Glantz, 1985; Wilhite, 2005; Changnon, 1987). The slow start (onset), demise, temporal and spatial extent of drought is characteristics that complicates the drought event (Wilhite, 2005: Mo, 2011; Shah & Mishra, 2020)

However, all drought definitions consent to the fact that drought is an event of inadequate moisture arising or triggered by prolonged precipitation deficit in time and space (McKee *et al*., 1993; Bonacci, 1993). The four conventional drought types are meteorological, hydrological, agricultural and socioeconomic droughts (Wilhite & Glantz, 1985) with meteorological drought, which hinges on precipitation shortage, being the forerunner to all the other drought types.

All drought monitoring, planning, early warning system, management and forecasting are linked to the early detection of drought or detection of drought onset and demise, as shown in figure 1 (Nhamo *et al*., 2017).

Naturally, there are certain factors used for the assessment or determination of the presence of drought condition in a location and they include weather conditions, soil moisture, water table conditions, water quality, streamflow, runoff, precipitation and temperature (Alireza *et al.*, 2015; Byun & Wilhite, 1999; Changnon, 1987)

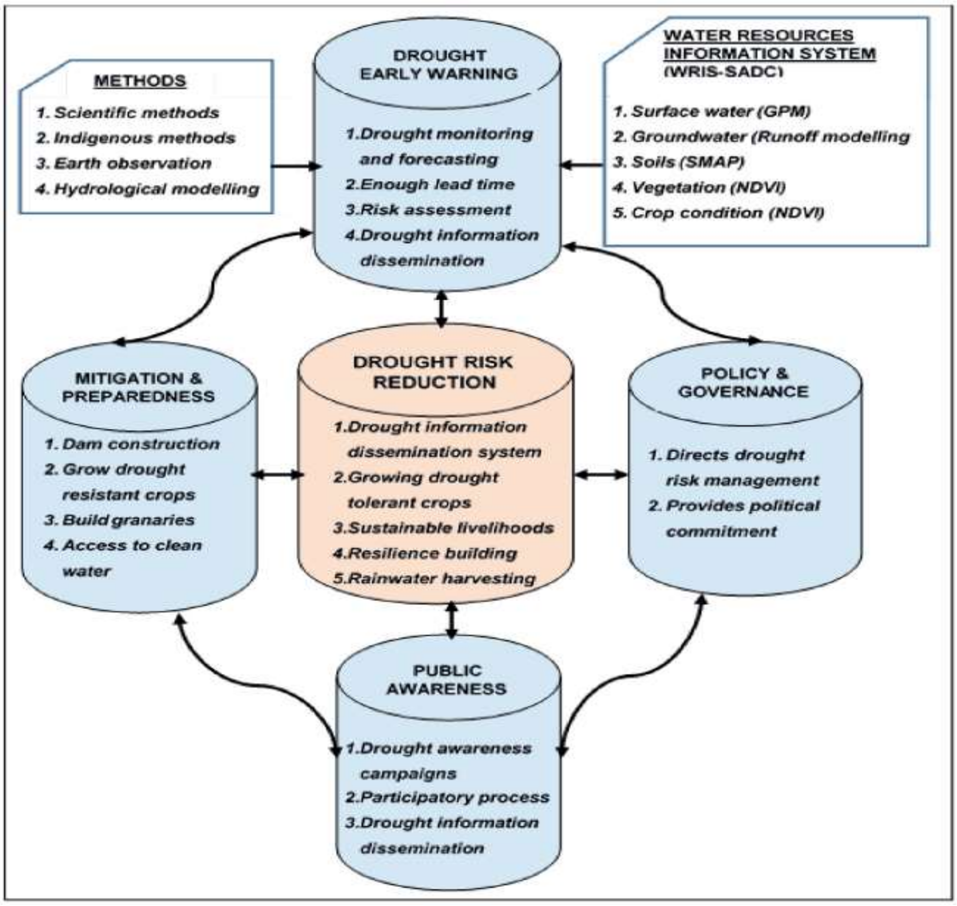


**Fig. 1:** Components of drought early warning system.

Despite several developments or researches in the assessment of drought using various types of indices, studies in drought onset and demise or termination is still nascent or not well developed. So, this paper is aimed at highlighting some key efforts made in the area of onset and demise of drought based on past studies, while the objectives of this paper are to assess and/or spotlight the main research findings and gaps in each of the research paper.

### A) Drought Onset and Recovery Over the United States

In this paper by Kingtse (2011), precipitation (P) and Soil Moisture (SM) data for the period of 1916 to 2007 was used to examine the drought onset and end, in the United States.

Meteorological and agricultural droughts were studied or identified, employing Standardized Precipitation Index (SPI), derived from observations and the Soil Moisture (SM) anomaly percentiles, from the Northern American Land Data Assimilation System (NLDAS).

**Research Main Findings**

a. The SPI and SM anomaly percentiles are used to classify drought events (Meteorological and agricultural droughts).

b. Within the study area, SPI and SM Indices were used to define certain thresholds for ʈ-duration, as a means of identifying drought onset of demise.

c. 3-months SPI (SPI-3), a 3-month P mean ($P_3$) time series was obtained.

d. It is possible to identify the beginning of drought event: the threshold for drought onset is less than -0.8 for SPI Index and the SM percentile is below 25% for the one season or longer.

e. While for drought demise or end, -0.2 for SPI and 35% for SM are the threshold (Svoboda, *et al.*, 2002).

f. The onset of drought has higher predictability than the demise of drought, which is quick to occur but difficult to predict, since heavy rainfall can alter it.

g. The beginning of rainy season marks the likely season for the start or end of drought, that is, as a preferred season for the onset or demise of drought.

h. Drought is related to persistent Sea Surface Temperature (SST) anomalies (SSTAs).

i. It is observed that drought in the Study area, is significantly impacted by El Nino Southern Oscillation (ENSO), though it is not known whether ENSO triggers or end drought.

j. The occurrence of drought over the study area is not of regular intervals.

k. Within a period of 2 to 3 months, the demise of drought can occur, with few strong raining episodes.

**Research Gap**

a. The exact influence or relationship between ENSO and drought is not certain or clear, within the study area.

b. The ability of the two indices (SPI and SM) to encapsulate or fully cover the same drought events are not known.

**B) A Vantage from Space can Detect Earlier Drought Onset: An Approach Using Relative Humidity**

Aliera *et al.*, (2015), proposed an alternative or complementary drought onset detection indicator (Standardized Relative Humidity Index, SRHI) and compared it to the well-known Standard Precipitation Index (SPI), which is a precipitation deficit evaluator, Standardized Soil Moisture Index (SSI) and soil moisture percentiles

The standard relative humidity data was obtained from the NASA Atmospheric Infrared Sounder (AIRS) satellite mission (Aliera, *et al*., 2015).

Precipitation data is a ground-based observation data, while near surface air relative humidity is a satellite-based data.

**Research Main Findings**

a. Due to limitations (uneven distribution, temporal inconsistencies, spatial inhomogeneous records) that are possible in ground-based observation data, it is important to monitor drought in other locations using satellite data.

b. Drought onset can be detected earlier than precipitation and soil moisture-based indices.

c. AIRS's (version 6, level 3 data) monthly surface relative humidity (at a $1^{o}$ spatial resolution) was employed for the detection of drought onset.

d. As a supplementary measure, the SPI and SSI data from Global Integrated Drought Monitoring and Protection System (GIDMaPS) are used.

e. The threshold used for the drought onset is the ***D0*-Drought** (abnormally dry) condition, drought with 30% occurrence probability.

f. To examine early detection of drought, three (3) time series of SPI, SSI and SRHI drought events of 2010 Russian drought, 2010 – 2011 Texas-Mexico drought and 2012 United Stated droughts were investigated.

g. From the time series, the SRHI detected drought earliest, followed by SPI and then SSI.

h. Though SRHI was shown to be capable of detecting drought earlier than SPI, some cases still exist are otherwise.

i. In most parts of the world incorporating SRHI to other indicators can enhance onset drought detection.

j. Despite its efficiency, the propounded SRHI is not intended to substitute the indicators currently available, but used concurrently with other drought indicators.

**Research Gap**

a. Further studies are needed in areas where SPI detect drought earlier than SRHI (covering more areas and extended periods)

b. Application of SRHI in other regions with longer lengths of data.

**C) Detecting Drought Conditions in Illinois**

In this quantitative evaluation of the drought conditions in Illinois carried out by Changnon (1987), it was intended to answer drought questions such as whether drought is developing, the severity of drought per time and the duration of drought, in order to assist key water stakeholders.

Drought and its various types were defined long with their contributing/causative factors.

The study and/or report covers the four major aspect of hydrologic cycle, which are precipitation conditions, soil moisture conditions, shallow ground water levels and streamflow's; monitoring these conditions made room for the identification and assessment of drought presence (or detection of drought onset), drought-severity quantification and drought termination estimation measures. Also, Changnon, 1987, reported that the following are common natural factors or indicators to determine the presence of drought; weather conditions, soil moisture, water table conditions, water quality, and streamflow.

In this study, 50-well-distributed weather stations was used, and average precipitation pattern for a given period (3-months or longer) was determined.

**Research Main Findings**

a. Precipitation is the basis for start and end of drought.

b. Drought conditions varies from region to region in Illinois, with their unique pattern, are relevant for explaining the occurrence and intensity of drought.

c. Precipitation-based scale criteria, for monitoring the occurrence of drought, were drawn for periods spanning from 3 to 60 months. With the developed criteria, the presence or onset of drought can be determined.

d. Guidelines or procedures for examining the severity of drought was developed for periods from 3 to 24-months duration and two categories of severity were established (moderate and severe)

e. Relationship between precipitation deficiency and resultant drought impacts, was developed into a chart.

f. For crop drought severity, there is no stand-alone indicator that exist, therefore various soil moisture values were approved or proposed to be used for its assessment.

g. Drought starts and ends on the basis of precipitation.

h. Procedures for the detection of drought onset or initiation and termination were listed.

i. Less than 3-months dry periods do not signifies drought, except in some abnormal conditions of severe hot and dry weather in June, July and/or August, which may affect crop yields.

j. The criteria that precipitation drought are as follows;

- A 3-month precipitation drought exists if the state average is ≤ 60% of the mean value.

- A 6-month precipitation drought exists if the state average is ≤ 70% of the mean value.
- A 12-month precipitation drought exists if the state average is ≤ 80% of the mean value.
- A 24-month drought exists if the state average is ≤ 90% of the mean value.
- A 30-month to 60-month drought exists if the state average is ≤ 95% of the mean value.

k. The detection of the initiation of drought, requires two activities;

- A routine, month-to-month continuous monitoring of precipitation conditions in Illinois at up to 40 locations, and
- A continuing operation of the models provided in this report for estimating soil moisture, shallow ground water levels and low flow values.

**Research Gap**

a. The involvement or use of drought indices for the detection of drought onset of termination, was scarce or not mentioned.

**D) DROUGHT ONSET AND TERMINATION IN INDIA by Deep Shah and Vimal Mishra.**

In this study, Shah and Mishra (2020) opined that the multi-faceted negative impacts of drought (socioeconomic, agricultural, environmental and financial) are also felt in India. Several researchers have concluded that the definition of drought is influence or dependent on lots of factors such as rainfall, soil moisture, streamflow, groundwater and vegetation and as such there is no universally accepted or acclaimed definition that fits all, due to drought complexity and multiple hydro-climatic variables (Wilhite, 2005; Wilhite and Glantz, 1985; Van Loon, 2015; Lloyd-Hughes, 2014)

**Main Research Finding**

a. Integrated Drought Index (IDI), that incorporates precipitation, runoff, soil moisture, and groundwater, was used for drought assessment in India.

b. IDI provides better drought monitoring (in the study area) and management information based on several hydrological variables.

c. Meteorological drought is the main lens through which all other forms of droughts are viewed.

d. $0.25^{o}$ daily gridded precipitation (6995 rain gauge stations), minimum and maximum temperatures (1951 – 2016) from India Meteorological Department, IMD, (Pai *et al.*, 2015; Srivastava *et al.*, 2009)

e. The whole of India was divided into eight clusters, based on similarity of drought event.

f. Drought onset and termination in India was detected based on IDI, using 1951 – 2016 data set.

g. Drought onset was defined the first month in which basin average IDI of a cluster is negative and remains negative for 3-months consecutively.

h. The drought termination was defined as the first month averaged IDI of a cluster is positive and is sustained for three consecutive months.

i. The number of months between drought onset and termination was defined as the drought duration.

j. Drought event was ranked based on overall severity score, which is the production of duration, mean intensity and peak fraction area, according to Shah and Mishra (2020) description.

k. Relative contribution for the top three drought spells for each cluster was estimated using average of 12-months SPI, I-month SSI, 4-month SRI, to estimate overall severity scores.

l. Empirical Orthogonal Function (EOF) and Maximum Covariance Analysis (MCA) was performed and used to determine the linkage between long-term climate variability and i-month IDI for the 1951 – 2016 period.

m. Estimation of monthly SST departure field was done after removing the monthly mean of global SST from each grid for the 1951 – 2016 period (Mishra *et al.*, 2012)

n. VIC-SIMGM performs satisfactorily captured monthly streamflow temporal variations, groundwater storage variability, variations of groundwater table anomalies with 0.6 as correlation coefficient (r) in the majority river basin.

o. Drought onset and termination was found to occur during the monsoon months (June, July, August and September) in most of the drought clusters.

p. Drought onset and termination in parts of India, is highly affected by precipitation seasonal cycle, while SST anomalies and Atlantic Ocean affects other parts.

q. The two worst droughts occurrence in India (1987 and 2002) were primarily driven by precipitation (Meteorological drought)

r. The Arabian Sea, Bay of Bengal and the India Ocean are the major sources of moisture in most of the clusters.

**Research Gap**

a. The employed methods for the detection of drought onset and termination are complex, due to the diverse processes, estimations and additional correlating data's, from established bodies (National Aeronautics and Space Administration, NASA, IMD, India Water Resources Information System, India-WRIS, Central Groundwater Board, CGWB, National Oceanic Atmospheric Administration, NOAA, and National Centre for Environmental Prediction, NCEP) and GRACE Satellites data, followed by Variable Infiltration Capacity (VIC) model, Hybrid Single-Particle Lagragrian Integrated Trajectory (HYSPLIT) model then algorithmic clustering.

b. These bodies are not available in most countries of the world and the processes are not easily lucid enough for adaptability.

c. Lengthy time space is a major requirement for adoption and applicability of this procedure in other locations.

## Conclusion

The review of these drought onset and demise research works reveals vital information's concerning the useful indicators, indices and conditions for applicability of each method to any study area. Historical drought records or events, ground data and satellite data, with or without satellite indices and models were deployed to arrive at the several research findings.

Based on these reviews, the following conclusions can be made:

1. Long term data and meticulous assessment/analysis are crucial for the detection of drought onset and/or demise.
2. Drought trigger or driver agents vary from region to region.
3. The combination of drought indices is important in order to overcome the limitation of individual index and make informed conclusion about drought onset and demise; meaning that no matter the efficiency of any index, complementing it with other index is indispensable.
4. Larger study areas are to be grouped or divided into clusters for easy and accuracy of detection results.
5. Satellite-based index seems to give or detect drought onset earlier than the regular index, in some study area, however applying same procedure/methods to other regions or climatic regimes will broaden knowledge of its usefulness.

6. Some drought onset drivers may not be relevant in drought demise/termination situations, vis versa. However, some drivers influences both drought onset and demise in some regions.
7. It is possible to develop a better or robust index, that combines a number of drought indices.
8. The monitoring, planning, mitigation and prediction of drought can be enhanced by the detection of drought onset and demise, employing tested indices along with ground observational and/or satellite data.

**Recommendation**

These research works are laudable, however more researches are needed in other regions using same methods, modified methods, different methods and/or combined methods, for the detection of drought onset and demise, to improve global drought management, mitigative action and prediction, thereby reduction in drought related losses can be attained.

Similar research works in Northern Nigeria is of urgent need (whether local or foreign sponsored research), since northern Nigeria suffers most from the devastating effects of drought than other parts of Nigeria, lots of funds had been repeatedly reported as being spent as a result of drought (Adaega, 2011; FRN, 1999), and no published works was found in this area for northern Nigeria.

**References**


Adaega, O. (2011) Drought risks and impact on water resources in part of northern Nigeria. In: Hydro-climatology: Variability and Change (Proceedings of symposium J-H02 held during IUGG2011 in Melboume, Australia. IAHS Publisher. 344. IAHS Press, Wallingford, UK.

Alireza, F., Amir, A., & Joao, T., (2015). A Vantage from Space can Detect Earlier Drought Onset: an approach using relative humidity. Scientific reports, February 2015, vol.5, Issue 8553. DOI:10.1038/srep08553.

Byun, H.R. and D.A. Wilhite (1996). Daily quantification of drought severity and duration. Journal of Climate, 5:1181-1201.

Changnon, S. A., (1987). Detecting Drought Conditions in Illinois. Illinois State Water Survey, champaign, circular 169.

Federal Republic of Nigeria, FRN. (1999). Combating Desertification and Mitigating the Effects of Drought in Nigeria. The Revised National Report on the Implementation of the United Nations Convention to Combat Desertification (UNCCD) in those Countries Experiencing Series Drought and/or Desertification, particularly in Africa (CCD).

Kingtse, C. M., (2011). Drought onset and recovery over the United States. Journal of geophysical research, vol.116, D20106, doi:10.1029/2011JD016168.

McKee, T. B., N. J. Doesken, and J. Kleist. (1993). The relationship of drought frequency and duration to time scales. Eighth Conference on Applied Climatology. American Meteorological Society, Boston. 179 - 184

Nhamo, L., Mabhaudhi, T. & Modi, A. T. (2019). Preparedness or repeated short-term relief aid? Building drought resilience through early warning in Southern Africa. Int'l Water Management Institute (WMI), South Africa. ISSN 1816-7950 (online), water SA, vol. 45(1). https://doi.org/10.4314/wsa.v4sil.09

Ognjen, B. (1993). Hydrological Identification of Drought. Hydrological Processes, Vol. 7, 249-262.

Shah, D. & Mishra, V. (2020). Drought onset and termination in India. Journal of Geophysical Research: Atmospheres. J25, E2020JD032871.

Wilhite, D. A. (2005). Drought and water crises: science, technology, and management issues. Bosa Ration: CRC Press, New York. vol. 86. https://doi.org/10.1201/9781420028386

Wilhite, D. A. and M. H. Glantz. (1985). Understanding the drought phenomenon: The role of definitions. *Water International* 10:111-120. https://doi.org/10.1080/02508068508686328.

Wilhite, D.A. and M.H. Glantz. (1993). Planning for drought: A methodology. Pages 87-109 in Drought Assessment, Management, and Planning: Theory and Case Studies (D.A. Wilhite, ed.). Kluwer Academic Publishers, Dordrecht, The Netherlands.

Yohannes, Y., Babak, V., Radwan, A. A. (2019). Drought Indices and Indicators Revisited. Arabian Journal of Geosciences. https://doi.org/10.1007/s/2517-019-4237-z.

# ASSESSMENT OF THE CHALLENGES OF POTABLE WATER SUPPLY IN SOKOTO METROPOLIS BY SOKOTO STATE WATER BOARD

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**Abstract**
*Conventional water supply agencies in developing countries are unable to provide adequate potable water to metropolitan residents. The potable water produced by these agencies is periodic and unfairly distributed. In Sokoto metropolis, several cart-pushing water vendors are seen hawking water to residents. The agency tasked with producing and supplying adequate potable water to the metropolis (Sokoto State Water Board-SSWB) is convincingly facing several challenges. This research thus assessed the major factors responsible for inadequate supply of potable water in Sokoto metropolis. The study adopted a mixed method approach of data collection and analysis, Quantitative data was sourced through interviewing of 400 sampled households determined by Yamane's formula. Qualitative data: challenges of inadequate water supply was collected through Key Informant interviewing of selected serving and retired senior staff of the SSWB, Ministry of Water Resources, Ministry of Budget and Economic Planning and Sokoto Rima River Basin Development Authority data. The findings reveals that sources of water in the metropolis are SSWB, Community boreholes, Private boreholes and hand dug wells andthe major challenges of inadequate potable water supply are: rapid population growth; city expansion; non-application of the proposed new extension potable water supply plan; topography of Sokoto metropolis and political interferences. The research recommends; the construction of more booster stations; completion of proposed new extension water plants; use of smaller diameter pipes for supplying water to low-lying areas, provision of enough and timely funds to SSWB; revamping of the infrastructure, insulating management from interference by politicians and Public Private Sector engagement.*

**Keywords**: Challenges Potable Water Supply Sokoto Metropolis

## Introduction

A cursory transect survey within the Sokoto metropolis, especially in the morning hours will reveal most residents do not have adequate and regular supply of potable water. Several cart-pushing water vendors would be seen hawking water to the residents, while water tankers would be seen manoeuvring the streets to sell water to the business enterprises. It is thus, conclusive to posit that, the agency tasked with the function of producing and supplying adequate potable water to the study area-Sokoto State Water Board might be facing some challenges. The importance of potable water to the survival of human beings cannot be overemphasized and several authors have conceded to this fact. Young (2006), opines that apart from air, water is the most important resource to man. Humans can survive longer without food, but not without water. Water is thus a unique liquid necessary for the lives of animals and plants. Ashley (2007) adds that, every living cell has water as its primary composition. Life, health and hygiene all depend on access to an adequate and safe supply of drinking water. For this reason, the possibility of life (or man's existence in any particular place), depends on the presence or accessibility to water. The worldwide water issue made the United Nations general assembly in December, 2003, to proclaim year 2005 to 2015 as the international Decade for Action "water for life. This has woken the world awareness to the pressing water issue. But in 2018, the UN estimated that a child dies from a water related disease every 15 seconds.

Notably, Sokoto metropolis is blessed with two major sources of surface water supplies which are Rivers Rima and Sokoto, as well as ground sources. A preliminary survey conducted for this study reveals that the total design capacities of the plants in the study area if functioning optimally is 61.6 million gallons, per day (277.2 million litres per day). This capacity is quite a substantial amount and yet the metropolis is still suffering from inadequate supply of potable water. Hence, this study was conducted to assess the challenges of potable water supply in Sokoto Metropolis by Sokoto State Water Board.

**Methods of Data Collection**

This research used mixed methods for collecting the data. The methods used for collecting data are; Questionnaire, Interviewing and Key Informant Interview (KIIs). The key informants were selected from both serving, as well as retired senior staff and General Managers of the State Water Board, Ministry of Water Resources, Ministry of Budget and Economic Planning and Rima River Basin Development Authority (SRRBDA), for vital information.

**Sampling Frame; Sampling Size & Sampling Technique**

There are 27 wards, with 138,905 households, covering the study area. The wards were categorized into high, medium and low density neighbourhoods on the basis of the perceived number of people in the households and standard of living in the social stratification ladder in the metropolis. Applying Yamane's formula to the 138,905, a total of 400 households were surveyed. Finally, random number table was used to pick the households

**Data Analysis and Presentation**

Mixed method of data analyses, was used in this research. Descriptive statistics from the exploratory function of SPSS was used to draw conclusion.

The data was presented using findings of information from key Informant Interview and related to the challenges that contribute to any deficiency of supply of potable water to Sokoto metropolis.

**Study Area**

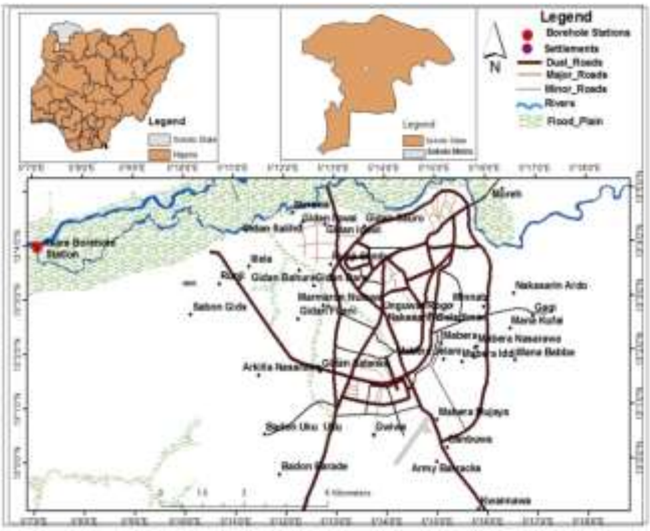


**Fig. 1:** Location of Sokoto metropolis in Nigeria

**Location**

The study area (i.e. Sokoto metropolis), lies between latitudes 12° 55′and 13° 10′N and longitude 5° 07′E and 5°19′E. Specifically, Sokoto metropolis covers a radius of $16\ km^2$ from the Giginya memorial stadium. The study area is the entire landmass of Sokoto North and Sokoto South Local Government Areas (LGAs), as well as some portions of Dange-Shuni LGA (Army Barracks, Danbuwa; Kwannawa); Wamakko LGA (Arkilla, Ruggar Waru, Bado, Gwiwa, Nufawa, Gidan Fulani and Kalambaina), as well as Kware LGA (More).

**Climate**

The mean annual temperature of Sokoto metropolis is 28°C, indicating it is in a hot climate; however, in the coolest months of December and January, night and early morning temperature could be far below 20°C. Also, during the hottest months of April and May, the temperature rises to about 40˚C, making the area very hot (Arnborg, 1988 and NIMET, 2000).

**Relief**

Sokoto metropolis was built at the crest and western end of a ridge, stretching from Kwannawa in the south-east to Gidan Igwai in the north-west; topographically. Specifically, the core of Sokoto metropolis (referring to Sokoto North and Sokoto South LGAs), lies on top of a 300 meter hill which slopes gently into plains which fringe the city all around. The hill on which Sokoto metropolis is located which has an east-west alignment is about a 12-kilometre long and about 7 kilometres wide.

**Hydrology**

Although Sokoto climate is drier, the state is endowed with both surface and ground water resources. Water board obtains raw water from the Sokoto and Rima rivers through the intake chambers.

**Results and Discussion**

**Sources of Water Supply**

Figure 2a indicates that, the major supply sources are Sokoto State Water Board, accounting for 41% of the water supply. Private boreholes are next in supply, accounting to 23%; 18% of the supply comes from community boreholes and 18% from hand dug wells. Further analysis on stratification of the metropolis as shown in figure 2b and figure 2c, the research indicates 56% of residents in high density area depends on SSWB, while 22% depends on Community boreholes, 13% on private boreholes and only 18% depends on hand dug wells. For the low density population, only 37% depends on SSWB, 5% depends on community boreholes 42% on private boreholes and 18% on hand dug wells.

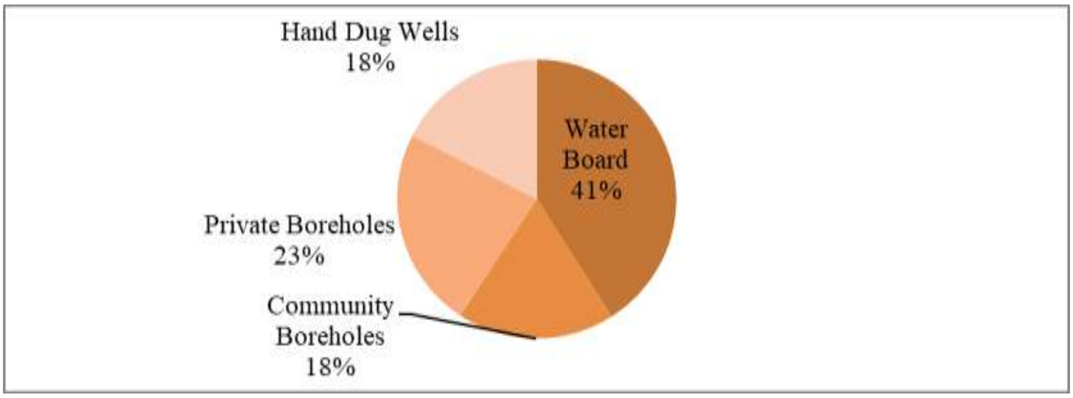


**Fig. 2a:** Sources of Water Supply in Sokoto Metropolis.

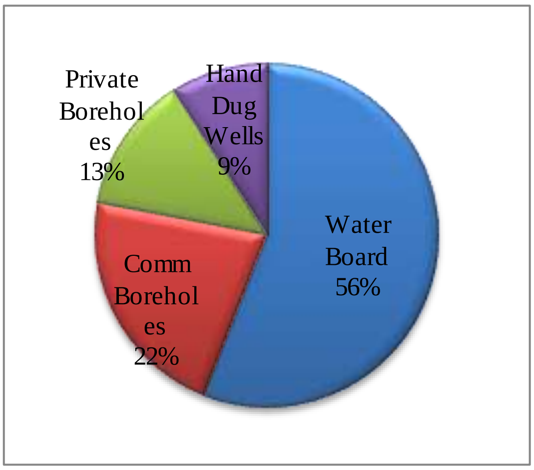


**Fig. 2b:** Sources of water Supply for High Density Areas Source: Fieldwork 2019

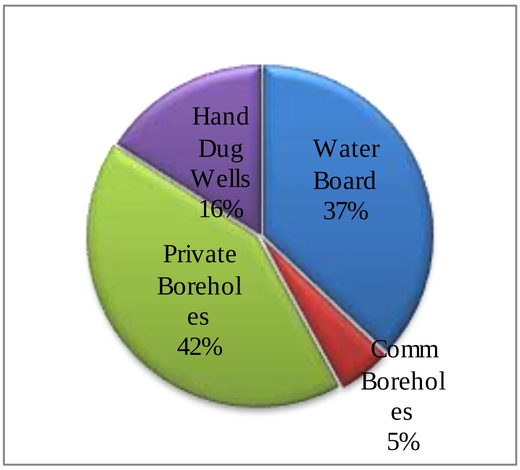


**Fig. 2c:** Sources of Water Supply for Low Density Areas. Source: Fieldwork 2019

**Days without Potable Water Supply to the Residents in Sokoto Metropolis**

Figure 3 reveals that about 39% do not get water supply for more than a week, while 17% do not get water for 4 to 5 days in a week, and about 6.3% of the households are living without water supply for almost 6 to 7 days in a week. It can be deduced from the figures presented that only 17% of the households enjoy daily supply of potable water in a week. This means that, the rest (83%) receives water only once or twice, in a week. The 17% was further stratified within the metropolis, the analysis shoes that 25% of the residents in the high density area enjoy daily water supply while only 23% enjoy daily water supply in the low density area.

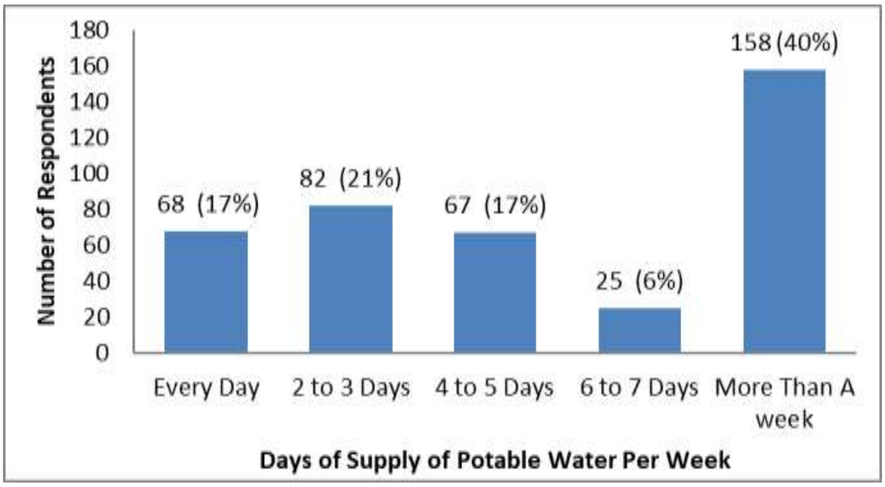


**Fig. 3:** Days of potable water supply;

**Source:** Fieldwork 2019

**Major Challenges Associated With the Water Supply in Sokoto Metropolis**

**1. Rapid Population growth**

According to information gathered from a serving Senior Director in SSWB, the key informant said, *"A major challenge causing water supply problem is the rapid growth of population across the metropolis. The demand for potable water is always increasing in the city due to ever growing population and migration from the rural areas in search of jobs."*

Rapid population growth has increased the demand for water to such a point that, the initial design for the metropolis has become grossly inadequate to supply the existing daily demand

## 2. Areal Expansion of Sokoto City

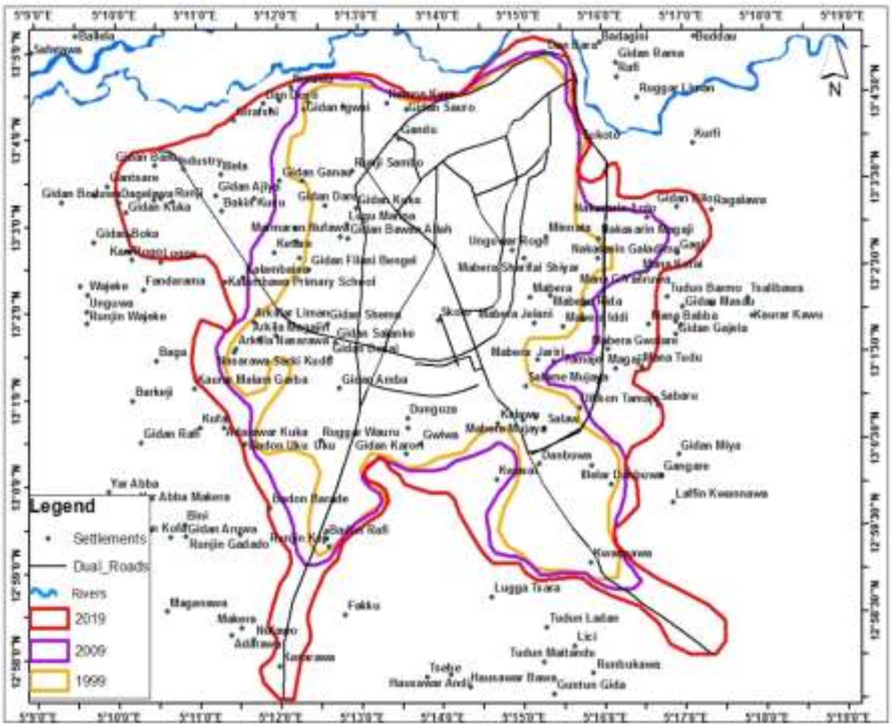


**Fig. 4:** Areal Expansion of Sokoto metropolis from 1999 to 2019

**Source;** ArcGIS 10.22, Fieldwork 2019

Figure 4 reveals that, the city experienced 21% (7,196 he) areal expansion in 2009, as compared to its size in 1999. By 2019, the city had increased by 70% (10,114 he), its size as compared to 1999.It is easy to argue that, the rapid areal extension of the city was due to demand for more land to build residential houses and other facilities for human habitation.

## 3. Non Application of New Extension Water Treatment Plan

A former General Manager of the Sokoto State Water Board said:

According to the informant, the Sokoto State government abandoned the second and third phases of what had been planned.

## 4. Political Interference

Key Informant Interview reveals that political parties lobby for their members to be recruited into the board without due regards to their technical expertise.

## Conclusion

The major challenges are rapid population growth, areal expiation of the study area, non-application of the new extension water plant and topography of the study area. The study area is only getting about half of potable water requirement therefore the hypothesis is rejected.

**Recommendations**

i. Government should resume construction of the abandoned new extension potable water treatment plants. This will provide more potable water for the ever increase demand.
ii. The Sokoto State Government should give more consideration to water supply sector bearing in mind the importance of water to life, by appointing political office holders with requisite knowledge and interest in potable water supply.
iii. It is important that the infrastructure of the sector is revamped
iv. In order to ensure that workers of the SSWB are proactive, politicians must desist from interfering in the management and recruitment processes of the board.
v. There is still the need for the SSWB to enter into Public Private Partnership (PPP).

**References**

Ashley, W. (2007). The Importance of Water. http://www.srfboy.com/greensuferers/cleanwater/importanceofwater.htm.

Arborg,T. (1988) " *where Savannah Turns Into Desert Experience from the Sudan Savannah in Sokoto State Nigeria"* International Rural Development Centre, Uppsale.

Castro, J. (2018) What is the percentage of Drinking Water on Earth. In water crisis, World water Reserve

Davis, G. (1982) "Geology in Swindell K (ED) Sokoto State in Maps. Ibadan: University Press Ltd.

FMWR (2006) Water Resources Strategy. Commission of the European Communities Support to the Federal Ministry of Water Resources, Nigeria.

Offodile (2002), Ground Water Supply and Development in Nigeria, Second Edition, Mecon Geology and Eng. Services Limited Jos, Nigeria. P 277.

Orebiyi, E. O., Awomeso, J. A., Idowu, O. A., Martins, O., Oguntoke, O. and Taiwo, A. M. (2010).Assessment of pollution hazards of shallow well water in Abeokuta and Environs, Southwest,Nigeria. American Journal of Environmental Sciences 6(1), 50-56.

Ritchie H. and Rose M. (2019) Water Use and Sanitation. *Our World in Data .Org*. Retrieved online from http://our world in data.org/water-use-sanitation.

U.N. (2003) "Impact of Population Growth on Water and Quality of Life" United Nations International Year of Freshwater Report. New York

Young, G. (2006) 'Preface'. United Nation's World Water Development Report, Wilfrid Laurier University, Waterloo, Ontario. http://www.freedrinkingwater.com/water education/waterhealth.htm

# SUB-THEME 7:

# COASTAL WATER RESOURCES AND GROUNDWATER MANAGEMENT

**DETECTION OF GROUNDWATER LEVEL AND HEAVY METAL CONTAMINATION: A CASE STUDY OF OLUBUNKU DUMPSITE AND ENVIRONS, EDE NORTH, SOUTHWESTERN NIGERIA**

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***Abstract***
*This research presentsresult of the application of PQWTElectromagnetic Groundwater detector and analysis of heavy metal contamination around an open dumpsite in Olubunku, Ede North, Southwestern Nigeriawhich has been in operation for the past fifty years.PQWT-300S 300 meter was used to acquire 8 profiles at the site.Quantitative analysis of heavy metals was conducted for seven well water samples and five surface soil samples, the water and soil samples(digested) was read on BuckScientific Atomic Absorption Spectrophotometer model 210/211 vap to determine the concentration of Pb,Cd,Cr,Co,Ni in the samples. Ar and Hg in the samples were read colorimetrically using a Niesa Spectrophotometer.From the PQWT results,profiles 1,4,5,6,7 and 8 indicate a shallow level groundwater at depth around 30m which are prone to contamination as most water in the study area are obtained from hand dug wells less than 20m deep. Profiles 2 and 3 show a contact that indicate a boundary between fresh basement and well fractured basement which serves as the water bearing rock. The fractured basment appears to be highly conductive as seen on the conductivity range. The heavy Metal results obtained shows that the average value of Pb and Ni in both water and soil samples were found to be higher than other metals. Heavy metals analyzed in water and soil samples indicated that amongst the seven heavy metals tested, Pb was maximum in concentration, followed by Ni, Co, Cd, Cr, Hg and As respectively.The elemental concentrations ofPb, Cd, Cr, Co, Ni, Hg and As in the soil samples located at the periphery of the dumpsite are much higher and are above the permisible WHO limitwhile in water Pb is above thepermissible WHO limit and only Cr is below or at the permissible limit. The depth of ground water in the study area are predominatly at shallow level at around 30m and the high conductivity of the top shallow depth is suspected to be due to contamination by leachates from the dumpsites.The soil and the groundwater in the vicinity of investigated dumpsite may be polluted.The study has indicated vulnerability of the unconfined shallow aquifer underlying the predominantly clayey sandand the effectiveness of PQWT EM as groundwater detector.*

**Keywords**: Groundwater level; Heavy metal contamination; Olubunku Dumpsite; Southwestern Nigeria

## 1.0 Introduction

Waste dumpsites have been one of the major potential sources of groundwater pollution (Fatta *et al.*, 1999).and expeditious rise in population within a society leads to surge in waste generation .Further expansion had forced some of these dumpsites to be abandoned and, in most cases, they are not properly closed and contained using geomembrane (modern sanitary landfills including clay and plastic). These wastes may contain toxic substances and as they are decomposed or biodegraded, with the presences of infiltrating watereffluent know as leachate can be produced and pollute groundwater with time as they migrate (Dareand Fatoba, 2014). The assessment of the spread of groundwater contamination from landfill proves to be a very demanding task as the high cost of drilling limits the number of monitoring wells near the site and in many cases not available in developing countries. In this respect, geophysical methods have emerged as useful tools to characterize and discern the contamination both laterally andvertically. The PQWT electromagnetic groundwater detector has proved its efficacy in addressing problems such as: To find the subsurface rock resistivity, characterization of rocks mainly into sedimentary and igneous/metamorphic type of rock,identifications of structures(e.g, fractures),determination of lateral extent and thickness as well as rock distribution. In addition, it also help in detection of aquifer and aquifer types, determination of groundwater depths and flow direction. Finding the aquifer and its types, subsurface groundwater levels and prospects zones, groundwater depth as well as flow direction of the subsurface (Harinath, 2017). Groundwater contamination from dumpsite typically form a “plume” that move outward and downward into surrounding and underlying aquifer. A high concentration of chlorine ions in solution (referred to as chloride),in particular it make landfill leachate electrically conductive. Acid dissolved in water release hydrogen ions into solution which also enhance electrical conductivity (Carpenter *et al*., 2012). Soluble surface chemical substances can move through the soil and end up in the groundwater(Adebayo *et al.*, 2017).Heavy metal contamination may cause changes in the composition of the water and finally become inappropriate for human consumption (patil et al., 2011). The Government of Nigeria needs to accord top priority to sound management of solid waste in megacities as well as rural areas on indiscriminate waste disposal. Accordingly, the National Environmental Standards and Regulations Enforcement Agency (NESREA) promulgated by Federal Ministry of Environment have to come into effect. The present work seek to detect groundwater depth and investigate the extent of heavy metals generatedfrom the site.A vast literature exists showing the applications of geochemical and geophysicalmethods in environmental problems associated with groundwater contamination due to leachate percolation. Olafisoye *et al.*(2013)used the electrical resistivity (vertical electrical sounding) andhydro-physicochemical methods to map the contamination patches at the subsurfaceand investigate the contamination level of the various hand dug wells situated in theAarada area, Ogbomoso, Oyo State, Nigeria.

Govindarajan *et al*.(2014)works on groundwater quality and its health impact analysis in an industrial area.

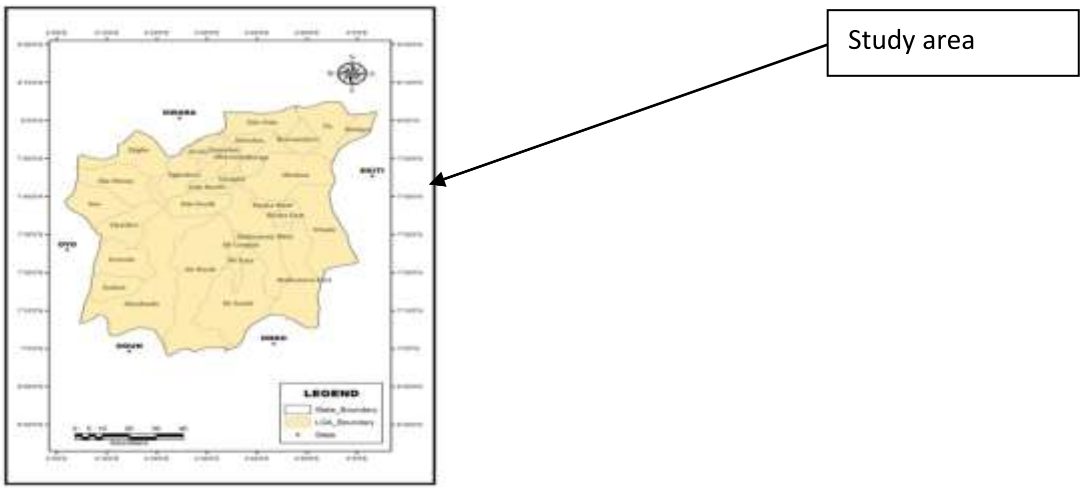


**Fig. 1:** Map of osun state showing the study area

## 2.0 Materialsand Methods

### 2.1 Study Area

The survey area is located within geographical co-ordinates of Longitude 4.438583E and 4.102389E and Latitudes 7.738917N and 7.736944N on the Universal transverse Mercator (UTM Zone31).The area is used as dumpsite by Olubunku community and its environs which runs parallel to a drainage channel, emptying its content in Osun river at Oke-gada, Ede North, Osun state. Topographically, the area is of low relief above the sea level and the slope trends in an approximately S-N direction which is parallel to the drainage channel. The drainage channel is the natural collector of the community surface flow, generating a strong environmental impact due to discharge of the untreated sewage effluent and open defecation on the drainage channel. The boundaries and surface of the waste are irregular, following the geometry that comes from alignment of cells and providing a soft and notable undulation It has an area of $111km^2$. The site is in operation for more than 50 years, it covers an area of approximately 1km in length and maximum of 100m in width with irregular waste dumps. It is located within the central area of Ede, town of Oja timi(fig.1.1). It has a population of 83,831 at the 2006 census, and many constructed houses around it. Dug wells and few boreholes are the sources of water extraction. Geologically, the study area lies entirely within the Basement Complex of Southwestern Nigeria (Rahaman, 1976) and is underlain by schist pegmatite and a sequence of lateritic clay, clayey sand/sand and weathered / fractured bedrock.

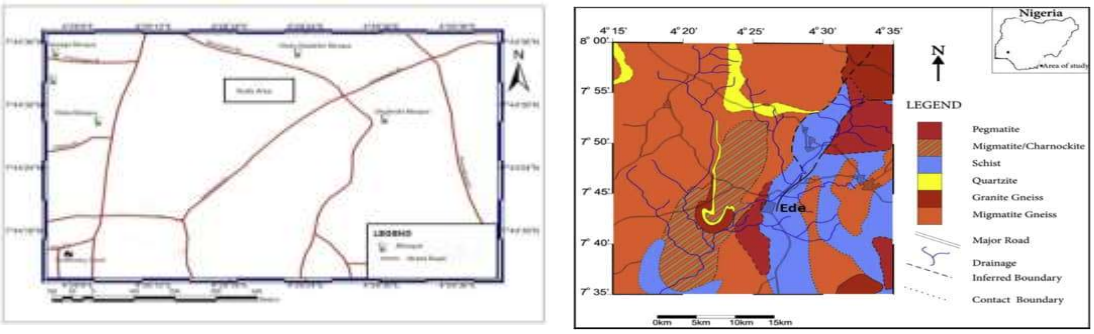


**Fig. 1.1a and b:** A Schematic map showing location of the study area and general Geologic map of the study area

**2.2 PQWT Groundwater detector**

PQWT-300S 300 meter 0.1mv Profile 128x64 DC7.2V 300mAh Rechargeable Battery was used. the data wascollected by the instrument transmitted to the computer for mapping to form a profile, according to a clear understanding of the geological structure of the profile, it can quickly determine cavity, water level (aquifer) and other geological structure of specific information.Withthe measurement speed, high efficiency**,** 500-5000 metersprofile measurement can be completed in one day. Delineating depths of geological anomalies, compared with the traditional artificial electric fieldmethod of exploration, speed and efficiency are improved many times.

In this research eight profiles wereacquired,the data is typically collected as point readings of ground conductivity or in-phase taken at regular intervals along a survey grid that has been set out over the site area. The spacing of the grid lines and reading stations is dependent upon the target size, generally smaller target require closer survey lines and denser spaced readings, 2m interval was adapted.

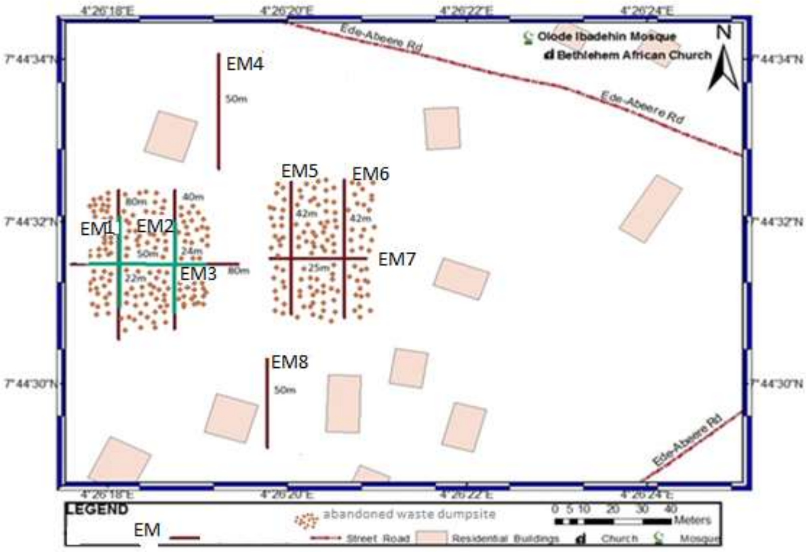


**Fig.2:** A Shematic map showing the EM profile locations

**Sample Locations**

The samples were taken from seven (7) locations which are detailed in the table below showing their source and coordinates in olubonku area, Ede, Osun State, Nigeria.

**Table 1:** Showing the locations of the samples.

| Sample ID | Source | Latitude | Longitude |
|---|---|---|---|
| **Balogun Oyesanm L1** | Hand-dug well | N 07° 44' 13.0" | E 004° 26' 14.9" |
| **Ologun Agabaakin L2** | Bore-hole | N 07° 44' 18.9" | E 004° 26' 18.9" |
| **Babanlapegba L3** | Hand-dug well | N 07° 44' 16.3" | E 004° 26' 10.4" |
| **Alaje L4** | Hand-dug well | N 07° 44' 20.1" | E 004° 26' 11.4" |
| **Babanlapegba L5** | Hand-dug well | N 07° 44' 17.1" | E 004° 26' 14.1" |
| **Olubunku L6** | Hand-dug well | N 07° 44' 18.1" | E 004° 26' 12.6" |
| **Isibo L7** | Hand-dug well | N 07° 44' 30.0" | E 004° 26' 08.6" |

**Fig 2.1a and b:** plane view of the abandoned dumpsite and a dumpsite around the bridge at Olubunku.

### 2.3 Analysis of heavy metals

10ml of the water sample was measured with the aid of 25ml measuring cylinder into a 50ml beaker. 5ml of an acid mixture of perchloric and nitric acid in ratio 2:1 was added, and the beaker content was placed on a hot plate under a fume cupboard and allowed to undergo heating at 90°C for 30minutes. The beaker content was removed from the hot plate and allowed to cool. The water sample(digested) was then reed on Buck Scientific Atomic Absorption Spectrophotometer model 210/211 VAP to determine the concentration of Pb,Cd,Cr,Co,Ni in the samples. Arsenic and mercury in the water sample was reed colorimetrically using a Niesa Spectrophotometer.The soil samples were air dried for 24hours and sieved using 2mm sieved and then 0.5mm sieve. O.5g of the 0.5mm sieved soil was weighed into a beaker and 5ml of an acid mixture of perchloricand nitric acid in ratio 2:1 was added, and the beaker was placed on a hot plate under a fume cupboard and allowed to undergo heating at 90°C for one hour and there was a colour changed from brown to colouless milky. The beaker was allowed to cooled and the digest was reed on buck Scientific Atomic Absorption Spectrolphotometer model 210/211 VAP to determine the concentration of Pb,Cd,Cr,Co,Ni in the sample. Arsenic and mercury in the sample was reed colorimetrically using a Niesa Spectrolphotometer

### 3.0 Results And Discussion

Profiles 1,4,5,6,7 and 8 indicates high probability of a shallow level groundwater at depth around 30m which are prone to contamination as most water in the study area are obtained from hand dug wells less than 20m.

Profiles 2 and 3 shows a contact which indicates a boundary between fresh basement and well fractured basement, the contact can as well be said to represent a boundary between different types of rocks in the area. The fractured basment appears to be highly conductive as seen on the conductivity range in profiles 2 and 3 with deeper presence of blue band which may indicate saturated zone . Curve 2 and 3 of the respective profiles clearly show the point where the sharp contrast occur and signify a change inproperties of the rock materials(fig.3). The top central whitish band in profile 1 indicates an area of poor compaction filled with irregular materials and thus no reflection.The top shallow depth across the profiles appears more conductive, indicating the top shallow sediments may have been contaminated by the leachates from the dumpsite

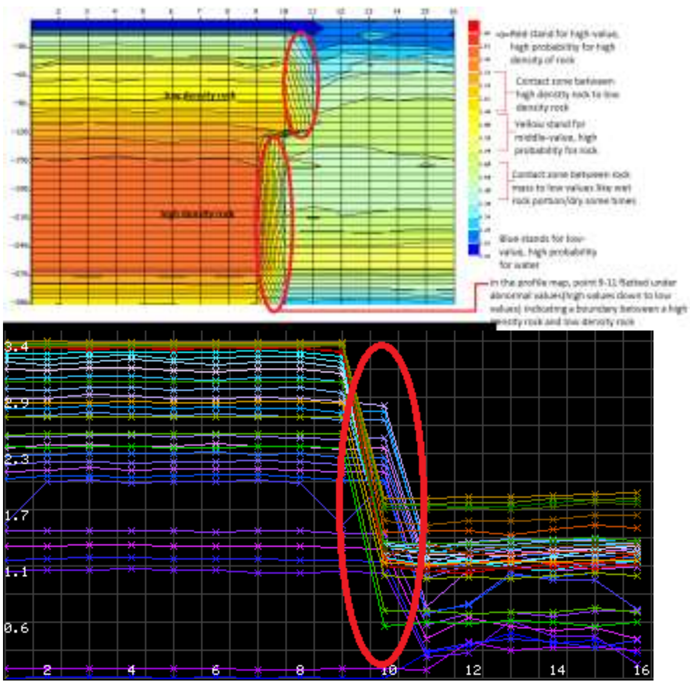


**Fig. 3**: profile 3 and the frequency Curveshowing the drop in frequency due to change in rock density

**Heavy Metals in Water Sample**

The results from the water samples of seven hand dug well are given in table below. Heavy metal concentration in water was found in theorder: Ni>Pb>Co>Cd>Hg>As>Crinthe located area.

**Table 2:** Heavy metals concentration (mg/L) in the watersamples

| S/N | ID | Hg mg/l | As mg/l | Pb | Cd | Cr mg/l | Co | Ni |
|---|---|---|---|---|---|---|---|---|
| **L1** | BalogunOjesanmi | 0.05 | 0.02 | 0.072 | 0.040 | 0.0180 | 0.010 | 0.368 |
| **L2** | OlogunAgbaakin | 0.10 | 0.05 | 0.061 | 0.039 | 0.000 | 0.066 | 0.377 |
| **L3** | Babanlapegba | 0.03 | 0.01 | 0.017 | 0.032 | 0.000 | 0.128 | 0.426 |
| **L4** | Alaje | 0.14 | 0.08 | 0.050 | 0.026 | 0.015 | 0.201 | 0.361 |
| **L5** | Babanlapegba | 0.08 | 0.12 | 0.144 | 0.032 | 0.024 | 0.280 | 0.424 |
| **L6** | Olubonku | 0.05 | 0.09 | 0.180 | 0.035 | 0.005 | 0.342 | 0.484 |
| **L7** | Isibo | 0.03 | 0.08 | 0.224 | 0.042 | 0.000 | 0.368 | 0.473 |
| **PL** | 1.00 | 1.00 | 1.00 | 0.05 | 0.2 | 0.01 | 0.02 | 3.29 |

PL: Permissible limit according to USEPA and WHO.

The difference between the sevensamples in metal content is in(Table 1). Ni is higher than other metal in the water sample follow by Pb then Co and the lowest is Cr. This shows that the water is affected by the dumps being disposed in the area. The higher nickel is suspected to be caused by anthropogenic activities in the area.

**Heavy Metals in Soil Sample**

The results from the soil samples are given in table below. Heavy metal concentration in soil was found in theorder:Pb>Ni>Co>Cd>Cr>Hg>Asinthe located area.

**Table 3:** Heavy metals concentration (mg/L) in soil samples

| S/N | ID | Hg mg/l | As mg/l | Pb | Cd | Cr mg/l | Co | Ni |
|---|---|---|---|---|---|---|---|---|
| **1** | L1 | 0.90 | 0.10 | 63.80 | 3.30 | 2.36 | 13.36 | 26.50 |
| **2** | L2 | 0.65 | 0.08 | 91.30 | 2.20 | 1.93 | 12.05 | 21.80 |
| **3** | L3 | 0.41 | 0.18 | 74.80 | 1.60 | 2.17 | 6.50 | 19.80 |
| **4** | L4 | 0.53 | 0.21 | 67.20 | 2.17 | 1.70 | 8.90 | 22.00 |
| **5** | L5 | 0.32 | 0.14 | 86.50 | 1.70 | 2.68 | 5.35 | 17.50 |
| **Pl** | 1.00 | 1.00 | 1.00 | 0.05 | 0.2 | 0.01 | 0.02 | 3.29 |

PL: Permissible limit according to USEPA and WHO.

The difference among the fivesamples in metal content is in (Table 2). Pb is higher than other metal in the soil sample follow by Ni then Co and the lowest is As. This shows that the soil is also affected by the dumpsite

**Assay correlation of heavy metals in soil and water**

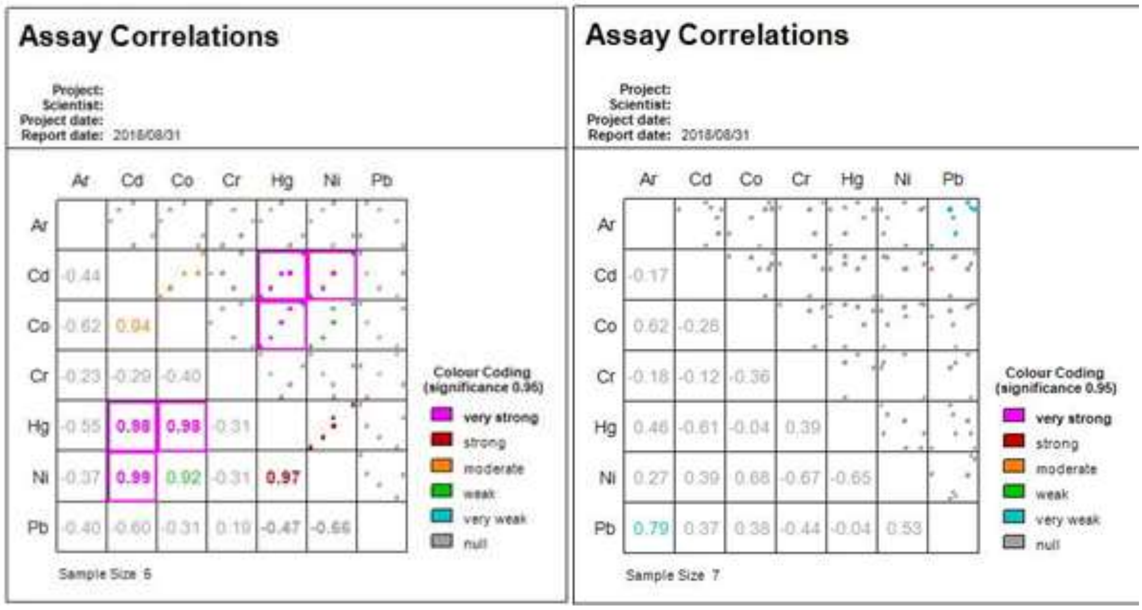


**Fig.3.1:** Assay correlation plots for heavymetals in soil and Assay correlation plot for heavymetal

Based on the principal components analysis (PCA), we observed a very strong positive correlation between thecontent of mercury, nickel, cadmium and cobalt in surface soil. The correlations of these metals could evidence theirsimilar sources. In turn, a negative correlation of mercury and chromium, nickel and chromium, mercury and arsenic, nickel and argon factors was observed in the soil also. The content of (positive correlation) and (negative correlation)depends on the location of soil. There is no strong correlation between the content of the water but a very weak correlation was observed between lead and argon.

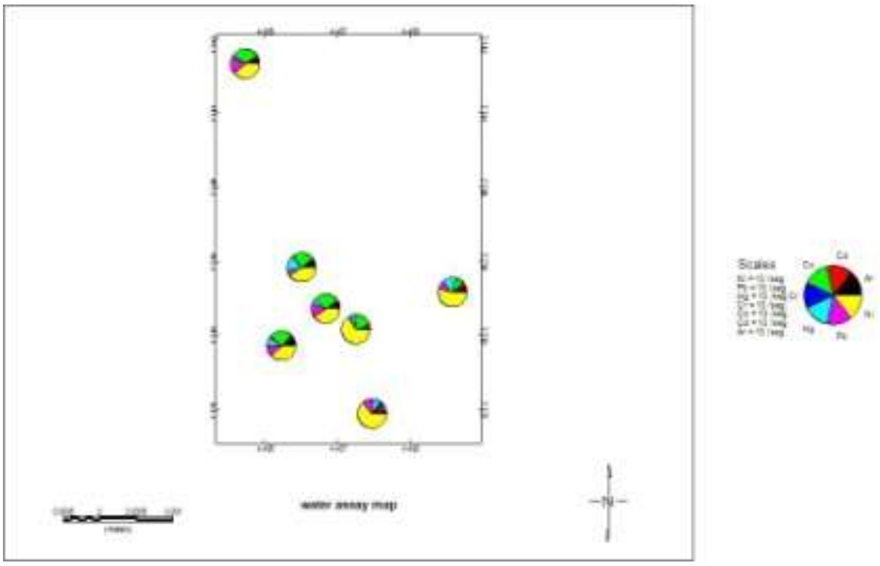

Fig. 3.2: The pie chart of heavy metals present in water  and sample locations. The control point is about 150m away from other sample points

**4.0 Conclusion**

This research has demonstrated the effectiveness of PQWT in delineating groundwater and characterization of geologic material at depth of 300m with maximum accuracy and heavy metal analysis of the groundwater in study area for contamination. Shallow depth of about 30m was delineated in profiles 1, 4, 5, 6, 7 and 8, maximum depth of 300m was observed in profile 2 and

3which indicates high conductivity due to fracturing of the rock.The study revealeddifferent samplingsites have different concentrations of the metals, keeping in view the concentration levels of certain heavy metals are alarminglyhigh in all the areas considered for sampling. Health risks involved due to the high levels of metals whenthey enter the human metabolism.The study suggests that groundwater extraction should be sited away from the dumpsite and it should be deeper as most of the groundwater in the area is at shallow level and consequently prone to contamination

**Reference**

Adebayo, A. S., Ariyibi, E. A., Awoyemi, M. O., & Onyedim, G. C. (2015). Delineation of contamination plumes at olubonku dumpsite using geophysical andgeochemical approach at Ede town, southwestern Nigeria. *Geosciences Scientific&Academic Publishing,* 5 (1), 39 – 45. doi:10.5923/j.geo.20150501.05

Carpenter, P.J., Ding, A. and Cheng, L. (2012) Identifying Groundwater Contamination using Resistivity Surveys at a Landfill near Maoming, China. Nature Education Knowledge, 3(7): 20

Dare Omolayo and Fatoba Julius.(2014). 2D electrical imaging surveys for leachate plume migration at an old dumpsite in ibadan, southwestern Nigeria: a case study *International journal of geophysics.volume 14,article ID 879530. http://doi.org/10.1155/2014/879530*

Fatta D, Papadopoulos A, Loizidou M . A. A study on landfill leachate and its impact on the groundwater quality of the greater area. Environ Geochem Health. 1999; 21(2): 175-190.

Gautam Patil, Irfan Ahmad. Heavy Metals Contamination Assesment of Kanhargaon Dam Water near Chhindwara City. Acta Chim. Pharm. Indica 2011; 1(1):7-9.

Govindarajan, M., and Senthilnathan T.(2014). Groundwater quality and its health impact analysis in an industrial area. *International journal of current microbiology and applied sciences.ISSN: 2319-7706, Volume 3 number 7 (2014) pp. 1028-1028*

Harinath Vukkisala, PQWT Water detector-Power Point Presentation. Published Dec.12,2017

M. A. Rahaman, Review of the Basement Geology of Southwestern Nigeria. Geology of Nigeria,

Kogbe, C.A;(Ed). Elizabethan Publ. Co; Lagos, Nigeria, pp. 41 – 58, 1976.

Olafisoye, E. R., SunmonuL. A., Adagunodo and O P. Oladejo, Groundwater Contaminants' investigation at Aarada Waste Disposal Site Using Geophysical and Hydro-Physicochemical Approach. *Journal of Environmental Science, Toxicology And Food Technology, Vol. 2(4): pp. 01-10, 2013.*

Operation Manual for PQWT-100S/200S/300S Hunan puqi Geologic Exploration equipment Institute.

United States Environment Protection Agency (USEPA)**,**Quality criteria for water. EPA 440/5- 86-001, May 1986.Office of Water Regulation and Standards, Washington DC., USA, 1986.

World Health organisation (WHO). Guidelines for drinking water quality. Vol.1: recommendation Genevation, 1984, 1967, 1993, 2010.

# OPTIMIZATION OF INFILTRATION PARAMETERS OF TWO MODELS USING MEASURED FIELD DATA FROM VOLUME BALANCE APPROACH

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**Abstract**
*In this study, the ability of two infiltration models (Revised modified Kostiakov model and Soil Conservation Service model) were evaluated and verified for their prediction of infiltration rates under specified field conditions. The measurements were carried out at the experimental field located at Samaru College of Agriculture, Division of Agricultural Colleges, Ahmadu Bello University, Zaria. Irrigation events were monitored in plots A, B and C. Infiltration parameters were also generated from the data collected from plot A and B and fitted into the models for predictions of water intake rates. Thereafter, the predictions from the models were compared with the measured field intake rates from plot C. Three comparison criteria including coefficient of determination ($R^2$), root mean square error (RMSE) and a detailed T-test at 5% level of significance were used to determine the best performing model. The results of the evaluation showed that the Revised modified Kostiakov model performed best with $R^2$ value of 0.999, RMSE of 2.45 and T-test value 1.95, next was the SCS model following closely with $R^2$ value of 0.998, RMSE of 2.46 and T-test value 2.48, respectively. The study recommends that the revised modified Kostiakov's model should be used in predicting water intake rates in the study area.*

**Keywords**: infiltration rates and depths, infiltration parameters, volume balance, models

## 1.0 Introduction

There are many factors that can influence the infiltration behaviour of soils and these include: initial soil moisture content, soil type, soil hydraulic conductivity, and surface properties (such as slope, vegetation cover and plant roots). Infiltration has been investigated by many authors such as Green and Ampt (1911), Kostiakov (1932), SCS model (1974) and Argyrokastritis and Kerkides (2003). Infiltration models have been revised by authors such as Jury *et al.* (1991), Singh (2007) and Parhi (2007) amongst others. While recently, contributions were subsequently made on them by other set of authors such as Amir *et al.* (2011), Salman *et al*. (2013), Guiguis*et al*. (2014) and Lentz *etal*. (2014). Furrow infiltration plays an important role in surface and subsurface hydrology, soil erosion, runoff generation, design of irrigation systems, management of irrigation systems, and simulating models for performance prediction or optimization for the whole field (Salman *et al.*, 2013). The volume balance method has been the basis for most design and field evaluation procedures, and has subsequently been proven with field and laboratory data (Walker and Skogerboe, 1987). These infiltration methods and models must be properly used in the field so as to accurately obtain information that would be relevant to farmers for improving crop production and describing field conditions. The aim of the study is to optimize infiltration parameters of two models using data measured from volume balance approach. This will be achieved through the following sets of specific objectives:

1. To measure the infiltration rates of Samaru soils using volume-balance method
2. To generate the parameters of the selected water intake models
3. To compare the model's predictions with field measured data

## 2.0 materials and Methods

The research was carried out in Samaru College of Agriculture, Division of Agricultural Colleges, Ahmadu Bello University, Zaria. Samaru town which is located in Zaria lies between latitude 11°11'N and longitude 7° 38'E, and at an altitude of about 686m above mean sea level. The soils in the area varied between loam, sandy loam and clay loam and have bulk densities ranging between 1.25g/cm$^3$ – 1.80g/cm$^3$.

## 2.1 Experimental Procedure

The field layout that was used for this research work consisted of three plots A, B and C of six furrows each plus a waste furrow of 0.5m for surplus discharge. Footpaths of 1m were also provided after every 6$^{th}$ furrow at the center line between each plot. The total area of the field was 45m by 16.25 m, while the width for each plot within the field was 4.5m. The length and width of each furrow selected were 40m and 0.75m, respectively. Measuring stations were established at every 5m along the furrow length where successive measurements of depth of flow, surface storage, advance and recession times were recorded. Water delivered into the field channel was diverted into the furrows through siphon tubes and cutthroat flumes were placed at the upper and lower ends of the furrows to measure the inflow and outflow rates. The inflow flume was placed 2m from the field inlet for measuring depth of flow.

The volume of water at every point was obtained by multiplying the inflow discharge which is assumed to be constant with the time taken for the wetted front to move from one point to another at successive measurement stations established on the field. Furthermore, the surface storage at every point was also obtained by multiplying the average flow area at every 5m along the 40m furrow length with the distance the water front moves to the measuring stations. The infiltrated volume of water was finally obtained by subtracting the soil surface storage from the product of the discharge and time at successive intervals from one point to the other along the furrow length.

## 2.2 Infiltration Measurements

The volume balance equation suggested by Mudiare (1982) and Oyebode (1989) is given as:

$$Q = S + V_f \qquad (1)$$

The equation can also be simplified in the form

$$qt_L = V_y(t) + V_z(t) \qquad (2)$$

where;
Q = cummulative inflow (m$^3$/min) = $\int_0^T q\,dt$
S = surface storage
$V_f$ = cummulative infiltrated volume
T = advance time to a point, L ($0 < t_L \leq T$)
$t_L$= advance time (min)
q = inflow rate per unit with
x = advance distance to any point along the field ($0 < x < L$)
$V_y(t)$ = surface storage (m$^3$)
$V_z(t)$ = cummulative infiltrated volume (m$^3$)

The quantity $V_f$ can be evaluated assuming that the infiltration rate can be represented by a power function of the intake time, and also that the advance distance can be given by a power function of time of advance (Mudiare, 1982). This can be expressed as:

$I = kt^n$ (3)

$X = pt_x^m$ (4)

where;
I = infiltration rate
t = intake time ($T - t_x$)
x = advance distance (m)
$t_x$ = advance time (min)
k, n = infiltration coefficients
p, m = advance coefficients

The accumulated infiltrated depth (mm) can be expressed as:

$$I_d = \frac{Vf}{X} = \frac{Q-S}{X} \quad (5)$$

All other parameters are previously defined.

## 2.3 Infiltration Models

A brief description of the infiltration models used in this study include the following:

### Revised Modified Kostiakov Model (RMK)

Parhi *et al*. (2007) revised the Modified Kostiakov model (MK) and obtained a four parameter model. The idea was that increasing the number of parameters for each model generally improves the model performance. The model is given as:

$$I = \frac{\alpha 4}{\beta 3+1} t^{\beta 3+1} + \frac{\propto 5}{1-\beta 4} t^{1-\beta 4} \quad (6)$$

where:
I = cumulative infiltration (mm)
t = infiltration time (min)
$\alpha_4$, $\beta_3$, $\alpha_5$ and $\beta_4$are parameters to be determined, and other terms as previously defined.

### SCS Model

Jury *et al*. (1991) also reported that the SCS model is an empirically developed approach which could be used to determine the water infiltration process in the soil and also classify the soils into different intake families. It is given as follows:

$I = at^b + 0.6985$ (7)

where:
a and b are empirical coefficients and other terms as previously defined.

## 3.0 Results and discussion

## 3.1 Soil Intake Rates

Soil intake rate is an important parameter to be determined particularly in irrigated soils due to spatial and temporal variability of the soil as reported by Camacho *et al*., (1997). As it has been noted, the soil intake rates are not only affected by the variability of the soils but also from one irrigation period to the other due to surface sealing of pores resulting from previous irrigation events on the field (Mudiare, 1982). The soil intake rates were measured from the field using the volume balance method and results obtained are presented in Table 1.

**Table 1:** Soil intake rates for plot A obtained during the first irrigation

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| X (m) | $T_X$ (min) | $A_O$ ($m^2$) | Q ($m^3$/m) | S ($m^3$/m) | Z ($m^3$/m) | Z/X (mm) |
| 5 | 1.1 | 0.020 | 0.297 | 0.100 | 0.197 | 39 |
| 10 | 2.3 | 0.020 | 0.621 | 0.200 | 0.421 | 42 |
| 15 | 3.9 | 0.020 | 1.053 | 0.300 | 0.753 | 50 |
| 20 | 5.8 | 0.020 | 1.566 | 0.400 | 1.166 | 58 |
| 25 | 8.2 | 0.020 | 2.214 | 0.500 | 1.714 | 69 |
| 30 | 10.1 | 0.020 | 2.727 | 0.600 | 2.127 | 71 |
| 35 | 12.6 | 0.020 | 3.402 | 0.700 | 2.702 | 77 |
| 40 | 14.5 | 0.020 | 3.915 | 0.800 | 3.115 | 78 |

*Obtained from volume balance approach

Col. 1: Advance Distance
Col. 2: Advance Time
Col. 3: Average Flow Area
Col. 4: Cumulative inflow
Col. 5: Surface storage
Col. 6: Cumulative infiltrated volume
Col. 7: Accumulated infiltrated depth

**Table 2:** Optimized intake parameters for revised modified Kostiakov's model

| Parameters | PLOT A | PLOT B |
|---|---|---|
| $\alpha 4$ | 1.04 | 1.02 |
| $\beta 3$ | 0.31 | 0.30 |
| $\alpha 5$ | 1.12 | 1.06 |
| $\beta 4$ | -0.03 | -0.01 |
| R | 0.984 | 0.932 |

**Table 3:** Estimated intake parameters for Soil Conservation Service model

| Parameters | PLOT A | PLOT B |
|---|---|---|
| A | 4.14 | 3.56 |
| B | 0.793 | 0.847 |
| R | 0.973 | 0.979 |

The results in Table 1 shows the accumulated infiltrated depths measured from the experimental field using the volume balance approach. The minimum and maximum accumulated infiltrated depths recorded for plot "A" during the first irrigation event were 39mm and 78mm, 26mm and 58mm for the second irrigation, 25mm and 60mm for the third irrigation. Similarly, the minimum and maximum infiltrated depths recorded for plot "B" were 32mm and 54mm during the first irrigation event, 20mm and 42mm during the second irrigation, 26mm and 45mm during the third series. Furthermore, the minimum and maximum infiltrated depths recorded for plot "C" were 34mm and 67mm during the first irrigation event, 18mm and 46mm during the second irrigation, 23mm and 48mm during the third irrigation event.

The parameters for the revised modified Kostiakov's model were obtained from optimization techniques while the parameters for SCS model were obtained by linearization. A least square regression analysis was chosen to evaluate the ability of the three infiltration models to accurately describe the experimental data and also to determine the values of the parameters for the different models as suggested by Shukla *et al.*, (2003). The regression coefficients (r) were obtained from the graphs of cumulative infiltration plotted against time. The parameters for the revised modified

Kostiakov's model are presented in Table 2. These intake parameters determined from the volume balance data provided estimates of regression coefficients as high as 0.984 recorded in plot A and 0.932 in plot B. The parameters for SCS presented in Table 3 have values of regression coefficients of 0.973 and 0.979 in plot A and B. The parameters for revised modified Kostiakov's model presented the highest least square regression value of 0.984, followed by the Soil Conservation Service model with a value of 0.979. These values of regression coefficients (r) for the two models have magnitude within the same range which are both considered strong. However, the parameters for the revised modified Kostiakov's model were considered more suitable. This can best be explained by noting that, the idea of having an infiltration model with more number of fitting parameters is always considered to be the best in predicting soil infiltration rates as reported by Parhi *et al*. (2007).

Parameters of revised modified Kostiakov's model generated from the data measured using the volume balance method showed variations in the predictions of cumulative infiltration for plot A and B. Minimum and maximum values of 12mm and 273mm were predicted for plot A, while 12mm and 223mm were predicted for plot B. Furthermore, the parameters of Soil Conservation Service model generated from the data measured from the field using the volume balance method were also used to predict cumulative infiltration for plot A and B. These predictions provided lower estimates of maximum cumulative infiltrated depths when compared with the predictions of the revised modified Kostiakov's model. However, the minimum values were within the same range. The minimum and maximum infiltrated depths predicted for plot A and B were 12mm and 139mm, 12mm and 114mm, respectively. The results of the predicted cumulative infiltration were close to the measured field data but showed some variations towards the end of the predictions. The variations of predicted infiltrated depths for the revised modified Kostiakov's model were observed above 30 minutes, while the variations for the SCS model were observed above 50 minutes. However, the predictions for the SCS model were relatively closer to the measured field data as compared with thepredictions from the revised modified Kostiakov's model. These variations observed could be attributed to the different assumptions used to develop these infiltration models, the number of parameters and methods used to determine the parameters for each model. More so, the variability in the measured field data used to generate the infiltration parameters could also account for the differences in the predicted depths for the models. In the analysis, it was observed that the revised modified Kostiakov's model provided higher estimates of predicted cumulative infiltration when compared with the other two models. This is consistent with findings of Salman *et al*. (2013) and Miles (2013).

Two of the resulting curves as shown in Figs. 1 and 2 are curves of measured infiltrated depths versus the predicted infiltrated depths for the two models. The degree of association of the data points to the fitted curves can be determined from the coefficient of determination $R^2$, the higher the value of $R^2$ the better the agreement of the points to the fitted equation. The coefficient of determination for revised modified Kostiakov's model and SCS model were 0.865 and 0.924, respectively. The magnitude 0.924 for the SCS model indicated that there was a good agreement between the measured and predicted infiltrated depth, while the magnitude 0.865 for revised modified Kostiakov's model is the least and this indicated that there were variations between the measured and predicted infiltrated depth. Thus, in order to determine the best performing model, the results were further subjected to statistical analysis.

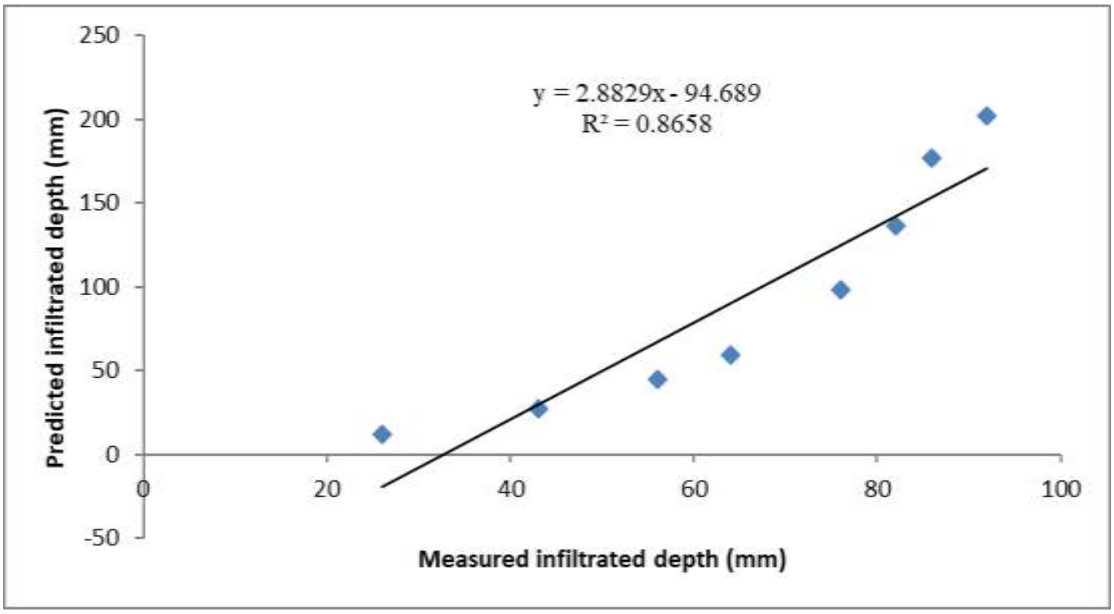


Fig 1: Average infiltration rates and cummulative revised modified Kostiakov's model

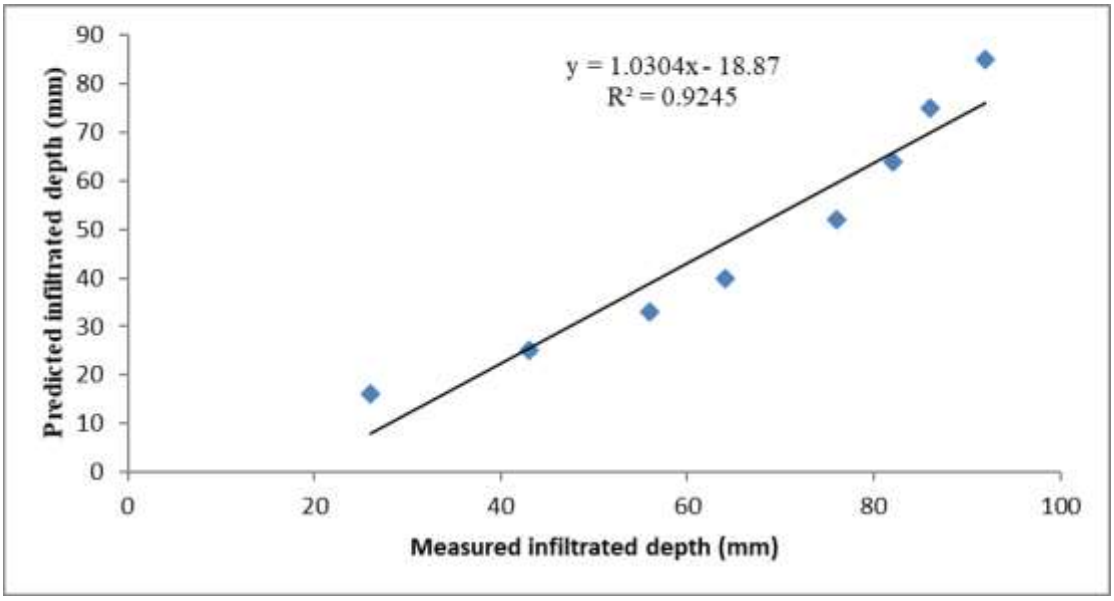


**Fig 2:** Average infiltration rates and cummulative infiltration for SCS model

## 4.0 Statistical Analysis

In order to determine the best fit model, three comparison criteria were employed. The $R^2$, RMSE and value of 't' formodified Kostiakov's model were 0.999, 2.45 and 1.95. Furthermore, the $R^2$, RMSE and value of 't' forSoil Conservation Service model were 0.998, 2.46 and 2.48. The results indicated that, revised modified Kostiakov's model is considered superior with the Soil Conservation Service model following closely in terms of performance. However, the four parameter revised modified Kostiakov's model was recommended to be the most suitable model because it presented the highest value of $R^2$ and least value of RMSE of 0.999 and 2.45. Models having highest $R^2$ value and smallest RMSE are considered the most suitable according to goodness of fit statistics as pointed out by Gifford (1976), Shukla *et al*. (2003), Machiwal *et al*. (2006), Ghorbani *et al*. (2009), and Zolfaghari *et al*. (2012). Similarly, the t – test results also indicated that the four parameter revised modified Kostiakov's model was considered the best fit model because it presented the least calculated value of ‘t’ 1.95 from the data generated from the volume balance approach.

**Table 4: Statistical parameters**

| Models | Parameters | | |
|---|---|---|---|
| | $R^2$ | RMSE | t |
| RMK | 0.999 | 2.45 | $1.95^{NS}$ |
| SCS | 0.998 | 2.46 | $2.48^{NS}$ |

$R^2$ = coefficient of determination, RMSE = root mean square error, t = t-test value

## 5.0 Conclusion

The parametersof the selected water intake models were generated from the measured field data. These parameters were used in predicting the cummulative infiltration and infiltration rates for the soils in the study area. The average values of parameters$\alpha_4$,$\beta_3$, $\alpha_5$ and $\beta_4$ for the revised modified Kostiakov’s model were 1.03, 0.31, 1.09 and -0.02. Similarly, the parameters a and b for the Soil Conservation Service Model were also determined with values 3.85 and 0.820, respectively. The soils in the area varied between loam, sandy loam and clay loam and have bulk densities ranging between 1.25g/cm$^3$ – 1.80g/cm$^3$. The accuracy of the revised modified Kostiakov’s model was found to be the highest because it had $R^2$ value (0.999) and least value of RMSE (2.45) for the predicted and measured values. The differences between the predicted and measured had the least value of t (1.95) which was not significant at 5% confidence interval. The study recommends that the revised modified Kostiakov’s model should be used in predicting water intake rates in the study area.

## References

Amir, H.H., Jahangir, A.K., Manouchehr, H. and Jahansir, M.H. (2011). A New Method for Estimating the parameters of Kostiakov and Modified Kostiakov Infiltration Equation. *World Science Journal*. University of Isfahan, Iran. 15(1): 129-125.

Argyrokastritis, I. and Kerkides, P. (2003). *A note to the Variable Sorptivity Infiltration Equation*. Water Resource Management. 17: 133-145.

Camacho, E., Lucena, C.P., Canas, J.R. and Alcaide, M. (1997). Model for Management and Control of Furrow Irrigation Real-time. *Journal of Irrigation and Drainage Engineering*. 123(4): 264-269.

Ghorbani, S.H., Homaee, M., Mahdian, M. and Kouchakzadeh, M. (2009). Site-dependence Performance of Infiltration Models. *Water Resource Management*. 23: 2777-2790.

Green, W.H. and G.A. Ampt, (1911). Studies on Soil Physics: 1. The Flow of Air and Water Through Soils. *Journal of Agricultural Science*, 4: 1-24. 14.

Guiguis, A.E. and Zyton, A.M. (2014). Modelling of Furrow Irrigation Design and Predicting Infiltration Parameters under Different Inflow Rates. *Agricultural Engineering. Resources.* 93(1).

Jury, W.A., Gardner, W.R. and Gardner, W.H. (1991). *Soil Physics 5thEdition.* New York (NY): John Willey and Sons.

Kostiakov, A.N. (1932). On the Dynamics of the Coefficient of Water Percolation in Soil and on the Necessity for studying it a Dynamic Point of View for Purposes of Amelioration. Transactions. 6th Comm. *International Society of Soil Sciences*, Moscow, Part A., pp: 17-21.

Lentz, R.D., and Bjorneberg, D.L. (2014). *Influence of Irrigation Water Properties on Furrow infiltration.*10th Comm. *International Soil Conservation Organization.* 705-709.

Machiwal, D., Madan, K. and Mal, B.C. (2006). Modelling Infiltration and Quantifying Spatial Soil Variability in a Watershed of Kharagpur, India. Biosyst. Eng. 95:569-582.

Miles, D. Monoucherhr, G., and Shoja, G.D. (2013). Evaluation of Infiltration Models with Different Numbers of Fitting Parameters in Different Soil Textural Classes. *Journal of Soil Science Soil*. 124: 522-543.

Mudiare, O.J. (1982). Development of Design Procedure for an Automated Border Dyke System. M.Sc. Thesis. Univ. of Sask. Saskatoon, Sask.

Oyebode, M.A. (1989). Development of Design Procedure for Border Irrigation System. M.Sc. Thesis, Department of Agricultural Engineering, A.B.U., Zaria. Pp. 20-26.

Parhi, P.K., Mishra, S.K. and Singh, R. (2007). A Modification to Kostiakov and Modified Kostiakov Infiltration Models. *Water Resource Management*. 21: 1973-1989.

Salman, M., Ali, A.Z., Monoucherhr, G., Miles, D. and Shoja, G.D. (2013). Evaluation of Infiltration Models with Different Numbers of Fitting Parameters in Different Soil Textural Classes. *Journal of Soil Science Soil*. 168(3): 681-693.

Shukla, K., Lal, R. and Unkefer, P. (2003). Experimental Evaluation of Infiltration Models for Different Land use and Soil Management Systems. *Journal of Soil Science Soil.* 168(3): 178-191.

Soil Conservation Service, (1974). Soil Survey of Eastern Maricopa and Northern Pinal Counties. US Dept. of Agriculture, Washington, DC.

Walker, W.R and Skogerboe, G.V. (1987). *Evaluation of Surface Irrigation Systems*. Prentice Hall, Inc., Englewood Cliffs, New Jersey.

Zolfaghari, A.A, Mirzaee, S and Gorji, M. (2012). Comparison of Different Models for Estimating Cumulative Infiltration. *International Journal of Soil Science,* 7: 108-115

# THE IMPACTS OF SEWAGE ON THE QUALITY OF GROUNDWATER IN SAMARU AREA OF GUSAU, ZAMFARA STATE

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**Abstract**

*This paper assessed the potential effects of sewage on the quality of groundwater in Samaru area of Gusau, Zamfara State. The data collection tool used was a questionnaire which was applied to assess the implication of the quality of the boreholes' water and to explore the prevailing diseases in the study area. Twenty five (25) questionnaires were distributed in each of the three sampled locations making a total of 75 copies of questionnaires.Water samples were collected from three different bore holes and three deep wells across the study area as sampled. Soil samples at a depth of 90cm were collected and used for sieve analysis and natural moisture content. Physical and chemical analyses were then carried out every two weeks making use of the C100 multi-parameter ion specific meter.From the analysis of the questionnaires, the result shows that typhoid fever which is a water borne disease is the second frequently occurring diseases in the study area; The results of the study shows that the pH value for sampled well 1 is 7.5, well 2 is 7.2 while that of well 3 is 7.3. For turbidity, well 1 yielded a value of 0.64NTU, well 2 has turbidity value of 3.5NTU while that of well 3 is 0.91NTU. Turbidity values for the three wells are below the maximum permissible limit of 5NTU as specified by both NSDWQ and WHO.The result of the sieve analysis and moisture content on soils around the sampled wells indicated that the soil are to some extent porous and can allow infiltration of sewage. Physicochemical analysis shows that most of the samples still lie within the ranges specified by both NSDWQ and WHO except for some cases. One total coliform was found in well 2 which indicated contamination by the environment.Bacteria were also found in all the samples which indicated sewage in the environment is sipping in to the water system.However, the study concluded that the three wells are still portable based on NSDWQ and WHO except for some cases.The study therefore recommends for well water treatment before consumption, Routine tests on well waters and wells should maintain a distance of 30 metres away from any source of sewage for guaranteed safety from contamination.*

**Keywords:** Groundwater, Sewage, Samaru Area, Gusau. Zamfara

## Introduction

The pattern and level of life development depend to a great extent on the quality, quantity, and rate of water supply to the species. Accessibility and availability of fresh, clean water is a key to sustainable development and essential element in health, food production and poverty reduction.

There has been an increasing concern about the environment in which man lives. Solid wastes, garbage and sewage are being produced every day in urban environments. In an attempt to dispose of these materials, man has carelessly polluted the environment (Masella et al., 2012). These pollutions have over the years contributed to the degradation of the human environment which evidence could be seen in the various dumpsites and sewage drainage all over the study area.

Groundwater which is used for domestic, industrial and irrigation water supply is very essential particularly in semi-arid areas of Nigeria where it is the major source of drinking water (Orubu&Omotor, 2011). In the last few decades, there has been a tremendous increase in the demand for clean water due to the rapid growth of the population and the accelerated pace of industrialization. Human health is closely related to the groundwater quality and is threatened by the poor quality of groundwater caused by excessive application of fertilizers and unsanitary conditions. Rapid urbanization which caused groundwater pollution has affected the availability and quality of groundwater, (Orubu&Omotor, 2011).

Access to potable water supplies in major cities across the country has been increasingly difficult. More than 70% of the population lack access to improved water sources, hence, the populace would only but rely on hand-dug shallow wells and some few boreholes with motorized pump (Majolagbe et al., 2017). The problem of groundwater contamination by sewage not properly disposed of is posing a great challenge to the health concern of society. However this can be tackled by improved knowledge of groundwater, hydrology, groundwater quality, sewage characteristics, and best disposal systems and possible effluent reuse.

In this study area every household and industry generates sewage on a daily basis which is illegally discharged in open drainages and on the ground surfaces. The sewage eventually finds its way into the open surface and thus as rain falls, these contaminants infiltrate into the soil and are being transported horizontally and downward into the soil mass thereby contaminating groundwater. Hence, this study was carried out to assess its implication if there exist.

## The Study Area

The study area is Samaru in Gusau. It is located between Latitudes 12°09’ N and 12°150’ North of the equator and Longitudes 6°40’E and 6°67”East of the Greenwich Meridian. It has an area of 3,364 km² and located in northwestern Nigeria. It is the capital city of Zamfara state. It is located on the Sokoto River in the savanna region of Nigeria. The river provides access to water supplies during the dry season. It serves as a major industrial center of northern Nigeria. The city is active in mining the deposits of gold and diamonds in the surrounding countryside. The study area has an estimated population of 383,162 in 2006 (NPC). As a result of the high population, the area represents a zone of high domestic activities as well as commercial activities which leads to a very high level of sewage and solid waste generation.

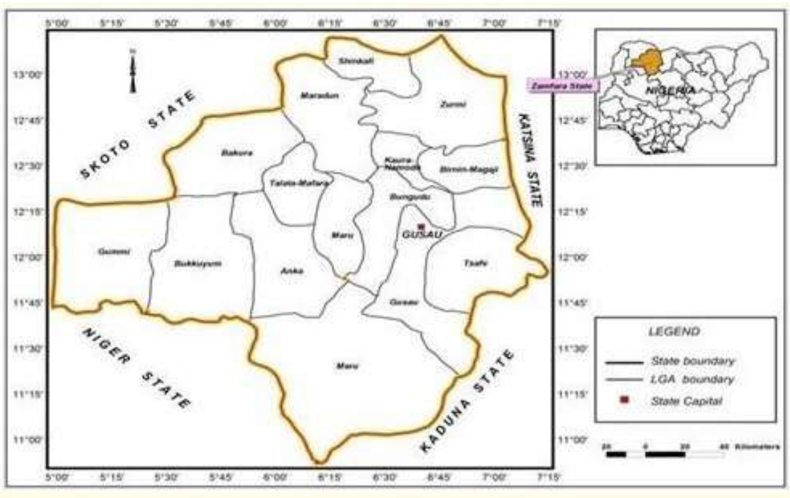



**Figure 1:** Map of Nigeria showing the Study Area
**Source:** Nigerian Institute of Social and Economic Research, (2020)

**Methodology**

The use of a questionnaire as described by Pei-Yue *et al*., (2011) was used in other to assess the community’s observation concerning the quality of water from the bore-holes under study. The questions were basically structured to explore the importance of these boreholes to the community and to examine the prevailing disease in the study area.

A total number of 25 questionnaires were distributed in each of the three locations amounting to a total of 75 questionnaires in all. A total of 16 were retrieved at location 1, 19 at location 2 and 20 at location 3. Another five questionnaires were administered to the health personnel centers in the areas in order to obtain their opinion on the regularly reported cases of diseases contacted within the community. Three wells were chosen at a considerable distance to each other to form triangle direction of flow of water table.

The reliability of data on chemical, physical and bacteriological constituents of groundwater is influenced by sample collection and analysis as described by Manage et al., (2019). For the purpose of this paper, water samples were collected from three different bore-holes all located in the study area. The locations were named as:

i. Well number one (1) (HayanMallamKahilu)
ii. Well number two (2) (Bayan Sambo) and
iii. Well number three (3) (HayanMallam Sani)

In all these locations the water samples were collected on the day the test was to be carried out in order to prevent any change in temperature that may result from storing which may alter the properties of the water. The water samples were collected in a new plastic bottle which was sealed. Each bottle was raised with the water before it was filled to two-thirds of its volume. This is done in other to provide oxygen for the microorganism in the water so that they will not die before the test. Soil samples were also collected from the three different locations near the wells at a depth of 90cm which were used for sieve analysis and natural moisture.

**Physico-chemical analysis of the samples**

The physical and chemical tests were carried out every two weeks making use of the C100 multi-parameter ion-specific meter. The water sample was examined for pH, phosphate, Nitrate ($NO_3$), Copper, Dissolved oxygen, Total dissolved solids, Nitrite ($NO_2$), Conductivity, Nitrogen, Chloride, Turbidity, Colour, Odour and Temperature. The examination was conducted in accordance with Ranjana, (2009).

**Bacteriological test**

For Faecal Coliform (FC), Total Coliform (TC), and Total Bacteria (NA) the standard plate and the spread plate method were used for Salmonella and shigella. The procedure for the microbiological analysis is as follows:

**Results**

**Results of Physico-Chemical Analysis**

Figure 2 shows that typhoid fever is the second frequently occurring diseases in the study area; this signifies some aspects of contaminations with the quality of drinking water in the area. Most of the people responded negative on boiling the water they got from boreholes or hand-dug wells before consumption. This shows that they conceived the quality of the groundwater as pure and potable without any treatment.

Table 3 shows that pH value for well 1 is 7.5, well 2 is 7.2 while that of well 3 is 7.3. These results show that the water in the three wells is alkaline in nature. WHO and NSDWQ standards are given between 6.5 and8.5.The copper value for well 1 is 0.07mg/l, well 2 is 0.06mg/l while that of well 3 is 0.04mg/l. All the three values lie below the maximum permissible limit of 1.0 mg/l specified by the NSDWQ and 2.0 mg/l specified by the WHO. For well 1 & 2, the Nitrate value is zero which is within the limit specified by the NSDWQ. For well 3 the Nitrate value is 18.3mg/l which is above the limit specified by the NSDWQ but still within the limit of 50mg/l specified by WHO standard.

**Table 3:** Physico-Chemical Analysis

| Parameters | Well Number One | Well Number Two | Well Number Three |
|---|---|---|---|
| Date of sample collection | 10th July 2017 | 10th July 2017 | 10th July 2017 |
| Date of analysis | 11th July 2017 | 11th July 2017 | 11th July 2017 |
| pH meter | 7.5 | 7.2 | 7.3 |
| Phosphate LR (mg/l) | 2.2 | 3.7 | 2.3 |
| Copper hr(mg/l) | 0.07 | 0.06 | 0.04 |
| Nitrate (mg/l) | 0 | 0 | 18.3 |
| Nitrite (mg/l) | 0 | 0.008 | 0.409 |
| Total dissolved solid (mg/l) | 263.31 | 188.27 | 540.02 |
| Chloride (mg/l) | 17 | 25 | 93 |
| Dissolved oxygen (mg/l) | 2.36 | 1.93 | 2.19 |
| Turbidity (NTU) | 0.64 | 3.50 | 0.91 |
| Conductivity (us/cm) | 393 | 281 | 806 |
| Colour (Pt -Co) | 0 | 21 | 0 |
| Odour | Nil | Nil | Nil |
| Taste | Nil | Nil | Nil |
| Nitrogen (mg/l) | 0 | 0.002 | 0.124 |
| Temperature ($^{O}$C) | 25.9 | 25.9 | 25.8 |

**Source:** Field Work, 2017

For well 2 & 1 Nitrite value is 0 and 0.008mg/l, well 3 the value of Nitrite, is 0.409mg/l which is above the maximum permitted by the NSDWQ. Conversely, the entire three samples meet the maximum permissible limit of the WHO. Well 2 &1 value for total dissolve solid lies below the maximum permissible limit of 500mg/l as specified by the NSDWQ while well 3 has total dissolve solid above the 500mg/l. For the entire three wells, chloride value lies below 100mg/l maximum permissible limit of NSDWQ. For the entire three wells, dissolve oxygen value lies below 5mg/l maximum permissible limit by the WHO. For well 1 turbidity value is 0.64NTU, well 2 have turbidity value is 3.5NTU while that of well 3 is 0.91NTU. Turbidity values for the three wells are below the maximum permissible limit of 5NTU as specified by both NSDWQ and WHO. For the entire three wells, the conductivity value lies below 1000 us/cm maximum permissible by the NSDWQ, (Isa *et al*, 2013).

**Bacteriological Parameters**

**Table 4:** Microbiological Analysis

| Locations | Total Coliform (cfu/100ml) | Faecal Coliform (cfu/100ml) | Total Bacteria Count (cfu/1ml) | Samonella& Shigella (cfu/1ml) |
|---|---|---|---|---|
| Date of Sample collection: 10th July, 2017 | | | | |
| Date of Sample analysis: 11thJuly, 2017 | | | | |
| Well 1 | 0 | 0 | 14 | 0 |
| Well 2 | 1 | 0 | 6 | 0 |
| Well 3 | 0 | 0 | 15 | 0 |

**Source:** Author’sField work, 2017

The table shows that no coliform was found in well 1 and well 3, but one total coliform was found in well 2. This according to the NSDWQ standard indicates resent contact with the environment and seepage of sewage into the groundwater below. In all the wells no fecal coliform was detected showing that the water is safe and in compliance with the NSDWQ standard for drinking water. Well 1 has a total of 14 counts; well 2 had 6 counts while well 3 had a total of 15 counts. According to the NSDWQ standard, a maximum of 10 counts is permissible, from above only well 2 lies in the range specified. No Salmonella and/or Shigella were found in all the three wells. This also is in accordance with standards.

**Natural Moisture Content and Sieve Analysis Results**

**Table 5:** Natural Moisture Content for Soil around the Wells

| Date of sample collection: 22nd July, 2017 | | | | Date of sample analysis: 23rd July, 2017 | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Well One | | | Well Two | | | Well Three | | |
| CAN NO. | $Z_9$ | H | $C_8$ | E | C | $F_3$ | B | $C_4$ | $C_2$ |
| | | 7 | | 2 | 3 | | 2 | 5 | |
| Weight of empty Can (g) | 23.8 | 24.7 | 25.2 | 23.0 | 24.5 | 23.2 | 24.9 | 22.5 | 24.5 |
| Weight of can + wet sample (g) | 79.5 | 64.4 | 79.5 | 76.9 | 68.5 | 68.8 | 66.0 | 54.0 | 51.4 |
| Weight of can + dry sample (g) | 72.0 | 59.1 | 72.3 | 69.4 | 62.1 | 62.1 | 60.4 | 49.6 | 47.6 |
| Moisture content (%) | 15.56 | 15.41 | 15.3 | 16.2 | 17.0 | 17.2 | 15.8 | 16.2 | 16.7 |
| AVERAGE (%) | 15.42 | | | 16.80 | | | 16.23 | | |

**Source:** Author’sField work, 2017

In fine-grained soil, where the grains are smaller than 0.075mm, the mineralogy of the soil grains, water content, etc has greater influence than the grain sizes, on the engineering behavior. The following can be deduced from the graph:

i. Percentage fine in well 1 = 34.47% (well-graded coarse-grained soil)
ii. Percentage fine in well 2 = 56.81% (well-graded fine-grained soil)
iii. Percentage fine in well 3 = 62.53% (well-graded fine-grained soil)

From the above result well 1 is more pervious and will have more interconnected pore spaces followed by well 2 and finally well 3.

The assessment of the study area through the stated methodology shows that deep wells (boreholes) and shallow wells (hand-dug wells) are the major sources of water in the area and most of the wells are surrounded by houses and business premises which generate sewage at a high rate either by wastewater or through septic tanks all around the wells. The location of each well used for this study and its distance from sewage is tabulated in the table below:

**Table 1:** Locations and Distances of sampled Wells

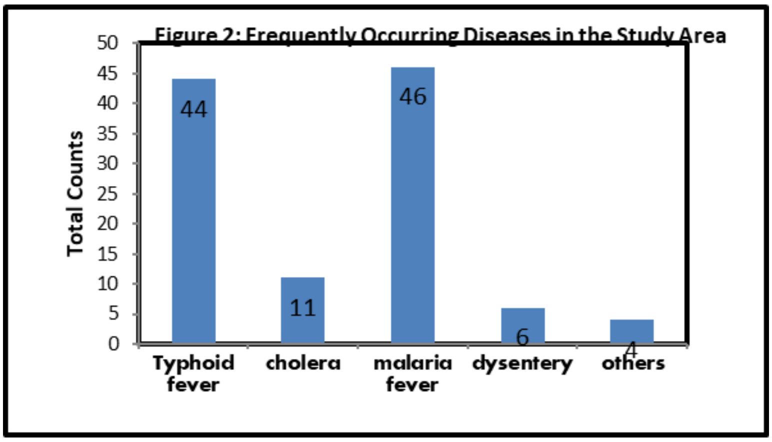
| Wells Locations | Well Number | Distances to Sewage System (m) |
|---|---|---|
| Hayanmallamkahilu | 1 | 14 |
| Bayan sambo | 2 | 30 |
| Hayanmallamsani | 3 | 11 |



**Table 2:** Community Assessment of Water Quality

| Location | Counts | Colour | Taste | Odour | Consumption (Drinking) | Treatment (Boiling) | Disease out break |
|---|---|---|---|---|---|---|---|
| Well No 1 | Positive | 2 | 2 | 1 | 14 | 1 | 4 |
| | Negative | 14 | 14 | 15 | 2 | 15 | 12 |
| Well No 2 | Positive | 1 | 5 | 1 | 14 | 1 | - |
| | Negative | 18 | 14 | 18 | 5 | 18 | 19 |
| Well No 3 | Positive | 4 | 4 | 1 | 12 | 7 | 14 |
| | Negative | 16 | 16 | 19 | 8 | 13 | 6 |

The table 2 presents the outcome of the information obtained from the field where positive and negative responses are clearly shown. It is obvious to deduce from the table that in most of the sampled wells, the water does not carry color as well as unusual taste. The odour does not change as well, even though it was positively reported that the water is taken mostly without treatment. Disease outbreak is also reported at a considerable rate of 30 – 45 percent in areas around well number one (1) and three (3). This provides ground for further analysis of the frequency of the diseases in figure 2.




## Conclusion

From the discussion of results, it can be concluded that the three wells are still portable. The results of the physicochemical analysis show that most of the samples still lie within the ranges specified by both NSDWQ and WHO except for some cases. One total coliform was found in well 2 which indicated contamination by the environment. Bacteria were also found in all the samples which indicated that sewage in the environment is infiltrating into the water system.The result of the sieve analysis and moisture content conducted on all the soils around the wells indicated that the soil is to some extent porous and can allow dissolved sewage to penetrate.

## Recommendations

Groundwater contamination by sewage is a gradual process which may take years before it can render an aquifer unfit for use, in light of this it is important for the authorities and populace to ensure that:

- Wells are sited at a minimum horizontal distance of 30m away from any sources of sewage or contamination.

- Groundwater especially that meant for consumption are to be treated before being consumed.

**References**

Angima, S., Terry, T. A., Dobkowski, A., Campbell, S., Grizzel, J. D., Harrison, R. B. Page-Dumroese, D. S. (2011). Best management practices for maintaining soil productivity in the douglas-fir region.

Fisher, M. B., Williams, A. R., Jalloh, M. F., Saquee, G., Bain, R. E., & Bartram, J. K. (2015). Microbiological and chemical quality of packaged sachet water and household stored drinking water in Freetown, Sierra Leone. PLoS One, 10(7), e0131772.

Goetsch, D. L., & Davis, S. (2014). Quality management for organizational excellence: Introduction to total quality.

Isa, M. A., Allamin, I. A., Ismail, H. Y., & Shettima, A. (2013). Physicochemical and bacteriological analyses of drinking water from wash boreholes in Maiduguri Metropolis, Borno State, Nigeria. African Journal of Food Science, 7(1), 9-13.

Majolagbe, A. O., Adeyi, A. A., Osibanjo, O., Adams, A. O., & Ojuri, O. O. (2017). Pollution vulnerability and health risk assessment of groundwater around an engineering Landfill in Lagos, Nigeria. Chem. Int, 3(1), 58-68.

Manage, M., Lashya, P., Katuwal, S., Norgaard, T., Knadel, M., Moldrup, P., . . . Greve, M. H. (2019). Estimating soil particle density using visible near-infrared spectroscopy and a simple, two-compartment pedotransfer function. Soil Science Society of America Journal.

Masella, A. P., Bartram, A. K., Truszkowski, J. M., Brown, D. G., & Neufeld, J. D. (2012). PANDAseq: paired-end assembler for illumina sequences. BMC bioinformatics, 13(1), 31.

Organization, W. H. (2009). Beryllium in drinking-water: background document for development of WHO guidelines for drinking-water quality: Geneva: World Health Organization.

Orubu, C. O., & Omotor, D. G. (2011). Environmental quality and economic growth: Searching for environmental Kuznets curves for air and water pollutants in Africa. Energy Policy, 39(7), 4178-4188.

Pei-Yue, L., Hui, Q., & Jian-Hua, W. (2011). Application of set pair analysis method based on entropy weight in groundwater quality assessment-a case study in Dongsheng City, Northwest China. Journal of Chemistry, 8(2), 851-858.

Pennel, R. D., Newton, M. S., Morrison, J. D., Toft, A. J., & Rhodes, N. P. (2015). Water-insoluble, iron-containing mixed metal, granular material: Google Patents.

# GEOPHYSICAL AND GEOCHEMICAL ASSESSMENT OF HEAVY METAL POLLUTION OF GROUNDWATER AND SOIL IN THE ONIBU-EJA OPEN DUMPSITE, OSOGBO OSUN STATE

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**Abstract**

*Pollution of groundwater and soil at the government approved dumpsite was assessed with 2-D resistivity profiling and Heavy metal analyses on the soil samples obtained from the representative locations in and around the site. The dumpsite is sited on the Basement Complex rock mainly fractured quartzite and gneiss. Soil samples obtained were air dried, sieved and wet digested by refluxing with $HNO_3$ and the digest analyzed for the presence of heavy metal. The chemical analyses on the soil samples obtained in the dumpsite showed concentration of heavy metals in the order of Mn>Zn>Cu>Cr>Pb>Cd. However, contamination factors and geo-accumulation index indicates are less than unity, indicating uncontamination by heavy metal. The evaluated degree of contamination level of the soil samples varied from -5.21 to -2.85. The electrical resistivity profile showed zones with infiltrated pollution plumes in the groundwater. The profile showed low resistivity values of less than 30Ωm and thickness of various layers of less than 5 to 25m. The 2-D profile shows that the top soil part is not contaminated while at depths into the groundwater there are pollution plumes. This indicated that the dumpsite is old with pollution of groundwater at depths. The uncontaminated nature of the top soil could be attributed to high rate of leaching, farming and metal scavenging activities on the dumpsite.*

**Keystone:** Groundwater, Heavy Metals, Contamination Factor, geo-accumulation, 2-D profiling

## Introduction

The Oshogbo in Osun State is growing in population with the attendant generation of waste of various sources including industrial, municipal and domestic. This growth in the urban population and industrial development has resulted in the production of toxic solid wastes however, urban waste materials generated are predominantly domestic garbage. These wastes are usually disposed off inadequately in waste disposal sites, thereby, constituting a high risk to the groundwater resources (Ogbonna, et al, 2002; Jhamnani and Singh 2009; Parimala et. al, 2020). Industrial wastes are generally made up of sludges, product residues, kiln dust, slags, and ashes, though it may vary from industry to industry the world industrial waste has been estimated to be approximately 9.2 billion tons and per capita industrial waste of about 1.74 tons per year, with developing countries facing more threats from this wastes, Parimala et. al, 2020; Vignesh, et al, 2021. Nigeria receives 71,000 tonnes of used consumer goods (Irene G. 2019) with some of the e-waste finding its way to Osogbo as any other part of the country.

## Study Area

The study area, Onibu-Eja open dumpsite is within Osogbo, Southwestern Nigeria and sited between latitudes N07° 45.505′ and N07° 48.552′ and longitudes E04° 29.611′ and E04° 34.321′. The study area is located within the basement complex rocks of southwestern Nigeria. The geology of the area is mainly metamorphic rock type of highly fractured quartzite and banded gneiss.

The dumpsite is located along Osogbo-Iwo highway (Fig.1) and is reachable through an untarred road. Dumping of wastes started nearly two and a half decades ago without any engineering works and serves as the dumping place for residents of Osogbo and adjoining towns. Different types of materials dumped there were domestic, municipal, commercial, agricultural, pharmaceutical and industrial wastes. It is noteworthy that there is high waste sorting activity in this site.

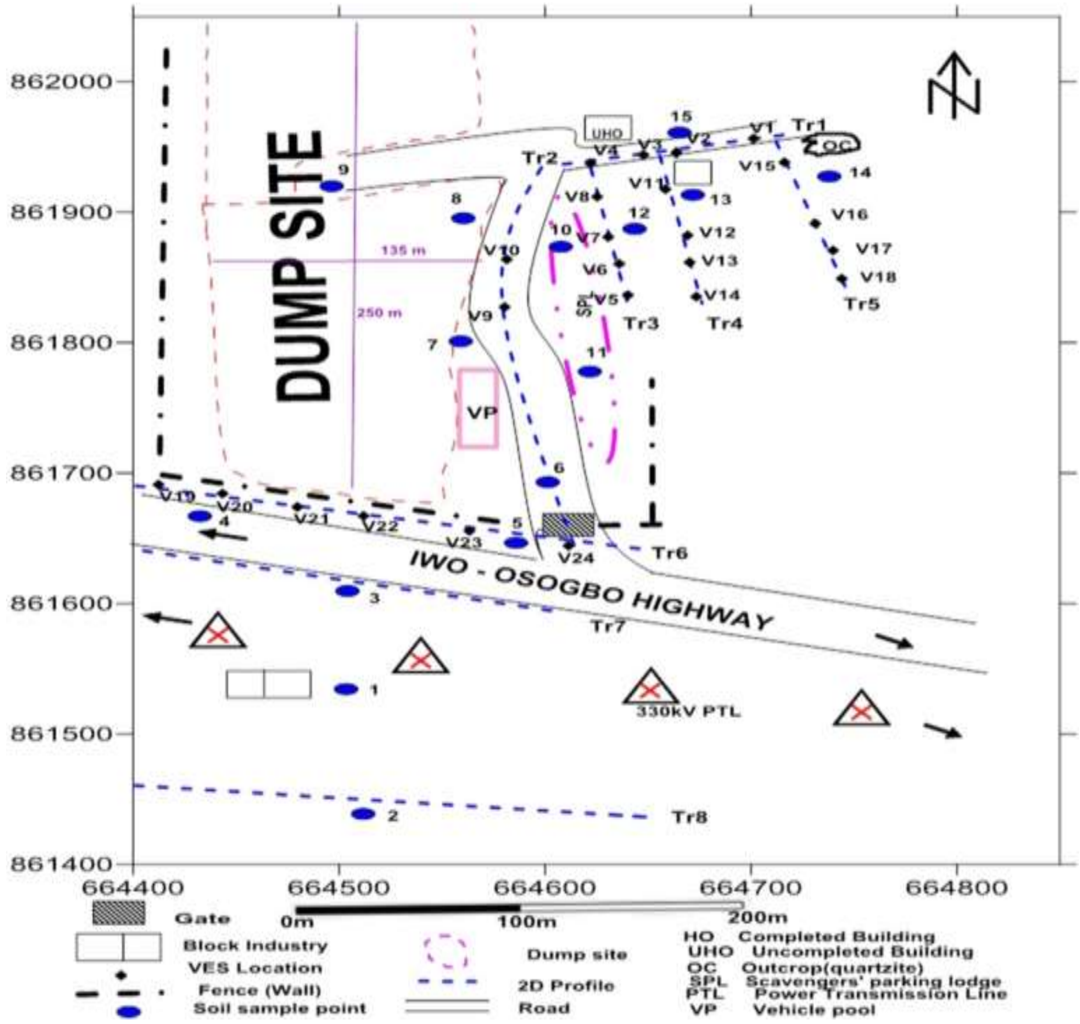


**Fig. 01:** The survey map of the study area and soil sampling positions at the active Onibu-Eja dumpsite and environs.(Ugwu, *et al*., 2016)

## Aim and Objective

This study was aimed at determining the impact of the dumpsite on the groundwater and the potentiality of the soil as a secondary source of contamination of the groundwater on long and short terms. The objective was to determine if the dump has contaminated the groundwater resources and the possibility of the soil to act as a secondary source of contamination of the groundwater after decommissioning of the site.

## Research Methodology

Groundwater contamination can occur by infiltration, recharge from surface water, direct migration and inter-aquifer exchange (Robert, et al, 1994, Ujile, et al., 2013). Percolating groundwater provides a medium through which wastes, particularly organics can undergo degradation into simpler substances through biochemical reactions involving dissolution, hydrolysis, oxidation and reduction processes (Taylor and Allen, 2001). In such context, chemical analysis integration with geophysical method provides an important tool in the evaluation and characterization of contaminants (Heitfeld and Heitfeld, 1997; Green *et al.*, 1999; Lanz *et al*., 1994: Krishna k.k. et al, 2016).

**Soil Sample collection and analysis**

Fifteen soil samples were collected from within and out the dumpsite at the surface (depth of about 15-20 cm) into clean polyethylene bags. The soil samples were thoroughly mixed to form a composite. The fresh soil was spread on a clean plastic sheet and air dried at room temperature for 48 hours.

The homogenized samples were oven - dried and sieved through an equivalent 0.5 mm sieve. One gram (1g) portions of soil sample were separately digested by refluxing in 10ml 1:1 $HNO_3$ for 10mins. This procedure was repeated with additional 5 ml of conc. $HNO_3$ until digestion was completed. The evaporated (5 ml) was treated with 2 ml water and 3 ml 30% $H_2O_2$ in 1 ml sequential aliquot addition until bubbling ceased. The digest was further reduced to 5 ml and refluxed in 10 ml conc. HCl for 15 mins. This was filtered and made up to 100 ml volume. The *Aglient* 710 Series ICP-OES (USA) was used for the analysis. Samples were analyzed under the instrumental operating conditions: RF Power 1.0 kW, Outer argon flow 12.0 L/min, Intermediate and Inner argon flow 1.0 L/min and the Nebulizer uptake rate (mL/min) 1.0. Standards calibration curves for the metal analyte already prepared covering the optimum working range stored in the system software was used to produce the computerized analysis report.

**Data analysis**

**(a) Contamination factor and Geo-accumulation index**

Contamination factor (CF) and geo-accumulation index (GeoI) are quantitative check used to describe concentration trend of metals in soils. Contamination factor (CF) is a quantifier of the degree of contamination relative to either the average crustal composition of the respective metal or the measured background values from geologically similar and uncontaminated area (Tijani et al., 2004). It is expressed as:

$$CF = \frac{Cm}{Bm} \qquad (1)$$

where $C_m$ is the mean concentration of metal in the soil and $B_m$ is the background concentration (value) of metal m, either taken from the literature (average crustal abundance). CF values were interpreted as suggested by Hakanson (1980), where: CF < 1 indicates low contamination; 1 < CF < 3 is moderate contamination; 3 < CF < 6 is considerable contamination; and CF > 6 is very high contamination.

Also Geo-accumulation index (GeoI) as proposed by Mueller (1979) and cited by Lokeshwari and Chandrappa (2006) is expressed as:

$$GeoI = In(\frac{Cm}{1.5} * Bm) \qquad (2)$$

where $C_m$ and $B_m$ are as defined above, while 1.5 is a factor for possible variation in the background concentration due to lithologic differences. GeoI is classified into seven descriptive classes (Mueller, 1981) as follows: < 0 = practically uncontaminated; 0-1 uncontaminated to slightly contaminated, 2-3 = moderately to highly contaminated, 4-5 = highly to very strongly contaminated, > 5 = very strongly contaminated. The latter is an open-end class that is indicative of all values greater than 5, and a GeoI of 6 is said to be indicative of 100-fold enrichment of a metal with respect to the baseline value (Bhuiyan *et al*., 2010).

**(b) Pollution load index (PLI)**

For the entire sampling site, PLI has been determined as the n$^{th}$ root of the product of the n CF:

$$PLI = (CF1 \; X \; CF2 \; X \; CF3 \; X.....X \; CFn)^{1/n} \quad (3)$$

This empirical index provided a simple, comparative means for assessing the level of heavy metal pollution. When PLI > 1, it means that pollution exists and if PLI < 1, there is no metal pollution (Tomlinson *et al*., 1980).

**Results and Discussions**

The soil samples collected were analysed to determine the elemental concentration level of manganese, zinc, copper, chromium, lead and cadmium. The concentration levels (mg/kg) are presented (Fig. 2).Samples close to the dumpsite exhibited significant higher elemental concentrations of the most metals as seen in sample points 6 – 11.

The bar charts of the mean elemental concentration level are shown in figure 2. The order of concentration level is Mn > Zn > Cu > Cr > Pb > Cd.

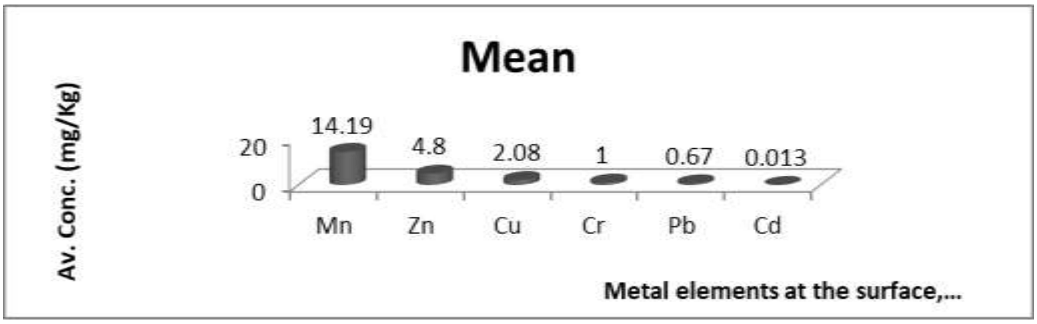


**Fig. 2:** Metal elements at the surface (Onibu-Eja dumpsite) showing order of average concentration.

Standard Statistical computation was carried on Tables 1. The calculated metal contamination factors (CFs) in all metals are CF < 1 indicating low contamination (Hakanson, 1980) and pollution load indices (PLIs) also are PLI < 1, showing that there is no metal pollution (Tomlinson *et al*., 1980), Tables 2. The evaluated degree of heavy metal contamination GeoI (geo-accumulation index) using the mean values (Tables 2) of the metal concentration levels for the dumpsite varies from -5.21 to -2.85 which indicate uncontamination (Bhuiyan *et al*., 2010).

**Table 1:** Metal contamination factors (CFs) and pollution load indices (PLIs) for the soil sample at the surface in Onibu-Eja dumpsite

| Sample Points | Contamination factors (CFs) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Mn | Zn | Cu | Cr | Pb | Cd | PLI |
| A1 | 0.0104 | 0.0085 | 0.0051 | 0.0043 | 0.0244 | 0.1333 | 0.0136 |
| A2 | 0.0039 | 0.0039 | 0.0014 | 0.0037 | 0.0138 | 0.0667 | 0.007 |
| A3 | 0.0055 | 0.0148 | 0.0033 | 0.0027 | 0.0131 | 0.0667 | 0.009 |
| A4 | 0.0094 | 0.0036 | 0.0029 | 0.0049 | 0.0244 | 0.0000 | 0.016 |
| A5 | 0.0083 | 0.0148 | 0.0106 | 0.0063 | 0.0350 | 0.0000 | 0.012 |
| A6 | 0.0164 | 0.0671 | 0.0459 | 0.0059 | 0.0000 | 0.0667 | 0.0288 |
| A7 | 0.0172 | 0.0787 | 0.0709 | 0.0089 | 0.0969 | 0.1333 | 0.0472 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A8 | 0.0163 | 0.0082 | 0.0789 | 0.0074 | 0.0450 | 0.0667 | 0.0248 |
| A9 | 0.0234 | 0.0992 | 0.0971 | 0.0140 | 0.0906 | 0.1333 | 0.0580 |
| A10 | 0.0282 | 0.1114 | 0.0843 | 0.0157 | 0.0950 | 0.1333 | 0.0612 |
| A11 | 0.0174 | 0.0132 | 0.0186 | 0.0146 | 0.0925 | 0.1333 | 0.0302 |
| A12 | 0.0141 | 0.0133 | 0.0056 | 0.0089 | 0.0144 | 0.1333 | 0.0162 |
| A13 | 0.0075 | 0.0066 | 0.0021 | 0.0096 | 0.0144 | 0.0667 | 0.0099 |
| A14 | 0,0176 | 0.0205 | 0.0099 | 0.0076 | 0.0381 | 0.1333 | 0.0227 |
| A15 | 0.0171 | 0.0212 | 0.0096 | 0.0085 | 0.0313 | 0.0667 | 0.0199 |
| Mean | 0.0142 | 0.0364 | 0.0297 | 0.0082 | 0.0419 | 0.0867 | 0.0277 |

**Table 2:** Metal contamination factors (CFs) and pollution load indices (PLIs) for the soil sample at 10-20 cm depth in Onibu-Eja dumpsite.

| Parameters | $C_m$ | $B_m$ | CF | GeoI | Overall summary of contamination level |
|---|---|---|---|---|---|
| Mn | 14.19 | 1000 | 0.014 | -4.67 | Uncontaminated |
| Zn | 4.80 | 132 | 0.036 | -3.72 | Uncontaminated |
| Cu | 2.08 | 70 | 0.030 | -3.92 | Uncontaminated |
| Cr | 1.00 | 122 | 0.008 | -5.21 | Uncontaminated |
| Pb | 0.67 | 16 | 0.042 | -3.58 | Uncontaminated |
| Cd | 0.013 | 0.15 | 0.087 | -2.85 | Uncontaminated |

CF- contamination factor; GeoI- geo-accumulation index; $C_m$- mean concentration of the metal in the soil; $B_m$- average crustal abundance (background value) was adopted from (Dineley *et al*., 1976; Amadi and Nwankwoala, 2013).

The result of soil analysis showed higher concentrations of manganese, zinc, copper, chromium, lead and cadmium on the dumpsite than at the periphery and order of concentration is Mn>Zn>Cu>Cr>Pb>Cd. However, the standard statistical parameters computed revealed that the areas are uncontaminated of heavy metals. This was attributed to scavenging of materials for recycling, leaching of the topsoil by rain and farming exercise because crops might have absorbed part of the metals.

**2-D Electrical Resistivity Structure**

However, electrical resistivity survey (dipole-dipole array) was carried out on the dumpsite (Ugwu, *et al*., 2016). The 2-D resistivity structure profiles Fig 4(a-c) delineated the subsurface layers and some contamination zones were interpreted within the aquifer units for the study area. These zones occurred as low resistivity with values < 31 Ωm and layer thicknesses < 5 m to 25 m. The leachate plume leaked to the bottom as observed at the eastern part of the dumpsite. This could be as a result of the relative permeability of the overburden, linear features and the downward sloping topography of the bedrock towards the dumpsite.

**Recommendations and Conclusions**

The weathered materials from the quartzite and banded gneiss that made up different layers of the overburden are feldspatic and clayey. This material has adsorptive properties and could prevent migration of the contaminants into the groundwater. In another hand it can also act as a secondary pollution sources. Hence it is important to engineer a dumping ground before using as waste dumping site to avoid infiltration. Contamination plume is observed on the south eastern part of the aquifer site, consequently to remediate the aquifer the following methods proffered are pump and treat and bioremediation, even though the soil did not show significant increase in the heavy metal concentration bioremediation could also be implode to absorb contaminants that could have adsorped by clayey material.

Chemical analysis carried out on soil samples collected from the Onibu-Eja active open dump site showed the concentration levels of heavy metals; manganese Mn, zinc Zn, copper Cu, chromium Cr, lead Pb and cadmium Cd. The data from the chemical analysis showed higher concentrations of these elements on the dumpsite than at the periphery. The order of concentration level of the elements was Mn>Zn>Cu>Cr>Pb>Cd. The statistical parameters computed revealed that the soil in the area is uncontaminated of heavy metals. This was attributed to scavenging of materials for recycling, leaching of the topsoil by rain and farming exercise because crops might have absorbed part of the metals. Pollution plume was noted in the aquifer on the down slopping southern part of the dumpsite.

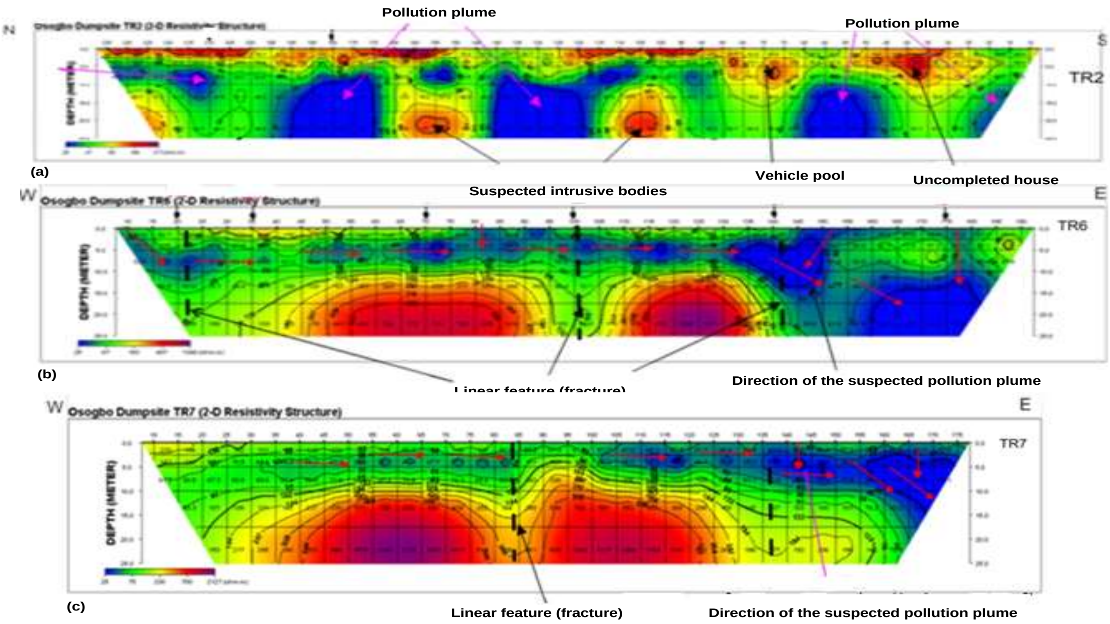


**Fig. 3:** 2-D Resistivity structure (a,b,c) along traverses TR2, TR6 and TR7 about 3 - 55 m away from the dumpsite (Ugwu et al., 2016).

## References

Amadi, A. N. and Nwankwoala, H. O. (2013). Evaluation of Heavy Metal in Soils from Enyimba Dumpsite in Aba, Southeastern Nigeria Using Contamination Factor and Geo-accumulation Index. *Energy and Environment Research*, *3*(1), 125 – 134. https://doi.org/http://dx.doi.org/10.5539/eer.v3n1p125

Bhuiyan, M. A. H., Parvez, L., Islam, M. A., Dampare, S. B and Suzuki, S (2010). Heavy metal pollution of coal mine-affected agricultural soils in the northern part of Bangladesh. *Journal of Hazardous Materials*, *173*, 384–392.

Dineley, D., Hawkes, D., Hancock, P and Williams, B (1976). *Earth resources – a dictionary of terms and concepts*.Lodon: Arrow Books Ltd.

Green A, Lanz Eand Maurer H (1999). A template for geophysical investigations of small landfills. Leading Edge 18(2):248–254

Hakanson, L. (1980). Ecological risk index for aquatic pollution control. A sedimentological approach. *Water Resources*, *14*, 975–1001.

Heitfeld K. Hand Heitfeld M (1997). Sitting and planning of waste disposal facilities in difficult hydrogeological conditions. In: Marinos, Koukis, Tsiambaos, Stournaras (eds) Engineering geology and the environment. Balkema, Rotterdam, pp 1623–1628.

Irene Galan (2019): Dark Skies, Bright Future: Overcoming Nigeria's E-waste Epidemic. United Nation Environmental Programme. Retrieved May 1, 2021 from http://www.unep.org/news-and-stories/stories/

Jhamnani B and Singh S. K(2009). Groundwater contamination due to Bhalaswa landfill site in New Delhi. *International Journal of Environmental Science and Engineering* 1(3):121–125.

Krishna, K.K., Yedluri, I., Prasad, S, (2016). Integrated Geophysical and Geochemical Assessment or comprehensive Study of the Groundwater. Water Air Soil Pollut 227, 211. https://doi.org/10.1007/s11270-016-2902.3.

Lanz E, Jemmi L, Muller R, Green A, Pugin Aand Huggenberger P. (1994). Integrated studies of Swiss waste disposal sites: results from georadar and other geophysical surveys. In: Proceedings of the *5th international conference on ground penetrating radar* (GPR'94). Kitchener, Ontario, pp 1261–1274.

Lokeshwari, H.and Chandrappa, G. T (2006). Impact of heavy metals content in water, water hyacinth and sediments of Laibagh tank, Bangalore. *Indian Journal Environmental Science and Engineering.*, *48*, 183 – 188. https://doi.org/http://www.neeri.res.in/jesevo14803006.pdf

Mueller, G. (1979). Schwermettale in den sedimenten des Rheins – Veraenderungen seit. *Umschau*, *79*, 778 – 783. In Lokeshwari, H.and Chandrappa, G. T (2006). Impact of heavy metals content in water, water hyacinth and sediments of Laibagh tank, Bangalore. *Indian Journal Environmental Science and Engineering.*, *48,* 183 – 188. https://doi.org/http://www.neeri.res.in/jesevo14803006.pdf

Mueller, G. (1981). Die Schwermetallbelstung der sedimente des Neckars und seiner Nebenflusse: eine estandsaufnahme. *Chem. Zeitung*, *105,* 157 – 164.

Ogbonna, D.N., Ekweozor, I.K.E. and Igwe F.U. (2002). Waste Management: A Tool for Environmental Protection in Nigeria. Ambio, 31(1), 55-57. Retrieved May 1, 2021 from http://www.jastor.org/stable/4315211.

Parimala Gnana Soundari Arockiam Jeyasundar,Amaajad Ali and Zengqiang Zhang (2020). Waste Treatment Approaches for Environmental Sustainability. Microorganism for Sustainable Environment and Health. ScienceDirect, 119-135.

Robert P, Shirly C, and Keith Parmer, (1994): Potential Groundwater Contamination From intentional and Nonintentional Stormwater Infiltration. Environmental Protection Authority USA. EPA/600/R-94/05

Taylor R., &Allen A., (2001) Nature and subject in Landfill, Impact problem (Memorandum).

Tijani, M. N., Jinno, K., & Horoshiro, Y. (2004). Environmental Impact of Heavy Metals Distribution in Water and Sediments of Ogunpa River, Ibadan Area, Southwestern Nigeria. *Journal of Mining*

Tomlinson, D. C., Wilson, J. G., Harris, C. R.and Jeffery, D. W. (1980). Problems in the assessment of heavy metals levels in estuaries and the formation of a pollution index, Helgol. *Wiss.Meeresunters*, *33*, 566–575.

Ugwu N.U, Ranganai R.T, Simon R.E.and Ogubazghi G., (2016). Application of Geo-electrical Resistivity Method to the Assessment of Groundwater Pollution: A case Study of Onibu-Eja Active Open Dumpsite, Osogbo, Southwestern Nigeria. *International Journal of Environmental Protection*, Vol. 6(1), 160-174. DOI: 10.5963/IJEP0601018.

Ujile, A. A. (2013): Evaluating Groundwater Contaminant and Delevolping Framwork for Qualitative Management in Parts of Nigeria. International Journal of Innovative Research in Science, Engineering and Technology. Pp 3890-3899.

USEPA: (1999). United States Environmental Protection Agency. Method 3050B: Acid Digestion of Sediments, Sludges and Soils. USEPA Office of Resources Conservation and Recovery (5305P) 1200 Pennsylvania Avenue, NW, Washington, DC 20460.

Vignesh K.S, Suriyaprakash Raajadesingu and Kantha Deivi Arunachalam, (2021): Concept of Advanced Zero Waste Tools: Present and Emerging waste Management Practices. Sciencedirect 69-90.

# A GEOPHYSICAL APPROACH FOR GROUNDWATER PROSPECTING AT FEDERAL POLYTECHNIC EDE, SOUTHWESTERN NIGERIA

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**Abstract**

*Occurrence of groundwater in the Basement environment is mostly in some geological structures such as joints, faults and in the weathered zones which also serve as aquifers. This study involved geophysical investigation to probe into the depth of the subsurface, the estimation of the thickness of the overburden, and assessment of the feasibility of drilling a productive borehole within the premises of the study area. The area investigated is located in the North Campus of Federal Polytechnic Ede, Osun State Nigeria, which has grown in terms of student and staff population, and therefore the need for increased water availability. Seven VES stations were established using Schlumberger array, the current electrode spacing (AB/2) expanded from 1 m to 65 m and data was analysed using WinResist. Interpretation of data indicates a four layered earth structure which were interpreted to be top soil (clayey/sandyclay), lateritic clay, weathered basement, fresh basement rock, with resistivity of 46-226 Ohm-m, 72-372 Ohm-m, 34-204 Ohm-m and 1347-4367 Ohm-m and thickness of 0.3-8.6 m, 1.6-18.2 m, and 3.3- 16.7 m respectively. The study indicates that the probable aquiferous unit in the geo-environment is the weathered basement rocks(third resistivity layer)occurring at depth between 14.6-33.8 meters from the earth surface, which can supply probably moderate to high water in the borehole in the area*.

**Keywords:** Borehole, Aquifer, Weathered basement, WinResist, Geological structures

## Introduction

As a result of growing population of students and staff in Federal Polytechnic Ede, Osun State there is necessity for groundwater development to increase supply of adequate water for the consumption of everyone within the school premises. Water is considered an important necessity in the sustenance of life; this is why nature has bestowed the world with much of it. However the availability of good quality water for drinking has been characterised with problems ranging from pollution to inadequate information to explore it for use. As portable water is not everywhere in the subsurface but found only in aquifers that can accumulate and release it, therefore modern geophysical techniques are employed to search for it (Mohamed et al., 2013; Mogaji 2016). The knowledge of the geology of the area under investigation is very crucial as the understanding of the geology of the site helps to delineate possible saturated zones from unsaturated zones beneath the crust (Hassan et al. 2017).

Ground water exploration however means determining whether the water occurs under conditions that permit utilization through well. It is essential to appraise the available ground water resources qualitatively and quantitatively. Knowledge of geological condition and hydrologic parameters are important for the proper design and construction of an open well.

Geophysical investigation using electrical resistivity technique/method was carried out in the study area to locate the ground water aquifer accurately, and reduce cost and time spent on drilling dry wells arising from poor knowledge of the hydro-geophysical characteristics of the basement aquifers by determining suitable hydrological characteristics like weathered zone, fractured zone, and joint zones.

**Site Description and Geology**

Federal Polytechnic Ede is located in Ede North Local Government area of Osun State which falls within the South Western part of Nigeria. It lies between latitude 7°43’38’’N and 7°44’36’’N° and longitude 4°25’18’’E and 4°25’29’’E. The study area is accessible through network of roads and well developed footpaths. The climate of the study area is related to that of the tropical rain forest of Nigeria which has two definite climatic conditions. Ede is located in the high forest belt which is characterized by good vegetation cover ranging from thick bushes to tall trees of different heights and is mostly perennial. The rivers and streams in the study area flow over a slightly undulating valley. The drainage could be said to be dendritic in pattern because the streams within the area are topographically controlled and the homogeneous nature of the underlying rocks and their resistance also relate to the drainage.

Geologically, the study area lies entirely within the Basement Complex of Southwestern Nigeria (Rahaman, 1976). The primary rock type constituting the local geology of the area is pegmatite which is underlain by migmatite schist and a sequence of lateritic clay, clayey sand/sand and weathered / fractured bedrock. (Fig. 1)

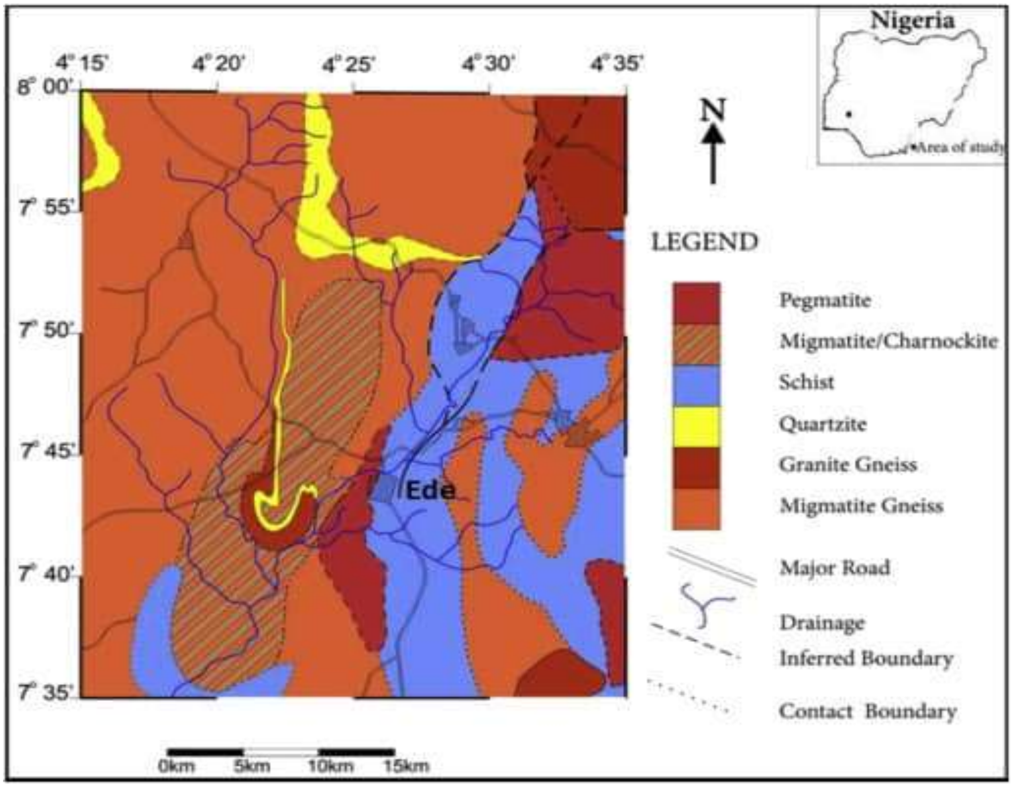


**Fig.1:** General Geologic Map of the study area (After NGSA, 2004)

**Materials and Method**

The geoelectrical sounding or vertical electrical sounding (VES) technique measures the distribution of electrical resistivity in the subsurface. This technique is widely used for aquifer delineation as it can penetrate deeper into the subsurface (Oyeyemi et al., 2019).

The electrical resistivity method measures both lateral and vertical variations in ground resistivity from different points on the earth surface. The resistivity of the ground is measured by sending current into the ground at the current electrodes and the corresponding potential difference is measured at the potential electrodes, which is then converted to apparent resistivity value by multiplying with an appropriate geometrical factor. The survey technique used for this study was the Vertical Electrical Sounding (VES) technique (Schlumberger array). The Vertical Electrical

Sounding technique measures the vertical variations in ground apparent resistivity with respect to a fixed centre of array. The VES technique employs the collinear arrays designed to output a one-dimensional (1-D) vertical apparent resistivity versus depth model of the subsurface at a specific observation point. In this method, a series of potential differences are acquired at successively larger electrode spacing while maintaining a fixed central reference point. The induced current passes through progressively deeper layers at greater electrode spacing. Apparent resistivity values calculated from measured potential differences can be interpreted in terms of overburden thickness, water table depth, and the depths and thicknesses of subsurface strata (Telford et al., 1990). A total of seven (7) Vertical Electrical Sounding (VES) points were acquired at different locations within the Polytechnic using AECM Terameter.The electrode separation (AB/2) varied from 1 to 65 m. Current was passed into the ground through the current electrodes, and the resulting potential was measured through the potential electrodes, and was converted to resistance, which was recorded by the terrameter. (Fig. 2)

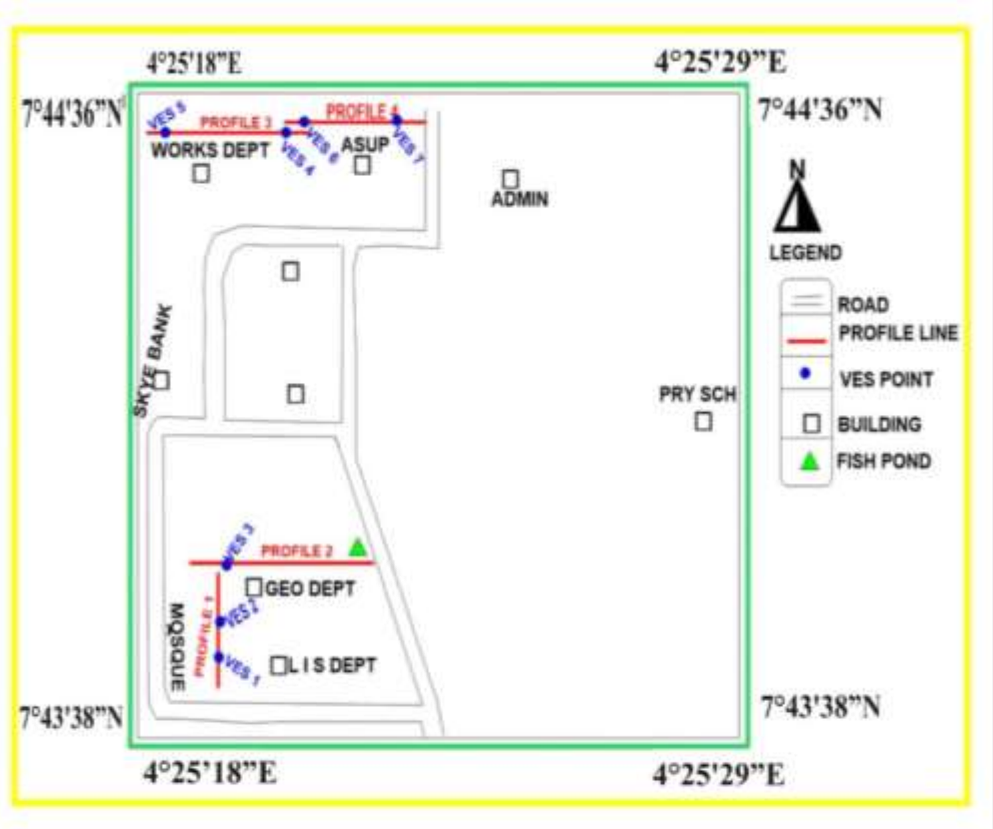


**Fig 2:** Topographical Map of the study area showing the profile line and VES points

**Data Analysis**

Analysis and interpretation of the measurements required forward modelling of the data by plotting apparent resistivity values versus the horizontal distance and matching these plots to master curves. A partial match against the master curves provided initial parameters for the second part of the data analysis which utilized a resistivity computer program called WinResist

**Results and Discussion**

Figures 3a-d are geo-electric sections drawn through VES locations 1and 2,1, 2 and 3, 4 and 5,also 6 and 7. They show the geo-electric layers. Also Figures.4a-g show the inverted model interpretation for VES 1, 2, 3, 4, 5, 6, and 7. The top soil (clayey/ sandy clay) , which, is characterized by resistivity values between 46 Ohm-m and 226 Ohm-m and thickness between 0.3 m and 8.6 m. Underlying the top soil, the profile reflects a layer identified to be lateritic clay in nature with resistivity value between 72 Ohm-m to 372 Ohm-m, with thickness between 1.6 m and 18.2 m, the layer that follows this is weathered basement which is also the aquiferous unit with resistivity between 34 Ohm-m and 204 Ohm-m, which is about 3.3 m and 16.7 m in thickness. The next layer is characterized by resistivity values between 1347 Ohm-m and 4367 Ohm-m, and is believe to be fresh basement (fig. 3) except in VES 4 and 5 that the fourth layer is fractured basement with resistivity between 316 Ohm-m and 503 Ohm-m. Olayinka (1992) opined that the Basement Complex rocks of Nigeria are generally poor aquifers except when fractured and jointed. He further stated that the presence of joints and fractures within the bedrock may lead to the development of a high permeability which can support a productive borehole. The Basement rocks are hard with low permeability but despite their poor hydrologic characteristics,they are still very important in ground water supply in Nigeria. The search for groundwater in this region therefore requires a good understanding of the hydrogeology of this area. Generally the overburden of the study area is relatively shallow, about 26 m when compared to the range given by Olorunfemi and Okhue (1992), for south west basement rocks. They gave overburden greater than 30m as thick overburden. This underscores the need for a more systematic approach to groundwater studies under these geological conditions.

The area under study is underlain by pegmatite and gneissic rocks. The pegmatite is more responsive to stress by fracturing than gneisses and this is why the VES points around quartzite rocks give a good value for productive borehole.

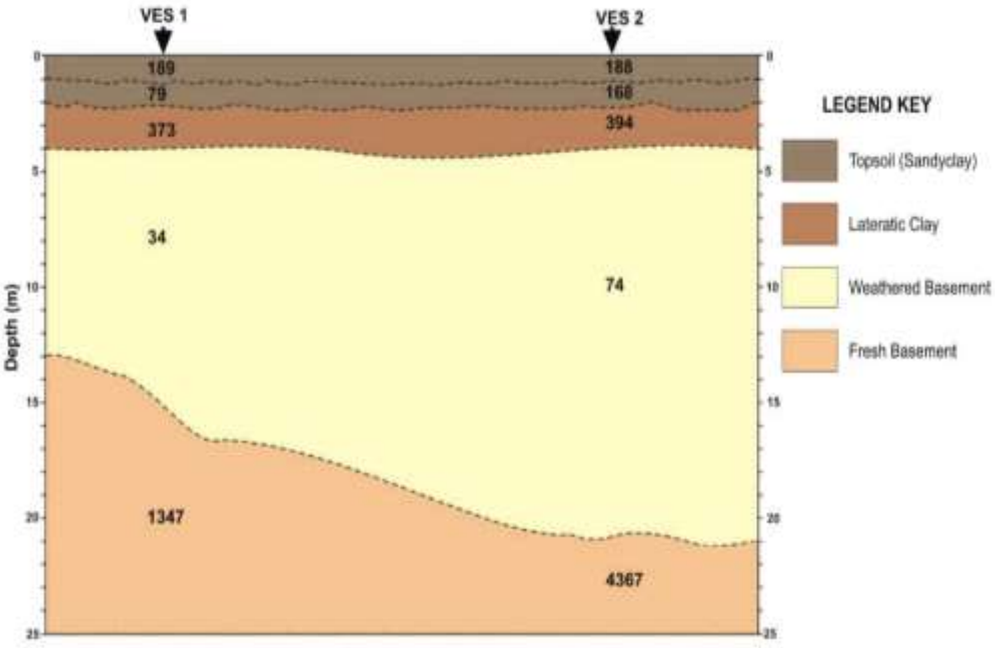


**Fig. 3a:** Geo-electric Section across VES 1 and 2

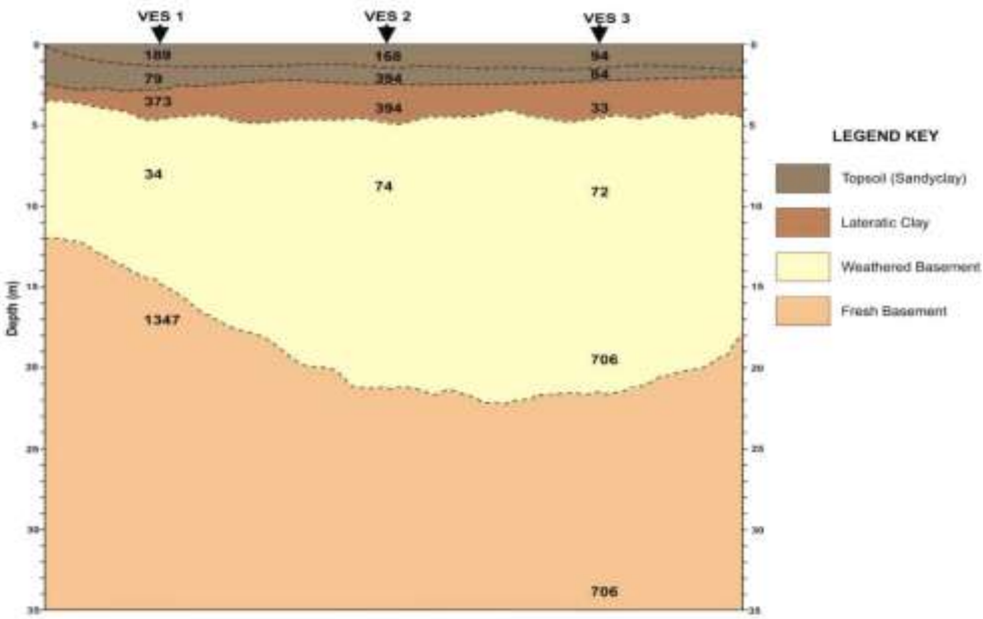


**Fig. 3b:** Geo-electric Section across VES 1, 2, and 3

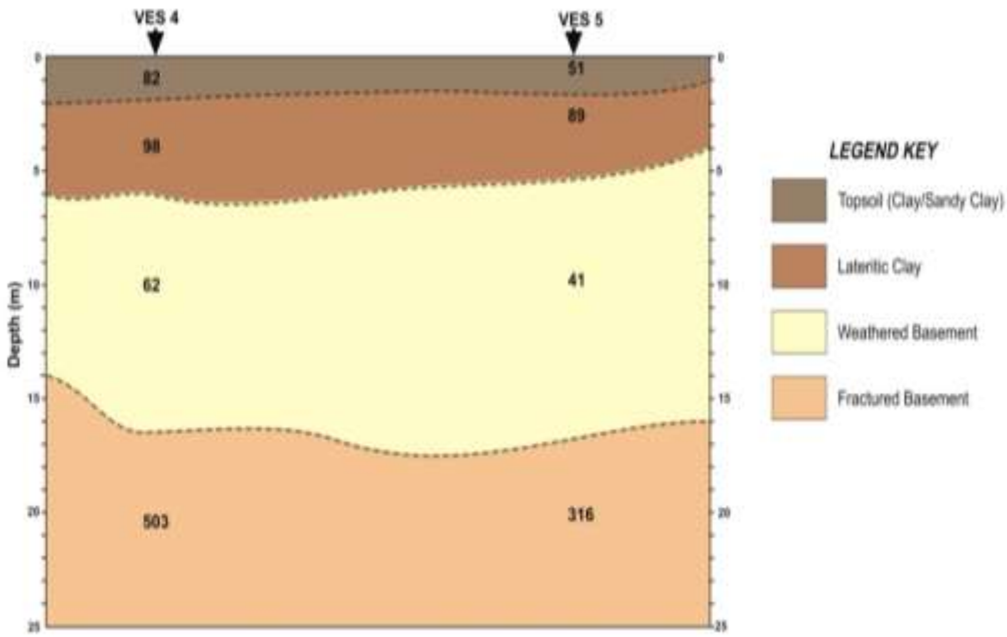


**Fig. 3c:** Geo-electric Section across VES 4 and 5

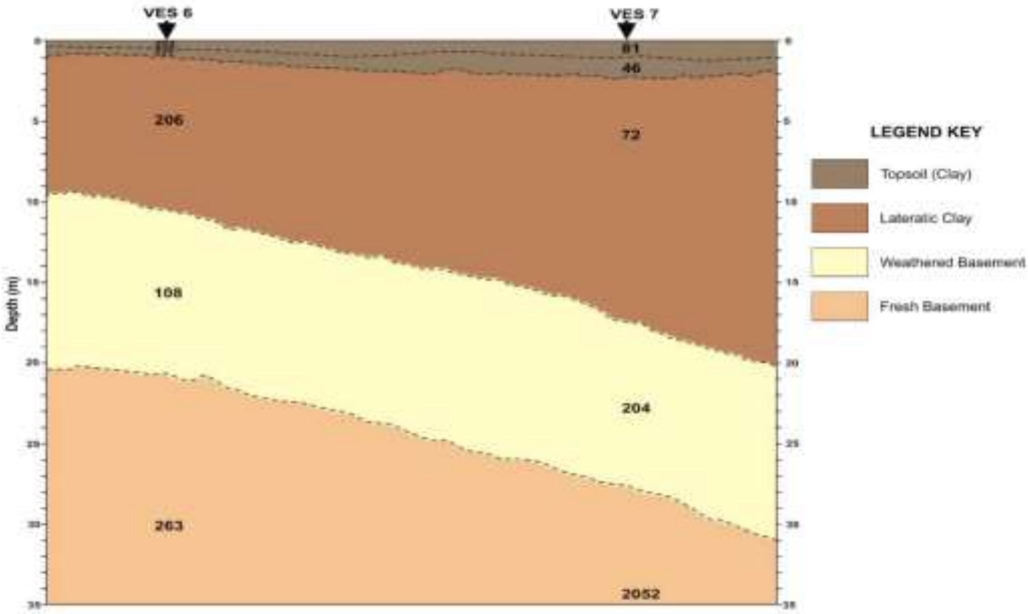


**Fig. 3d: Geo-electric Section across VES 6 and 7**

## Conclusion

From the results gathered from the geophysical investigation and interpretation of the study area, the study area is very good for groundwater development because the aquifer is highly weathered and fractured, therefore will contain enough water that will supply boreholes in the vicinity of the study area. Also the overburden water should be taken into consideration, because the deeper the well the fresher the basement becomes, and this can only create enough reservoir for the well.

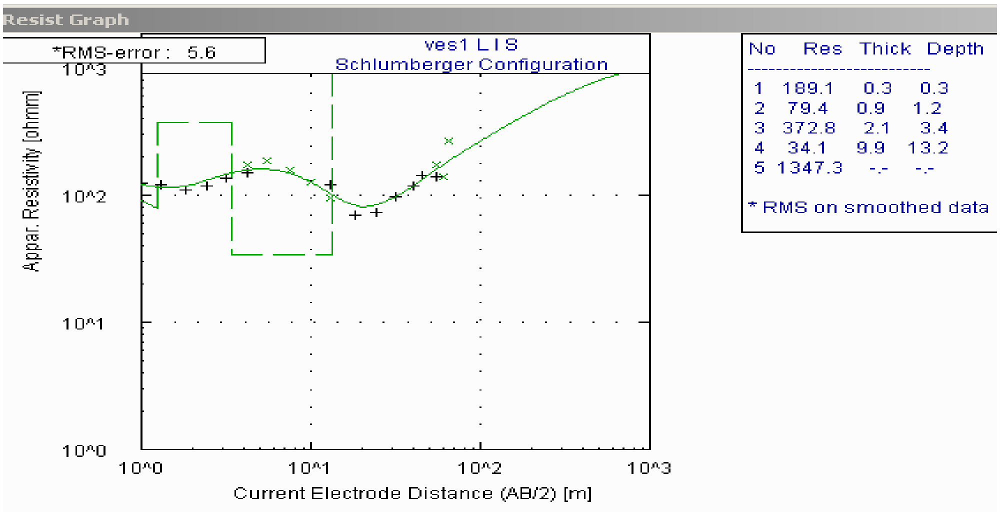


**Fig 4a:** Layer model interpretation for VES1

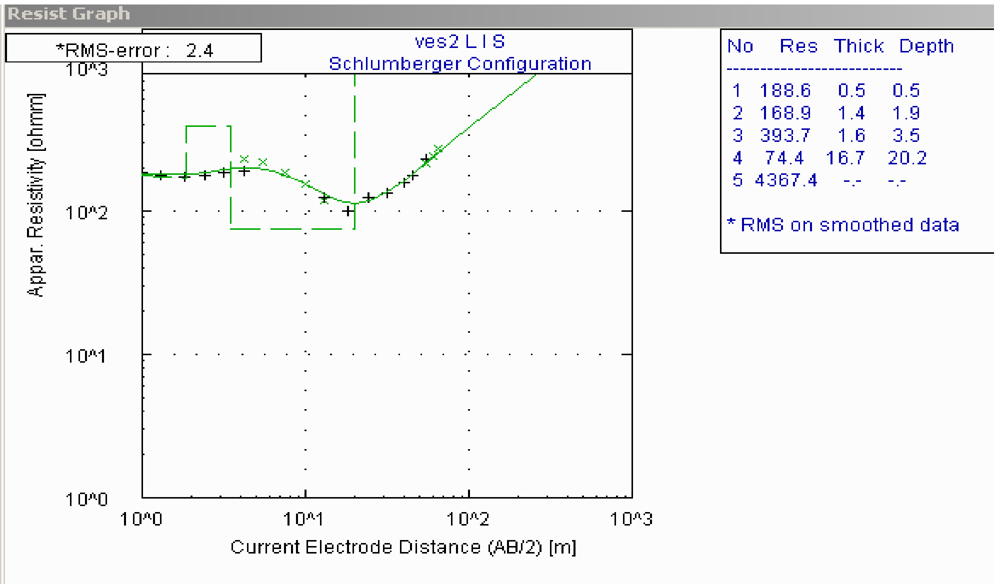


**Fig 4b:** Layer model interpretation for VES 2

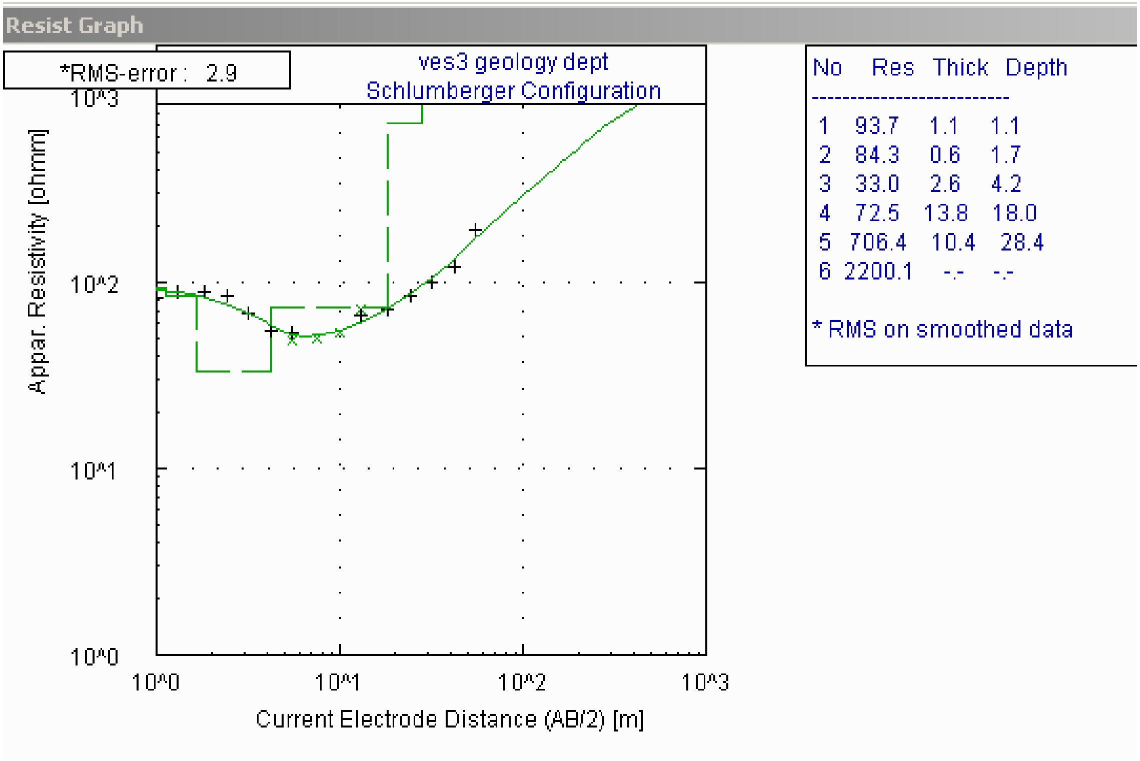


**Fig 4c:** Layer model interpretation for VES 3

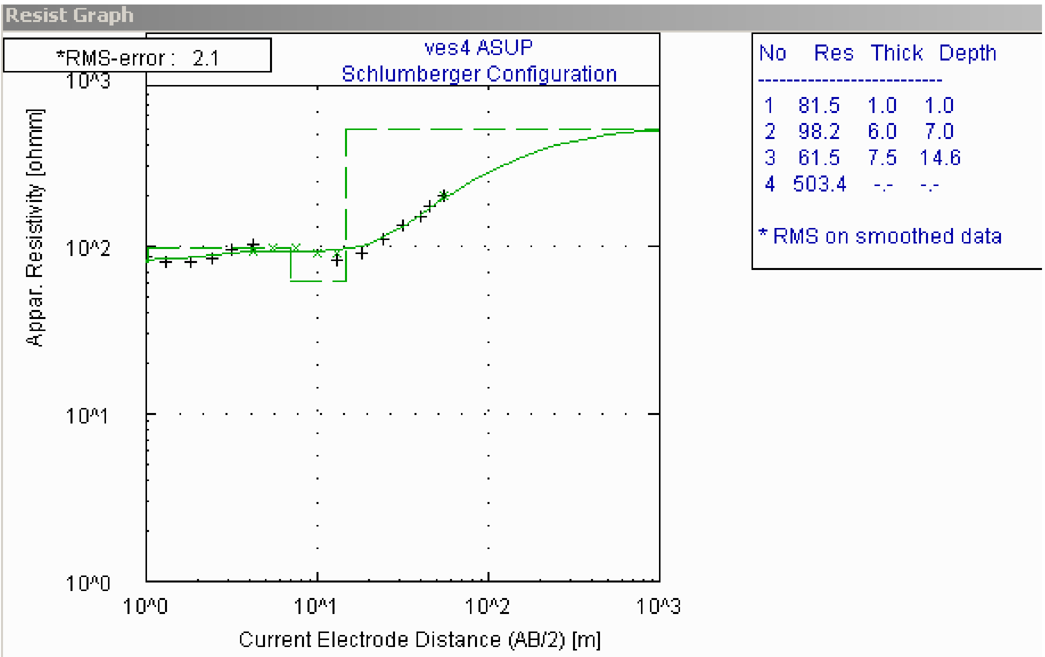


**Fig 4d:** Layer model interpretation for VES 4

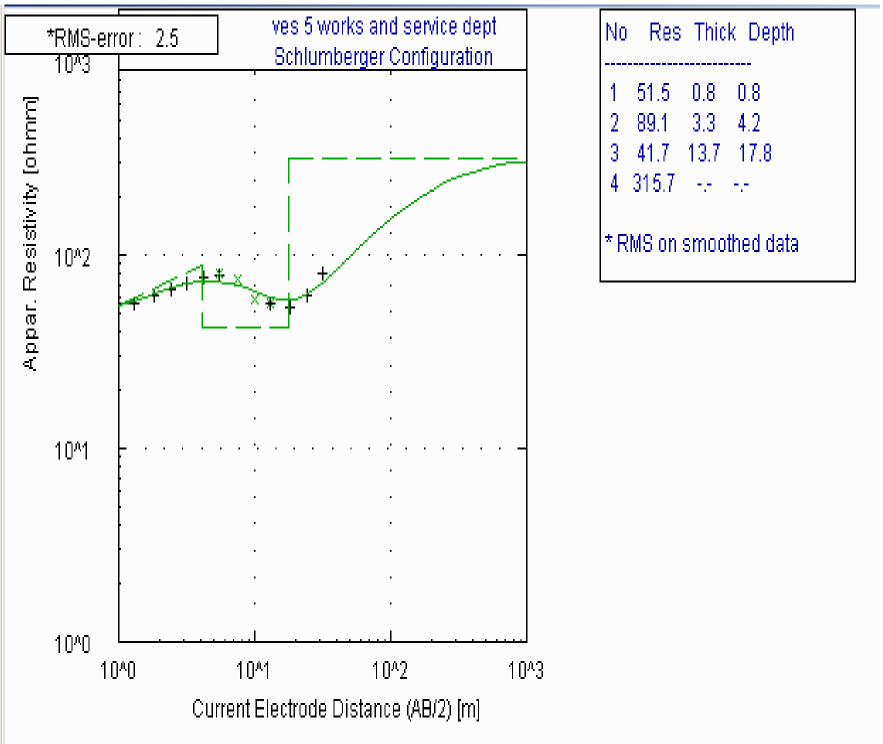


**Fig 4e:** Layer model interpretation for VES 5

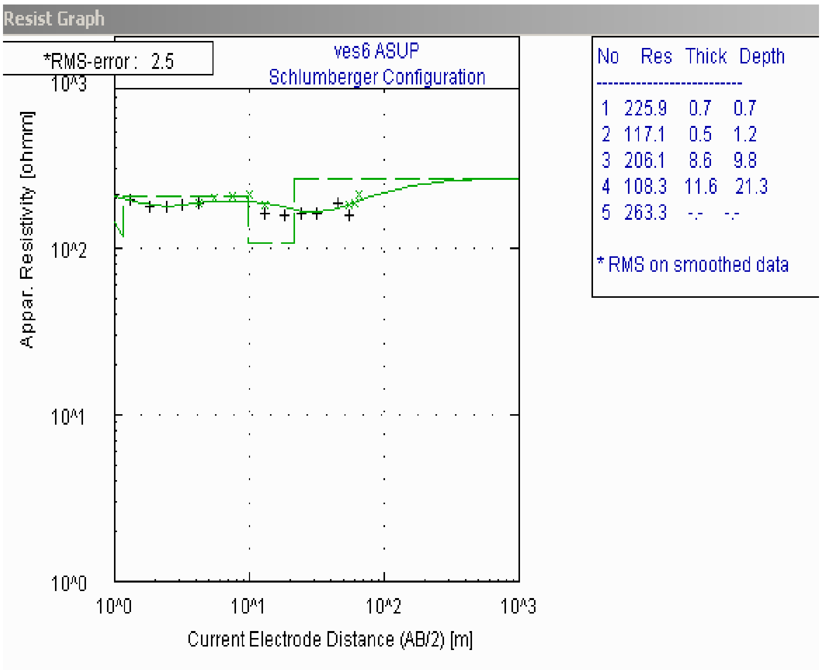


**Fig 4f:** Layer model interpretation for VES 6

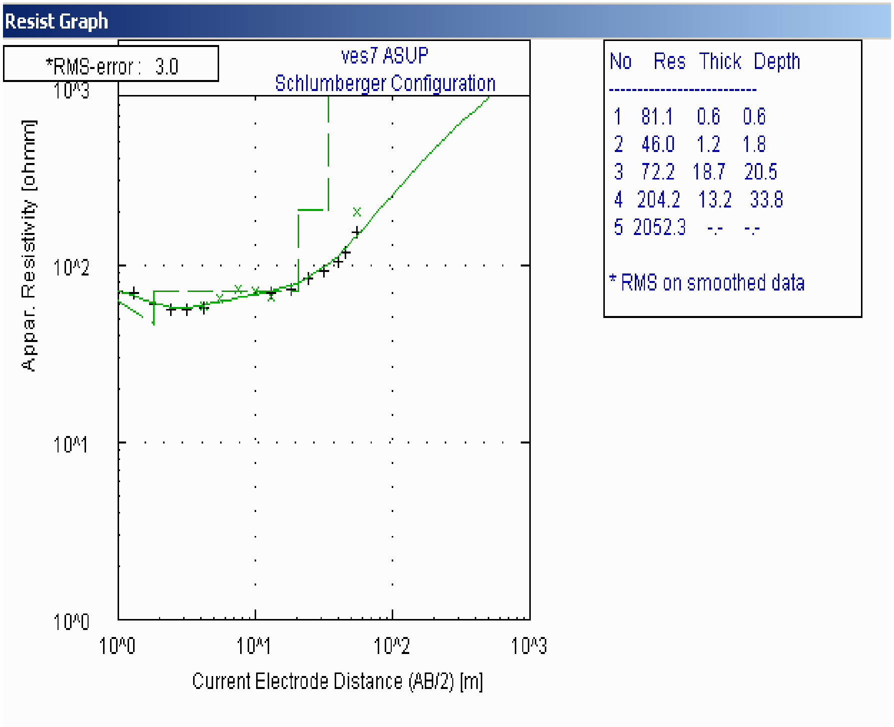


**Fig 4g:** Layer model interpretation for VES 7

## References

Hassan L, Abdellatif M, Moumtaz R (2017**)**. Modeling of transient two dimensional flows in saturated unsaturated porous media. Eur Sci J 13(12):1857–7881

Mogaji, K.A. (2016). Combining geophysical techniques and multicriteria GIS-based application modeling approach for groundwater potential assessment in southwestern Nigeria. Environmental Earth Sciences, 75,1181. doi.org/10.1007/s12665-0165897.

Mohamed, S.E.J., Shaharin, I., Wan, N.A.S., Puziah, A.L. (2013). Groundwater resources assessment using integrated geophysical techniques in the southwestern region of Peninsular, Malaysia. Arabian Journal of Geosciences, **6**(11):4129–4144

Nigeria Geological Survey Agency (2004). Geological map of Southwestern Nigeria.

Olayinka, A.I. (1992). Geophysical siting of boreholes in crystalline basement of Africa. *Journal of Africa Earth Science*. 14:179-207

Olorunfemi, M.O. and Okhue,E.T. (1992). Hydrogeologic and Geologic significance of a Geoelectric survey at Ile-Ife, *Nig. Journal of Mining and Geology*. 28:221-229.

Oyeyemi, K.D., Aizebeokhai, A.P., Sanuade, O.A. (2019): Geological-geophysical investigations for hydrological studies in a basement complex terrain, southwestern Nigeria. In: Chamine, H.I., et al. (Eds.), Advances in Sustainale and Enviromental Hydrology, Hydrogeology, Hydrochemistry and Water Resources, Advances in Science, Technology and Innovation. Springer. https://doi:10.1007/978-3-0 1572-5_58.

Rahaman, M.A., (1976):. Review of the Basement Geology of Southwestern Nigeria. Geology of Nigeria, Elizabethan Publ. Co; Lagos, Nigeria, pp. 41 – 58

Telford, W.M. et al (1990). Applied Geophysics (Second Edition: Cambridge University Press, p. 344-536

# IMPACT OF LEACHATE ON GROUND AND SURFACE WATER QUALITY IN LEMNA DISTRICT, CALABAR MUNICIPALITY LOCAL GOVERNMENT AREA, CROSS RIVER STATE – NIGERIA

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**Abstract**

*The aim of this study was to examine the impact of leachate on ground and surface water quality in Lemna District of Calabar Municipality in Cross River State – Nigeria. Water samples were collected from both surface and groundwater source for physio-chemical and bacteriological analysis. The results showed the mean values of the measured parameters to be: pH = 6.2, Electrical conductivity = 63.38, temperature = 24.43, $BOD_5$ = 1.08, Do = 5.35 and Zinc = 0.08. Others were coliform = 166.00, turbidity 24.50, lead 0.097 and total hardness = 30.73. The statistical analysis revealed significant differences between the measured parameter of BOD, Do, coliform, zinc, iron, turbidity, potassium, nitrate, copper, total hardness and sodium and the WHO minimum permissible standards for the above measured variables. It was concluded that surface and groundwater in the study area has been significantly affected by leachate. It was recommended that open dumpsite should be sited away from streams and groundwater aquifers that are used for domestic purposes.*

**Keywords:** Open dumpsite, municipality, leachate, contamination, treatments

## Introduction

Water is a highly valuable but finite natural resource, on which all life depends for survival. All faces of the hydrological cycle are utilized by man for multifarious purposes such as for his survival and comfort, in domestic and commercial water supplies, agricultural production, fishing, energy generation, and transportation, industrial and recreational activities. However, many factors including population pressure, rapid urbanization and social-economic development have interfered with or impaired the life supporting characteristics and capacity of water for beneficial uses to the present and future generations and mankind (Eze and Abua 2003 and Abua and Ajake 2014).

The inability of government to holistically manage solid waste in lemna open dumpsite has resulted to contamination of ground and surface water quality around the study area through the infiltration of leachate from waste management and disposal. In Nigeria there is a major problem, in which waste if not properly managed can lead to contamination of surface and ground water quality and its surroundings. Open dumpsite is a land where, household wastes and debris from the streets are dumped. It is also a disposal site where wastes from industries, markets are indiscriminately disposed without good environmental safety measures. It is also known as a tip, dump, rubbish dump, garbage dump or dumping ground for the disposal of waste materials.

In recent times, due to the increasing demand for potable water, there is upsurge in the construction of boreholes by individuals. This situation was caused by inability of government to supply potable water to the people. The poor supply of potable water has led to indiscriminate sinking of boreholes by private individuals in the area as a way to meet the increasing water needs of the people. Unfortunately, water from these boreholes is pumped and sold to the people for drinking and household uses without any form of treatment (Ebin, 2016). Leachate has adverse impact on ground and surface water quality as well as on living beings. It contains high level of organic, inorganic, heavy metals and xenobiotics which peculates through the sub-soil and contaminate the ground and surface water quality. Leachate are composed of organic and inorganic substances that consist of micro-organisms and their metabolic product and materials from living organisms which are undergoing decay and it consist of ammonium, phosphorous, sulphate and metals. Leachate generation is a major problem.

Improper and indiscriminate disposal of municipal solid waste has led to innumerable environmental disquiet like water, air and soil pollution. This needs immediate attention to reduce impact of municipal solid waste on environment and health (Rish, Rajiv and Ashok, 2016). Leachate is a contaminated liquid that is generated from water percolating through a solid waste disposal site, accumulating contaminants, and moving into subsurface areas.

The present study is to examined the impact of leachate on ground and surface water quality in Lemna open dumpsite in Calabar Municipality, Cross River State, Nigeria. Various physio-chemical parameters, heavy metal were studied in groundwater and surface water. The main aim of the study is to examine the extent of surface and groundwater pollution due to leachate percolation from Lemna open dump site.

**Material and methods**

The study area is Lemna in Calabar Municipality Local Government Area is situated between latitudes $5.0340302^0$& $5.036451^0$ and longitude $8.365722^0$& $8.365442^0$. The Lemna open dumpsite is approximately 6 square meters and the dumpsite has been used since 1999 and the dump contains household wastes and a mixture of wastes.

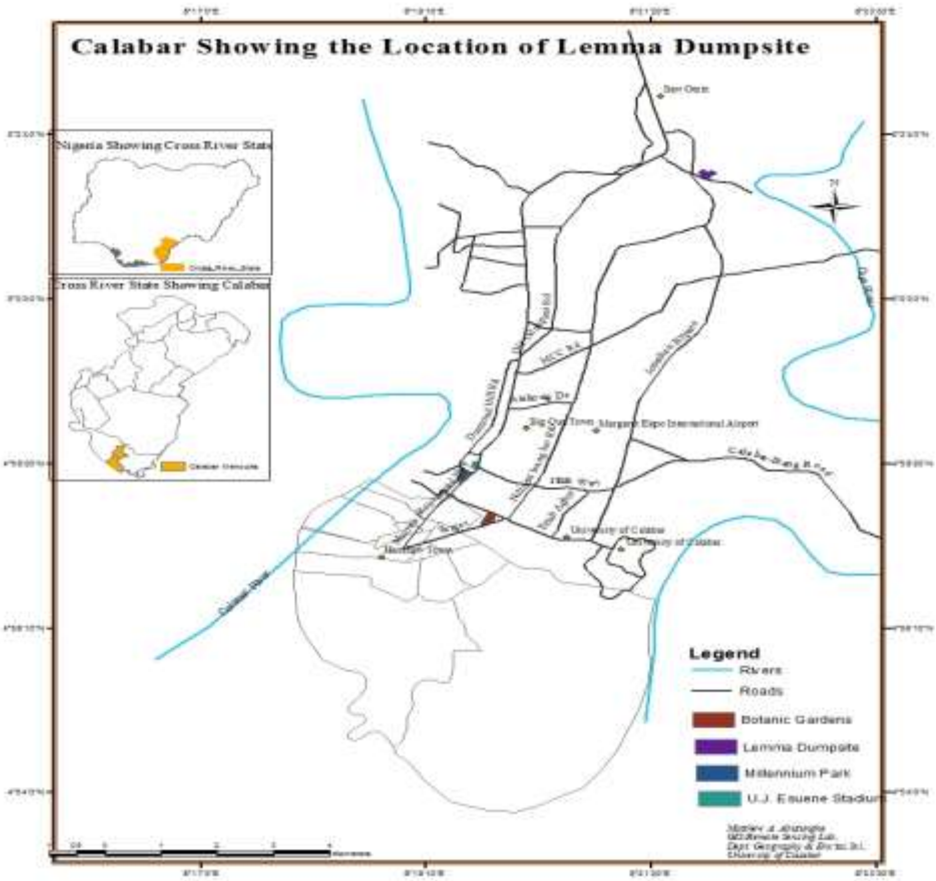


**Fig. 1:** Map of Calabar Showing the Location of Dumpsite

**Plate 1:** Showing waste dumpsites

**Plate 2:** Showing leachate direction to water bodies

**Samples collection**

The study was proceeded with a reconnaissance survey to the study area, a stream was identify close to the dumpsite, water samples were collected from the upper and the middle courses as prescribe by America Public Health APHA (2005), the stream was chosen because of the regular use by inhabitants for domestic use and the closeness of the stream and the boreholes to the flow of leachate down the stream. The water samples were collected during the rainy season May, June and July 2019 and dry season, October, November and December 2019. A composite method of sampling was adopted to make a total of twelve sampling points in both the upper and the middle courses. And two samples were collected from two different boreholes in the study area. Prior to the sampling collection the plastic bottles were washed with diluted Nitric acid and rinsed with distilled water and then dry the bottles and then rinsed with the water to be collected, the water samples were collected and the samples bottles were labeled with date and sources respectively and taken to University of Calabar Oceanography laboratory in a cold box of $4^0$C temperature for analysis of physic-chemical and biotechnological parameters and some parameters where measured in-situ like turbidity, temperature, conductivity, Do and PH.

**Result and discussion**

The water quality parameters for surface and ground water quality and acceptable values of World Health Organization (WHO) are presented in Table 1, 2 and 3 respectively.

**Table 1:** T-test difference between W.H.O standard and dry season water quality samples of surface water in Lemna open dumpsite in Calabar Municipal

| | Sample 1 | N | Mean | Std. Deviation | Std. Error Mean | t | Sig. (2-tailed) | Remark |
|---|---|---|---|---|---|---|---|---|
| Ph | W.H.O | 1 | 6.5000 | . | . | | | Not |
| | dry season | 6 | 6.2000 | .55321 | .22585 | .502 | 0.637 | Sig. |
| Conductivity | W.H.O | 1 | 1.000 | . | . | | | Not |
| | dry season | 6 | 63.383 | 23.2941 | 9.5098 | -2.4709 | 0.056 | Sig. |
| Temperature | W.H.O | 1 | 25.000 | . | . | | | Not |
| | dry season | 6 | 24.433 | .8189 | .3343 | .641 | 0.550 | Sig. |
| Bod | W.H.O | 1 | 6.000000 | . | . | | | Not |
| | dry season | 6 | 1.083333 | .5706721 | .2329759 | 7.976 | 0.000 | Sig. |
| do | W.H.O | 1 | 309.00000 | . | . | | | |
| | dry season | 6 | 5.350000 | .6252999 | .2552776 | 449.585 | 0.000 | Sig. |
| coliform | W.H.O | 1 | .00 | . | . | | | |
| | dry season | 6 | 166.00 | 38.262 | 15.620 | -4.017 | 0.010 | Sig. |
| zinc | W.H.O | 1 | 3.000000 | . | . | | | |
| | dry season | 6 | .076000 | .0113842 | .0046476 | 237.794 | 0.000 | Sig. |
| iron | W.H.O | 1 | .300000 | . | . | | | |
| | dry season | 6 | .085167 | .0262406 | .0107127 | 7.580 | 0.001 | Sig. |
| turbidity | W.H.O | 1 | 5.00 | . | . | | | |
| | dry season | 6 | 24.50 | 3.017 | 1.232 | -5.985 | 0.002 | Sig. |
| potassium | W.H.O | 1 | 12.000000 | . | . | | | |
| | dry season | 6 | .574500 | .2179686 | .0889853 | 48.530 | 0.000 | Sig. |
| nitrate | W.H.O | 1 | 50.000000 | . | . | | | |
| | dry season | 6 | .004000 | .0020976 | .0008563 | 226066.61 | 0.000 | Sig. |
| copper | W.H.O | 1 | 1000.0000 | . | . | | | |
| | dry season | 6 | .041833 | .0119066 | .0048608 | 77753.755 | 0.000 | Sig. |
| total harsdness | W.H.O | 1 | 600.00000 | . | . | | | |
| | dry season | 6 | 30.733333 | 16.75549 | 6.8404028 | 31,455 | 0.000 | Sig. |
| sodium | W.H.O | 1 | 200.00000 | . | . | | | |
| | dry season | 6 | 1.594000 | .6177475 | .2521944 | 297.352 | 0.000 | Sig. |
| lead | W.H.O | 1 | .010000 | . | . | | | |
| | dry season | 6 | .097500 | .0398836 | .0162824 | -2.031 | 0.098 | Not Sig. |
| manganese | W.H.O | 1 | .100000 | . | . | | | |
| | dry season | 6 | .162000 | .2842147 | .1160302 | -202 | 0.848 | Not Sig. |

**Source:** Author, 2019

Note: W.H.O = World Health Organization standard; Sig. = Significant

Result in table 1 shows the significant difference of WHO standard and dry season surface water quality samples for BOD (7.976) DO (449.585) coliform (-4.017) zinc (237.794) Iron (7.580) turbidity (-5.985) potassium (48.530) Nitrate (22066.605) Copper (77753.755) Total hardness (31.455) Sodium (297.352) lead (-2.031) and manganese (-202).

**Table 2:** T-test difference between W.H.O standard and rainy season water quality samples of surface water in Lemna open dumpsite in Calabar Municipal

| | Sample 1 | N | Mean | Std. Deviation | Std. Error Mean | t | Sig. (2-tailed) | Remark |
|---|---|---|---|---|---|---|---|---|
| ph | W.H.O | 1 | 6.5000 | . | . | | | Not |
| | rainy season | 6 | 6.1000 | .52356 | .21374 | .707 | .511 | Sig. |
| Conductivity | W.H.O. | 1 | 1.000 | . | . | . | . | |
| | rainy season | 6 | 56.817 | 6.8572 | 2.7995 | -7.536 | .001 | Sig. |
| Temperature | W.H.O. | 1 | 25.000 | . | . | . | . | Not |
| | rainy season | 6 | 25.867 | 1.2094 | .4937 | -.663 | .536 | Sig. |
| Bod | W.H.O. | 1 | 6.000000 | . | . | . | . | |
| | rainy season | 6 | 1.200000 | .6752777 | .2756810 | 6.581 | .001 | Sig. |
| Do | W.H.O | 1 | 309.0000 | . | . | . | . | |
| | rainy season | 6 | 4.966667 | .2503331 | .1021981 | 1124.422 | .000 | Sig. |
| Coliform | W.H.O | 1 | .00 | . | . | . | . | |
| | rainy season | 6 | 150.67 | 41.283 | 16.854 | -3.379 | .020 | Sig. |
| Zinc | W.H.O | 1 | 3.000000 | . | . | . | . | |
| | rainy season | 6 | .069000 | .0109727 | .0044796 | 247.303 | .000 | Sig. |
| Iron | W.H.O | 1 | .300000 | . | . | . | . | |
| | rainy season | 6 | .048433 | .0282932 | .0115507 | 8.232 | .000 | Sig. |
| Turbidity | W.H.O | 1 | 5.00 | . | . | . | . | Not |
| | rainy season | 6 | 16.50 | 2.881 | 1.176 | -3.696 | .014 | Sig. |
| Potassium | W.H.O | 1 | 12.00000 | . | . | . | . | |
| | rainy season | 6 | .600167 | .1678242 | .0685139 | 62.888 | .000 | Sig. |
| Nitrate | W.H.O | 1 | 50.00000 | . | . | . | . | |
| | rainy season | 6 | .013833 | .0024014 | .0009804 | 19271.433 | .000 | Sig. |
| Copper | W.H.O | 1 | 1000.000 | . | . | . | . | |
| | rainy season | 6 | .054833 | .0096212 | .0039278 | 96222.243 | .000 | Sig. |
| total | W.H.O | 1 | 600.000 | . | . | . | . | |
| harsdness | rainy season | 6 | 21.250 | 7.3560 | 3.0031 | 72.841 | .000 | Sig. |
| Sodium | W.H.O | 1 | 200.0000 | . | . | . | . | |
| | rainy season | 6 | 2.539667 | 2.1065137 | .8599806 | 86.785 | .000 | Sig. |
| Lead | W.H.O | 1 | .010000 | . | . | . | . | Not |
| | rainy season | 6 | .090500 | .0375007 | .0153096 | -1.987 | .104 | Sig. |
| Manganese | W.H.O | 1 | .100000 | . | . | . | . | |
| | rainy season | 6 | .040667 | .0198461 | .0081021 | 2.768 | .039 | Sig. |

**Source:** Author, 2019
Note: W.H.O = World Health Organization standard
Sig. = Significant

Table 2 above shows the results of the significant difference of WHO standard and rainy season water quality sample analysis for conductivity (-7.536) BOD (6.581) DO (1124.422) Coliform (-3.379) Zinc (247.303) Iron (8.232) turbidity (-3.696) potassium (62.888) Nitrate (19271.433) Copper (96222.243) total hardness (72.841) sodium (86.785) and manganese (2.768).

**Table 3:** T-test difference between W.H.O standard and ground water quality samples of surface water in Lemna open dumpsite in Calabar Municipal

| | Sample 2 | N | Mean | Std. Deviation | Std. Error Mean | t | Sig. (2-tailed) | Remark |
|---|---|---|---|---|---|---|---|---|
| Ph | W.H.O | 1 | 6.5000 | . | . | | | |
| | BW sample | 2 | 5.1750 | .03536 | .02500 | 30.600 | .021 | Sig. |
| Copper | W.H.O | 1 | 1000.0000 | . | . | . | . | |
| | BW sample | 2 | .056500 | .0077782 | .0055000 | 104966.85 | .000 | Sig. |
| Temperature | W.H.O | 1 | 25.000 | . | . | . | . | Not |
| | BW sample | 2 | 27.700 | 1.1314 | .8000 | -1.949 | .302 | Sig. |
| Bod | W.H.O | 1 | 6.000000 | . | . | . | . | Not |
| | BW sample | 2 | 28.752000 | 4.456187 | 3.151000 | -4.169 | .150 | Sig. |
| Do | W.H.O | 1 | 309.00000 | . | . | . | . | |
| | BW sample | 2 | 1.972500 | .6399316 | .4525000 | 391.740 | .002 | Sig. |
| f.coliform | W.H.O | 1 | .00 | . | . | . | . | |
| | BW sample | 2 | 183.50 | 13.435 | 9.500 | -11.152 | .057 | Sig. |
| Zinc | W.H.O | 1 | 3.000000 | . | . | . | . | |
| | BW sample | 2 | .077500 | .0035355 | .0025000 | 674.922 | .001 | Sig. |
| Iron | W.H.O | 1 | .300000 | . | . | . | . | |
| | BW sample | 2 | .078000 | .0042426 | .0030000 | 42.724 | .015 | Sig. |
| Turbidity | W.H.O | 1 | 5.00 | . | . | . | . | |
| | BW sample | 2 | 19.50 | .707 | .500 | -16.743 | .038 | Sig. |
| Potassium | W.H.O | 1 | 12.000000 | . | . | . | . | |
| | BW sample | 2 | .568000 | .0664680 | .0470000 | 140.431 | .005 | Sig. |
| Nitrate | W.H.O | 1 | 50.000000 | . | . | . | . | |
| | BW sample | 2 | .012500 | .0035355 | .0025000 | 11544.119 | .000 | Sig. |
| t.hardness | W.H.O | 1 | 600.000 | . | . | . | . | |
| | BW sample | 2 | 32.450 | 1.4849 | 1.0500 | 312.072 | .002 | Sig. |
| Sodium | W.H.O | 1 | 200.00000 | . | . | . | . | |
| | BW sample | 2 | 1.866500 | .9128749 | .6455000 | 177.215 | .004 | Sig. |
| Lead | W.H.O | 1 | .010000 | . | . | . | . | Not |
| | BW sample | 2 | .012500 | .0007071 | .0005000 | -2.887 | .212 | Sig. |
| Manganese | W.H.O | 1 | .100000 | . | . | . | . | Not |
| | BW sample | 2 | .059000 | .0042426 | .0030000 | 7.890 | .080 | Sig. |

**Source:** Author, 2019

Note: W.H.O = World Health Organization standard
Sig. = Significant

The computed results of table 3 above shows a significant difference of WHO standard and ground water (Gw1 & Gw2) quality samples in the study area of pH at (30.600) copper (104966.845) DO (391.740) Zinc (674.922) iron (42.724) turbidity (-16.743) potassium (140.431) nitrate (11544.119) total hardness (312.072) and sodium (177.215). These findings are in consonance with the work of Eja and Ebin (2016) who work in Ugep on evaluating the activities of festival on surface water quality, and Rishi, Rajiv and Ashok (2016) who work on the impact of leachate from non-engineered landfill sites on groundwater quality in Northern India.

## Conclusion

The study examined the impact of leachate on ground and surface water quality in Lemna District of Calabar Municipality Local Government Area in Cross River State, Nigeria and the results of the physico-chemical and bacteriological analysis shows that open dumpsite has discharge leachates on both ground and surface water quality that makes the stream and ground water (borehole) unfit for direct human consumption and the contamination shows higher in rainy season due to rainfall that enhance speedy movement of leachate to the water bodies. We recommended that open dumpsite leachate should be treated before is accelerated to water bodies either surface or ground water quality and government should ensure palliative measures to protect surface and ground water quality around the study area and open dumpsite should be sited far away from standard streams and human inhabitance and also leachates samples should be sampled for treatment before it will be drained into streams and infiltrate into groundwater quality.

## References

Abua, M. A. &Ajake, O. A. (2014). Water quality status around animal doing in Adiabo river catchments of Odukpani L.G.A., Cross River State, Nigeria. *International Journal of Bioscience,* 4(4), 25-43.

APHA (2005). America Public Health Association Standard method for the examination of water and waste water.

Ebin, O. I. (2016). Domestic water quality in relation to water borne diseases in Yakurr Local Government Area, Cross River State, Nigeria. Unpublished Ph.D thesis.

Eja, E. I. & Ebin, O. I. (2019). Evaluating the activities of festival on surface water quality in Ugep, Cross River State, Nigeria. *Journal of Social Science Studies,* 6(2), 86-96.

Eze, B. E. &Abua, M. A. (2003). Water resources management. Calabar: Ushie printers and publishing Co Ltd.

Mohd, R. T., Wan, W. Y., Abd, R. S. &Jasni, Y. (2011). Groundwater quality at two landfill sites in Selangor, Malaysia. *Bulletin of the Geological Society, Malaysia,* 57, 13-18.

Rishi, R., Rajiv, G. & Ashok, K. G. (2016). Impact of leachate from non-engineered landfill sites in Northern India. *International Conference on Trends and Recent Advances in Civil Engineering,* 20(1), 183-191.

# SOCIO-ECONOMIC IMPLICATIONS FOR SWAMP RECLAMATION IN ABONNEMA

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**Abstract**
*Abonnema, a riverine domain is a large town in Kalabari Kingdom in Akuku-Toru local Government area Rivers State, is completely surrounded with water, the town is located at the southwest of Rivers State founded in 1882, with a population of 74468. Abonnema keyed into land reclamation because of its overcrowded condition and to satisfy the need for new homes. This research was aimed at evaluating the positive and negative implications of swamp reclamation on the livelihood and infrastructural delivery in Abonnema. For the purpose of this study, both quantitative and qualitative research method were adopted. Field observations, questionnaire survey and sky-view life-time drone photographs were achieved from Rivers State Ministry of works. Findings showed that land reclamation activities have caused the destruction of non-crop and crop vegetation, destruction and displacement of organisms and species; and on the other hand, most populations have benefited from land reclamation activities. These advantages include the development of infrastructure and the access to employment opportunities, extension of land capacity, improved living standard of citizens. The study therefore recommends that the institutions such as Rivers State Government and NGO should put in place laws and strategies to regulate reclamation activities across the area. Educational organizations should also carry out environmental awareness and perception of the environment, as part of their duty.*

**Keyword;** Swamp reclamation, Abonnema, Wetlands, Hydrology, Socio-economics

## Introduction

Abonnema grew to become a flourishing major Nigerian seaport during the colonial era. It was host to many European companies. One such company was the Royal Niger Company which later metamorphosed into U.A.C. Abonnema is the headquarters of Akuku-Toru Local Government Area of Rivers State in Nigeria.Wetland is an important ecosystem to fish and loss or degradation of wetland will have a direct consequence on sustainable fisheries [3]. Whenever a source of freshwater meets a floodplain that has no steep outflow, the water builds up to standing level. This is known as a swamp and is a productive ecosystem, although difficult for humans to live in.Niger Delta mangroves are the largest in Africa, but uncontrolled anthropo-genic activities had reduced their population size. The reduction from large to small mangrove stand has some ecological implications on species populations. For instance, stochastic events such as flooding, landslides, sea level rise, high temperature, and humidity affect small populations. Human-mediated actions of random deforestation for firewood production, canalization, and de-silting of waterways, lead to the complete elimination of mangrove stands in specific locations. The cumulative effect of these actions can result in local extinction and loss of genetic variation of mangroves. Destruction of mangroves over the years is detrimental to other species that inhabit the mangroves in the Niger Delta such as fishes, crabs etc.[1]. Mangroves provide several ecosystem services to the local people but mangrove has been impacted on in swamp reclamation sites with the aid of swamp buggies. The entry of big machinery into the swamp causes negative impact on the coast such as destroying many soil-dwelling and benthic organisms [2]. Although Land reclamation can be classified as a process of acquiring land from wetlands coast or sea[4], but land reclamation activities destroys habitat of organism and species.

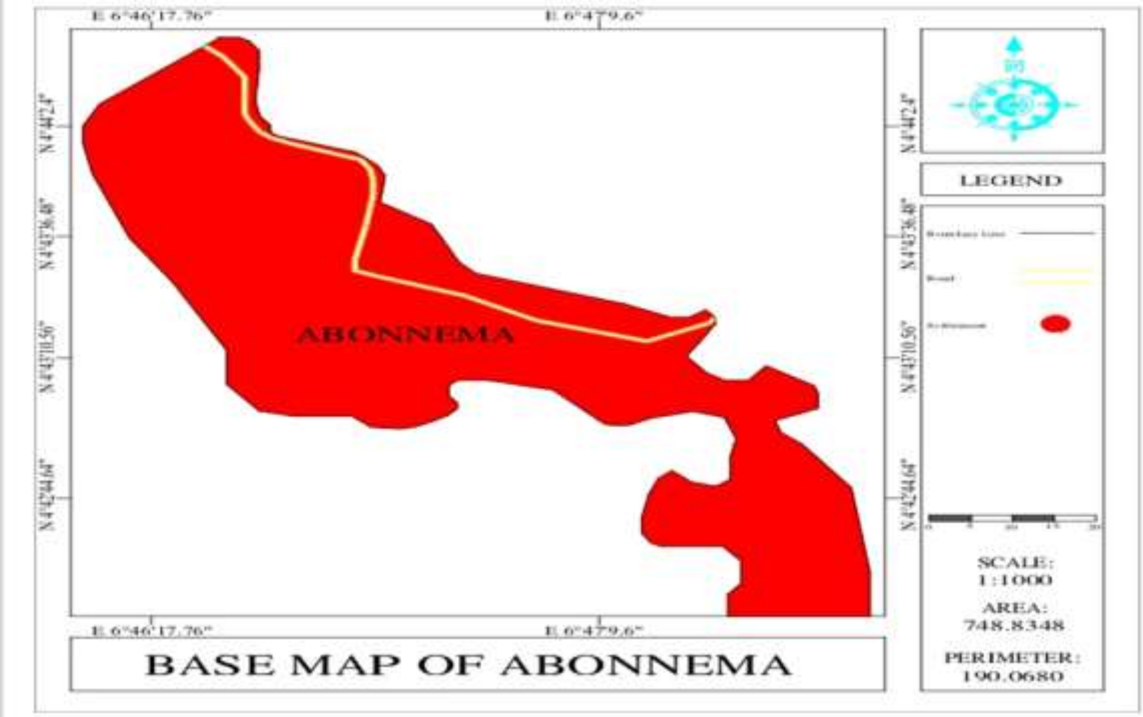


**Fig. 1:** Base Map of Abonnema

**Methodology**

For the purpose of this article lifetime drone imageries of Abonnema were achieved from Rivers State Ministry of Works to review and evaluate the present condition and clustering of buildings in Abonnema and to also see the Degema to Abonnema link bridge constructed in 1999 and the newly constructed ring road linking Abonnama to the new site. Field observations and questioners were administered to get a first-hand information on socio-economic impact of swamp reclamation in Abonnema.

Over the years the population of Abonnema has multiplied which has triggered the need for the expansion of land capacity specially after the construction of the Degema-Abonnema link bridge that has made it possible for residents to be based in Abonnema and work in other nearby LGAs in Rivers State. During the interaction with some of the elders in Abonnema, it was observed that due to lack of land, they experienced a slow pace of infrastructural development such as roads, industries, new homes, hotels to accommodate residents and visitors coming in for events such as weddings, burial and the famous Abonnema beach carnival. Figure 2 showed that Abonnema is surrounded with water and swamp making boats and canoe the only access in and out of Abonnema before the swamp reclamation paved way for infrastructural development such as the constructed bridge.

**Result and Discussion**

**Fig. 2:** Aerial View of Abonnema

**Fig. 3:** Abonnema ring-road view



Figure 3 showed one of the socio-economic benefits of swamp reclamation in Abonnema which is the recently constructed ring-road that links you directly to the area’s new site (Ogoin Piri) through the back of the Abonnema cemeterywithout having to drive through the main town.

Figure 4 marital status of respondents showed a high percentage of married residents and a low percentage of singe residents in Abonnema.

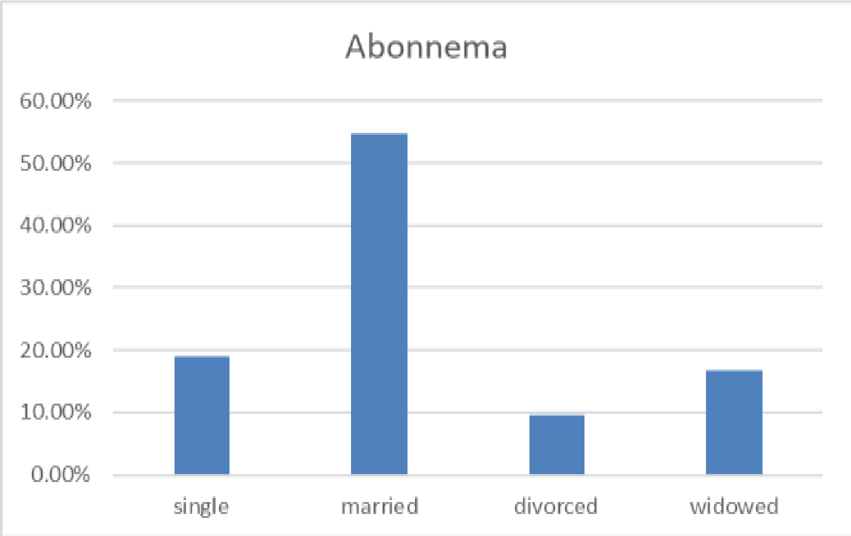


**Fig. 4:** Marital status of Respondents

Figure 5 showed that a very high percentage of residents are comfortable with swamp reclamation and a very low percentage of residents and not happy with reclamation activities in Abonnema,

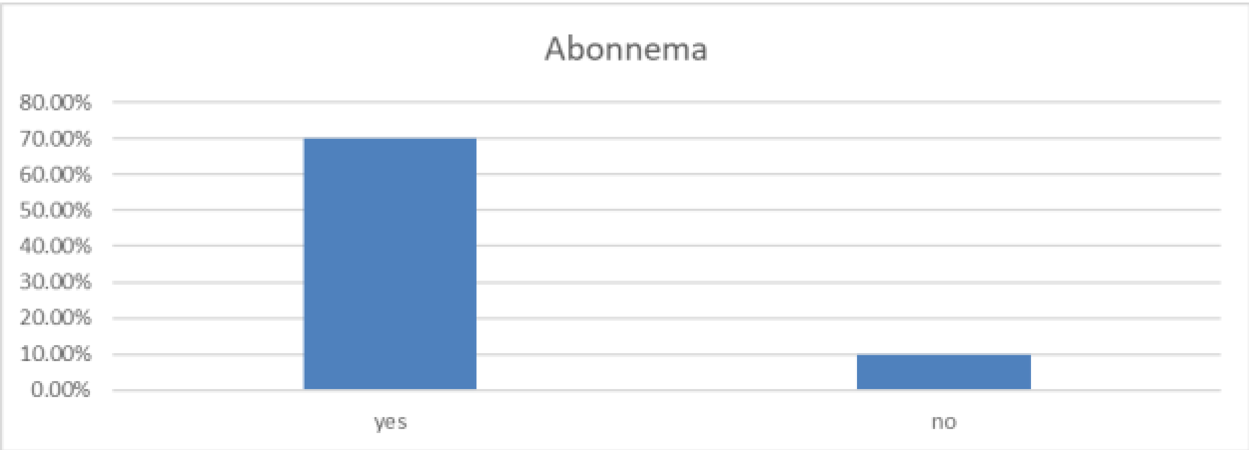


**Fig. 5:** Respondents comfortable with swamp reclamation

Figure 6 showed a very high percentage of residents that have not attained any level of education and a very good percentage of respondents that has attained primary, secondary and tertiary education in Abonnema

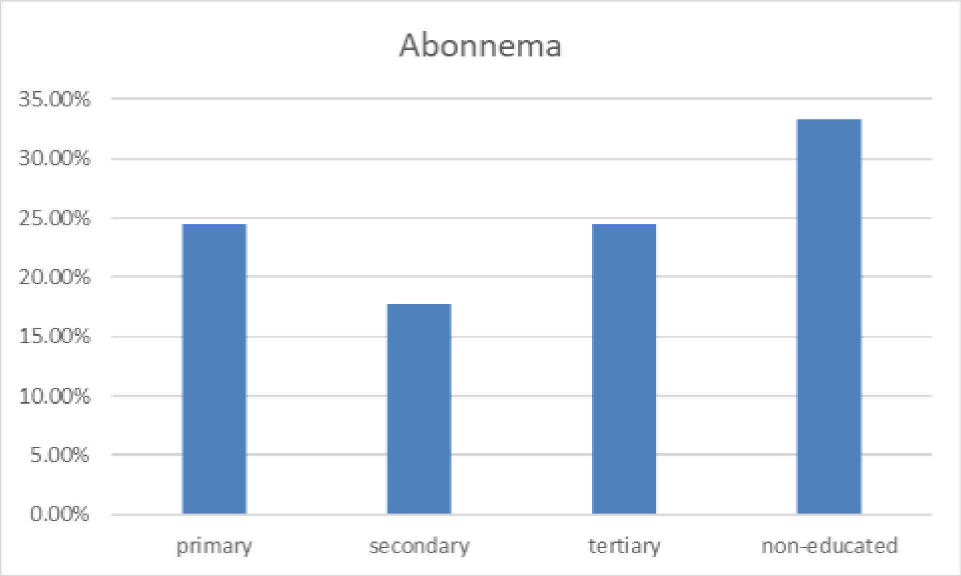


**Fig. 6:** Educational attainment of Respondent

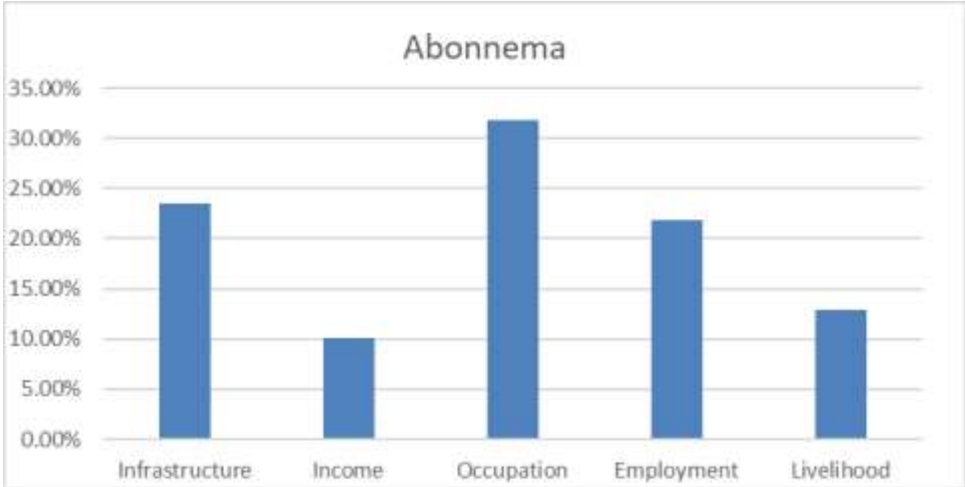


**Fig. 7:** Socio economic implication of swamp reclamation in Abonnema

## Conclusion

Transportation plays a very major role in urban and rural development because it aids the movement of humans, animals and goods from one location to another which is essential for the development of civilization. Before swamp reclamation took place in Abonnema, the only available mode of transportation was water. This article reviled that one of the major benefits of swamp reclamation in Abonnema is the construction of Degema to Abonnema link bridge, which has in return improved their livelihood. The second benefit of swamp reclamation in Abonnema is the newly constructed ring-road that links you directly to the New Site (Ogoin Piri) through the back of the Abonnema Cemetery as you can see in figure 3. Swamp reclamation in Abonnema has triggered the expansion of land capacity, created more land for infrastructural development such as roads, hotels, schools and residential building in return creating easy access in and out of the town and new job opportunities for the residents.

**References**

[1] Aroloye. O. Numbere (2019) Mangrove Habitat loss and the need for thee establishment of Conservation and protected areas in the Niger Delta, Nigeria, (pp, 1-15) Publisher: Interchopen.

[2] Aroloye O. Numbere (2020) The Impact of land Reclamation on Mangrove Forest and Coastal areas in the Niger Delta, Nigeria. Published: January 8th 2020, Dol :10. 5772/interchopen

[3] Ayorinde .O.A; Okunada K.M; Agboola. D.M; Adesokan Z.A. (2016) The Impact of Wetland Restoration on Fish Production. Published: American Geographical Union Ocean meeting.

[4] Powter, C. B. (2002). Prepared by Department of Community Health/Governor's Council on Physical Fitness, Health & Sports Alberta Environment.

# SUB-THEME 8:

# ENTREPRENEURSHIP AND JOB CREATION OPPORTUNITIES IN THE WATER SECTOR

# ENTREPRENEURSHIP OPPORTUNITIES IN THE WATER SECTOR IN NIGERIA

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**Abstract**

*Water is an essential component of national and local economies. Agriculture, forestry, fishery, energy, manufacturing, recycling, building and transport sectors are dependent on water. Sustainable water management, water infrastructure, access to safe, reliable and affordable supply of water and adequate sanitation improve living standards. This paper examines jobs and opportunities in the water sector in three categories namely, Water resources Management, water infrastructure and water-related services such as water supply, sanitation and waste-water management using literature and real world examples to demonstrate how to build micro enterprises and resilience programs in the water sector. It is concluded that businesses need to have their water resilience action plans in place in case of eventualities. Entrepreneurship potentials in the water sector is vast. Investing in water is good business.*

## Introduction

Water is an inorganic, transparent, tasteless, odorless and colorless substance vital to all forms of life (Wikipedia). Water is mankind's most unique and indispensable natural resource and plays a very important role in the world economy. Universal, affordable and sustainable access to Water, Sanitation and Hygiene (WASH)is the focus of the first two targets of Sustainable Development Goal 6 (SDG 6).Targets 6.1 and 6.2 aim at equitable and accessible water and sanitation for all. Access to WASH can reduce illness and death, and also affect poverty reduction and socio-economic development (World Bank, 2021).

## Problem Statement

Life depends on water. The relevance of water has increased progressively in Nigeria with increasing rate of urbanization of about 4% per annum, agriculture, industrial development and rapid population growth. Nigeria being one of the fastest growing nations is projected to reach 289 million by 2050. In the same vein, the projected population growth by years 2020 and 2025 would be 210 million and 225 million respectively; (Federal Ministry of Water Resources, 2011). Thus, Nigeria needs 56 billion litres of water per day of potable water supply for domestic use only, as well as enough water for industrial and agricultural use.Projected Urban Population of 75% will place additional pressure on government as it pertains to water supply. There is need for urgent action in terms of innovations and investments for provision of water and the supporting infrastructure needed to achieve this envisaged target. The imbalance in water infrastructure to rapid urbanization and population growth creates a great deficiency in the quality of life with dire consequences on sanitation, environment, food, security, health, employment and standard of living of an average Nigerian.

Also, the climate change phenomenon has the capacity to change water supply levels and the requirements for managing water resources in Nigeria. It is an undeniable fact that Nigeria is vulnerable to these climate changes already evident in increasing coastal inundation and flooding in low lying areas like Lagos, Port Harcourt, Calabar and Bayelsa; Desert encroachment in the North and loss of water from Lake Chad (from 27000sq.km in 1963 to 1800sq. km. at present) (Federal Ministry of Water Resources, 2011).

The challenges and opportunities in the water sector are so huge that they cannot be left for governments alone. It is imperative that individuals, organizations and cooperate bodies invest in this sector of the economy to boost job creation and provide means of livelihoods for Nigerians.

**Methodology**

This paper demonstrates how to build micro enterprises and resilience programs in the water sector, highlighting jobs andEntrepreneurship opportunities in three categories namely: Water resources Management; water infrastructure and water-related services using published literature and real world examples.

**Results and Discussion**

Micro enterprises are defined as those businesses with less than ten (10) employees (SMEDAN, 2007) or with assets less than five million Naira excluding land and buildings. In Nigeria, the micro and small (10-49 employees with above ₦5-50million) enterprises are a major contributor to the economy, with 95% of businesses in Nigeria (Olayinka,2016) and these account for a good portion of employment for the people. Unfortunately, the business environment in Nigeria is really challenging for the SMEs, poor infrastructure, unavailable access to cheap financing, and a host of other issues pose hindrances for small business growth.

Nigeria is endowed with adequate fresh water resources, with a coastline of about 800 km in the south and also Lake Chad basin in the north. From big rivers like, Niger, Benue, Kaduna, Anambra, Imo, Gongola etc. to small lakes, streams and ponds in the rural areas, these water resources are sources of livelihood and wealth creation to many families on a daily basis.

**Entrepreneurship and Job Opportunities**

Entrepreneurship is about stepping (entre) into the creative space and grasping opportunities (prend) in it (Hjort, 2005).Innovation and technology have a vital role to play in the water sector for efficiency, resilience and sustainability. The world is evolving, needing improved technologies, the internet of things, which enables smart use of water and helps in developing complex models for water management. This paper discusses opportunities for entrepreneurship and job creation in three broad categories:

i. Water Resources Management
ii. Water Infrastructure
iii. Water Related Services

**Water Infrastructure**

Most climate change issues are water related: sea-level rise, droughts and extreme weather. Sea level rise and extreme storm surge will affect the deltaic and coastal areas. To protect these coastal communities against flooding, hard engineering structures such as seawalls, dikes and levees may be necessary. Business opportunities lie in providing these services, another area for investment is in more sophisticated technologies such as modelling software and simulations that can enable understanding of the vulnerabilities and suggest solutions to best address storm surge risk and capacity of the storm water infrastructure.

Yet another avenue for investment is in Smart and Intelligent Network Technologies using Internet of Things (IoT) devices and data analytics to better manage infrastructure losses and support important changes to the ways in which water utilities and companies operate. Smart end-to-end water networks offer the opportunity to improve productivity and efficiency while enhancing customer service (DHI Blog, 2020).

**Water Resources Management**

1. Protecting Agricultural Production: Nigeria population is projected to reach 289 million by 2050. To ensure adequate food to cater for this population, there is a need for increased food production which includes crops and livestock which would challenge water resources. Investment opportunities lie in efficient irrigation management, erosion and flood management and precision farming systems which must be employed to optimize agricultural production.
   Another area for investment is in providing real-time actionable insights with predictive capabilities for agriculture and food systems. A good example of an innovative company is Ignitia, a company providing tropical weather forecasting platform, with over a million subscribers in Ghana and other West-African countries. Ignitia uses machine learning and remote sensing to send text messages to small-scale farmers with information on local climates and weather forecast leading to significant increase in yield across different staples. Similarly, Arable is a company in the United States using Sensor and analytics platform to provide insight for agriculture and food systems (Chloe, 2020).

2. Reusing water to support a circular economy: Recovery of nutrients from sludge and wastewater and its reuse will protect scarce and threatened resources thus achieving resource efficiency. A good example of innovative business solution is Ecosoftt, a company from Singapore that provides low-cost waste water and reuse solutions for communities not connected to water and sewer networks (Chloe, 2020).

**Water Related Services**

1. Sanitation: Nigeria is still grappling with the problem of open defecation and lack of toilet facilities even in the cities. Investing in provision of water efficient toilets and hand wash stations is an area worth looking into as proper sanitation has a direct effect on the health of the community
2. Supply of safe water for drinking and utilization: Many companies have invested in this sector, water packaging companies like Coca-Cola and several others, borehole drilling companies, and providers of water treatment options such as filters and packaged chemicals for household water treatment. With the vast population of Nigeria, there is still a great water poverty especially in the rural areas. Investment projects targeted at the rural populace is likely to attract foreign aid.In the Niger Delta region where people live on water, and accessibility is so poor, provision of portable water purification or desalination tools is a likely investment opportunity as exemplified by Oneka, a Canadian company providingWave-powered desalination for autonomous drinking water production targeting small island communities (Chloe, 2020).

**Securing Resilience**

There is increasing pressure on the water sector in Nigeria as a result of Climate change and its attendant effects, coupled with population growth, with direct effects on water supply, sewerage and wastewater systems. There is also the challenge of pollution of water supplies and network outages or even attacks on computer systems. The water sector needs to maintain resilience to a range of pressures in the short- and long-term,thus new water resources will be needed to meet the needs of people, businesses and the environment. This can be achieved through innovation, technology, planning, policy measures and community/stakeholder engagement.

**Innovation**

This is the use of more efficient and cost effective use and management of water thus reducing demand and waste of water, considering every option to balance supply against demand, minimizing leakages and reusing water (e.g. effluent reuse).

**Technology**

Efficient water management and forecasting can be achieved through adoption of new technologies such as automated metering and leakage prevention devices, operational intelligence for water and waste water utilities, satellite remote sensing monitoring and so many other emerging technologies.

**Planning**

Every business needs to plan for their water resilience. No matter the business sector, water is required, if for nothing else, at least for sanitary purposes. Thus, there should be an action plan to cover any shortage of water supply to the system.

**Policy Measures**

Strong National Policies and sector plans have been used in many countries around the world to provide sustainable water and sanitation services. Notable cases are Brazil, whose strong policy and sector plans resulted in increase in sanitation from 73% to 87%; Burkina Faso improved water access for 2.5 million people, Ugandan Utility turnaround, Manilla, in the Phillipines to mention but a few. The same can be applied in Nigeria to address the increasing water poverty and ensure resilience.

**Community/Stakeholder Engagement**

Communities rely on drinking water and wastewater utilities to provide vital services. Aging infrastructure, floods, and contamination of water sources are among the challenges that may be faced. Identifying the critical interdependencies between water utilities and building relationship with those sectors are essential for community resiliency. This is achieved through community workshop which provides an optimal setting for exchanging ideas and information between water utilities and members of the community they serve.

**Steps Toinvesting in Water**

The same principles guiding establishing a business in any other sector applies to the water sector. The key steps to starting the business or creating job for oneself in the water sector are briefly outlined in the following steps:

1. Identify your goals and objectives. Establish the need you wish to fill. There must be a compelling vision that goes beyond making money and building a business, it should be to create an institution that can stand the test of time (Olayinka, 2016).
2. Identify your strengths and weaknesses. Good knowledge of the chosen area to invest in is very important. Identify areas you may need to partner with others to be truly effective. Entrepreneurs should not be afraid to develop their people for fear they might leave, for they can be the source of new business development.
3. Leverage. Identify and collaborate with others either in the business or with similar ideas. It is really important that before you start, connect with others. Get mentorship from those experienced in the business. Share ideas with useful contacts to expand your knowledge, this will guide to avoid needless hurdles.
4. Know your customers and establish how to reach them. Customers are the life blood of any business. Continuous network and marketing is very important.
5. Know your sources of funds. All projects require funds according to their specification, you may need to apply for grants, or look for investors.
6. Develop your business plan. A well written plan may attract investors and also act as guide to success. This would tackle to a large extent the challenge of poor Management.

7. Start small and grow big. Many of the big companies around today started small. An example of one in Nigeria is JuNeng Nigeria Limited which started in 2005 as a centre for composite and engineering materials research and development. The company was incorporated five years later in 2010. Today, their services have expanded into Environmental Technology, with activities in Air Pollution Control, Thermal Waste Treatment, Water and Wastewater, Waste and Recycling, Renewable Energy and Geosynthetic Technologies.

## Conclusion

The water-related challenges in Nigeria and the urgency to resolve them have been confirmed and reaffirmed at the highest political levels. It is critical that the economic benefits of improved water supply, sanitation and water resources management be understood. In a country like Nigeria where citizens cannot rely on the Government for basic infrastructure, the potentials in the water industry remain vast. The future of sustainable water management lies heavily on creativity and Innovation and smart technology, thus job seekers and entrepreneurs need to be creative and invest in knowledge of smart technologies to remain relevant. Investing in water is good business.

## References

1. Chloe, O.V. (2020). The Future of Water: How innovations will advance sustainability and Resilience Worldwide. https://blogs.worldbank.org
2. DHI Blog. (2020). The reservoir/Drops of Knowledge
3. Federal Ministry of Water Resources, 2011.
4. JuNeng Profile. https://junengnig.com/about-us/#profile
5. Olayinka, D. (2016). Building MSMEs to Last in Nigeria: Insights and Opportunities. *The Cable.*
6. Sanctuary, M. (2007). Making Water a part of Economic Development
7. World Bank (2021) Monitoring COVID-19 Impact on Nigerian.

**ASSESSMENT OF THE IMPACT OF ABBATTOIR WASTE ON GROUND WATER QUALITY IN MINNA USING WATER QUALITY INDEX**

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**Abstract**
*This study is aimed at evaluating the impact of abattoir operations on quality of ground water in Tayi Village located in Minna, Niger State employing the National Sanitation Foundation Water Quality Index. This was done by subjecting water samples from the selected wells and pond to comprehensive physicochemical analysis using APHA standard methods of analysis. The values of the samples were compared with the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limits. Respective rating using the NSFWQI was achieved by selecting the results of parameters such as Dissolved Oxygen, E-coli, pH, $BOD_5$, Nitrite and Temperature for each sample and transferring them to a weighing curve chart which converted each selected parameter in their various standards units into a unit-less sub-index (Q-value). Weighs were assigned to the parameters based on their importance in drinking water. The NSFWQI for each sample was obtained by adding the product of Q-value with their associated weight for each parameter. The water quality rating for wells A, B, C and D62.809,59.27, 60.98 and 77.14 which fell within the medium range, hence not good for drinking.*

*Keyword: Abbattoir, water quality index, water quality, ground water*

## 1.0 Introduction

Ground water also called subsurface water are water that occurs below the surface of the earth. It is an important component of the hydrologic cycle and constitutes about two-third of the fresh water resources of the world (Garg, 2005). The value of groundwater lies not only in its wide spread occurrence and availability but also in its consistent good quality, which makes it an ideal supply for drinking water (UNESCO, 2000). Groundwater is harvested through construction of boreholes and wells in Nigeria as well as in Africa.

The reliance on ground water can be traced back to the early times as it was exploited for domestic use, livestock and irrigation (Garg, 2005). In the present times, many of the major cities of Africa and its rural environs are ground water dependent. For many millions more, particularly in Nigeria, who do not as yet have any form of improved supply, untreatedgroundwater supplies from unprotected wells with handpumps and boreholes are been resorted to, toprovide daily water need for domestic consumption, manufacturing and agriculture (Okeke and Igboanua, 2003).

Studies have shown that among many sources of pollutionthat could pose threat to surface and ground water sources, chief among is the indiscriminate discharge of untreated waste and/or effluent from abattoir (Osinbajo and Aide, 2007; Balogun et al., 2012; Ekpetere et al., 2019). Anthropogenic activities by man throughmechanizedagricultural practices, increased population density and rapid urbanization as well as domestic and industrial usage are also threats faced by this precious resource (Ashafa, 2020). The pollution load on a water body from abattoir effluent can be quite high (Hassan et al., 2014). Literatures in relation to impact of abattoir effluent in some cities in Nigeria showed very high contaminant level in abattoir effluent (Osinbajo and Aide, 2007; Balogun et al., 2012, Ekpetere et al., 2019). Most of these are known to be hazardous to human beings and aquatic life. Furthermore, indiscriminate disposal of abattoir effluent from slaughter house to surrounding water bodies and land has been reported to be responsible for the cause of diseases such as *Bacillus*, *salmonella* infection, typhoid fever, asthma, Wool Sorter disease, respiratory and chest disease which include pneumonia, diarrhoea, typhoid fever, asthma (Ogboru, 2001; Oyedemi, 2000). The presence of abattoir in Minna breeds a ground for a potential environmental quality problem. Hence, it is pertinent to analyse the quality of the surrounding ground water sources to ascertain the level of contamination.

Nouri et al. (2008) defines an abattoir (also called slaughter house) as a place approved and registered by the controlling authority for hygienic slaughtering and inspection of animals, processing and effective preservation and storage of meat products for human consumption. Hassan et al. (2014) opined that although butchering of animals brings about significant meat supplies and production of useful by-products, the processing activities involved could constitute environmental hazard to human and animal health when not regulated.The characteristics of abattoir wastes and effluents vary from day to day depending on the number and type of stocks being processed (Omole and Longe, 2008; Pejman et al., 2009). However, Weobong and Adinyira (2011) reveal that waste from slaughter house can affect water, land and air qualities if proper practices are not followed.Furthermore, wells in vicinity of abattoir which serves as source of water to abattoir constitute high risk for the butchers and users of the wells as they are prone to be contaminated (Hassan et al., 2014).

Water quality of any specific source can be assessed using physical, chemical and biological parameters. The values of these parameters pose a serious threat to human health if they exceed the defined limits (Tyagi, Shweta *et al.*, 2013). Therefore, the adequacy of water sources for human consumption can be determined using water quality index (WQI) which is one of the most effective tools to describe water quality. Water quality index (WQI) is a rating or a single number that expresses overall water quality at a specified location based on several water quality parameters. The use of individual water quality parameter to produce complex water quality data is not easily understandable to the layman, therefore the WQI reduces the mass of information into a single value to express the data in simplified and logical form (Tyagi, Shweta *et al.*, 2013).

The improper disposal of waste and/or effluent due to poor facility management in Minna abattoir and many others in Nigeria could lead to environmental pandemic. It is as result of this, that this study is aimed assessing the impact of abattoir waste on ground water quality in Tayi Village Minna, Niger state and to establish respective water quality index for the surrounding water source.

## 2.0 Materials and Methods

### 2.1 Study Area

Tayi village is a sub-district of Minna located in Bosso Local Government Area of Niger state. Top soil of loamy sand to sandy loam covers the top layer of the study area (King and Williams, 2020). Tayi has a latitude and longitude of 9$^{o}$39’02” N, 6$^{o}$33’12” E and the area is found at an altitude of 259.14 m. The major economic activities are farming, trading, service rendering like dry-cleaning and “okada” transportation. The abattoir is located in Tayi villa along Bosso road. The design of the abattoir is such that four matured cows can be butchered at once. The abattoir consists of the slaughtering section, the processing section where skiing and bone removal is carried out and waste dumping site.

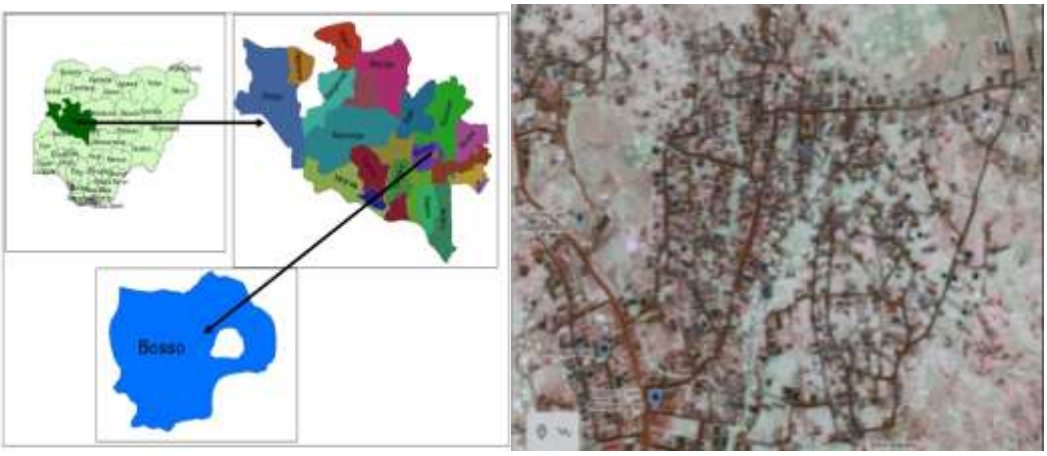


**Fig. 1:** Tayi Village.

**Source:** Google Map

## 2.2 Methods / Experiments

Four samples from hand dug wells labeled well A to well D located 40m away from the slaughter house were collected. In details the description of each sample is given as follows:
Well A: ground water sample selected from the neighborhood about 40m away from abattoir
Well B: well water sample obtained 10m away from the slaughter house
Well C: well water sample obtained 20 away from the slaughter house
Well D: well water sample obtained 30 away from the slaughter house
The samples were then transported to the department of Water Resources, Aquaculture and Fisheries technology for analysis using recommended standard procedures of American Public Health Association (APHA).

## 2.3 Water Quality Index determination

The National Sanitation Foundation Water Quality Index (NSF-WQI) was adopted to evaluate the quality of water samples of wells. Water samples from wells were used because in the study area the water source is mainly used for cooking, drinking and laundry. To achieve this, DO, E-coli, pH, $BOD_5$, Nitrate, $PO_4$, and temperature were selected which is in line with the work of Brown et al, (1970). The results of the physical, chemical and biological analysis were transferred to a weighing curve chart which converted standard unit of the selected parameters into a unit-less sub index also called Q-value. Associated weights were assigned to the parameters based on their importance in drinking water. The numerical values obtained from the quality index curve were multiplied by the associated weight. The total water quality index was then obtained by summing up water quality index (parameter index) for each of the selected parameter using equation 1. The obtained index value was compared against a range of value for water quality rating as given in table 1 in order to rank it appropriately as described by Tyagi, Shweta *et, al* (2013).

**Table1:** NSF WQI Analysis and Weights

| Parameter | WQI Weight |
|---|---|
| Dissolved Oxygen | 0.17 |
| Faecal Coliform Density | 0.15 |
| pH | 0.12 |
| $BOD_5$ | 0.10 |
| Nitrates | 0.10 |
| Total Phosphates | 0.10 |
| Temperature | 0.10 |
| Turbidity | 0.08 |
| Total Solids | 0.08 |

Source: Martin and Kim (1996)

The NSFWQI = $\sum_{i=1}^{n} q_i w_i$ (1)

Where: $Q_i$ = sub-index for $i^{th}$ water quality parameter.

$W_i$ = weight associated with $i^{th}$water quality parameter.

n = number of water quality parameter

Less than nine parameters (six or more), the WQI is calculated as:

The NSFWQI = $\frac{\sum_{i=1}^{n} w_i}{\sum w_i}$ (2)

Tyagi, Shweta *et al*. (2013) summarized a water quality rating based on NSF computation as seen in table 2.

**Table 2:** Water quality rating based on NSF

| Numerical Range | Quality |
|---|---|
| 0-25 | Very bad |
| 26-50 | Bad |
| 51-70 | Medium |
| 71-90 | Good |
| 91-100 | Excellent |

Source: Tyagi, Shweta *et al*. (2013)

## 3.0 Results and Discussions

### 3.1 Physico-chemical Analysis of ground water samples.

The pH for well A to well B ranged from 6.80 to 7.42 with a mean value of 7.20. The values fell within WHO standards of 6.5 to 8.5, which is in line with the study conducted by Ojekunle and Lateef (2017).

Temperatures for samples collected at well A to D were in-situ tested. Well B has a temperature of 28.2$^{o}$C being the highest value amongst the samples, while well A has a temperature of 27.8$^{o}$C the samples are a little bit above ambient temperature as specified by WHO standards.

The TDS value of the result obtained from the analysis of well B has the highest value 474.6mg/l while well A has the lowest value of 101.36mg/l. Although, the value ranged from 101.36mg/l to 474.16mg/l for the well samples, all the values obtained fell below the NSWDQ standard

(500mg/l). According to Ojekunle and Lateef (2017) high concentration of TDS are caused by the presence of potassium, chloride and sodium.

Electrical conductivity is the ease to which a substance allows free flow of electricity through the ions in electrolytes of water samples (Ojekunle and Lateef, 2017). Well B has a value of 1476mg/l which is above WHO standard of 1200mg/l and NSDWQ standard of 1000mg/l. All other ground water samples fell within both WHO and NSDWQ standard. Efe (2001) asserted that any concentration above WHO standard can pose health risk of defective endocrine functions and also total brain damage with prolong exposure. Hence, well B pose a high-risk level since its value is higher than the maximum permissible of both standards.

The chloride values ranged from 19.60mg/l to 107.8mg/l which falls within the WHO standard NSDWQ standard of 250mg/l. Well A and D have the same value of 19.60mg/l while well B and C have 107.8mg/l and 91.14mg/l respectively. Excess chlorides make water unpalatable for drinking.

Nitrate is a polyatomic ion and it is a problem when it is above the permissible limit in drinking water (Ekpetere et al, 2019). The result of this analysis shows that well C has high concentration of nitrate while well A, B, and D has concentration levels 0.8, 3.56 and 2.10mg/l respectively. However, all the samples were found to be below the permissible limit of 50mg/l set by NSDWQ.

The result obtained from the analysis reveals that the BOD in well B and C are slightly above the prescribed standard of 10mg/l. This could be related to the distance of the wells to the abattoir. The value of Well B and C are 13.0 and 11.0 mg/l respectively. This implies that water from both wells needs treatment as high BOD leads to dissolve oxygen which is detrimental to life. While wells A and D have concentration value of 8mg/l and 7 mg/l respectively which are within permissible limit of WHO and NSDWQ.

The hardness in the wells ranged from 90mg/l to 270mg/l. Well B and C are at variance with NSDWQ standard of 150mg/l, while Well A and D have concentrations that are within the permissible limit. The concentrations of calcium are found to be within the permissible limit of 200mg/l as set by WHO as it from 29.43 to 92.5mg/l. Well A and D have the same value of 29.43mg/l. The magnesium level for the four wells is all within NSDWQ standard of 200mg/l. Ogbonaya (2008) reveals that magnesium is essential for plant growth and development, and high concentration can result to hardness of water.

Phosphate was found to be within the permissible limit in the water samples. The average concentration of phosphate was found to be 2.09mg/l which is within the limits of 5mg/l by WHO while the iron concentration of the samples exceeded WHO 2004 limit 0.3mg/l.

The total coliform of the water samples from the wells ranged between 4cfu/100ml to 38cfu/100ml, this is above the WHO set permissible limit. Ekptere et al. (2019) asserts that the total coliform concentration above that set by WHO has health implications such as urinary tract infection, diarrhea and acute renal failure. Meanwhile the total bacteria plate count falls within the WHO standard of 100cfu/ml. These results agree with previous studies made by Oyedemi (2000) in Ogbomosho town that abattoir waste water has considerable range of biological and chemical pollutants.

**Table 3:** Physical parameters of wells A, B, C and D

| Parameters | A | B | C | D |
|---|---|---|---|---|
| Temperature ($^oC$) | 27.8 | 28.2 | 27.9 | 28.0 |
| Conducting (µ/cm) | 324 | 1476 | 1190 | 399 |
| TDS (mg/l) | 101.36 | 474.16 | 376.14 | 125.48 |
| pH | 7.62 | 6.80 | 6.97 | 7.42 |

**Table 4:** Biological parameters of wells A, B, C and D

| Parameters | A | B | C | D |
|---|---|---|---|---|
| Total Coli form Count (cfu/100ml) | 38 | 17 | 12 | 4 |
| Total Bacteria Count (cfu/100ml) | 48 | 68 | 68 | 72 |

**Table 5:** Chemical parameters of wells A, B, C and D

| Parameters | A | B | C | D |
|---|---|---|---|---|
| Iron (mg/l) | 3.50 | 2.70 | 1.10 | 2.30 |
| Total Hardness (mg/l) | 90 | 270 | 186 | 98 |
| Total Acidity (mg/l) | 72 | 76 | 142 | 108 |
| Calcium (mg/l) | 29.43 | 92.51 | 63.07 | 29.48 |
| Magnesium (mg/l) | 4.02 | 9.51 | 6.95 | 5.97 |
| Chlorine (mg/l) | 19.60 | 107.8 | 91.14 | 19.60 |
| BOD | 8.00 | 13.00 | 11.00 | 7.00 |
| COD | 40.00 | 44.60 | 28.00 | 80.00 |
| Phosphate (mg/l) | 2.30 | 2.55 | 1.82 | 1.70 |
| Nitrate (mg/l) | 0.80 | 3.56 | 5.88 | 2.10 |

### 3.2 Water Quality Index Computation

The WQI for each of the sources under investigation was determined using NSF-WQI. In line with the work of Brown *et al,* (1970), the parameters which were selected according to order of importance for physico-chemical and bacteriological analysis were DO, E-coli, pH, $BOD_5$, Nitrate, Phosphate, Temperature and total solid. Tables 6, 7, 8 and 9 present the value of $Q_i$ and $W_i$ with their respective parameter index or subtotal for Well A to Well D. Well A has a DO value of 7.41mg/l, which is equal to 90% saturation when converted to percentage saturation of oxygen using a level of oxygen saturation chart. The corresponding values of Qi and Wi gave 95 and 0.17 and their product gave subtotal of 16.15 The overall water quality index was obtained by adding the total parameter indices and dividing the result by the summation of the total weight factor to give WQI of 62.802. This shows that Well A can be rated as medium. Well B having a total coliform count of 17 cfu/100ml and corresponding values $Q_i$ and $W_i$ as 65.4 and 0.15 respectively has a subtotal of 9.81. The overall WQI was obtained like that of Well A which gives value of 65.08. Well B is rated as medium. The same procedure was used to obtain ratings for wells C and D. The result of the WQI for the water sources showed that none of wells can be used as a source of drinking water without proper treatment.

**Table 6:** Well A WQI

| Parameter | Test Value | Mean Q-value (Qi) | Weight Factor (Wi) | Parameter Index (Qi Wi) |
|---|---|---|---|---|
| Dissolved Oxygen (% sat) | 90 | 95 | 0.17 | 16.15 |
| E.colicfu/100mc | 38 | 57 | 0.15 | 8.55 |
| pH | 7.62 | 91.2 | 0.12 | 10.944 |
| BODS (mg/l) | 8 | 40 | 0.10 | 4 |
| Nitrate (mg/l) | 0.80 | 94.8 | 0.10 | 9.48 |
| Phosphate (mg/l) | 2.30 | 24.5 | 0.10 | 2.45 |
| Temperature | 27.8 | 11.76 | 0.10 | 1.176 |
| | | Total | 0.84 | 52.6 |
| | | | WQI | 62.802 |

**Table 7:** Well B WQI

| Parameter | Test Value | Mean Q-value (Qi) | Weight Factor (Wi) | Parameter Index (Qi Wi) |
|---|---|---|---|---|
| Dissolved Oxygen | 102.5 | 96.5 | 0.17 | 16.405 |
| E.coli | 17 | 65.4 | 0.15 | 9.81 |
| pH | 6.80 | 83 | 0.12 | 9.96 |
| BOD | 13.00 | 24.8 | 0.10 | 2.48 |
| Nitrate (mg/l) | 3.56 | 76.6 | 0.10 | 7.66 |
| Phosphate (mg/l) | 2.55 | 23.25 | 0.10 | 2.325 |
| Temperature | 28.2 | 11.44 | 0.10 | 1.144 |
| | | Total | 0.84 | 49.784 |
| | | | WQI | 59.27 |

**Table 8: Well C WQI**

| Parameter | Test Value | Mean Q-value (Qi) | Weight Factor (Wi) | Parameter Index (Qi Wi) |
|---|---|---|---|---|
| Dissolved Oxygen | 100 | 99 | 0.17 | 16.83 |
| E.coli | | | | |
| pH | 12 | 69.4 | 0.15 | 10.41 |
| BOD | 6.97 | 90 | 0.12 | 10.8 |
| Nitrate | 11 | 30.2 | 0.10 | 3.02 |
| Phosphate | 5.88 | 62.54 | 0.10 | 6.254 |
| Temperature | 1.8 | 27.44 | 0.10 | 2.744 |
| | 27.9 | 11.74 | 0.10 | 1.1714 |
| | | Total | 0.84 | 51.2294 |
| | | | WQI | 60.987 |

**Table 9:** Well D WQI

| Parameter | Test Value | Mean Q-value (Qi) | Weight Factor (Wi) | Parameter Index (Qi Wi) |
|---|---|---|---|---|
| Dissolved Oxygen | 95 | 97.5 | 0.17 | 16.58 |
| E.coli | 4 | 83 | 0.15 | 12.45 |
| pH | 7.42 | 92.73 | 0.12 | 11.13 |
| BOD | 7.00 | 69 | 0.10 | 6.0 |
| Nitrate | 2.10 | 90 | 0.10 | 9.0 |
| Phosphate | 1.70 | 28.4 | 0.10 | 2.84 |
| Temperature | 28.0 | 11.6 | 0.10 | 1.16 |
| | | Total | 0.84 | 60.06 |
| | | | WQI | 71.4 |

**Table 10: Water Quality Rating (WQR) for the selected wells**

| Sample | $\sum_{i-1}^{n} Qiwi/\sum Wi$ | WQR |
|---|---|---|
| Well A | 62.809 | Medium |
| Well B | 59.27 | Medium |
| Well C | 60.987 | Medium |
| Well D | 71.4 | Medium |

**4.0 Conclusion**

The physico-chemical and bacteriological parameters of water samples obtained from ground water samples around Minna abattoir in Tayi village were analyzed with a view to determining their quality. The results of the analysis were compared with those presented by World Health Organization and Nigerian Standard for Drinking Water Quality which showed that among all samples analyzed, wells B and well C have high concentrations of parameters above the WHO and NSDWQ standard of drinking water. The result obtained for the National Sanitation Foundation Water Quality Index (NSF-WQI) further indicated that all the samples drawn from each wellcan be classified as medium, that is, none of the three samples is qualified for usage as drinking water. Hence there is the need for proper treatment of the well before it can be used for drinking.This present study demonstrates the application of water quality index in understanding and appraising the quality of water. Hence the technique is a vital tool useful for the overall assessment of water quality.

**References**

American Public Health Association (APHA), (2000). System of analysis of waste water

Ashafa, A and Mohammed, A. S. (2020). Physico-chemical assessment of some selected hand dug wells water in Bida metropolis, Niger State, Nigeria. 2nd International Civil Engineering Conference Department of Civil Engineering Federal University of Technology, Minna, Nigeria.

Balogun, I.I., Akoteyon, I.S., and Adeaga, O. (2012). Evaluating Land Use Effects on Groundwater Reality in Lagos, Nigeria, Using Waste WATER index. Journal of Scientific Research 4(2), 397-409.

Chukwu O. (2008). Analysis of Groundwater Pollution from Abattoir Waste in Minna, Nigeria. Research Journal of Diary Science, 2(4):74-77

Ekpetere, O. K., Ekeh, O. F., and Ofodum, N.M. (2019). Impact of Abbattoir wastes on Gound water quality in the FCT, Abuja -Nigeria: A case study of Gwagwalada Satellite Town. Jour. Of Environmental and Earth Science Vol. No.4, 2019

Garg, S.K. (2005). Hydrology and water resources engineering, 3rd edition. Khanna publishers, New Delhi

Hassan I.A., Campbell, C., and Ademola, T. G. (2014). Effect of Abattoir Effluent on surrounding underground water quality: A Case Study of governor road abattoir at Ikotun, Lagos state. International Journal of Advances in Pharmacy, Biology and Chemistry. Vol. 3(4).

Ikomi, R.B. and Emuh, C.T. (2000). The Status of the Physicochemical Hydrology of Upper Warri River. Nigeria J.Sci. Environ. 2: 75-86

Nigeria Standard for Drinking Water Quality (2007).

Nouri, J., Karbassi, A. R. and Mirkia, S. (2008). Environmental Management of Coastal Regions in the Caspian Sea. International Journal of Environmental Science and Technology, 5 (1): 43-52

Ogboru, J.O. (2001). Environmental pollution and Disease Susceptibility: An analytical study of shallow well –water in Ondo town, Benin journal of Environmental Education Vol. 1 No.1, pg 33 – 42.

Okeke, C.O and Igboanua, A.H (2003). Characteristics and Quality Assessment of Surface Water and Groundwater SOURCES of Akwa town, Nigeria. Journal of Nigeria Association of Hydrological Geol., 14:71-77

Omole, D. O. and Longe, E. O. (2008). An Assessment of the Impact of Abattoir Effluents on River Illo, Ota, Nigeria. Journal of Environmental Science and Technology, 1 (2): 56 -64

Oyedemi, D.T.A. (2000). The Impact of Abattoir Location and Management on surrounding residents in Ibadan, Nigeria. M. Tech. Thesis (unpublished), LAUTECH, Ogbomoso.

Pejman, A. H., Bidhendi, G. R. N., Karbassi, A.R., Mehrdadi, N. and Bidhendi, M. E. (2009) Evaluation of Spatial and Seasonal Variations in Surface Water Quality using Multivariate Statistical Techniques. International Journal of Environmental Science and Technology, 6(3):467 – 476

Sridhar, M. K. C. (1988). Government/ Private Sector Partnership. Effective Tool for Solid Waste Evacuation and Management. In: A Tokun, A.A.A. (Eds.): Proceedings of the Workshop on Engineering Development and the Environment. Nigeria: Prost Publishing, pp. 41-50.

Thukral, A.K, Renu B., and Rupinder, K. (2015). Water Quality Indices. Journal of Department of Botanical and Environmental Sciences Guru Nanak University, India.

UNESCO (2000). Ground Water Pollution, International Hydrological Programme.

United Nations Educational, Scientific and Cultural Organization (UNESCO) and United Nations Environment Programme(UNEP) (1996). Water Quality Assessments - A Guide to Use of

Biota, Sediments and Water in Environmental Monitoring. 2nd Edition. Published by F & FN SPON

Weobong, C. A. and Adinyira, E. Y. (2011). Operational Impacts of the Tamale Abattoir on the Environment. Journal of Public Health and Epidemiology, 3(9): 386-393

World Health Organization (2004). Guidelines for Drinking Water Quality (3rd edition) vol.1

# IMPACT OF THE QUALITY OF SHALLOW WELL WATER IN SOME COMMUNITIES IN OGBIA LOCAL GOVERNMENT AREA OF BAYELSA STATE, NIGERIA

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**Abstract**

*The purpose of this study is on the impact of shallow well water in some communities in Ogbia Local Government. Well water samples were collected at three communities in the study area, two sampling points from each community and sent to the laboratory for analysis. The samples were analyzed for the physiochemical, bacteriological parameters and heavy metal concentration. Questionnaires were also administered to know the impact of the consumption of well water as it relates to health. The results of the analyzed samples were compared with the NSDWQ (2008) – Nigerian Standard for drinking water quality. Water quality data wereanalyzed using both descriptive and inferential statistics. The descriptive statistics included mean and comparism with NSDWQ standard. The one-way analysis of variance was used to test hypothesis one and two of the study while hypothesis three was tested using Pearson's correlation. The result of the tested hypothesis one shows that there is no significant variation in heavy metals concentration in the well water samples (since F=d. f=5, 36) = 1.184, P>0.05). It was also observed that there is no significant variation in the bacteriological characteristics of well water samples (since F=(d.f=5,12) = 2.682, p>0.05). Lastly, the Pearson Product Moment Correlation is significant at the 0.01 level (2-tailed) therefore we reject the null hypothesis and accept the alternative hypothesis. In conclusion there is a significant relationship between human health and consumption of well water in the study area.*

Keywords: *Impact, Quality, Shallow wells, and Water*

## 1.0 Introduction

The earth is made up of about 70 percent of water; it is undoubtedly the most precious natural resources that exist on earth. Man cannot survive without water and so other living things such as fishes, plants, animals and micro-organisms. Although water is essential for human survival, many do not have sufficient potable drinking water supply and sufficient water to maintain basic hygiene. In most rural settlements in Nigeria, access to clean and portable water is a great challenge, resulting in water borne diseases (Digha and Abua, 2018). The neglect of rural areas in most developing countries in terms of basic infrastructures such as pipe borne water and sanitation facilities, expose villagers to a variety of health related problems such as water-borne diseases. The quality of ground water is a function of natural processes as well as anthropogenic activities. Activities including soil fertility remediation, indiscriminate refuse and waste disposal, and the use of septic tanks, soak away pits and pit latrines are on the increase. These activities are capable of polluting groundwater which serves as source of water to the inhabitants of the communities.

It seems abundant as 70% of the earth is made up of water yet billions of people live in areas with chronic shortage of water. According to Asuquo and Etim, (2012b) ensuring that present and future generations will have adequate food and water and concurrent maintenance of the resources based on the environment are two of the most challenging tasks that have ever faced mankind".

Water contaminated has been reported to cause health problems like cholera, typhoid, dysentery, diarrhea etc. water of good quality is of basic importance to human physiology and man's continual existence depends very much on its availability. The average man requires about 3 litres of water in liquid and food daily to keep healthy (Onweluzo and Akuagbazie, 2008). This account for the fact why water is regarded as one of the most indispensable substance in life and like air it is most abundant (Okonko*et al.,* 2008; Etim *et al.,* 2013). Unsafe water is a global public health threat placing people or persons at risk for a host of diarrhea and other diseases as well as chemical intoxication (Nzeadibe and Ajacro, 2018, Edet *et al.,* 2012, Asuuo*et al.,* 2012; Koinyam*et al.,* 2013).

## 2.0 Statement of Problem

The impact of the quality of shallow well water has been a noticeable challenge since good water determines the quality of life of an individual. The deterioration of water quality is due to the discharge of various forms of pollutant into water bodies which alters the physical, chemical and biological components of water. (Ezenwanji and Anyaegbunam, 2006, Adekukunle et al, 2007,Mile and Dagba, 2012, Kojo and Steve, 2016).

Ground water is an important water resource in both the urban and rural area but in the cities, pipe borne water is also available. Rural dwellers make use of waters from hand dug wells and ponds and these are under threat of pollution from human lifestyle. The neglect of rural areas in most developing countries like Nigeria in terms of basic infrastructures such as pipe borne water and sanitation facilities exposes rural inhabitants to a variety of health related problems such as water borne diseases.

The level of some physical, chemical, microbial water quality parameters in shallow well in the study area were assessed. The data gathered can be used to assess any changes in the quality of well water and also aid environmental law enforcement agencies policy makers to promote the availability of portable water and also ensure that measures are put in place to control water pollution.

## 3.0 Aim and Objectives

The aim of this study is to examine the impact of quality of shallow well water in some communities in Ogbia Local Government Area of Bayelsa State.

The specific objectives include:

1. to examine the Heavy Metals, present in the well water of the study area.
2. to examine whether there is correlation between the bacteriological characteristics of the well water in the study area.
3. to identify the impact of the quality of well water on human health in the study area.

## 4.0 Research Hypothesis

1. There is no significant variation in the heavy metal concentration of the well water in the study area.
2. There is no significant variation in the bacteriological characteristics of the well water in the study area.
3. There is no relationship between human health and the consumption of well water in the study areas.

## 5.0 Study Area

Longitudinally, the study area is located between longitudes 6$^{o}$ 28'' East of the Greenwich meridian. It is bisected by Latitude 4$^{o}$15'' and 5$^{o}$08 North of the equator. The study area is within the Niger Delta Region of Nigeria, specifically in Ogbia Local Government Area of Bayelsa State. The study area is bounded by Nembe Local Government Area at the southern Ijaw Local Government Area at the south- west and lastly, Yenagoa Local Government Area at the North.

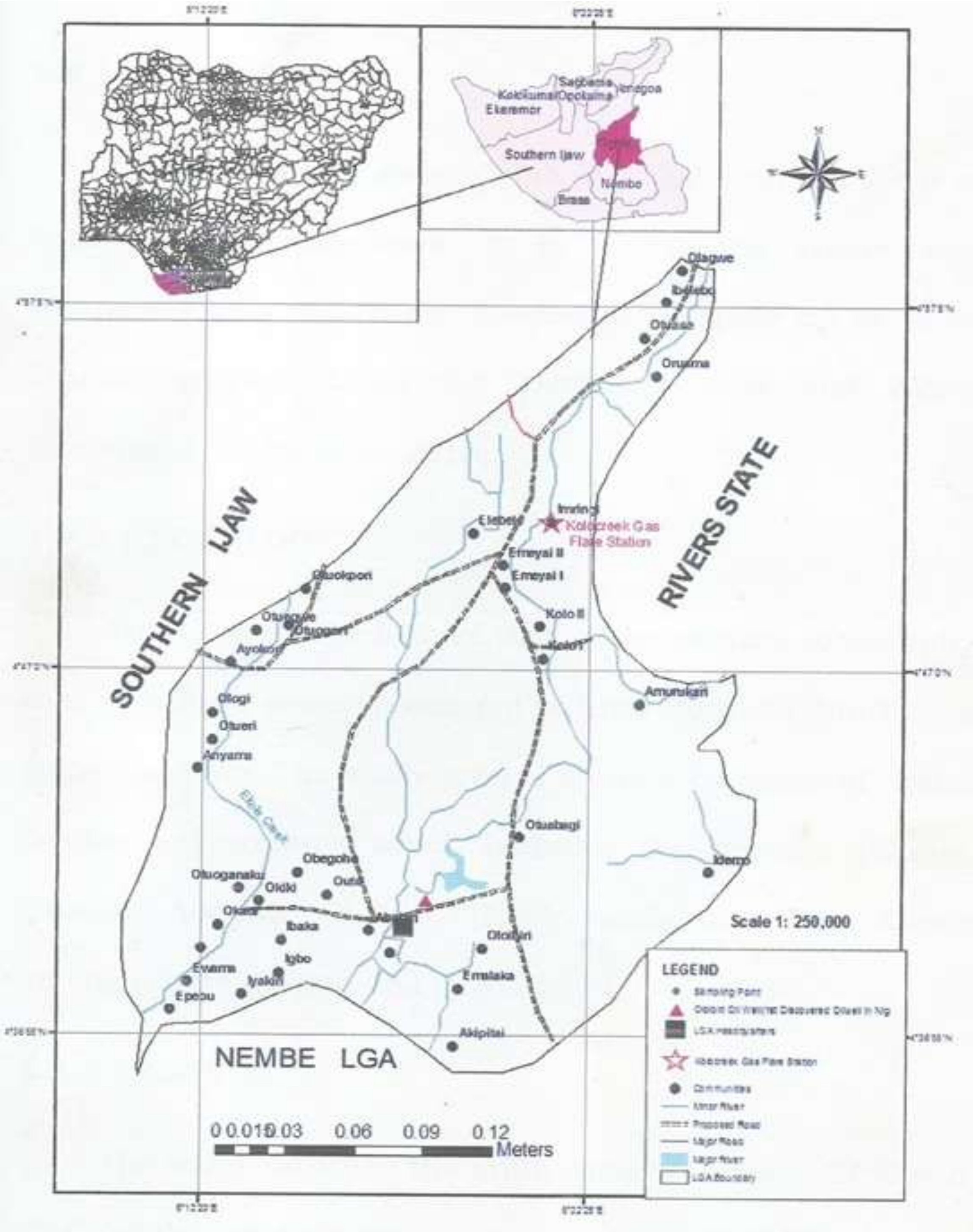


**Fig. 1:** Map of Ogbia Local Government Area showing the study area

The study area is part of the landscape of the Niger Delta Environment, South of Nigeria. According to Fubara (1987), the limit of Nigerian coast is within 30 to 40 km from the coastline inland. This delimitation appears to be realistic since the tidal influences are felt up to 45km inland (Oyegun, 1990). Based on that, the study area falls within the coastline and the inland alluvial plains of the coastal lowland of the Niger Delta. Akpokodje (1987, 1988) asserted that the area under study is about 8meters above mid sea level (A.M.S.L).

The Ogbia kingdom is dominated by two major soils - the fresh water/ salt water transition soil and the coastal plain terrace soils. Among these are other smaller soil units which also occur. These soils occurring in patches are likened to the soils of the high lying levees. Soils of the low- lying levees, meander belt soils, soils of the basins, silted river bed soils and soil of the transitional zone (Ogbia master plan ibid).

The soils of the high- lying levees are generally coarse in texture (sandy, loamy sand), moderately coarse textured and medium texture. The soils of the low-lying levees are mainly clay-loam or sometimes silt, while the soils of the basins consist predominantly of silt-loam at the surface underlain by coarse textured sub-soil to sandy –silt (Ogbia master plan, 1978).

The study area lies in the rainy belt of the Niger Delta. It is hot and wet throughout the year. There are two types of air masses- the tropical maritime and the tropical continental air masses dominating the climatic events in the area. The former is associated with the south-west trade wind blowing from the Atlantic Ocean onshore. While the tropical continental air mass is usually associated with the cool dry and dusty Harmattan wind (Udo, 1981).There are two main seasons – the dry season and the rainy season, with a double maximum rainfall regime. This is accompanied with a break in August locally called “August break” (Egiran, 1995). Contrary to this perspective, Kinoko, Wilcox- Evwereye and Sava (1989) observed that the area experiences July /August break. The actual month of occurrence varies both in time and space. It occurs either in July or August. By and large, four seasons are recognized. They are the long rainy season, the short dry season (August break), the short rainy season from late August to October and finally, the long dry season (mid- November to February).

The study area is crisscrossed by two major vegetation zones. Broadly, the vegetation of the study is the fresh water swamp forest type with transitional zone of the Brackish and swamp forest (mangrove Swamp forest) to the south and the fresh water swamp forest is characterized by raffia palms to the north (Udo, 1980; Oguntoyinbo*et al.,* 1983 and Nyananya, 1999).

Mangroves associated plants are replaced by fresh water vegetation as one move inland from the south of the North (Nynananyo, 1999). The entire geographical space of Ogbia is characterized by a maze of rivers, creeks as well as swamps crisscrossing the low lying plain. The area is drained by large and medium to small channels, rills, rivulets and steams of high tides (Ogbia Master Plan, 1973). The study area has a population density figure of 272 persons per square kilometer.

## 6.0 Materials and Methods

Samples from well water were collected from three communities in the study area. Two well water samples were collected from each of the three communities. Primarily, the levels of usage for domestic purposes were main consideration in the choice of the sampled well. For each location 2 litres volume were collected in clean bottles labeled using a maxing tape and a pen to identify each sample and their locations, for example; OWI, OW2, OGWI, OGW2, OTW1 and OTW2, where OW1 represents Oloibiri well 1 ,OW2 represents Oloibiri well 2, OGW1 represents Ogbia well 1, OGW2 represents Ogbia well 2, OTW1 represents Otuokpoti well 1 and OTW2 represents Otuokpoti well 2.after labelling of the sample collections, they were put in a cooler and transported to Cross River State were the samples were analysed. and transported to the laboratory for analysis of the following parameters. Acidity (pH), Electrical conductivity (EC), Dissolved Oxygen (DO) Total Dissolved Solids (TDS) Total Hardness (TH), Salinity, Chloride (Cl), Nitrate ($NO_3$), Iron (fe), Manganese (Mn), Zinc (Zn), Nickel, Copper (Cu), Cadmium (Cd), Chromium (Cr), Total heterotrophic count (THC), Total Coliform Count (TCC), Fecal Coliform Count (FCC).

The pH and EC were measured in-situ with portable pH/conductivity meters while DO was measured with M90 Mettler Toledo AG DO meter, TDS, TH, Salinity, Cl; $Ma^{2+}$, and $NO_3^-$ concentration were analyzed in the laboratory using standard methods by the American Public Health Association (1998). While, Fe, Mn, and Zn were determined using Atomic Absorption Spectrophotometer (AAS). The membrane filtration technique (MFT) was used for the bacteriological analysis.

## 7.0 Results and Discussion

The result of table 2 (mean values of the physiochemical parameters of the sampled well water) revealed that temperature was 26.6ºc, 26.ºc and 26.6ºc respectively for the three communities, the mean PH values were 6.8, 6.45 and 6.6 4 for the three communities. Again, turbidity was 0.79 NTU, 26.5NTU and 1.02NTU respectively. Total dissolved solutes were 256mg/l, 152mg/l and 358 mg/l respectively while Total hardness was 54.7mg/l, 96.1mg/land 59.2mg/l respectively. The result when compared with the Nigerian standard for drinking water quality (2008), the values were found to be below the permissible limit except for Otuokpoti community which is far above the permissible limit.

The result in Table 4,shows the mean values of the bacteriological parameters of the well water samples for the three communities revealed that Total Heterotrophic count (THC) per 100ml were 80,151 and 103 respectively, Total Coliform Count(TCC) per 100ml were 48, 95 and 79 respectively and Fecal Coliform Count (FCC) per 100ml were 40,84 and 41 respectively. This result when compared with the Nigerian standard for drinking water quality, permissible limit for all domestic water were found to be far above and higher than the recommended standard.

Finally, the result in Table 6 which is the mean values of the heavy metals concentration in the sampled well water revealed that Cadmium has values 0.038mg/l,0.315mg/l and 0.189mg/l respectively; Copper has 0.7mg/l, 1.03mg/l and 0.845mg/l for the three communities respectively, Iron concentration is 0.08mg/l, 0.49mg/l, and 0.025mg/l respectively, Lead concentration was 0.093mg/l, 0.158mg/l and 0.033mg/l respectively; Nickel has a concentration of 0.575mg/l, 0.875mg/l and 0.625mg/l while Zinc has a concentration of 1.565mg/l, 2.555mg/l and 1.145mg/l respectively. This result when compared with the Nigerian standard for all domestic water sources was found to be lower than the NSDWQ's permissible limit except for Zinc in sample well water in Ogbia town that is slightly above the permissible limit.

**Table 1:** Physiochemical characteristics of the water sample for the three communities

| Parameters | Oloribiri well 1 | Oloribiri well 2 | Ogbia well 1 | Ogbia well 2 | Otuokpoti well 1 | Otuokpot well 2 | NSDWQ (2008) |
|---|---|---|---|---|---|---|---|
| Temperature | 26.6 | 26.6 | 26.7 | 26.6 | 26.6 | 26.6 | Ambent |
| PH | 6.96 | 6.65 | 6.45 | 6.45 | 6.74 | 6.54 | 6.5- 8.5 |
| Conductivity | 443.3 | 410.5 | 106.3 | 398.9 | 616.0 | 576.9 | 500(cm) |
| Turbidity | 0.51 | 1.06 | 50.5 | 2.41 | 0.30 | 1.73 | 5.0(NTU) |
| TDS | 265.9 | 24.6 | 63.8 | 239.3 | 369.6 | 346.1 | 500(mg/l |
| Total hardness | 63.5 | 45.8 | 106.9 | 85.2 | 60.2 | 58.1 tabl | 100(mg/l |

**Sources:** Laboratory analysis result of the well water sample researchers fieldwork (2019)

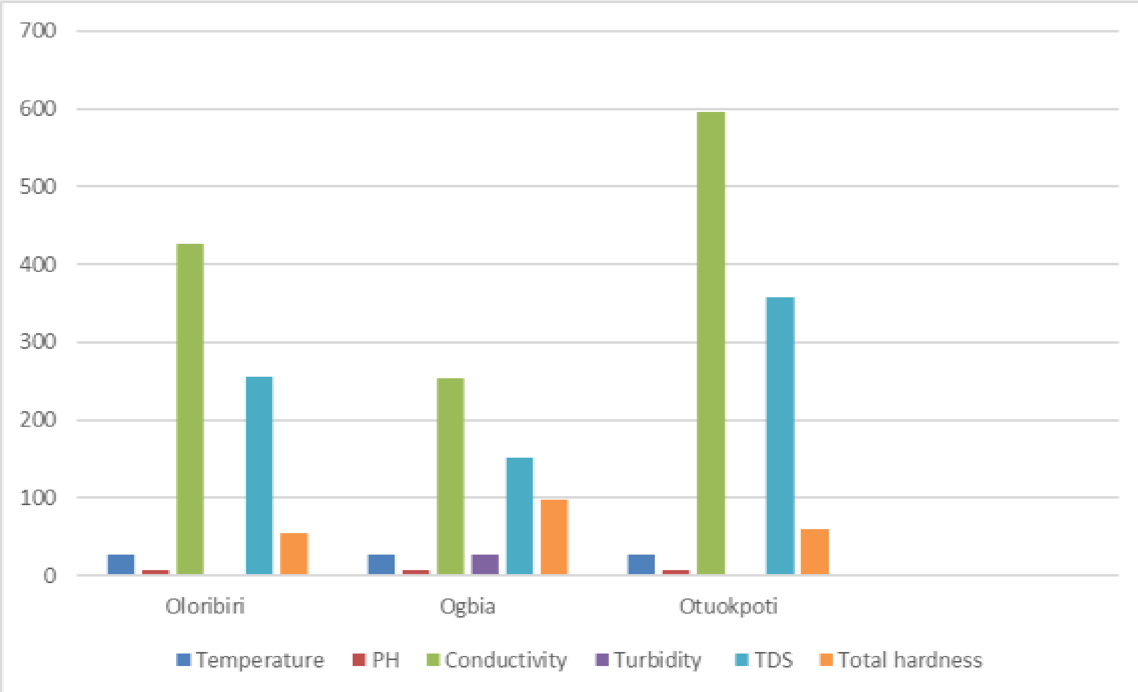


**Fig 2**: Mean ($\bar{X}$) values of the physiochemical characteristics of well water samples for the three communities

**Source:** Researcher fieldwork Report (2019)

**Table 2:** Bacteriological characteristics of the sampled well water for the three communities

| Parameter | Oloribiri | Oloribiri | Ogbia | Ogbia | Otuokpoti | Otuokpoti | NSDWQ (2008) |
|---|---|---|---|---|---|---|---|
| Total heterotrophic count (THC) | 69 | 91 | 175 | 126 | 108 | 97 | 3 |
| Total coliform | 31 | 65 | 113 | 76 | 73 | 84 | 0 |
| Fecal coliform | 32 | 48 | 105 | 68 | 23 | 59 | 0 |

**Source:** laboratory analysis results of the well water sample Researchers fieldwork report (2019)

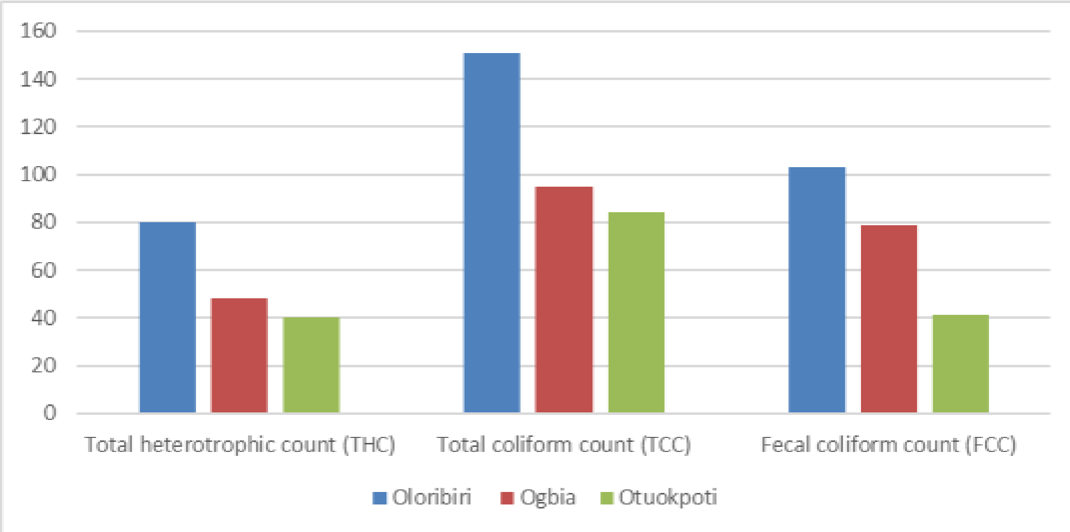


**Fig. 3**: Mean ($\bar{X}$) values of the bacteriological characteristics of well water samples for the three communities

**Table 3:** Heavy metal concentration in the sample well water

| Parameter | Oloribiri | Oloribiri | Ogbia | Ogbia | Otuokpoti | Otuokpoti | NSDWQ (2008) |
|---|---|---|---|---|---|---|---|
| Cadmium (Cd) | 0.063 | 0.014 | 0.608 | 0.022 | 0.046 | 0.331 | 0.004 |
| Chromium (Cr) | 0.02 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.001 |
| Copper (cu) | 0.77 | 0.63 | 1.20 | 0.86 | 0.094 | 0.75 | 2.0 |
| Iron (Fe) | 0.01 | 0.14 | 0.65 | 0.32 | 0.01 | 0.04 | 0.30 |
| Lead (pd) | 0.125 | 0.060 | 0.305 | 0.011 | 0.005 | 0.061 | 0.002 |
| Nickel | 0.055 | 0.060 | 1.15 | 0.60 | 0.60 | 0.65 | 0.004 |
| Zinc (Zn) | 2.03 | 1.10 | 4.08 | 1.03 | 0.96 | 1.33 | 2.0 |

**Source:** laboratory analysis results of the well water sample Researchers fieldwork report (2019)

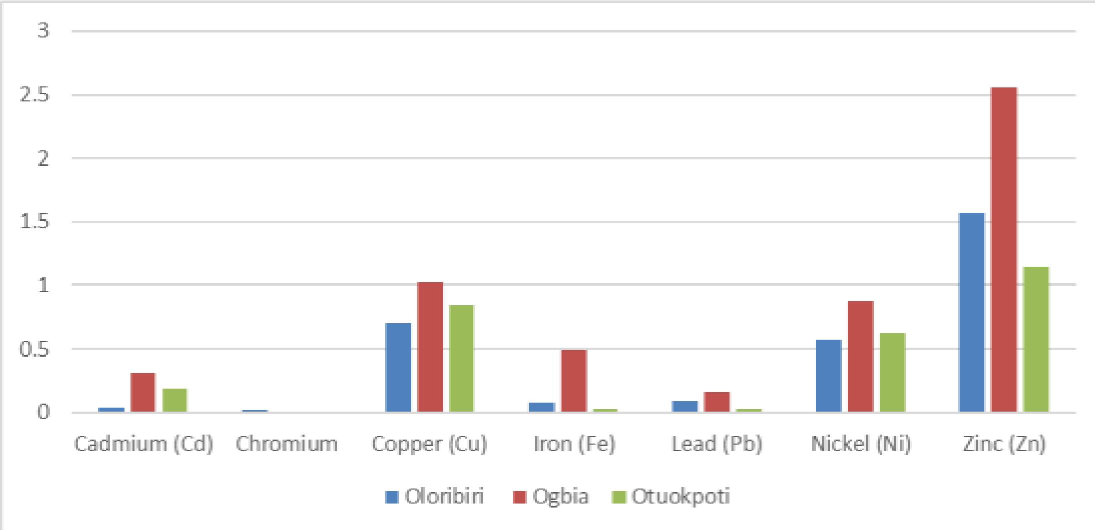


**Fig 4**: Mean ($\bar{X}$) values of the heavy metal concentration in sample well water for the three communities

**Table 4:** Distribution of respondents by Sex

| Sex | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Male | 118 | 42.4 | 42.4 | 42.4 |
| Female | 160 | 57.6 | 57.6 | 100.0 |
| Total | 278 | 100.0 | 100.0 | |

A total of 118 respondents (42.2%) are male while 160 respondents are females (57.6%)

**Table 5:** Age of respondents

| Age | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Below 20yrs | 44 | 15.8 | 15.8 | 15.8 |
| 21-30 years | 117 | 42.1 | 42.1 | 57.9 |
| 31-40 years | 83 | 29.9 | 29.9 | 87.8 |
| 41- 50 years | 17 | 6.1 | 6.1 | 93.9 |
| 51&above | 17 | 6.1 | 6.1 | 100.0 |
| Total | 278 | 100.0 | 100.0 | |

Forty-four, 44 (15.8) respondents are below 20 years, 117 (42.1%) respondents are between 21—30 years, 17 (6.1%) respondents are between the age range of 41—50 years and 17 (6.1%) respondents are between the age range of 51 and above.

**Table 6:** Marital status of respondents

| Marital status | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Single | 73 | 26.3 | 26.3 | 26.3 |
| Married | 130 | 46.8 | 46.8 | 73.0 |
| Separated | 45 | 16.2 | 16.2 | 89.2 |
| Divorce | 20 | 7.2 | 7.2 | 96.4 |
| Widow/widower | 10 | 3.6 | 3.6 | 100.0 |
| Total | 278 | 100 | 100 | |

Seventy-three, 73 (26.3%) respondents are single, 130 (46.8%) respondents are married 45 (16.2%) respondents are separated.

**Table 7:** Occupational status of respondents

| Occupation status | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Fishing/farming | 25 | 9.0 | 9.0 | 9.0 |
| Trading | 71 | 25.5 | 25.5 | 34.5 |
| Student | 80 | 28.8 | 28.8 | 63.3 |
| Civil servant | 45 | 16.2 | 16.2 | 79.5 |
| Artisan | 38 | 13.7 | 13.7 | 93.2 |
| Transporter | 19 | 6.8 | 6.8 | 100 |
| Total | 278 | 100.0 | 100.0 | |

A total of 25 (9.0%) respondents are engaged in fishing and farming, 71 (25.5%) respondents are traders, 80 (28.8) respondents are students, 45 (16.2% ) respondents are artisans while 19 (6.8%) respondents are transporters.

**Table 8:** Educational status of respondents

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| No formal education | 18 | 6.5 | 6.5 | 6.5 |
| FSLC | 38 | 13.7 | 13.7 | 20.1 |
| WAEC/NECO | 90 | 32.4 | 32.4 | 52.5 |
| OND/NCE | 54 | 19.4 | 19.4 | 71.9 |
| B.SC | 78 | 28.1 | 28.1 | 100 |
| Total | 278 | 100 | 100 | |

Eighteen, 18 (6.5%) respondents have no formal education, 90 (32.4%) respondents have WAEC/NECO, 54 (19.4%) respondents have OND/NCE while 78 (28.1%) have B.SC

**Table 9:** Quality of the well water

| | **Frequency** | **Percentage** | **Valid percent** | **Cumulative percent** |
|---|---|---|---|---|
| Low | 159 | 57.2 | 57.2 | 57.7 |
| High | 119 | 42.8 | 42.8 | 100 |
| Total | 278 | 100 | 100 | |

One hundred and fifty0nione, 159 (57.2%) respondents agreed that the quality of the well water is low while 119 (42.8%) respondents said the quality is high

**Table 10:** What is done to make the water safe for use?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Boil | 66 | 23.7 | 23.7 | 23.7 |
| Add chlorine/bleach | 42 | 15.1 | 15.1 | 38.8 |
| Let it stand and settle | 52 | 19.4 | 19.4 | 58.3 |
| Strain it through a cloth | 40 | 14.4 | 14.4 | 72.7 |
| Alum | 76 | 27.3 | 27.3 | 100 |
| Total | 278 | 100 | 100 | |

A total of 66 respondents (23.7%) boil their water, 42 respondents (15.1%) add chlorine/ bleach, 52 respondents (19.4%) let is and settle, 40 respondents (14.4%) strain it through a cloth and 76 respondents (27.3%) use alum before they use the well water.

**Table 11:** Is the water available throughout the year?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Yes | 121 | 43.5 | 43.5 | 43.5 |
| No | 157 | 56.5 | 56.5 | 100.0 |
| Total | 278 | 100.0 | 100.5 | |

One hundred and twenty-one, 121 (43.5%) respondents agreed that the water is readily available throughout the year while 157 (56.5) respondents agreed not having water readily throughout the year.

**Table 12:** Does the water smell?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Yes | 123 | 44.2 | 44.2 | 44.2 |
| No | 155 | 55.8 | 55.8 | 100.0 |
| Total | 278 | 100.0 | 100.0 | |

One hundred and twenty-three, 123 (44.2%) respondents reported that the well water smells while 155 respondents (55.8%) reported no smell from well water.

**Table 13:** How does the water look like?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Cloud | 55 | 19.8 | 19.8 | 19.8 |
| Muddy | 70 | 25.2 | 25.2 | 45.0 |
| Clean | 105 | 37.8 | 37.8 | 82.7 |
| Very dirty | 48 | 17.3 | 17.3 | 100 |
| Total | 278 | 100 | 100 | |

A total of 55 (19.8%) respondents observed the well water as cloudy; 70 (25.2%) respondents observed it as muddy, 105 (37.8%) respondents said it to be clean while 48 (17.3%) respondents said it to be very dirty.

**Table 14:** Do you drink water from the well?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| No | 188 | 42.4 | 42.4 | 42.4 |
| Yes | 160 | 57.6 | 57.6 | 100 |
| Total | 278 | 100 | 100 | |

A total of 118 respondents (42.4%) drink from the well water while 160 respondents do not drink water from the well.

**Table 15:** Has there being any case of illness or skin infection related to the use of water from the well?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Yes | 91 | 32.7 | 32.7 | 32.7 |
| No | 187 | 67.3 | 67.3 | 100 |
| Total | 278 | 100 | 100 | |

Ninety, 91 (32.7%) respondents reported that there have been cases of illness or skin infection related to the use of well water; while 187 (67.3) respondents reported said no case of illness as a result of use of the well water.

**Table 16:** What disease has resulted as a result of the use of well water?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Skin rash | 104 | 37.4 | 37.4 | 37.4 |
| Itching | 69 | 24.8 | 24.8 | 62.2 |
| Diarrhea | 25 | 9.0 | 9.0 | 71.2 |
| Cholera | 80 | 28.8 | 28.8 | 100 |
| Total | 278 | 100 | 100 | |

A total of 104 respondents (37.4%) observed that use of well water has caused skin rash, 69 respondents (24.8%) to have caused itching 25 respondents (9.0%) to have caused diarrhea and 80 respondents (28.8%) to have caused cholera.

**Table 17:** What other sources of water are available apart from well water?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| borehole | 105 | 37.8 | 37.8 | 37.8 |
| Water from river | 102 | 36.7 | 36.7 | 74.5 |
| Private borehole | 71 | 25.5 | 25.5 | 100 |
| Total | 278 | 100 | 100 | |

A total of 105 respondents (37.8%) uses water from borehole aside well water, 102 respondents (36.7%) use water from river while 71 respondents (25.5%) use water, from private borehole aside well water.

**Table 18:** Which month do you face scarcity of water from the well?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| January | 106 | 38.1 | 38.1 | 38.1 |
| December | 97 | 34.9 | 34.9 | 73.0 |
| February | 12 | 4.3 | 4.3 | 77.3 |
| March | 63 | 22.7 | 22.7 | 100 |
| Total | 278 | 100 | 100 | |

A total of 106 respondents (38.1%) agreed that well water is scarce during January, 97 respondents (34.9%) said December, 12 respondents (4.3%) noted February and 63 respondents (34.9%) said

December, 12 respondents (4.3%) noted February and 63 respondents (22.7%) agreed that in the month of march is where they face scarcity in well water.

**Table 19:** What do you use the well water for?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Cooking | 31 | 11.2 | 11.2 | 11.2 |
| Bathing | 48 | 17.3 | 17.3 | 28.4 |
| Washing /cleaning | 169 | 60.8 | 60.8 | 89.2 |
| All of the above | 30 | 10.8 | 10.8 | 100 |
| Total | 278 | 100.0 | 100 | |

A total of 31 respondents (11.2%) used the well water for cooking, 48 respondents (17.3%) use it for bathing, 169 respondents (60.8%) use it for washing and cleaning whereas 30 respondents (10.8%) uses it for cooking, bathing, washing/cleaning.

**Table 20:** How often do you get this water?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Twice a day | 25 | 9.0 | 9.0 | 9.0 |
| Four times a day | 78 | 28.1 | 28.1 | 37.1 |
| As long as it is needed | 178 | 62.9 | 62.9 | 100 |
| Total | 278 | 100 | 100 | |

A total of 25 respondents (9.0%) get water twice daily from the well, 78 persons (28.1%) get it four times daily while 178 persons (62.9) gets it as long as it is needed.

**Table 21:** Is the frequency sufficient for your needs?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Yes | 168 | 60.4 | 60.4 | 60.4 |
| No | 110 | 39.6 | 39.6 | 100 |
| Total | 278 | 100 | 100 | |

One hundred and sixty-eight, 168 (60.4%) respondents have sufficient supply of water for their needs while 110 (39.6) respondents do not have sufficient water for their needs.

**Table 22:** Do you have any colour strain on your fixtures

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Yes | 208 | 74.8 | 74.8 | 74.8 |
| No | 70 | 25.2 | 25.2 | 100 |
| Total | 278 | 100 | 100 | |

Two hundred and eight, 208 (74.8%) Respondent identified colour strains in their water fixtures while 70 (25.2%) do not.

**Table 23:** What time of the year is the well water more dirty?

| | Frequency | Percentage | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Dry season | 118 | 42.4 | 42.4 | 42.4 |
| Rainy season | 79 | 28.4 | 28.4 | 70.9 |
| Harmattan | 81 | 29.1 | 29.1 | 100 |
| Total | 278 | 100 | 100 | |

A Total of 118 respondents (42.4%) pointed out that well water is more dirty during the dry season, 79 persons (28.4%) said it is during the rainy season that the well water becomes dirty while 81 persons (29.1%) see it to be during the harmattan.

### 7.1 Hypotheses testing

**Hypothesis one**

There is no significant variation in the heavy metal concentration of the well water in the study area. Statistical tool: analysis of variance (ANOVA)

**Table 24:** Statistical table for the analysis of heavy metal characteristics of the well water samples

| Parameters | OW1 | OW2 | OGW1 | OGW2 | OTW1 | OTW2 | $OW1^2$ | $OW2^2$ | $OGW1^2$ | $OGW2^2$ | $OTW1^2$ | $OTW2^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cadmium | 0.063 | 0.014 | 0.608 | 0.022 | 0.046 | 0.331 | 0.004 | 0.0002 | 0.369 | 0.0005 | 0.002 | 0.109 |
| Chromium | 0.02 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.0004 | 0.0001 | 0.0001 | 0 | 0.001 | 0.0001 |
| Copper | 0.77 | 0.63 | 1.20 | 0.86 | 0.94 | 0.75 | 0.593 | 0.397 | 1.44 | 0.739 | 0.884 | 0.5623 |
| Iron | 0.01 | 0.14 | 0.65 | 0.32 | 0.01 | 0.04 | 0.0001 | 0.019 | 0.423 | 0.102 | 0.0001 | 0.002 |
| Lead | 0.125 | 0.60 | 0.305 | 0.011 | 0.005 | 0.061 | 0.016 | 0.004 | 0.093 | 0.0001 | 0.00003 | 0.004 |
| Nickel | 0.55 | 0.60 | 1.15 | 0.60 | 0.60 | 0.65 | 0.303 | 0.36 | 1.323 | 0.36 | 0.36 | 0.423 |
| Zinc | 2.03 | 1.10 | 4.08 | 1.03 | 0.96 | 1.33 | 4.121 | 1.21 | 16.646 | 1.061 | 0.922 | 1.769 |
| Total | 3.568 | 2.554 | 8.003 | 2.843 | 2.571 | 3.172 | 5.0375 | 1.9903 | 20.2941 | 2.2626 | 2.16823 | 2.8701 |

**Table 25:** Summary ANOVA table for the heavy metal concentration in the well water sample

| | SS | Df | ms | f | Sig |
|---|---|---|---|---|---|
| Between groups | 3.156 | 5 | .631 | 1.184 | 0.336 |
| Within groups | 19.184 | 36 | .533 | | |
| Total | 22.340 | 41 | | | |

The result of the analysis of variance is presented in table. From the result, it was observed that there is no significant variation (since F=d. f=5, 36) = 1.184, P > 0.05) in the variation of heavy metal content in the well water samples in the study area. Therefore, uphold the null hypothesis that there is no significant variation in the heavy metal concentration in the well water sample in the study area.

**Hypothesis two**

There is no significant variation in the bacteriological characteristics of the well water in the study area. Statistical tool: analysis of variance (ANOVA)

**Table 26:** Analysis of the bacteriological characteristics of the well water samples

| Parameters | OW1 | OW2 | OGW1 | OGW2 | OTW1 | OTW2 | OW1² | OW2² | OGW1² | OGW2² | OTW1² | OTW2² |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total heterotrophic count (THC) | 69 | 91 | 179 | 126 | 108 | 97 | 4761 | 8281 | 30625 | 15876 | 11664 | 9409 |
| Total coliform (TCC) | 31 | 65 | 113 | 76 | 73 | 84 | 961 | 4225 | 12769 | 5776 | 5329 | 7056 |
| Fecal coliform count (FCC) | 32 | 48 | 105 | 63 | 23 | 59 | 1024 | 2304 | 11025 | 33969 | 529 | 3481 |
| Total | 132 | 204 | 393 | 265 | 204 | 240 | 6746 | 14810 | 54419 | 25621 | 17522 | 19946 |

**Table 27:** Summary ANOVA table for the bacteriological characteristics of the well water samples

| Sources of variation | SS | df | Ms | F | Sig |
|---|---|---|---|---|---|
| Between groups | 1276.111 | 5 | 2552.622 | 2.682 | 0.075 |
| Within groups | 11420.667 | 12 | 951.722 | - | - |
| Total | 24183.778 | 17 | - | - | - |

The result of the analysis of variance is presented in Table 27. From te result it was observed that there is no significant variation (since F = (d.f = 5, 12) = 2.682, p > 0.05) in the variations of bacteriological characteristics of water in the study areas. Therefore, we uphold the null hypothesis that there is no significant variation in the bacteriological characteristics of well water in the study areas.

**Hypothesis three**

There is no relationship between human health and the consumption of well water in the study area

Statistical tool: Pearson's Product Moment Correlation

**Table 28:** Summary of Pearson correlation for health impact of the consumption of well water

Correlations

| | | Q11 | Q12 |
|---|---|---|---|
| Q11 | Pearson Correlation | 1 | .300** |
| | Sig. (2-tailed) | | .000 |
| | N | 278 | 278 |
| Q12 | Pearson Correlation | .300** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 278 | 278 |

Correlation is significant at the 0.01 level (2-tailed). The result of Pearson product moment shows that the p value is lesser than 0.05. Therefore, we reject the null hypothesis and accept the alternative hypothesis. In conclusion there is a significant relationship between human health and the consumption of well water in the study area.

## 8.0 Discussion of Findings

From table four, it was observed that the mean (X) value of the bacteriological characteristics of the well water are far above the Nigerian standard for drinking water quality (NSDWQ, 2008) or permissible limit for domestic water quality. This means that the water is threatened and impaired the water quality for domestic purpose. Again table 6, shows that the mean value of heavy metals concentration is below the permissible limits of the NSDWQ, 2008) standard for domestic water quality except for zinc in sample well water in Ogbia community that is slightly above the permissible limit. This means that the availability of good quality water for domestic usage is threatened in the area whereas because the concentration of zinc in sample well water in Ogbia community is above the permissible limit, it therefore implies that the well water in the area will be impaired and therefore not fit for domestic usage.
Moreso, Table 15 and 16 reveals that there has been some cases of illnesses and skin infections as a result of the use of well water in the study area. This implies that the water is not safe for human consumption and is detrimental to health.

## 9.0 Summary of Findings

The study revealed that the mean values of the bacteriological characteristics of the well water are above the NSDWQ standard or permissible limit for domestic water quality. Again, the mean value of heavy metals concentration of the well water was lower than the permissible limit of the NSDWQ for domestic water sources except for Ogbia town which has a mean value of Zinc higher than the permissible limit. Again, the study revealed that 42.4% of the study population drinks water from the well while 57.6% do not; 32.7% also reported that there have been cases of illness or skin infection related to the use of well water whereas 67.3% reported no case at all.
Giving a critical view, there is deterioration in the well water quality of the study area which may not only result to the well water contamination but also affects human health and safety.

## 10.0 Conclusion

From the well water samples collected analyzed, it was observed and concluded that the well water from the study area is not free from pollution and contamination and as that cannot be used for domestic purposes and drinking without undergoing proper treatment. Also, from the questionnaire administered and retrieved it was observed that the use of well water has impacted on the health of the inhabitants in the study area.

## 11.0 Recommendation

- Water treatment should be carried out before use
- Provision of pipe borne water to local communities
- Water quality assessment is recommended
- Wells should be well constructed
- Human activities around the well should be regulated
- Keep pollutants as far as possible from the well
- Older wells without proper casing, sealing and protective slabs, or with other problems should be brought up to current standards for your own protection
- Upgrade wells by getting rid of well pits and moving activities as pesticide mixing or gasoline storage farther from well.

## References


Adekunle, I. M., Adetunji, M. T., Gbadebo, A. M. & Banjoko, O. B. (2007). Assessment of ground water quality I a tropical rural settlement in southwest Nigeria. *International Journal of Environmental Research and Public Health,* 2, 161-182

Akpokodje, E.G. (1987) The Engineering Geological Characteristics and Classification of the Major Superficial Soils of the Niger Delta. Engineering Geology, 23, 193-211.

Akpokodje, E.G. (1988): Preliminary studies on Geotechnical Characteristics of the Niger Delta sub-soil. Engineering Geology 26:120-126.

Asuquo, J. E. & Etim E. E. (2012b). Physic-chemical and bacteriological analyses of Borehole water in Selected Areas in Uyo, Metropolis. International Journal of Modern Chemistry, 2 (1): 7-14

Asuquo, J.E. & Etim, E.E (2012). Water quality Index for assessment of borehole water quality in Uyo Metropolis Akwa Ibom State, Nigeria. International journal of Modern Chemistry. 1 (3): 102-108.

Digha, O.N and Abua, M.A (2018). Assessment of Pollution Status of Ikwette Stream at Obudu Cattle Ranch Bottom Hill, Cross River State Calabar Nigeria. *International Journal of Environment and Pollution Research. 6(1) pp.8-12.*

Egiran, E.E. (1995). *Essentials if Technical and Applied Geography.* Almond Publishers.

Essays, U. K. (2018). Effect of toxic pollutants on food chains. Environmental Sciences Essay. Retrieved from https://www.ukessays.com/essays/environmental.

Ezenwaji, E. E. &Anyaegbunam, B. C. (2006). Spatial appraisal of shallow well water in Awka, Nigeria. *Nigerian Journal of Microbiology*, 20(3), 34-45.

Kojo, S., Boateng, A. & Steve, A. (2016). Investigating the potability of water from dug Wells: A case study of the Bolgatana Township, Ghana. *African Journal of Environmental Science and Technology,* 10(10), 307-315.

Mile, J. A. &Dagba, B. I. (2012). Bacteriological contamination of well water in Makurdi town,benue state Nigeria. *Pakistan Journal of Biological Sciences,*15, 1048-1051

Nyanayo B.L. (1999). *"Vegetation" In Alagoa E.J. (ed) The Land and People of Bayelsa State: Central Niger Delta.*Onyoma Research Publications (1999) pp. 44-57.

Ogbia Master Plan (1975). *Climate.* Handasah Consultants Beirut Lebanon pp. 2-3.

Oguntoyinbo J.S. (1983). "Climate" In Oguntoyingo et al (ed). *A Geography of Nigerian Development.* 2nd edition, Heinemann Educational Books Ltd. Pp. 105-126.

Onweluzo, J. C. and Akuagbazie, C. A.(2010). Assessment of the quality of bottled and sachet water Sold in Nsukka Town. Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension Volume 9 Number 2, pp. 104 - 110

Onweluzo, J. C. and Akuagbazie, C. A. (2010). Assessment of the Quality of Bottled and Sachet Water Sold in Nsukka Town. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*. 9(2), 104 – 110.

Okonko, I. O., Ogunjobi, A. A., Adejoye, A. D., Ogunnusi, T. A. and Olasogba, M. C. (2008). Comparative studies and microbial risk assessment of different water samples used for processing frozen sea foods in Ijora-olopa,LagosState,Nigeria. *African Journal of Biotechnology, 7* (16):2902-2907.

Okonko IO, Adejoye OD, Ogunnusi TA, Fajobi, EA, Shittu OB (2008). Microbiological and physicochemical analysis of different water samples used for domestic purposes in Abeokuta and Ojota, Lagos State, Nigeria. Afr. J. Biotechnol. 7(3): 617-621.

Timothy, R.W., Cliff, L. R. & Marie, E. & Quasius, R. (2018). What's the point (Source)? New developments in the ongoing debate concerning clean water act jurisdiction over indirect discharges via groundwater. *Journal of Social Sciences*, 1(3), 6-9.

Udo R. K (1978). *Comprehensive Geography of West Africa.* Heinemann Education Books Nigeria Ltd. Ibadan.

Udo R.K. (1981). *Geographical Regions of Nigeria.* Heinemann, London, Nairobi/Ibadan.

**POTABLE WATER SUPPLY FOR DAY-TO-DAY HUMAN USE IN EDUCATIONAL INSTITUTIONS: A WEALTH-WAY FOR THE ENTREPRENEUR IN A CHANGING WORLD**

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**Abstract**

*Water is one of the most important elements on the planet earth for human sustenance. Apart from its need for domestic, agricultural, industrial, engineering and other natural functions, its role in day-to-day human use cannot be overstated. Averagely, it is recommended that human beings drink a minimum of two (2) litters of water a day to keep the human system in proper function. The study surveyedpotable water supply in the University of Calabar. The study identified the locations, type of water supply systems, method of supply, and demographic characteristics of the supplier of water in the study area. The convenient sampling technique was adopted in drawing a sample for questionnaire administration and semi-structured interviews. Results indicate that bottle and sachet packaged water are the major potable water supplied in the study area. It also revealed water is supplied at the Main campus, New Library, Malabo Republic areas of the institution, while gainfully created jobs for people. The job of water supply is mostly done through disposable plastic bottles and sachets, by both male (23.5%) and female (76.5) of mostly young adults. Hawking was the major means of supplying sachet water while some through rentedkiosk/stationary shops. It further shows that water supply has employed a significant number of persons engaged in business activities in the study area. Although it may not require much capital, funding (*41.18%*) and harsh environment (*35.30*) was found to be a major problem in portable water supply in the study area. It was therefore recommended that government and other stakeholders in water supply chain should provide small-scale loans or grants for start-ups in water supply in the study area.*

**Keywords:** Portable water supply, human use, educational institution, entrepreneur, changing world.

## Introduction

Water is an essential daily need of man. Its intake for various functions. One of the most important functions is its utilization by human being for drinking. In a bid to provide creative ways of making the water available for use, it creates opportunities for jobs in its value chain. In built environments like educational institutions, large volume of water is required for drinking. Addressing the demand for potable water is to enhance livelihoods. Its chain creates jobs as well as challenges.

Water is an importance substance constituting a major part of human body weight. Water performed critical functions such as flushing of waste from the body, body temperature regulation and helping brain function (, 2021). As important as clean water intake is, a number of persons do not have access to it. In educational institutions, it is perceived that average institution community members (staff, students and other stakeholders) access potable water.

How potable water is supplied in educational institutions and the jobs it generates in the University of Calabar is the aim of this study.The demographics and constraints in supplying water adequate for such a geographic space leaves a lot of questions that are often unanswered.

As essential as water is, about 783 million people do not have access to potable water, while six to eight million people die yearly as a result of water-disasters and water-related diseases (unwater.org). This study was undertaken to assess potable water supply for day-to-day human use in educational institutions as a wealth-way for the entrepreneur in a changing world, using the University of Calabar.

**Objective of the study**

1. To identify the location, type and mode of potable water supply in the study area
2. To assess the demographic attributes of potable water suppliers in the study area
3. To identify the challenges of supplying potable water in the study area.

**Literature review**

The word 'potability' is derived from the root word potable, which means clean, filtered or drinkable. We can safely see potability as clean and safe drinking water available to human beings. It is essential for health in many ways. Plastic containers and cellophane bags have served the current generation in supplying potable water for various uses and at various points in educational institutions. Hawkers of potable water have been found in lecture rooms or theatres, along school streets and sit-outs among others making water available to willing users. The use of mobile water containers to keep up with changing water use and need for various purposes necessitates and enhances the popularization of potable water supply.

The use of water as an important biological need has been documented (Amahmid, *et al*, 2019). One of the major means by which people sense dehydration is through thirst (Thornton, 2010), this is one of the influences of intake of water. Water makes up 75% of brain mass (Na Zhang et al., 2019). The functions of water is included in maintenance of electrolyte. According to International Journal Environmental Research and Public Health (2019), adequate electrolyte balance is vital to keeping an individual function optimally. This is essential for the survival and growth of life. Research has shown that rehydration improves fatigue, short term memory and attention. Drawing attention to the importance of water intake and hydration is very vital to the survival and development of life.

Engaging in water production, processing and supply is one avenue to creating sustainable low-cost jobs in educational institutions. This substance makes up a majority of your body weight and is involved in many important functions, including:flushing out waste from your body, regulating body temperature, and helping your brain function (Brander, 2003). Potable water containers are very potable and often single use. They, however, now constitute one of the biggest waste materials in urban environments. They are found blocking drainage channels, littering streets, roads, open spaces, and even green areas.

**Materials and Methods**

The survey design was adopted for the study. The study location was the University of Calabar, comprising of the Main Campus, Management Sciences, Medical College, and the New Library areas. The major instrument for data collection was the questionnaire and oral interview. The population of the study was made up of 17 potable water vendors identified across the study area using the convenient sampling technique.

During questionnaire administration, copies of the questionnaire were administered to the respondents on items such as location of respondents, sex, age-range, educational qualification, type of potable water supply, among others. The completed questionnaire was retrieved, collated and analyzed. Also, oral interviews were conducted on some of the respondents. The results of the findings were presented in tables and discussed for better appreciation of the findings.

**Results**

A total of twenty (20) structured questionnaires were administered to potable water vendours in the University of Calabar. Out of the 20 copies, 17 (85%), while 3(15%) were poorly completed, hence, discarded. The 17 properly completed were used for analysis.

**Table 1:** Location of respondents**.**

| S/N | Location | Frequency | Percentage |
|---|---|---|---|
| 1 | Main Campus | 6 | 35.29 |
| 2 | Management Science | 2 | 11.76 |
| 4 | New Library | 4 | 23.53 |
| 5 | Medical College | 2 | 11.76 |
| 6 | Malabo Republic | 3 | 17.65 |
| Total | | 17 | 100 |

**Source:** Field survey, 2021.

**Table 2**: Sex distribution of respondents**.**

| Item | Sex | Frequency | Percentage |
|---|---|---|---|
| 1 | Male | 4 | 23.5 |
| 2 | Female | 13 | 76.5 |
| Total | | 17 | 100 |

**Source:** Field survey, 2021.

**Table 3:** Age-range of respondents

| Item | Age-range (years) | Frequency | Percentage |
|---|---|---|---|
| 1 | Below 10 | 0 | 0.0 |
| 2 | 11-20 | 6 | 35.3 |
| 3 | 21-30 | 4 | 23.5 |
| 4 | 31-40 | 5 | 29.4 |
| 5 | 40 and above | 2 | 11.8 |
| Total | | 17 | 100 |

**Source:** Field survey, 2021.

Table 4: Educational qualification of respondents

| Item | Educational qualification | Frequency | Percentage |
|---|---|---|---|
| 1 | No education | 3 | 17.65 |
| 2 | Primary education | 1 | 5.88 |
| 3 | Secondary education | 7 | 41.18 |
| 4 | Others (tertiary) | 6 | 35.29 |
| **Total** | | 17 | **100** |

**Source:** Field survey, 2021.

**Table 5**: Type of potable water

| **Item** | **Type of portable water** | **Frequency** | **Percentage** |
|---|---|---|---|
| 1 | Plastic bottle | 2 | 11.76 |
| 2 | Sachet | 15 | 88.24 |
| **Total** | | 17 | **100** |

**Source:** Field survey, 2021.

**Table 6:** Do you have staff working with you**?**

| S/N | Response | Frequency | Percentage |
|---|---|---|---|
| 1 | Yes | 7 | 41.18 |
| 2 | No | 10 | 58.82 |
| **Total** | | **17** | **100** |

**Source:** Field survey, 2021.

Table 7: Mode of supply

| Item | Response | Frequency | Percentage |
|---|---|---|---|
| 1 | Hawking | 9 | 52.94 |
| 2 | In kiosk/shop | 8 | 47.06 |
| **Total** | | 17 | **100** |

**Source:** Field survey, 2021.

Table 8: Do you pay for space to do this business?

| Item | Response | Frequency | Percentage |
|---|---|---|---|
| 1 | Yes | 17 | 100 |
| 2 | No | 0 | 00 |
| **Total** | | 17 | **100** |

**Source:** Field survey, 2021.

Table 9: Do you think that this business is giving you money?

| Item | Response | Frequency | Percentage |
|---|---|---|---|
| 1 | Yes | 9 | 52.94 |
| 2 | Not so much | 4 | 23.53 |
| 3 | Manageable | 4 | 23.53 |
| **Total** | | 17 | **100** |

**Source:** Field survey, 2021.

Table 10: What is your major challenge in this business?

| Item | Response | Frequency | Percentage |
|---|---|---|---|
| 1 | Funds | 7 | 41.18 |
| 2 | Harsh operating environment | 6 | 35.30 |
| 3 | Security issues | 2 | 11.76 |
| | All the above | 2 | 11.76 |
| **Total** | | 17 | **100** |

**Source:** Field survey, 2021.

**Discussion of Findings**

Findings of the study revealed that the respondents were both male (23.5%) and female (76.5%) of mostly young adults. The age-range of the respondents occurring within the age brackets of 11-20 (35.3%), 31-40 (29.4%) and 21-30 (23.5) respectively. On educational level, a large proportion of the respondents were within the secondary level of education representing 41.18%, others (tertiary) representing 35.29%, while no education was 17.65%. Results further revealed that sachet water was the predominant type of potable water supplied in the study area representing 88.24%, while plastic bottle water represented 11.76%.

Hawking (52.94%) was the major means of supplying sachet water while some through rented kiosk/stationary shops (47.06%). It was discovered that the challenges of potable water supply in the study area include funding (41.18%), harsh environment (35.30), and security issues (11.76%). Some of the respondents agree they make money from the water supply business (52.94%), some agree they make money but not so much or manageable (23.53%) respectively.

During the oral interviews, the respondents agreed that the potable water supply business was a good business. The problem however is the start-up funds. According to some of them, they are students and trying to raise support for themselves but it is not easy to raise funds to start and maintain the business. Other issues generated were issues of getting a space for the business on campus and paying for a space that is environmentally friendly, and also free from theft.
They blamed space allocation and poor security of their location to the management of the business premises in the study area, which they believed could be better managed.

**Recommendations and Conclusion**

Water is life and one of the most important elements on earth for all living things. From the findings of this study, potable water supply has been key to the socio-economic wellbeing of the educational institution. Bottle and sachet water were the available water supply types in the study area providing livelihood opportunities for those engaged in potable water supply. It provides livelihood opportunities and solves water need problem on the campus. Hence, should be given priority in management decision among stakeholders of water supply chain.
The study therefore recommended that government and other stakeholders in water supply chain should provide small-scale loans or grants for start-ups in water supply in the study area; management of school environment should provide well secured and dedicated areas for business premises.

**References**

Amahmid, O., Guamri, Y., Yazidi, M, Razoki, B., Rassou, K. K. &Rakibi, Y. (2019). Water education in school curricula: impact on children knowledge, attitudes and behaviours towards water use. *International Research in Geographical and Environmental Education, 28(3), 178-193.*

Brander, N. (2003). Drinking water in schools. *Nursing Times*, 99(1), 50.

Na Zhang, Song M. Du, and Guan S. Ma (2019): Effects of Dehydration and Rehydration on Cognitive performance and mood among College Students in Cangzhou, China: A self Controlled Trial.

Thornton S.N. (2010), Thirst and hydration: Physiology and consequences of dysfunction. Physiol. Behav. 2010;100:15–21. doi: 10.1016/j.physbeh.2010.02.026.

UN (year unknown). Clean Water Fast Facts. Retrieved June, 2021 from unwater.org.