Nigerian Institution of Water Engineers

(A Division of the Nigerian Society of Engineers)

...Water is Life

6th NIWE INTERNATIONAL WATER CONFERENCE

September, 2023

Nigerian Institution of Water Engineers

(A Division of the Nigerian Society of Engineers)

6th NIWE International Water Conference

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PREFACE

This book of conference proceedings is for the 6th International Water Conference of the Nigerian Institution of Water Engineers (NIWE), a division of the Nigerian Society of Engineers (NSE). In fulfilment of one of its core mandate as a professional engineering body in the water sub-sector, a call for submission of paper was made by NIWE in May, 2023 with the main theme of the conference as “Water, Sanitation and Hygiene Governance in Nigeria: Rethinking Strategies and Strengthening Policies”.

The Proceedings contains twenty two peer-reviewed papers from all over the country and beyond. The technical committee received over thirty abstracts, while only twenty two submitted full papers that were peer-reviewed and found worthy in substance. It is worthy to mention that the acceptance of the papers for publishing in this Proceedings was based on the recommendations provided in the reviewer reports.

Sincere gratitude is due to the individual members of the 6th IWC and all reviewers for their important contribution of ensuring the high quality of this Proceedings. The following organizations are gratefully acknowledged for their significant financial and technical support to the conference: Ogun-Oshun River Basin Development Authority, Ogun State Water Cooperation, SGI Consulting Engineers Limited, Dankarau Habitat Engineering Services Limited and E+D Multi Consult Design Limited.

On behalf of the Organizing Committee, the Editors of the Proceedings wish to extend special thanks to all authors for the technical contribution of their high quality research, expertise and knowledge through this Proceedings. Finally, thanks are due to all members of the Conference Organizing Committee.

BRIEF HISTORY OF NIWE AND ITS INTERNATIONAL WATER CONFERENCES

The Nigerian Institution of Water Engineers is a division of the Nigerian Society of Engineers established in the year 2009. The activities of NIWE includes but are not limited to the following:

- ✓ Organisation of Conferences/Trainings/Workshops/Seminars/Public lectures/Technical Sessions on water/public health/renewable energy and related issues
- ✓ Collaboration with International Partners to Organise Water Africa and West Africa Building and Construction Exhibition and Seminars etc.
- ✓ Establishment of Water & Hygiene Clubs in Junior and Senior Secondary Schools.
- ✓ WASH outreach to Water Clubs and Secondary Schools.
- ✓ Sponsorship of Prizes for best performing students in Science subjects in schools with Water Clubs.
- ✓ International Technical Visits
- ✓ Local Technical and Industrial Visits
- ✓ Journal Publication
- ✓ Courtesy Visits to Relevant Water and Public Health Related Agencies.
- ✓ News Conferences on the position of the Association on Burning National Water related issues.
- ✓ Attend and contribute to public hearings of the National Assembly on issues pertaining to the water sector.
- ✓ Annual General Meetings and International Conferences.
- ✓ Membership Drive and Awareness Campaign.
- ✓ Participation in the activities of the Nigerian Society of Engineers.
- ✓ Participation at the National Council for Water Resources (NCWR)

In furtherance of the above objectives, three International Water Conferences have been held thus far. They are:

- ✓ 1st NIWE International Water Conference/Water Africa & West Africa Building and Construction Exhibition – Abuja, November 14 - 16, 2017.
- ✓ 2nd NIWE International Water Conference –Abeokuta, October 15 – 17, 2018.
- ✓ 3rd NIWE International Water Conference (Virtual) – February 18 - 20, 2021.
- ✓ 4th NIWE International Water Conference – Abuja, October 12 – 14, 2021.
- ✓ 5th NIWE International Water Conference – Abuja, September 12 - 15, 2022.

At these conferences, high quality papers were presented and communiques issued and circulated to relevant agencies of government and the private sector for further necessary actions.

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Paper 01 *Integrating Knowledge, Strategies and Decision-Making for Water, Sanitation and Hygiene in Nigeria*

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ABSTRACT: Integrating knowledge, strategies and decision-making are major driving forces for the realization of water, sanitation and hygiene (WASH) practices in all nations of the world. This paper highlights various ways of integrating knowledge, strategies and decision-making into water, sanitation and hygiene in Nigeria. The methodology used includes expert opinions, review studies and case studies. Various challenges such as issues linked with the source, treatment, distribution and utilization of water were identified. Strategies and decision-making processes were identified for effective and optimal performance of water, sanitation and hygiene in rural and urban centres. The challenges facing communities are traceable to scarcity of potable water and climate change. With proper coordination, managerial skills, adequate bridging of the human resources gap and good governance from the three tiers of government, water experts can solve this problem and many promising avenues exist to strengthen the water sector. It was concluded that knowledge, strategies and decision-making can be integrated and adequately deployed for effective WASH in various geopolitical zones in Nigeria**.** The government should support all initiatives that are geared towards the achievement of this development.

Keywords: integrating knowledge, strategies, decision making, managerial skills, water sanitation and hygiene

1.0 INTRODUCTION

Knowledge comes from two words, know and edge. To know is to have a leading edge over others. Knowledge must be integrated for effective policies and decision-making in the water sector. Knowledge, strategies and decision-making must be integrated for meaningful water, sanitation, and hygiene (WASH) in Nigeria. The health, economic productivity, and quality of life of the population are all significantly impacted by access to a reliable water supply. But one of the biggest issues that Nigeria's rural communities are currently confronting is addressing this requirement. For human livelihood, survival, and well-being, access to safe water, sanitation, and hygiene (WASH) facilities is a basic requirement. The provision of adequate WASH facilities is a crucial issue for the majority of developing nations worldwide, including Nigeria. Effective and sustainable WASH facility provision depends on WASH knowledge, attitudes, and practices. Water is humanity's lifeblood, flowing across all forms of life, cultures and economies around the world. It is a human right and a common development denominator for shaping a better future. There is a need to reduce the pressures on our hydrological system and ensure good decision-making and smart, inclusive policies. We need to develop innovative, efficient food systems to reduce the unsustainable use of water in food production and agriculture.

The term WASH is used as shorthand for a vast array of infrastructure, behavioural and policy interventions implemented to increase the access to and use of water supply and sanitation services. The term is usually applied to households and public settings such as schools and healthcare facilities in low-income contexts where access to these services remains challenging due to poverty, inequality, lack of public funds, and physical and geographic conditions. WASH mainly refers to:

i. **Water**: Supplies for drinking and other domestic purposes such as cooking and laundry, and improvements to drinking water quality through water treatment. It tends to exclude water for productive purposes such as agriculture or energy.
ii. **Sanitation**: Access to and use of facilities and services for the safe disposal of human excreta. It is sometimes, although not usually, extended to refer to other waste aspects such as household solid waste. The term applies to the entire 'chain' of services related to excreta disposal from toilet capture and containment through emptying, transport, treatment and final disposal or end use.
iii. **Hygiene**: While the term usually refers to conditions and practices to maintain health and prevent disease, in WASH, hygiene focuses on personal cleanliness, often narrowly on hand washing with soap as after toilet use and before cooking or eating

These various aspects, separately and as a whole, play a vital role in protecting population health since inadequate services lead to the spread of harmful pathogens. The most recognised role of WASH for public health is the prevention of infectious diseases, such as diarrhoeal diseases, neglected tropical diseases (see below), vector-borne diseases, and further health consequences such as malnutrition. However, the impact of inadequate WASH on human well-being extends to broader aspects such as perpetuating the vicious cycle of disease and poverty,

2.0 LITERATURE REVIEW

Knowledge, attitudes, and practices (KAP) associated with WASH are of pertinent concern towards sustainable and effective implementation of WASH programs in communities (USAID, 2011). KAP regarding WASH are contributing factors to waterborne disease prevalence in communities; poor WASH knowledge leads to unhygienic practices and poor attitudes which pollute water and spread illness (Yusuf et al., 2014; Miner, 2015). Such inadequate WASH knowledge leads to wrong perception of the quality of water resulting in large dependence on surface waters for drinking (Kaoje, 2019; Omarova et al., 2019), open defection practices being perceived as normal and commonly practised, minimal household water purification practices to prevent diseases (Orimoloye et al., 2015; Soboksa et al., 2019), and poor water collection and storage behaviours contaminating water and causing illnesses (Kurui et al., 2019; McGuiness, 2020). Household and environmental hygiene also tend to be poor, and children's stool is often overlooked and perceived harmless in sanitation programs, hence increasing the risk of disease transmission (Islam et al., 2018; Brown et al., 2011), all due to limited WASH understanding and poor attitudes and practices towards WASH. Therefore, there is a need to provide hygiene education programs and increased awareness towards promoting good WASH practices and ensuring good public health in the communities. In Nigeria, it is expected that there is currently a dearth of data on the status of WASH; thus, it is increasingly becoming difficult to plan any meaningful WASH program to improve health and well-being.

Water is essential to many facets of human endeavour, making the sustainable management of water resources essential to the growth of a community. For home, business, industrial, agricultural, and recreational uses, water is necessary. Only 69% of Nigerians have access to a basic water supply service, even though the total renewable water resources (TRWR) per person in Nigeria are projected to be 2514 m3/year (Grey and Sadoff, 2006). Even in areas of the country where water is abundant, access to water is limited due to increased pressure from population growth and urbanization (Merem et al., 2017). As a result, there is competition for water resources across many industries. Water is a necessity for many aspects of human endeavour, therefore the development of a society depends on the sustainable management of water resources. Water is required for agricultural, commercial, industrial, and recreational purposes. All wealthy nations have historically made significant investments in their ability to manage water resources efficiently (Grey and Sadoff, 2006; Ngene et al., 2021).

WASH primarily addresses healthy living through clever control of human behaviour and waste production to prevent harm to the environment and ecosystems (Sridhar and Adejumo, 2020). The promotion and distribution of inexpensive technology that enables better WASH practices are seen as a viable solution for reducing the high rates of morbidity and mortality from enteric infections in low-income nations. Several theoretical models, explanatory frameworks, and decision-making models have emerged to guide behaviour modification programs related to WASH. For the creation and assessment of such programs, a summary of this body of knowledge guiding WASH behaviour modification and maintenance would be helpful. The promotion or provision of low-cost water, sanitation, and hygiene (WASH) technologies at the individual, family, or community level in conjunction with hygiene promotion is a crucial strategy for reducing diarrhoeal diseases in resource-constrained contexts (Peal et al., 2010). Some of these household-level technologies include chlorine dispensers to treat water at the point of collection from wells or standpipes, improved latrines, and handwashing stations to encourage soap-based handwashing (Watt, 1988). Other examples include home-based water treatment with filters or chemical additives (Clasen et al., 2007; Arnold and Colford, 2007). Figure 1 presented the components of action-driven water policy and sustainable water resources Management.

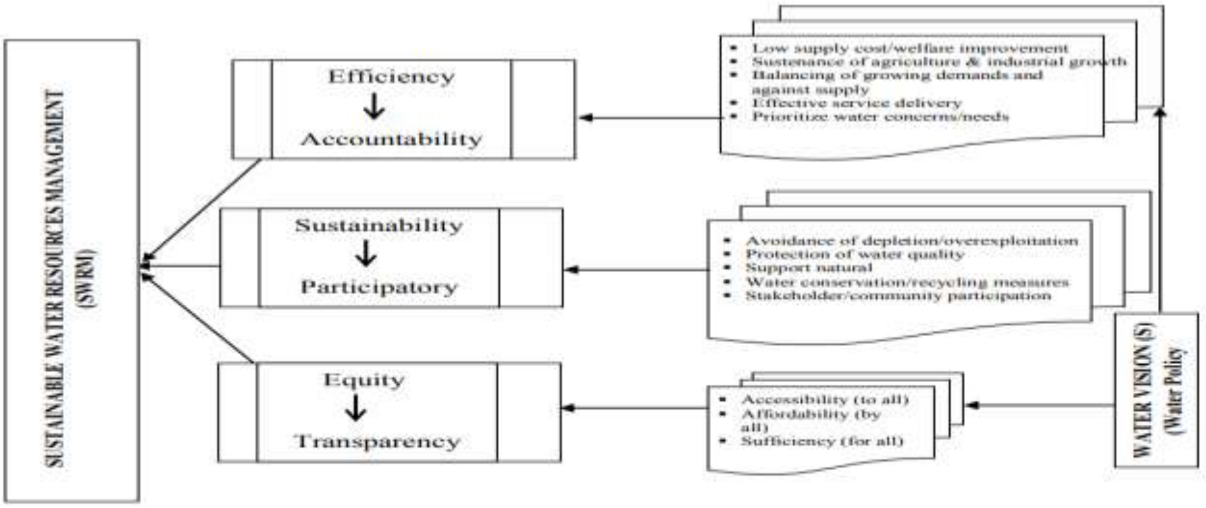

Figure 1: Components of action-driven water policy and sustainable water resources Management
Source: (Arntzen, 1999)

Water is necessary for recreational, industrial, commercial, and agricultural uses. All industrialized countries have a history of making significant investments in water infrastructure, institutions, and the ability to effectively manage water resources. WASH primarily addresses healthy living through clever control of human behaviour and waste production so that the environment and ecosystems are not adversely affected. WASH (water, sanitation, and hygiene) are essential for raising people's living standards. Better physical health, environmental protection, better educational outcomes, more convenient time management, the assurance of lives lived with dignity, and equitable treatment for men and women are just a few of the improved standards made possible by WASH. There is an alarming shortage of fundamental water, sanitation, hygiene (WASH), and waste management services in many public healthcare facilities in low- and middle-income nations. Water is essential to many facets of human endeavour, making the sustainable management of water resources essential to the growth of a community. Water is necessary for recreational, industrial, commercial, and agricultural uses. According to Grey, D., and Sadoff, C. W. (2006), all developed countries have a history of making significant investments in water infrastructure, institutions, and the ability to manage water resources effectively.

Additionally, a growing population and urbanization are placing more strain on the available water resources, resulting in competition for those resources across many sectors and limited access to water, even in regions of the nation where it is abundant (Nwankwoala, 2014; Merem et al., 2017). For humans to survive, water is a necessity. As a result, water resource managers have looked for ways to use this crucial resource throughout time while taking into consideration its uneven spatiotemporal distribution and finite nature to maximize its many positive effects on both man and the environment (Winpenny, 1994). The failure of water supply systems (including water points, wells, and boreholes) and sanitation systems has been cited as a major challenge in national government planning and evaluation efforts, as well as post-project monitoring by NGOs or scientists. The technical challenges (such as inadequate provincial planning and logistical problems) in providing basic water and sanitation services to underserved populations are being reduced on the off chance that they won't completely stall efforts to improve water and sanitation (Bayu et al., 2020). Sustainability has always been a question of whether the materials used for construction are of good quality and whether the design methods used are of high standards (Oyebode, 2022).

Many water and sanitation systems are not long-term viable and fail to take into account the population's long-term health needs. Costs, a lack of local investment and ownership, inadequate use of new facilities, and a lack of technical training for duties and maintenance have all been cited as reasons for this (Carter et al., 1999). Access to WASH is essential for sustaining life and the environment as well as for revitalizing and securing economic growth. The Nigerian government has now agreed to the new, challenging global goals for sustainable development as a result of the SDGs' approval. 60 million people lacked access to water for essential requirements in 2015. Public health is supported by water, sanitation, and hygiene (WASH) services, which also improve quality of life, environmental health, social development, and economic growth (Adesogan, 2018). Public health is supported by water, sanitation, and hygiene (WASH) services, which also improve quality of life, environmental health, social development, and economic growth. Services for WASH, which also enhance the quality of life, environmental health, social development, and economic growth, benefit public health. Numerous subtypes of translational research have developed since the middle of the 20th century in response to the need for better integration of scientific development into policy and practice. WASH development programs have aimed to reduce morbidity and mortality rates and improve service delivery; as a result, there is a strong emphasis on applied studies in this field that use a variety of approaches to support decision-making.

3.0 METHODOLOGY

The methodology used includes expert opinions, literature review and case studies. We conducted a systematic review of articles available online through a combination of search terms associated with water, sanitation, and hygiene practices, with terms related to conceptual frameworks and models. The experts are engineers and professionals in the water sector. They source from ministries, government parastatals and private establishments across various states in Nigeria. Salient projects, articles and notable questions were answered by water engineers.

The Water Resources Act of 1993, the Minerals Act of 1990, the RBDA Act of 1990, the NIWA Decree 13 of 1997, and State Water Edicts are the sole statutory legislation governing the development and management of water resources in Nigeria, according to the National Water Policy, 2004. The Water Resources Act of 1993 gives the Federal Ministry of Water Resources (FMWR) exclusive authority over the management and development of Nigeria's water resources. Table 1 presents primary water resources management statutes in Nigeria and their functions.

Table 1: Primary Water Resources Management Statutes in Nigeria and their Functions

Statute	Year Enacted	Description concerning water resources development
The Water Resources Act	1976, 1993	The act established the FMWR and gave the ministry the responsibility of overseeing water resources management in the country, providing water for various uses, collecting basic hydrological data, and coordinating the activities of all other water resources agencies.
Minerals and Mining Act	1990	The act empowers the Mining Cadastre Office (MCO) to issue water use permits, among other functions.
The River Basin Development Authority (RBDA) Act	1990	The act established 12 RBDAs and empowered them to develop and manage surface and groundwater resources within their jurisdiction to promote agricultural development and provide domestic water supply.
Nigeria Hydrological Services Agency (NIHSA) Act	2010	The act enables NIHSA to collect and store accurate and reliable hydrological and hydrogeological data on the status and trends of water resource development in the country.
The Nigerian Meteorological Agency (NIMET) Act	2003	The act established NIMET as an organ to advise the government on meteorological issues, issue weather and climate forecasts, collect, collate and disseminate meteorological data, and encourage meteorological research to support socio-economic development in the country.
State Water Edicts	Diffuse	Each state including the FCT has policies uniquely tailored to meet the water needs of their respective localities. These policies are implemented without prejudice to the Water Resources Act.
The National Inland Waterways Authority (NIWA) Act Cap N47	2004	The act empowers NIWA to supervise facilities and indigenous technical and managerial human resources needed to meet the challenges of modern inland waterways transportation.

Through several smaller ministries and parastatals, the Federal Ministry of Water Resources controls the development and administration of all water resources in the nation. Sectoral interests and a lack of coordination among stakeholders obstruct the effective management of water resources, which leads to overuse and waste of water resources as well as environmental contamination that harms vital ecosystems. Additionally, a growing population and urbanization are placing additional strain on the existing water resources, resulting in competition for those resources across many sectors and limited access to water, even in regions of the nation where it is abundant. Figure 2 presents components of SDG 6: Ensure Availability and Sustainable Management of Water and Sanitation for All.

Figure 2: Components of SDG 6: Ensure Availability and Sustainable Management of Water and Sanitation for All

Source: (Venkatesh and Velkennedy, 2023)

4.0 RESULTS AND DISCUSSIONS

Regionally, the north-central (NC), northeastern (NE), and north-western (NW) zones of Nigeria have improved access to drinking water by respective percentages of 52.2%, 27.3%, and 42.5%, as opposed to 72.7% and 54.1% in the SW and SE zones, respectively. However, compared to 55.5% and 55.0% in the SE and SW zones, respectively, 29%, 34.4%, and 34.1% of people in the NC, NE, and NW regions use enhanced sanitation (NBS, 2007). According to the data, some regions and locations (such as the SW, NW, and metropolitan areas) have relatively greater access to water supplies and sanitary facilities than others (Akpabio, 2012a). On the other hand, it's oddly the case that some regions (SE and SS) perform better in terms of sanitation and water availability than others. Table 2 presents the evaluation of Regional Indicators and Access to Water and Sanitation Related Services.

Table 2: Evaluation of Regional Indicators and Access to Water and Sanitation-Related Services

Indicators	NE	NW	NC	SE	SW	SS	National	Rural	Urban
Safe water source (%)	30.7	50.64	48.9	40.8	73.5	45.9	51.4	40.4	73.4
Safe sanitation (%)	45.4	61.6	46.6	69.5	62.1	55.0	57.6	47.6	77.0
Improved waste disposal (%)	6.2	10.7	8.8	9.0	36.0	13.2	16.1	4.8	37.9
Incidence of diarrhea (%)	5.5	4.8	5.5	5.7	4.1	4.1	4.9	5.1	4.3
Water treatment before drinking (%)	4.6	7.5	14.1	11.4	20.4	5.8	11.3	14.5	9.7
Health access (%)	48.4	55.3	61.1	37.1	73.1	45.9	55.1	47.8	70.9
Poverty incidence (%)	72.2	71.2	67.0	26.7	43.0	35.1	54.4	63.3	43.2

(Source: Akpabio, 2012a).

Safe and reliable provision of water is essential for individual welfare and community development. Water is an indispensable natural resource for the survival and well-being of human being (Oyebode and Muzammil, 2019). Only when accurate information is obtained regarding the anticipated frequency, nature, and severity of hazardous events in a region can natural catastrophes be mitigated effectively. There is a significant geographical component to many sorts of information that are required in natural disaster management (Oyebode et al., 2022). Table 3 also presents a brief summary of Nigeria's budget allocation for the past ten years (₦ billion).

Table 3: Summary of Nigeria's budget allocation for the past ten years (₦ billion)

Year	Total Expenditure (Billion Naira)	Allocation to Water Supply (Billion Naira)	allocation to Water supply (USD million)	Population (million)	Per capita/per annum investment (cents)	Percentage of Water Supply to Total Expenditure (100%)
2002	724.5	5.5	34.4	129	8	0.76
2003	921.2	6.4	40.0	133	9	0.69
2004	1125.1	18.5	115.6	136	30	1.64
2005	1478.6	26.2	163.8	139	35	1.77
2006	1586.8	29.7	185.6	143	39	1.87
2007	2116.1	22.7	141.9	146	29	1.07
2008	3107.8	28.0	175.0	150	35	0.90
2009	2776.9	47.7	298.1	154	58	1.72
2010	3266.2	37.5	234.4	158	46	1.15
2011	3542.0	20.4	125.0	162	23	0.58

Source: (Samuel *et al.*, 2020)

International aid has been a significant source of finance for Nigerian water projects in addition to national financial allocations. However, given that Nigeria continues to be listed as one of the nations with a water shortage, this has also not remedied the problem of water provision. The administration of water resources in Nigeria is currently organized schematically in Figure 3.

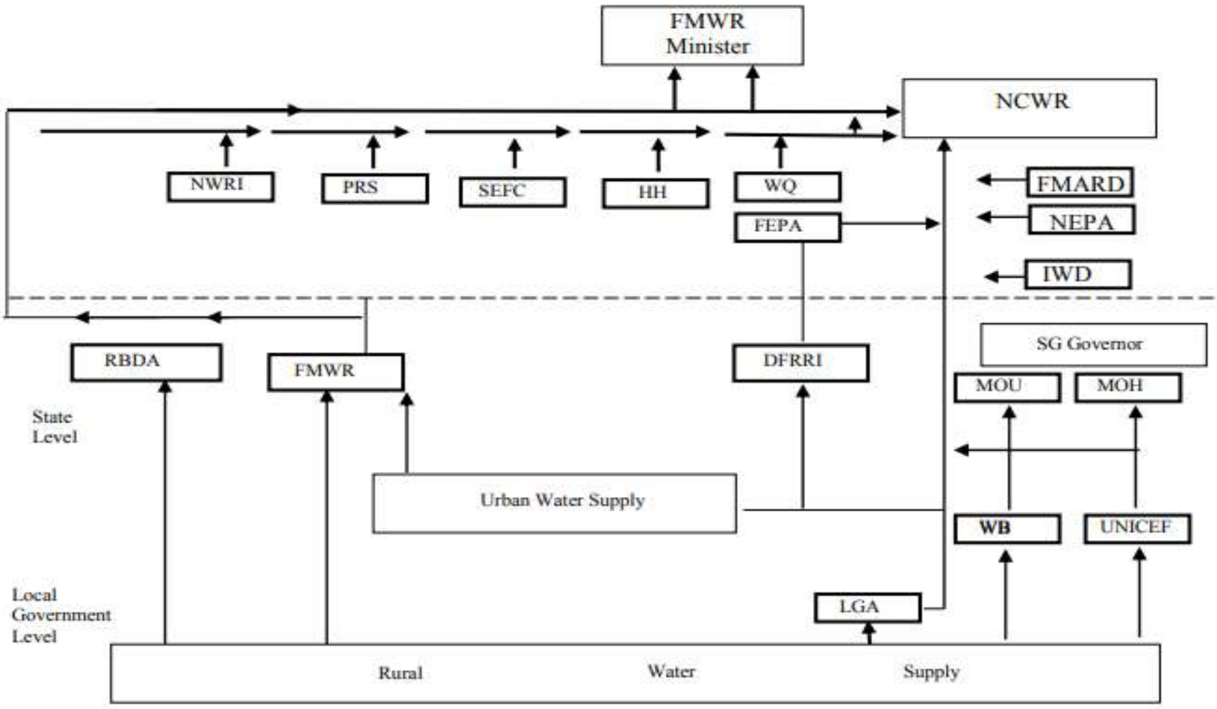

Figure 3: Schematic Representation of the present Organization of Water Resources Management in Nigeria.

LEGEND FMWR = Fed. Min. of Water Resources SG = State Governments NWRI = National Water Resources Institute MOU = Min. of Utilities PRS = Planning, Research and Statistics MOH = Min. of Health SEFC = Soil Erosion/Flood Control HH = Hydrogeology and Hydrology WB = Water Boards WQ = Water Quality LGA = Local Govt. Area NCWR = National Council on Water Resources FEPA = Fed. Env. Prot. Agency RBDA = River Basin Dev. Authority ADP = Agric. Dev. Project IWD = Inland Waterways Dept.

The sanitation management chain in Figure 8 as suggested by UNICEF can assist in reducing the unsafe discharge of faecal wastes into the environment. This will include promoting and supporting a range of technologies and systems from containment to reuse and disposal, but will generally not include support for large sewerage systems. The focus will be on those parts of the management chain that particularly impact the poorest and most vulnerable people, and that provide the largest return in terms of health and non-health benefits. Figure 4 presents the Sanitation Management Chain. Figure 5 also presents the context-specific sanitation programming response. Figure 6 presents typical borehole facilities provided for a community in Nigeria.

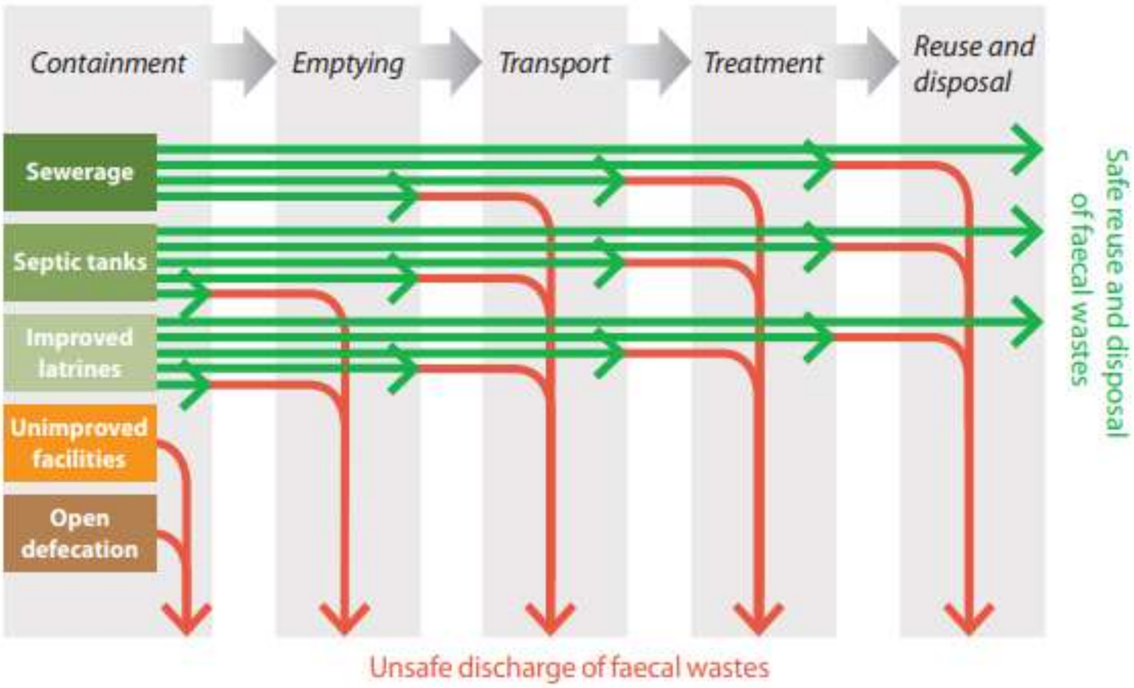

Figure 4: Sanitation Management Chain
Source: (Khan *et al*., 2017)

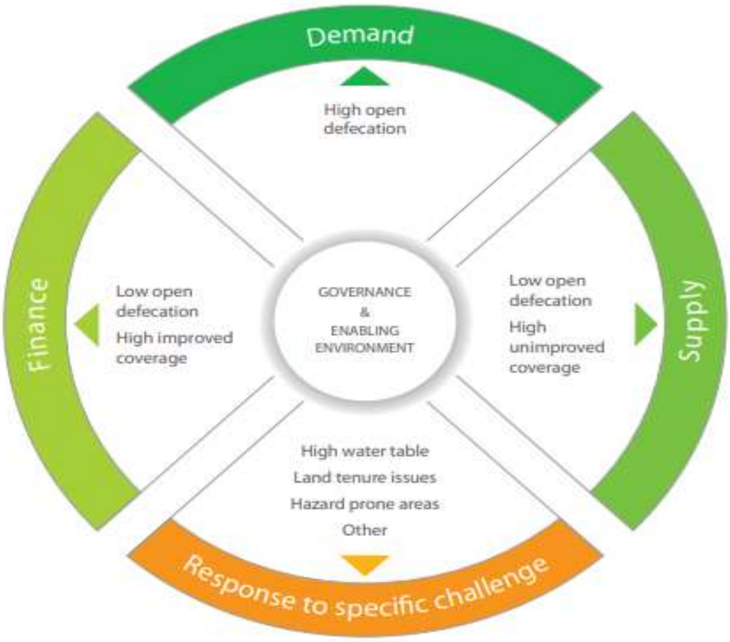

Figure 5: Context-specific Sanitation Programming Response
Source: (Ricau *et al.*, 2023)

Figure 6: Typical borehole facilities provided for a community in Nigeria

Source: (Oyebode, 2022)

A basic requirement, water has significant effects on industrialization, development, food production, sanitation, and hygiene. The Sustainable Development Goal (SDG) No. 6 aims to supply all of the world's water needs by 2030. Despite having more than 200 cubic kilometres of surface water and a huge pool of untapped underground water, more than 60 million Nigerians lack access to potable water. In certain crucial areas, particularly in the north of the country, the demand for water resources has also led to conflicts and violence. Sanitation and access to clean water are fundamental human rights. Meeting this demand has a direct impact on people's health and well-being, which in turn affects their capacity to work productively. Groundwater is a significant issue in both rural and urban areas of emerging nations. Water governance in Nigeria will greatly benefit from the development of dependable institutions that can quickly adjust to changes in the water sector and are attentive to the demands of their host communities. These institutions will require the proper equipment and technical capabilities to function properly. To make informed decisions, these organizations will need to be able to collect and maintain crucial hydrological data. Such data are necessary for efficient management and to ensure that the nation's water resources are used responsibly. Organizations like NIMET, NIHSA, and the RBDAs, who are in charge of gathering information on topics like rainfall, stage height, and river discharge, rarely carry out their responsibilities correctly to ensure sustainability in the development of these businesses.

5.0 CONCLUSIONS

The integration of knowledge, policies, approaches, and decision-making is a major force behind the adoption of water, sanitation, and hygiene (WASH) practices in every nation on Earth. Information, tactics, and decision-making can be efficiently blended and applied throughout Nigeria's numerous geopolitical zones. Along with the contribution of engineers to design and construction, the value of WASH is crucial in enhancing both environmental and human health. Fundamentally crucial factors are a nation's socioeconomic growth, capacity to sustain life and the environment, and accessibility to WASH. In conclusion, Nigeria has a lot of work to do before 2030. Nigeria has established legislation, like the National Action Plan (NAP), to resuscitate the WASH industry, but it is, by all accounts, a little late. In both urban and rural areas, a sizable segment of the population continues to fight to guarantee that everyone has access to water. Sound water management is crucially important for achieving SDG 6. Rural communities need to take water and sanitation seriously because they are necessary for human survival. Every citizen has a right to access clean water and adequate sanitation, and only concerted efforts can guarantee their ongoing availability. Every year, billions of people are directly impacted by underinvestment and poor maintenance in water management and vital infrastructure for sanitation, water treatment, and storage, leaving them without access to clean, safe, and healthy water. The role of WASH in peacebuilding, disaster risk reduction, climate change adaptation, and environmental protection is essential to creating resilience. The progress accomplished by communities, governments, and development partners could be halted by disasters, armed conflict, and other shocks. The negative consequences of climate change and environmental degradation increase these risks. To increase both sector system resilience and community resilience, program designs must take hazards into account.

6.0 RECOMMENDATIONS

The paper recommends the following:

i. Every effort aimed at the integration of knowledge, policies, approaches, and decision-making in water, sanitation, and hygiene (WASH) practices should be supported by the government and everyone in the country.

ii. Continuous sensitization on the need for clean water and proper sanitation. Also, sensitization on how to maintain public facilities and infrastructures as lack of maintenance has rendered a lot of these infrastructures useless.

iii. Decentralized/small-scale systems, participatory planning, innovative financing techniques, water conservation and reuse, and the development of laws and policies that serve as the cornerstone for successful WASH techniques are all viable alternatives to conventional sewer systems for sanitation and hygiene.

iv. To ensure that novel solutions are developed at the proper scale to meet specific needs and provide opportunities for the acquisition of knowledge and skills, personal experiences of efficacy, and the ability to identify and solve problems, sustainable and equitable WASH management requires research that goes beyond raising awareness to fully engage, at the grassroots level, with communities.

v. Policies for WASH services should be incorporated into the curriculum in schools and current national regulations for environmental health in healthcare institutions. There is a need for policies at the national, regional, district, and health-setting levels for the effective governance and management of WASH services and standards.

vi. Considering the range of livelihoods, social, cultural, and economic influences, participatory design and co-design are potential approaches to addressing WASH concerns and issues from the viewpoints of communities and co-creating locally meaningful solutions.

vii. It is necessary to strengthen data management frameworks, capacity building as well as the local and national authorities' ability to administer and control sanitation systems. To enhance local water governance, governments at all levels must collaborate with the major WASH stakeholders. The government should sufficiently avail funds to facilitate the availability of water and sanitation services and be adequately monitored to ensure funds are efficiently used for the intended purpose.

REFERENCES

Adesogan, S. Assessment of Sustainable Development Goals 6.1 and 6.2 in rural small communities of Ondo State, Nigeria. *J. Glob. Ecol. Environ.* 2018, *8*, 104–111.

Arnold B, Colford J: Treating water with chlorine at point-of-use to improve water quality and reduce child diarrhoea in developing countries: A systematic review and meta-analysis. Am J Trop Med Hyg. 2007, 76 (2): 354-364.

Bayu, T.; Kim, H.; Oki, T. Water Governance Contribution to Water and Sanitation Access Equality in Developing Countries. *Water Resour. Res.* 2020, *56*, e2019WR025330.

Brown J., Cairncross S., Ensink J. H. J. Water, sanitation, hygiene and enteric infections in children. *Archives of Disease in Childhood*. 2013;98(8):629–634. doi: 10.1136/archdischild-2011-301528.

Carter, R.C.; Tyrrel, S.F.; Howsam, P. The Impact and Sustainability of Community Water Supply and Sanitation Programmes in Developing Countries. *Water Environ. J.* 1999, *13*, 292–296.

Clasen T, Schmidt WP, Rabie T, Roberts I, Cairncross S: Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis. BMJ. 2007, 334 (7597): 782-10.1136/bmj.39118.489931.BE.

Clasen TF, Bostoen K, Schmidt WP, Boisson S, Fung IC, Jenkins MW, Scott B, Sugden S, Cairncross S: Interventions to improve disposal of human excreta for preventing diarrhoea. Cochrane Database Syst Rev. 2010, CD007180-6.

Grey, D., and Sadoff, C. W. (2006). Water for growth and development: Thematic Documents of the IV World Water Forum. *Comision Nacional del Agua: Mexico City*.

Islam M., Ercumen A., Ashraf S., Rahman M., Shoab A. K., Luby S. P. Unsafe disposal of faeces of children < 3 years among households with latrine access in rural Bangladesh: association with household characteristics, fly presence and child diarrhoea. *PLoS One.* 2018;13(4) doi: 10.1371/journal.pone.0195218.

Kaoje A., Yahaya M., Raji M., Hadiza S., Sylvanus A., Musa T. Drinking water quality, sanitation and hygiene practices in a rural community of Sokoto state, Nigeria. *International Journal of Medical Science and Public Health.* 2019;7(11):p. 1. doi: 10.5455/ijmsph.2019.0824324102018.

Khan, S. M., Bain, R. E., Lunze, K., Unalan, T., Beshanski-Pedersen, B., Slaymaker, T., ... and Hancioglu, A. (2017). Optimizing household survey methods to monitor the Sustainable Development Goals targets 6.1 and 6.2 on drinking water, sanitation and hygiene: A mixed-methods field-test in Belize. *PloS one*, *12*(12), e0189089.

Kurui E. J., Ogendi G. M., Moturi W. N., Nyawanga D. O. *The Relevance of Hygiene to Health Developing Countries.* London, UK: IntechOpen; 2019. Household water handling practices in the arid and semi arid lands in Kenya.

McGuiness S. L., O'Toole J., Barker S. F., et al. Household water storage management, hygiene practices and associated drinking water quality in rural India. *Environmental Science and Technology.* 2020, 54(8):4963–4973. doi: 10.1021/acs.est.9b04818.

Merem, E. C., Twumasi, Y., Wesley, J., Isokpehi, P., Shenge, M., Fageir, S., ... and Nwagboso, E. (2017). Analyzing water management issues using GIS: the case of Nigeria. *Geosciences*, *7*(1), 20-46.

Miner C. A., Dakhin A. P., Zoakah A. I., Afolaranmi T. O., Envuladu E. A. Household drinking water; knowledge and practice of purification in a community of Lamingo, Plateau state, Nigeria. *E3 Journal of Environmental Research and Management.* 2015;3:230–236.

Ngene, B. U., Nwafor, C. O., Bamigboye, G. O., Ogbiye, A. S., Ogundare, J. O., and Akpan, V. E. (2021). Assessment of water resources development and exploitation in Nigeria: A review of integrated water resources management approach. *Heliyon*, *7*(1).

Nwankwoala, H. O. (2014). Problems and options of integrated water resources management in Nigeria: administrative constraints and policy strategies. *International Letters of Natural Sciences*, (09).

Omarova A., Tussupova K., Hjorth P., Kalishev M., Dosmagambetova R. Water supply challenges in rural areas: a case study from Central Kazakhstan. *International Journal of Environmental Research and Public Health.* 2019, 16(5):p. 688. doi: 10.3390/ijerph16050688.

Orimoloye E. O., Amadi C. O. A., Amadi A. N., et al. Assessment of water sanitation and hygiene practices in Ibadan. *International Journal of Research.* 2015;2(2):94–100.

Peal A, Evans B, van der Voorden C: Hygiene and Sanitiation Software: An Overview of Approaches. In. 2010, Geneva, Switzerland.

Soboksa N. E., Hailu A. B., Gari S. R., Alemu B. M. Water supply, sanitation and hygiene interventions and childhood diarrhoea in Kersa and Omo Nada districts of Jimma Zone, Ethiopia: a comparative cross-sectional study. *Journal of Health, Population and Nutrition*. 2019;38(1) doi: 10.1186/s41043-019-0205-1.

Oyebode, O. J., and Muzammil, M. (2019). Strategic evaluation of cost and benefit analysis of a rural water supply project: a case study of Dei-Dei community in Abuja, Nigeria. *Journal of Water Resources Engineering and Management*, *6*(2), 11-28.

Oyebode, O. J., Oyebode, F. A., and Elesa, B. L. (2022). Flood Risk Assessment and Disaster Management through Data Applications and Engineering Interventions.

Oyebode, O. J. (2022). Design of water retaining structures and application of environmental engineering for a sustainable environment. In *Advanced Manufacturing in Biological, Petroleum, and Nanotechnology Processing: Application Tools for Design, Operation, Cost Management, and Environmental Remediation* (pp. 287-299). Cham: Springer International Publishing.

Ricau, M., Ali, C., Yates, T., String, G., and Lantagne, D. (2023). Developing context-specific water, sanitation and hygiene guidance for National Cholera Plans: Qualitative inputs. *PLOS Water*, *2*(6), e0000087.

Samuel, U. E., Abner, I. P., Inim, V., and Ededem Jack, A. (2020). SARS-CoV-2 Pandemic on the Nigerian educational system. *International Journal of Management*, *11*(10).

Sridhar, M. K. C., and Adejumo, M. (2020). Water, sanitation and hygiene (WASH) disease prevention and control in low resource countries. *Sustainable Water Engineering. Edited by S. Charlesworth. Elsevier*, 99-120.

Venkatesh, B., and Velkennedy, R. (2023). Formulation of citizen science approach for monitoring Sustainable Development Goal 6: Clean water and sanitation for an Indian city. *Sustainable Development*, *31*(1), 56-66.

Paper 02

Strategies for Effective Utilization of Hydrological Models in Water, Sanitation, and Hygiene (WASH) Programs

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ABSTRACT: The relationship between Hydrological models with Water, Sanitation, and Hygiene (WASH) is indirect but interconnected. To ensure effective planning and implementation of WASH programs, it is essential to have a comprehensive understanding of the hydrological processes that govern water resources management, sanitation planning, and hygiene promotion. This paper highlights key strategies to maximize the utility of hydrological models in the WASH context, including stakeholder engagement, data integration, capacity building, and decision support system integration. It emphasizes the need for collaboration between researchers, policymakers, and practitioners to ensure that models are tailored to specific program objectives and local contexts. The paper provides insights into the benefits of these strategies and offers practical recommendations for integrating hydrological modeling tools into WASH initiatives.

Keywords: hydrological model; Nigeria; WASH; strategies; decision support system

1.0 INTRODUCTION

WASH initiatives encompass a range of interventions aimed at ensuring access to clean water, adequate sanitation facilities, and promoting good hygiene practices (Giné-Garriga et al., 2021). The SDGs, adopted by the United Nations in 2015, include a specific goal (Goal 6: Clean Water and Sanitation) that focuses on ensuring availability and sustainable management of water and sanitation for all (Le Blanc, 2015). However, the successful achievement of this goal requires a comprehensive and integrated approach that combines WASH initiatives with accurate and reliable decision-support tool such as hydrological modeling. On the other hand, hydrological modeling involves the use of mathematical and computational tools to simulate and analyze the movement of water within a specific hydrological system (Singh, 2015). It provides crucial insights into water availability, quality, and distribution, thereby, prudent for supporting evidence-based decision-making in WASH initiatives.

Despite the interdependence between WASH interventions and hydrological systems, there is often a lack of coordination and collaboration between the stakeholders involved (Akpabio & Rowan, 2021). This results in ineffective planning and implementation of WASH projects, inefficient utilization of water resources, and limited progress towards the SDG targets related to water and sanitation. The paper discusses achievable strategies for enhancing integration and utilization of hydrological modeling in the design and implementation of WASH programs with emphasis on Nigeria.

2.0 CURRENT STATE OF WASH INFRASTRUCTURE IN NIGERIA

Understanding Nigeria's WASH situation is crucial, as it is intricate and varies significantly between regions and communities. Efforts have been made by the government, NGOs, and international partners to improve the WASH infrastructure and address the challenges. In 2018, Nigeria's WASH sector was declared to be in a state of emergency due to multiple issues such as insufficient infrastructure, lack of human resources, inadequate investment, and weak regulations (Shehu & Nazim, 2022). Women and children are disproportionately affected, needing to travel long distances to fetch water, resulting in negative impacts on their well-being, school attendance, and an increased risk of gender-based violence. To address these issues, a 13-year strategy was initiated to achieve universal access to sustainable and safe WASH services by 2030, aligning with the Sustainable Development Goals (World Bank, 2019). However, a vital decision support tool, Hydrological modeling, was not adequately integrated, creating a gap that needs to be enhanced to achieve the said target.

Consequently, as the global demand for effective water management and environmental conservation intensifies, countries and regions have progressively embraced advanced hydrologic modeling tools to tackle their specific water-related challenges. Noteworthy examples include the successful implementation of the

Hydrological Information System in India, which has been instrumental in flood risk management and early warnings (Dorle & Ranade, 2021). Similarly, Australia has effectively utilized the Source modeling platform for water resource planning during periods of frequent droughts (Pittock & Connell, 2010). In the United States, hydrologic tools like HEC-HMS have been employed to support river basin management and flood risk mapping (Dotson, 2001), whereas Brazil's INPE has integrated hydrologic models with satellite data to monitor the Amazon rainforest and its hydrological processes (Pereira et al., 2014). Remarkably, China's IWHR has developed tools for flood forecasting and management, particularly along the Yangtze River (Jia, 2016). In Africa, Kenya's WRMA relies on hydrologic models to assess water resources and devise sustainable water use strategies (Ondieki, 2013).

3.0 ROLE OF HYDROLOGICAL MODELS IN WASH PROGRAMS

UNICEF's global strategy for wash 2016-2030 advocates for a climate resilient WASH (UNICEF, 2016) paving a way for innovative risk-informed framework to support water allocation, sanitation planning, and hygiene promotion strategies. Other roles may include but not limited to;

i. *Water Availability Assessment*: Models can estimate the quantity of water that can be sustainably abstracted for various uses, including drinking, sanitation, and agricultural needs. Thus, essential for identifying potential water sources for WASH projects.
ii. *Groundwater Exploration*: Models assist in characterizing aquifers, understanding groundwater flow patterns, and estimating the sustainable yield of wells. Thus, guides the selection of appropriate locations for installing hand pumps or boreholes.
iii. *Climate Change Impact Assessment*: Models help assess the potential impact of climate change on water availability, allowing WASH programs to design resilient water supply and sanitation solutions that can adapt to future conditions.
iv. *Water Quality Monitoring*: Hydrological models can also be coupled with water quality data to track the movement of pollutants and contaminants in water bodies.
v. *Flood and Drought Management*: Hydrological models provide insights into flood and drought patterns, helping WASH programs develop appropriate strategies for disaster risk reduction and water storage solutions.
vi. *Optimizing Water Allocation*: In regions facing water scarcity, hydrological models can assist in optimizing water allocation between various sectors, to ensures that adequate water is available for WASH activities, safeguarding public health and sanitation.
vii. *Infrastructure Planning and Design*: Models aid in designing water supply and sanitation infrastructure that is suitably sized to meet the needs of the target population.
viii. *Educational and Awareness Purposes*: Models can be used to visualize and communicate complex water-related data to enhance understanding and raise awareness about water resource challenges, fostering community engagement and participation in WASH programs.
ix. *Impact Assessment of WASH Projects:* Before implementing WASH projects, hydrological models can be used for impact assessment, estimating the potential benefits and environmental consequences of the interventions.

4.0 INTEGRATING HYDROLOGICAL MODELING IN WASH INITIATIVE

WASH initiatives are intricate systems with interdependent natural and human-made elements, which implies that a one-size fits all approach might not yield desired results. Consequently, to ensure long-term success in a dynamic and competitive landscape, the integration of a hydrological model into Nigeria's WASH program demands strategic alignment. Adopting a SWOT (Strengths, Weaknesses, Opportunities, Threats) strategy (Christine et. al., 2019) is proposed as a means to empower WASH programs in making well-informed decisions, optimizing resource allocation, and effectively addressing crucial water-related challenges. Below are the essential steps for seamlessly incorporating a hydrological model into the WASH program in Nigeria:

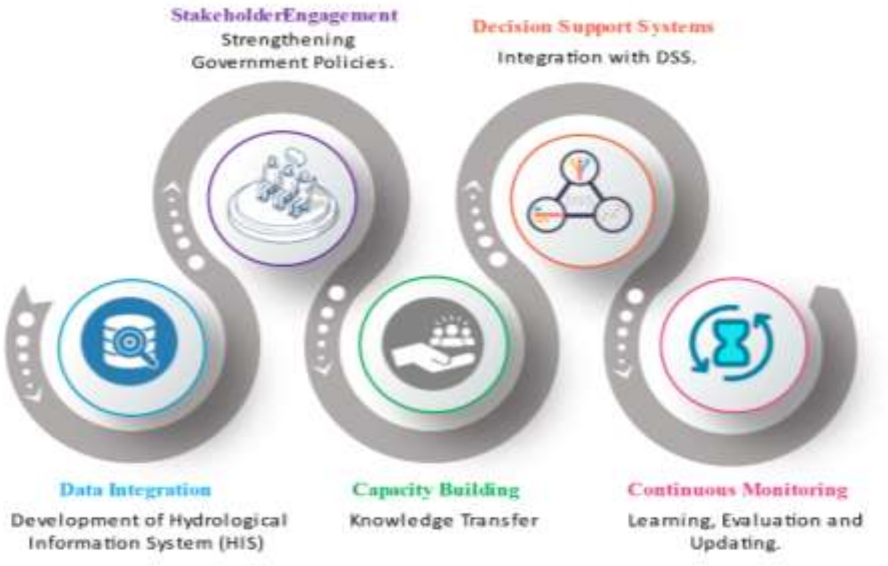

Figure 1: Strategy Nexus

4.1 DATA INTEGRATION AND QUALITY CONTROL

In Nigeria, data-driven modeling can be vital for overcoming data gaps and generating valuable insights and predictions, even with limited direct data (Wang et al., 2022). Utilizing available data from diverse sources like historical records, satellite observations, and proxy indicators, decision-makers can estimate and project important WASH parameters. However, the process of integrating heterogeneous data can be complex and time-consuming, requiring significant resources and technical expertise (Tamayo et. al., 2018). Nigeria may face challenges due to limited data collection infrastructure in certain regions, potentially leading to gaps in the analysis (Ekeu-wei, 2018). To address this, continuous efforts to improve data collection and validation are essential to ensure accuracy and reliability in modeling approaches.

Globally, data integration for hydrologic modeling has been highly successful, with various countries implementing effective systems. For example, Southeast Asia's Mekong River Commission (MRC) have utilized integrated data to improve flood forecasting and water resource management (Sawangphol et. al., 2001). Countries like Australia (Ward et. al., 2020), Bangladesh (Ayeb-Karlsson et. al., 2016), and China (Shao et. al., 2016) have also leveraged data integration to enhance flood preparedness, drought management, and ecological protection.

To advance water resource management and flood forecasting in Nigeria through data integration, key steps can be taken. Establishing a National Hydrological Monitoring and Data Integration Program that gathers data from various sources is essential to create a comprehensive database; Investment in advanced hydrologic modeling tools and collaboration with international organizations and neighboring countries to enhance accuracy and scope; Promoting public-private partnerships to harness data from different sources and raising awareness among government agencies and stakeholders about the benefits of data integration are vital for successful implementation. These efforts will strengthen Nigeria's ability to respond to water-related challenges and improve resilience to hydrological events.

4.2 STAKEHOLDER ENGAGEMENT

Stakeholder engagement is a key strategy for ensuring the effective utilization of hydrological models in WASH programs. Hydrological systems are complex and interconnected, often transcending geographical boundaries, necessitating a collective effort from diverse stakeholders including government agencies, local communities, water management authorities, non-governmental organizations, and academic institutions (Weber et. al., 2019). This participatory decision-making process ensures alignment with real-world needs and enhances acceptance and application in sustainable water management strategies in Nigeria. However, there are challenges, such as bureaucratic processes, inadequate funding, and policy implementation issues, that can hinder the integration of hydrological modeling in WASH programs. Nevertheless, Countries like Bangladesh (Azam & Sarker, 2013) provides an example of successful integration by involving various organizations and local communities, the models have been fine-tuned to consider factors like traditional water management practices, land-use patterns, and climate change impacts, resulting in more relevant and sustainable solutions.

Adapting the strategy for Nigeria may involve a participatory approach, capacity-building initiatives, and a sustainable governance structure. These measures will empower stakeholders, foster collaboration, and ensure successful implementation of inferences derived from hydrological modeling.

4.3 CAPACITY BUILDING

Capacity building is an essential aspect that must be prioritized to ensure the long-term success and sustainability of Nigeria's WASH program. This entails enhancing the skills and knowledge of water resource management professionals, improving data collection and management methods, fostering collaboration among various agencies, involving local communities, and reinforcing policy and governance structures to effectively utilize hydrological modeling tools (Fletcher et. al., 2022). Accomplishing this requires organizing workshops, training sessions, and knowledge-sharing platforms, as well as implementing monitoring and evaluation systems. Moreover, effective collaboration with research institutions and government agencies can help tackle challenges faced by Nigeria's WASH sector, such as population growth, limited access to safe drinking water, inadequate sanitation facilities, and poor hygiene practices, which often lead to waterborne diseases and other health problems. Furthermore, there are disparities in WASH services between rural and urban areas, with rural communities being more underserved (Anthoni, 2021).

By placing emphasis on capacity building, the WASH program can reinforce its technical foundation, promote sustainable water resource management, and enable informed decision-making based on reliable hydrological modeling practices.

4.4 DECISION SUPPORT SYSTEM

The development of a decision support system (DSS) that leverages the outputs generated from a sophisticated hydrological model holds significant promise for enhancing decision-making processes within the WASH program. Successful implementations of this approach have been observed globally. For instance, in flood-prone countries like the Netherlands, the government has successfully integrated advanced hydrological models into their DSS. This integrated system offers real-time data on water levels, flood predictions, and potential impact areas, enabling authorities to swiftly carry out evacuation and relief efforts (Levy et. al., 2016).

In the context of Nigeria, where water scarcity and waterborne diseases are prevalent (Ishaku et. al., 2011), incorporating hydrological modeling into the WASH program's DSS can prove beneficial in optimizing water distribution, identifying vulnerable areas, and devising effective sanitation measures. By embracing this integration, Nigeria's WASH program can enhance its efficiency, adaptability, and resilience in addressing water-related challenges, ultimately improving the overall well-being and health of its population.

4.5 CONTINUOUS MONITORING AND UPDATING

Adapting a continuous monitoring strategy will ensure the accuracy and dependability of hydrological models, particularly in areas where environmental conditions change rapidly or due to human influences like urbanization and climate change.

A noteworthy example of successful global practice of the strategy is the European Flood Awareness System (EFAS), which combines real-time data from social media and monitoring stations with updated meteorological forecasts to issue early flood warnings across Europe. EFAS consistently updates its models by incorporating new data, leading to enhanced model performance over time. Real-time monitoring and adaptation are crucial for reliable flood forecasts, enabling prompt responses and mitigating the impacts of flooding on communities and infrastructure (Lorini et. al., 2019).

In the context of Nigeria, several measures can be recommended to improve hydrological modeling. Firstly, significant investments should be made in establishing and maintaining a comprehensive and well-distributed network of hydrological monitoring stations. These stations must capture relevant parameters such as rainfall, streamflow, groundwater levels, and water quality. Secondly, the integration of modern technologies like remote sensing and satellite data can supplement ground-based measurements, providing a more comprehensive dataset for modeling purposes. Lastly, promoting interagency collaboration is vital to pool resources, expertise, and data, thus enhancing the effectiveness of hydrological modeling initiatives. Ultimately, this evidence-based approach will contribute to the development of robust water management policies and regulations, enhancing water security, and the overall well-being of Nigeria's population.

5.0 CONCLUSION

Effective utilization of hydrological models in WASH programs in Nigeria, holds immense potential to revolutionize water resource management and enhance the overall success of WASH initiatives in the country. By leveraging these strategies, WASH programs can benefit from critical insights into water availability, quality, and distribution, enabling them to design targeted interventions and optimize resource allocation.

Additionally, these models facilitate evidence-based decision-making, bolstering the resilience of WASH programs against climate change and other environmental challenges. Nonetheless, for this approach to realize its full impact, it demands close collaboration between researchers, policymakers, and local communities, as well as the integration of real-time data and continuous refinement of the models. By embracing such innovative methodologies, Nigeria can progress towards sustainable water management and achieve lasting improvements in public health and well-being.

REFERENCES

Akpabio, E. M., & Rowan, J. S. (2021). The political economy of coordinating water, sanitation and hygiene management policies and programmes for Nigeria. *Water International*, *46(3), 365-382*.

Anthonj, C. (2021). Contextualizing linkages between water security and global health in Africa, Asia and Europe. Geography matters in research, policy and practice. *Water Security*, *13*, *100093*.

Ayeb-Karlsson, S., Van der Geest, K., Ahmed, I., Huq, S., & Warner, K. (2016). A people-centred perspective on climate change, environmental stress, and livelihood resilience in Bangladesh. *Sustainability Science, 11, 679-694.*

Azam, M., & Sarker, T. (2013). Green tourism in the context of climate change towards sustainable economic development in the South Asian Region. *Journal of Environmental Management and Tourism (JEMT) 01 (03): 4-13.*

Dorle, P. K., & Ranade, S. D. (2021). Hydrology and Hydrological Information Systems (HIS) in India. *International Journal for Research in Applied Science & Engineering Technology (IJRASET) 9,(2).*

Dotson, H. W. (2001). Watershed modeling with HEC-HMS (hydrologic engineering centers-hydrologic modeling system) using spatially distributed rainfall. In Coping with Flash Floods (pp. 219-230). Dordrecht: Springer Netherlands.

Ekeu-wei, I. T. (2018). Evaluation of hydrological data collection challenges and flood estimation uncertainties in Nigeria. *Environment and Natural Resources Research*, *8(2), 44.*

Fletcher, S., Hadjimichael, A., Quinn, J., Osman, K., Giuliani, M., Gold, D., ... & Gordon, B. (2022). Equity in water resources planning: A path forward for decision support modelers. *Journal of Water Resources Planning and Management*, *148(7)*.

Giné-Garriga, R., Delepiere, A., Ward, R., Alvarez-Sala, J., Alvarez-Murillo, I., Mariezcurrena, V., & Jiménez, A. (2021). COVID-19 water, sanitation, and hygiene response: Review of measures and initiatives adopted by governments, regulators, utilities, and other stakeholders in 84 countries. *Science of the Total Environment*, *795*, *148789*.

Christine N., Shastri L. N. & Torsten R., (2019). Design of a SWOT Analysis Model and its Evaluation in Diverse Digital Business Ecosystem Contexts. *23rd International Conference on Knowledge-Based and Intelligent Information & Engineering Systems 1145–1154.*

Ishaku H. T, Majid R. M., Ajayi A.P., & Haruna A. (2011). Water supply dilemma in Nigerian rural communities: looking towards the sky for an answer. *Journal of Water Resource and Protection, 3. (8).*

Jia, J. (2016). A technical review of hydro-project development in China. *Engineering, 2(3), 302-312.*

Le Blanc, D. (2015). Towards integration at last? The sustainable development goals as a network of targets. *Sustainable Development*, *23(3), 176-187.*

Levy, J. K., Gopalakrishnan, C., & Lin, Z. (2016). Advances in decision support systems for flood disaster management: Challenges and opportunities. *Water Resources and Decision-Making Systems*, *81-100.*

Lorini, V., Castillo, C., Dottori, F., Kalas, M., Nappo, D., & Salamon, P. (2019). Integrating social media into a pan- european flood awareness system: A multilingual approach. *arXiv preprint arXiv:1904.10876*.

Ondieki, C. M. (2013). Hydrology and integrated water resource management for sustainable watershed management in Kenya. In Cases on the Diffusion and Adoption of Sustainable Development Practices (pp. 352-375). IGI Global.

Pereira, F. F., de Moraes, M. A., & Uvo, C. B. (2014). Implementation of a two-way coupled atmospheric-hydrological system for environmental modeling at regional scale. *Hydrology Research, 45(3), 504-514*.

Pittock, J., & Connell, D. (2010). Australia demonstrates the planet's future: water and climate in the Murray–Darling Basin. *International Journal of Water Resources Development*, *26(4), 561-578*.

Sawangphol, N., Yumuang, S., Sriburi, T., & Snidvongs, A. (2001). Real-Time Water Resource Management System in Mekong River System. *In 22nd Asian Conference on Remote Sensing, Singapore (pp. 5-9).*

Shao, W., Zhang, H., Liu, J., Yang, G., Chen, X., Yang, Z., & Huang, H. (2016). Data integration and its application in the sponge city construction of China. *Procedia Engineering*, *154, 779-786*.

Shehu, B., & Nazim, F. (2022). Clean water and sanitation for all: Study on SDGs 6.1 and 6.2 targets with state policies and interventions in Nigeria. *Environmental Sciences Proceedings*, *15(1), 71*.

Singh, V. P. (2018). Hydrologic modeling: progress and future directions. *Geoscience letters*, *5(1), 1-18*.

Tamayo-Mas, E., Bianchi, M., & Mansour, M. (2018). Impact of model complexity and multi-scale data integration on the estimation of hydrogeological parameters in a dual-porosity aquifer. *Hydrogeology Journal*, *26(6), 1917-1933*.

UNICEF, & UNICEF. (2016). Strategy for water, sanitation and hygiene 2016-2030.

Wang, J., Bretz, M., Dewan, M. A. A., & Delavar, M. A. (2022). Machine learning in modelling land-use and land cover-change (LULCC): Current status, challenges and prospects. *Science of the Total Environment*, *822, 153559.*

Ward, P. J., de Ruiter, M. C., Mård, J., Schröter, K., Van Loon, A., Veldkamp, T., ... & Wens, M. (2020). The need to integrate flood and drought disaster risk reduction strategies. *Water Security*, *11, 100070.*

Weber, N., Patrick, M., Hayter, A., Martinsen, A. L., & Gelting, R. (2019). A conceptual evaluation framework for the water and sanitation for health facility improvement tool (WASH FIT). *Journal of Water, Sanitation and Hygiene for Development*, *9(2), 380-391*.

World Bank Group. (2019). Nigeria Biannual Economic Update, April 2019: Water Supply, Sanitation and Hygiene–A Wake-up Call. *World Bank*.

Paper 03

Groundwater Modelling Of Upper Benue River Basin

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ABSTRACT: Groundwater modelling is an important tool for understanding and managing groundwater resources. In this paper, we present the groundwater modelling study of the Upper Benue River Basin in Nigeria using Modflow 6 in a Muse Graphic User Interface (GUI). The objectives of the study were to simulate the groundwater flow regime, estimate the recharge and discharge rates, and assess the potential impacts of future groundwater development on the aquifer system. We used a combination of existing data and information related to the hydrogeology of the River Basin from Agencies, literature and the fast research documents. They include geological maps, topographic maps, hydrological data, well records, and reports from previous studies, satellite imagery, and hydrological (Rainfall, recharge, and Evapotranspiration) data of 2005 to 2015; to develop the conceptual model and parameterize the model inputs. The calibration of the model was done by changing the aquifer properties of the study area until the simulated and measured groundwater levels are matched with acceptable statistical measures. The model was validated using water level data sets from 2016 to 2020. The results of the study showed that the groundwater flow regime in the Upper Benue River Basin is controlled by the topography, geology, and hydrogeological formations that have relatively low permeability and usually provide poor to moderate water yields of about 1 to 5 l/s. They vary substantially in thickness and the water table depth is usually between 60 and 165 m. Boreholes range in depth from 30 to 300m in the area. The model estimates that the recharge rate is approximately 35.7 billion cubic meters per year, while the discharge rate is about 13 billion cubic meters per year. The simulation also indicates that increasing groundwater abstraction rates beyond sustainable limits could lead to significant declines in groundwater levels and reduced aquifer storage. Overall, the study provides valuable insights into the hydrogeology of the Upper Benue River Basin and can aid in the sustainable management of the groundwater resources in the area.

Keywords: groundwater, modelling, Modflow 6, hydrogeology, recharge rate

1.0 INTRODUCTION

Groundwater is one of the most valuable resource on the surface of the earth for drinking, irrigation, and industrial purposes. It offers around one-third of the world's water usage as well as about 90% of the freshwater available to humans (Sirsat *et. al.*, 2023) . Groundwater is also an important resource for many regions in Nigeria, including the Benue River Basin. However, the sustainable management of groundwater resources requires a thorough understanding of the hydrogeology of the area. Groundwater modelling is a useful tool for developing this understanding, as it can simulate the groundwater flow regime and estimate recharge and discharge rates. JICA (2014) modelled groundwater and suggested that climate change would lead to an overall decline in recharge in Nigeria, with the high impact in the Northern Nigeria and Chad basins. Their model indicates declining in groundwater levels within the country which will leads to drying of productive boreholes.

The Benue Valley has been subdivided into two basins, the Upper and Lower Benue Basin. The subdivision is for administrative convenience. The Upper Benue Basin covers Adamawa, Taraba, Gombe, and Bauchi with an area of approximately 156,500 km².and is fed by two major tributaries of River Gongola, Kilunga and Pai to the north, from the south of river Benue are Faro and Mayo Kabi with a discharge of about 3500 m³/s. The Lower Benue basin has a catchment area of about 74,519 km² and is fed by Upper Benue and two major tributaries of River Donga, Taraba, and Katina ala (Obateru *et, al.*, 2023). The major river in the basin flows out at the confluence of River Niger and Benue in Lokoja (Figure 1). The basement complex rock underlines most areas of Adamawa and Bauchi, and it covers 40% of the river basin. The remaining part of the region is underlain by aquifers of Bima and Yolde Sandstone that have low to moderate water productivity. These formations have relatively low permeability and usually provide poor to moderate water yields of about 1 to 5 l/s. They vary substantially in thickness and the water table depth is usually between 60 and 165 m. Boreholes range in depth from 30 to 300 m. Recharge is usually directly from rainfall. In this study, we present the results of a groundwater modeling study of the Upper Benue River Basin using Modflow 6 in a Muse GUI.

Figure 1: Topographic and River system map of Benue River Basin

2.0 MATERIALS AND METHODS

A combination of existing hydrological data and information related to the hydrogeology of the River Basin from Agencies, literature, and fast research documents were used to develop the conceptual model and parameterize the model inputs. The data used include rainfall, streamflow, recharge evapotranspiration, geological maps, topographic maps, and well records from 2005 to 2015 was used to develop the conceptual model and parameterize the model inputs. The model domain was discretized into 5,000 cells, and the model was calibrated using historical groundwater level data from 2005 to 2015. The model was validated using independent water level data sets from 2016 to 2020. Two time stress domain of steady state and transient were used in the analysis. The transient time used was divided in to 24 steps.

3.0 RESULTS AND DISCUSSION

The results of the study show that the groundwater flow regime in the Benue River Basin is controlled by the topography, geology, and hydrogeology of the area. The model estimates that the recharge rate is approximately 1.5 billion cubic meters per year, while the discharge rate is about 1.3 billion cubic meters per year. The variation of groundwater level in the basin is shown in Figure 2.

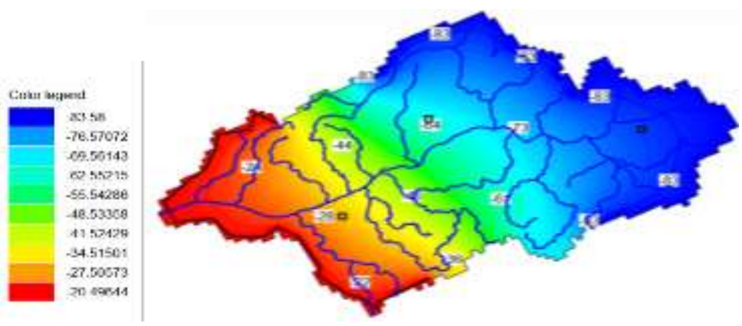

Figure 2: The variation of groundwater level in the basin.

The volume budget results for the entire groundwater model at the end of the transient analysis are shown in Table 1, The cumulative total volume of water from rivers, and rainfall recharge is 97.7 Mm^3/day and the model result indicate 0(zero) perccent descripancy.

TABLE 1: VOLUME BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 24, STRESS PERIOD 2 TRANSIENT

CUMULATIVE VOLUME L**3		RATES FOR THIS TIME STEP L**3/T		PACKAGE NAME
IN:		IN:		
STO-SS =	5.5370E-02	STO-SS =	7.2680E-11	STORAGE
STO-SY =	4.0796E-04	STO-SY =	3.5510E-13	STORAGE
WEL =	3.5000E-04	WEL =	0.0000	WEL-1
DRN =	0.0000	DRN =	0.0000	DRN-1
RIV =	97571624.6039	RIV =	1129.2884	RIV-1
RCH =	105223.1357	RCH =	1.2178	RCH-1
EVT =	0.0000	EVT =	0.0000	EVT-1
CHD =	26547.6344	CHD =	0.3072	CHD-1
TOTAL IN =	97703395.4301	TOTAL IN =	1130.8134	
OUT:		OUT:		
STO-SS =	12.2336	STO-SS =	6.6483E-11	STORAGE
STO-SY =	8.6750E-02	STO-SY =	0.0000	STORAGE
WEL =	410.4050	WEL =	4.7500E-03	WEL-1
DRN =	37797.8168	DRN =	0.4375	DRN-1
RIV =	0.0000	RIV =	0.0000	RIV-1
RCH =	0.0000	RCH =	0.0000	RCH-1
EVT =	0.6840	EVT =	7.9167E-06	EVT-1
CHD =	97665275.7236	CHD =	1130.3712	CHD-1
TOTAL OUT =	97703496.9497	TOTAL OUT =	1130.8134	
IN - OUT =	-101.5196	IN - OUT =	-3.9325E-08	
PERCENT DISCREPANCY =	-0.00	PERCENT DISCREPANCY =	-0.00	

The comparison between observed and modeled groundwater depth during the model calibration and validation is shown in Figure 3. The Nash-Sutcliffe coefficient of efficiency E, was used to assess the performance of the model (Equation 1).

$$E = \frac{\sum(y_i - \bar{y})^2 - \sum(x_i - y_i)^2}{\sum(y_i - \bar{y})^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where y are the observed values and x are the modelled values. The maximum values of E is 1. A value of zero indicates that the model is only as good as using the mean of the observations. Results were considered acceptable if $E \geq 0.8$. The value of efficiency of this model is 0.84.

The results of this study provide valuable insights into the hydrogeology of the Upper Benue River Basin and can aid in the sustainable management of the groundwater resources in the area. The study highlights the importance of considering the impacts of future groundwater development on the aquifer system and the need for sustainable management practices. The simulation also indicates that increasing groundwater abstraction rates beyond sustainable limits could lead to a significant decline in groundwater levels and reduced aquifer storage. Furthermore, the study demonstrates the usefulness of Modflow 6 in groundwater modeling studies, particularly when coupled with a user-friendly interface such as Muse GUI.

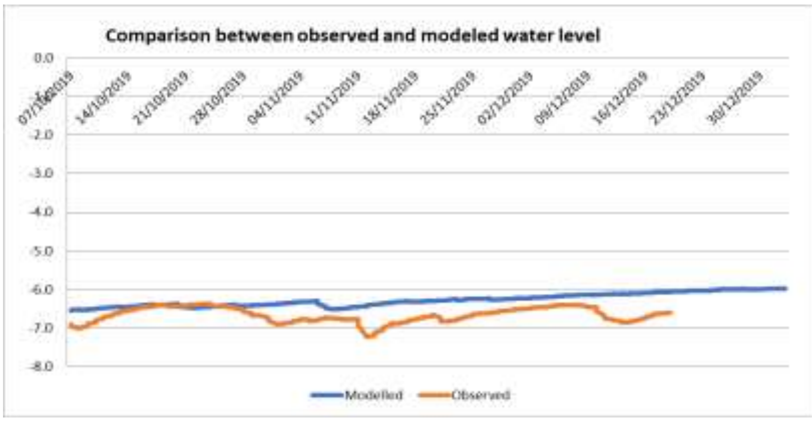

Figure 3: Comparison between observed and modeled water level

4.0 CONCLUSION

In conclusion, this study presents the results of a groundwater modeling of the Benue River Basin in Nigeria using Modflow 6 in a Muse GUI. The study highlights the importance of groundwater modeling in understanding and managing groundwater resources. The results of the study provide important information on the groundwater flow regime, recharge and discharge rates, and the potential impacts of future groundwater development on the aquifer system. The study also emphasizes the need for sustainable management practices to ensure the long-term availability of groundwater resources. Overall, the results of this study can aid in the sustainable management of groundwater resources in the Upper Benue River Basin, and similar studies can be applied to other regions to improve our understanding of groundwater resources and support sustainable management practices.

REFERENCES

Adejuwon, J. O., & Adelakun, M. A. (2012). Physiochemical and bacteriological analysis of surface water in Ewekoro local government area of Ogun state, Nigeria: A case study of Lala, Yobo and Agodo Rivers. *International Journal of Water Resources and Environmental Engineering, 4(3): 66-72.*

Adelana, S. M., & Macdonald, A. M. (2008). Groundwater research issues in Africa. In Applied groundwater studies in Africa (pp. 11-18). CRC Press. Adelana, S., & MacDonald, A. (Eds.). (2008). *Applied Groundwater Studies in Africa: IAH Selected Papers on Hydrogeology, Volume 13 (Vol. 13).*

Adesina, F. A., & Odekunle, T. O. (2011). Climate change and adaptation in Nigeria: Some background to Nigeria's response–III. *In International Conference on Environmental and Agriculture Engineering (Vol. 15, No. 2, pp. 146-154).*

Bello, I. E., & Ogedegbe, S. O. (2015). Geospatial analysis of flood problems in Jimeta Riverine community of Adamawa State, Nigeria. *Journal of Environment and Earth*, 5(12): 32-45.

Brown, J. D., Demargne, J., Seo, D. J., & Liu, Y. (2010). The Ensemble Verification System (EVS): A software tool for verifying ensemble forecasts of hydrometeorological and hydrologic variables at discrete locations. *Environmental Modelling & Software, 25(7): 854-872.*

Ezekiel, Y., Tukur, A. L., & Mubi, A. M. (2015). Morphometric characteristics of selected fluviatile lakes in the Upper Benue Valley area of Adamawa state, Northeastern Nigeria. *Journal of Geography and Regional Planning, 8(3), 56-64*

JICA (2014). The project for review and update of Nigeria national water resources master plan, vol 2. Japan *International Cooperation Agency (JICA report)*

Obateru, R. O., Ogunkoya, O. O., & Ajayi, D. D. (2023). Water availability in a Nigerian sub-catchment of River Niger and its implications for food security. *African Geographical Review, 42(2), 157-169.*

Sirsat, S. K., Sonar, M. A., Wanjarwadkar, K. M., & Kadam, V. B. (2023). Study of the aquifer vulnerability by longitudinal unit conductance, GOD and GLSI Models in the Painganga River Basin, Buldhana (Maharashtra, India). *J. Ind. Geophys. Union, 27(4), 281-291.*

Paper 04

Water Security: An overview of Groundwater Resources Development and Management in Abeokuta, Southwest Nigeria

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ABSTRACT: Natural reserves of fresh water supply are under the threat of becoming a limited natural resource as many cities are experiencing water scarcity due to rapid urbanization, increased industrialization, population growth and climate change. Many water-scarce cities now rely on groundwater because surface water resources cannot meet their demand. This paper presents an overview of groundwater resources development and management in Abeokuta, southwest Nigeria. Related literature on the study area as well as data from relevant agencies were reviewed. It focuses on water demand, supply, groundwater occurrence and quality, and its exploitation to bridge the gap between demand and supply. Abeokuta is underlain by Basement complex rocks and groundwater occurs in the weathered regolith and the fractured Basement rocks and is recharged through precipitation and lateral flows from rivers. The Ogun State Water Corporation supplies about 7.1% of water demand to Abeokuta from its two water treatment plants. This leaves a huge gap to be filled by groundwater abstraction. Groundwater abstraction is through dug wells and drilled boreholes. Yields are generally low to moderate and the quality is generally good and fit for human consumption. There are cases of abortive boreholes and dug wells drying up in the dry season because the required depths could not be reached. Government agencies and private individuals are involved in groundwater development. There is presently no legislation or regulation on groundwater use and development in Ogun State. This paper will provide baseline information for effective development and management of groundwater resources in Abeokuta.

Keywords: water security, Abeokuta, groundwater, development, management

1.0 INTRODUCTION

Water is very vital to human existence and is man's most used and consumed substance. However, the current natural reserves of fresh water supply are under the threat of becoming a limited natural resource in many parts of the world as many cities are experiencing water scarcity due to rapid urbanization, increased industrialization, population growth, leadership lapses and climate change. This poses a great challenge to water security which is the capacity to provide sufficient and sustainable quantity and quality of water for all types of water services and protect society and the environment from water-related disasters ((AfDB, 2008). The United Nations (UN) recommended five target areas for Sustainable Development Goals (SDGs 2016-2030) for water to comprise (i) Water supply, Sanitation and Hygiene (WASH); (ii) water resources; (iii) water governance; (iv) water quality and wastewater management; and (v) water-related disasters (UN-Water, 2015).

Nigeria, with an estimated population of over 200 million, is the most populous country in Africa and about 43 % of the populace are living in cities or urban areas (Charles, 2011). The rate of urbanization in Nigeria is alarming and the major cities are growing at rates between 10 to 15% yearly. Nigeria is made up of 36 states and Federal Capital Territory (FCT) Abuja.

In terms of water security, Nigeria has extensive surface water resources, including the perennial Niger and Benue rivers with their extensive tributaries which stimulate vast hydrological watershed. Surface water and groundwater are the sources of water for domestic, agricultural and industrial uses. However, Nigeria is currently experiencing an increasing dependence on groundwater for domestic and small-scale agricultural and industrial uses usually by self-supply. This is because groundwater is locally available, drought resilient, brings large economic benefits per unit volume and has quality requiring minimal treatment. The reliable supply of groundwater, uniform quality and temperature, relative turbidity and pollution-free, minimal evaporation losses and low cost of development make groundwater development more attractive when compared to other water sources. Many water-scarce cities now rely on groundwater. One of such cities is Abeokuta.

Abeokuta, located on the eastern bank of River Ogun, is the capital city of Ogun State in the southwestern part of Nigeria. The city has become increasing cosmopolitan since its elevation to the status of a state capital in 1976. In 2021 its estimated population was 544,000, in 2022 it was 557,000 while in 2023 it is estimated to be

571,000 (UN World Population Prospect).This has continued to place increasing stress on the existing infrastructural facilities, especially water supply in the town.

Major source of water supply in Abeokuta is the public water supply being undertaken by the Ogun State Water Corporation (OGSWC), which is a parastatal of the State Ministry of Special Duties. The OGSWC has two water treatment plants serving Abeokuta. The old treatment plant was commissioned in 1962 with an installed capacity of 15 million litres per day, while the second treatment plant was commissioned in 1988 with an installed capacity of 82 million litres per day. In the month of February 2023, the total water supply to Abeokuta from these plants was 73, 609, 260 litres or 2,628,902 litres per day (OGSWC, 2023). With a per capita water demand of 65 litres/day, the projected daily water demand for Abeokuta in 2023 is put at 37, 115, 000 litres per day. This indicates that public water supply accounts for only about 7.1% of the total water demand for Abeokuta. Thus this source of water supply is not sufficient and therefore does not meet the demand of the populace. As a result of this, a large number of people are dependent on the groundwater resource in the weathered regolith for basic water requirements and abstraction is largely through large diameter hand dug wells using a bucket tied to the end of a rope for withdrawing water, or, where affordable, through drilled boreholes equipped with centrifugal pumps which are capable of withdrawing large volume of water. However, developing groundwater for use in this area poses a great problem because of difficulty in locating high productive aquifers in different parts of Abeokuta and incidence of dry wells during dry season because the required depth could not be reached due to the terrain. This paper provides baseline information for effective development and management of groundwater resources in Abeokuta.

2.0 MATERIALS AND METHODS

The study area is Abeokuta and the study involved the desktop review of relevant literature on geology and hydrogeology, information on water resources development and supply from relevant stakeholders with a view to assessing water demand and supply, information on water quality to assess its suitability for the intended uses and recommendations for future groundwater development and management in the study area.

2.1 Location, Physiography, Climate and Drainage of Abeokuta

Abeokuta, located on the eastern bank of River Ogun, is the capital city of Ogun State in the southwestern part of Nigeria. The town which lies between latitudes 7° 10'N and 7° 19'N and longitudes 3° 30'E and 3° 40'E occupies a comparatively vast land mass of about 879 Km^2 at an elevation ranging from 100 m to 400 m above sea level (fig. 1). It is bordered by Ibadan and Iseyin to the north, Lagos to the south, Ayetoro, Yewa North to the west and Sagamu to the east. It is a historically important agrarian city and home to the famous Olumo Rock, which has continued to attract tourists and visitors from within and outside Africa and is only 77km from Lagos by road.

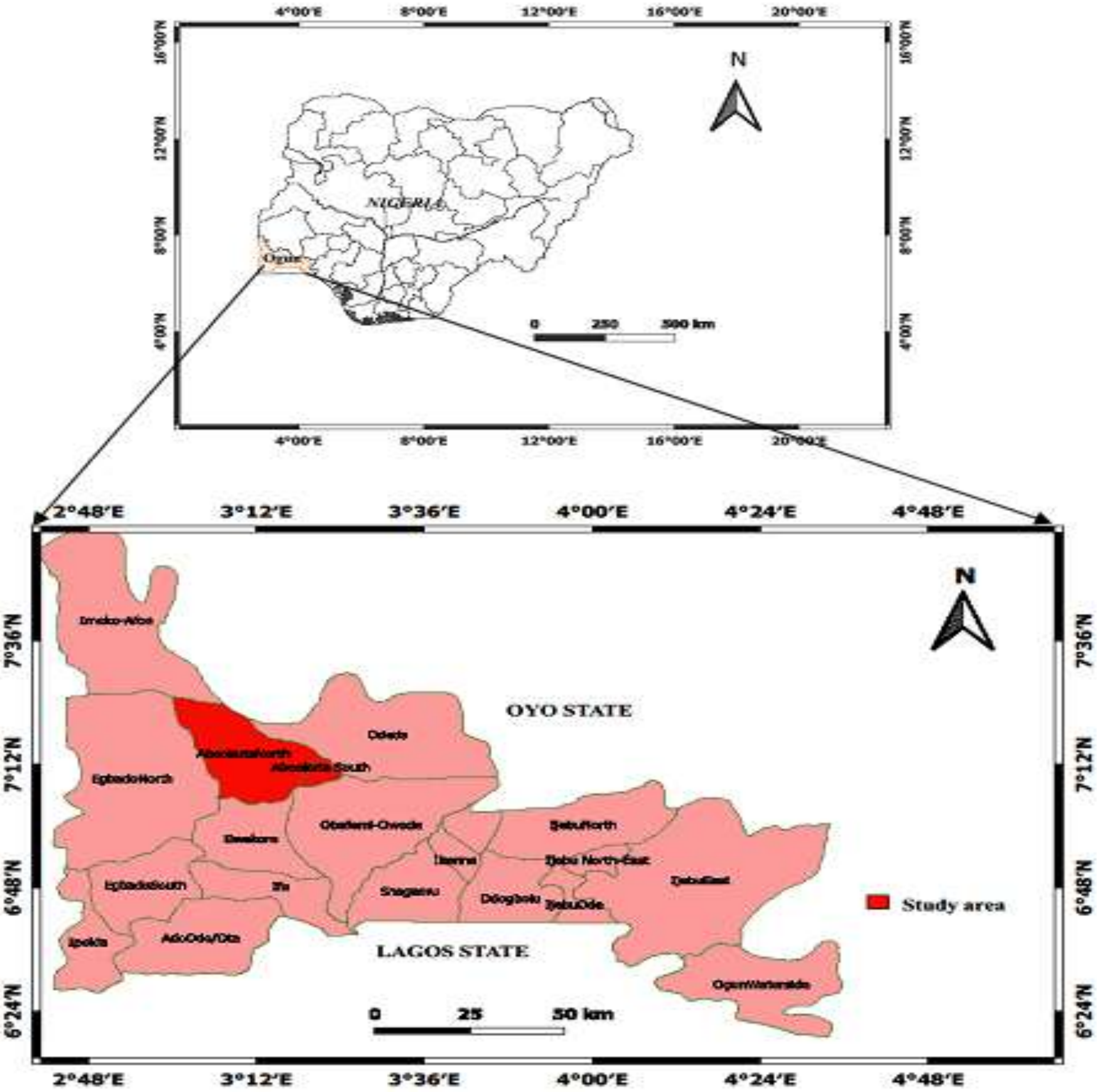

Fig. 1: Location map of Abeokuta

The physiography of Abeokuta is characterized by two types of landforms: sparsely distributed low hills and knolls of granite, other rocks of the basement complex and nearly flat topography. The rugged rock-strewn relief is prominent towards the north, in the central and south-eastern parts of the city.

Two main climatic conditions exist, the rainy season lasting for between seven and eight months between April and October with an interruption in August, and the dry season; running through November till February. Annual rainfall is about 1600 mm and the temperature is usually between 26^{0}C and 28^{0}C.

The city is drained by two major rivers, Ogun and Oyan and many streams (fig. 2). Some of these streams take their source from local rocky hills while some are small distributaries to the two major rivers (Adekunle *et al.*, 2013).

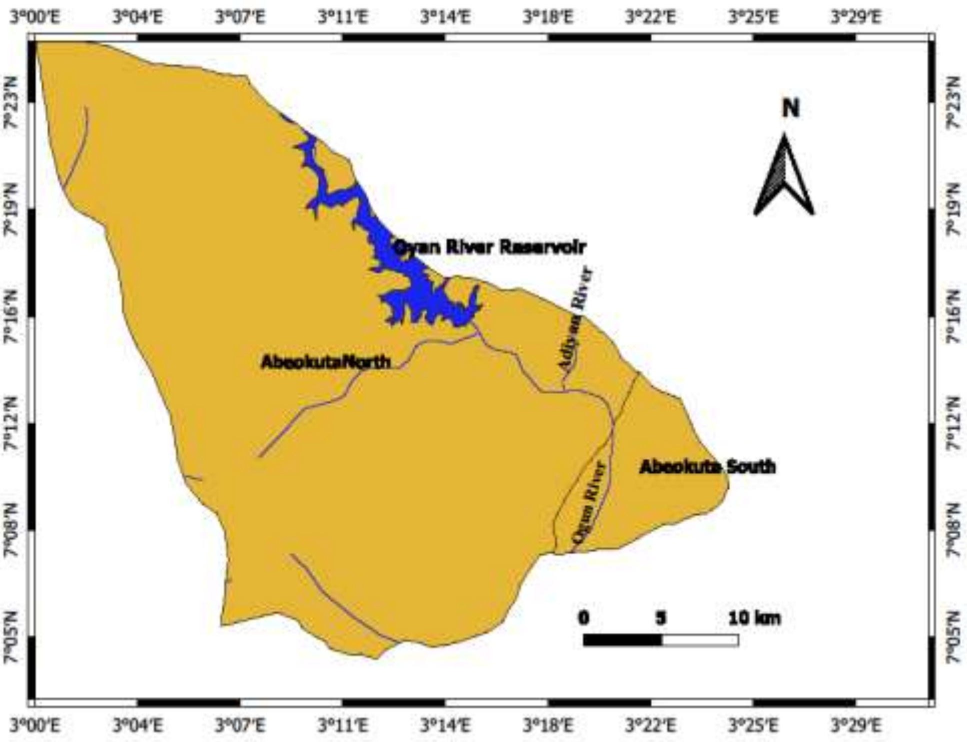

Fig. 2: Drainage map of Abeokuta

2.2 Socio-Economic Context

Abeokuta has become increasing cosmopolitan since its elevation to the status of a state capital in 1976. The 2006 national census exercise recorded a population of 449, 088 for Abeokuta. In 2021 its estimated population was 544,000, in 2022 it was 557,000 while in 2023 it is estimated to be 571,000. This population growth has continued to place increasing stress on the existing infrastructural facilities in the town. Originally founded in the year 1830, Abeokuta is home to a number of industrial and commercial activities, as well as a number of tertiary institutions of learning. The dominant tribe is Yoruba, and the commonly practised religious faiths are Christianity, Islam and African traditional religion. Ogun State is an economically viable state with an average estimated monthly IGR (Internally Generated Revenue) of US$ 16.4 Million (NGN 6 Billion) as at June 2017.

3.0 RESULTS AND DISCUSSION

3.1 Water Supply and Demand in Abeokuta

The public water supply is being undertaken by the Ogun State Water Corporation (OGSWC) which is a parastatal of the State Ministry of Special Duties. The OGSWC has two water treatment plants serving Abeokuta. The old treatment plant was commissioned in 1962 with an installed capacity of 15 million litres per day, while the second treatment plant was commissioned in 1988 with an installed capacity of 82 million litres per day. The average monthly water supply to Abeokuta from these plants is about 73, 609,260 litres. Different classes of customers are industrial customers, commercial customers, institutional customers, domestic customers and recreational facilities. These customers are charged service fees which depend on the quantity of water consumed. With a per capita water demand of 65 litres/day, the projected daily water demand for Abeokuta in 2023 is put at 37, 115, 000 litres per day. This indicates that public water supply by OGSWC accounts for only about 7.1% of the total water demand for Abeokuta.

The government, through the Rural Water Supply and Sanitation Agency (RUWATSSAN) under the Ministry of Rural Development also supplies water to rural dwellers by providing boreholes which supply water free of charge to the people. However, the maintenance of such borehole and water supply facilities is the responsibility of the host community. The Ogun-Osun River Basin Development Authority, a parastatal of the Federal Ministry of Water Resources also provides boreholes in some communities which supply free water to the people.

In addition, private home owners also have hand dug wells or boreholes installed with centrifugal pumps in their premises which supply their water needs. Factories which produce packaged water in form of sachet and bottle water also contribute to supply of drinking water in Abeokuta and very large proportion of the population patronize this source of water for their drinking water supply.

While various government agencies provide services in the development and supply of groundwater, there is currently no legislation or regulation on the development and use of groundwater in Ogun State. This leads to haphazard and indiscriminate drilling of boreholes and dumping of wastes in dried up wells which can result in serious contamination of groundwater.

3.2 Groundwater Resources

3.2.1 Geology and Hydrogeology of Abeokuta

Abeokuta lies within the Basement Complex rocks. These rocks are of Precambrian to early Palaeozoic age comprising older granite, quartzite, folded gneiss and schist, and they extend from the north-eastern part of Ogun state running southwest ward and dipping towards the coast (Ako, 1979) (fig. 3).

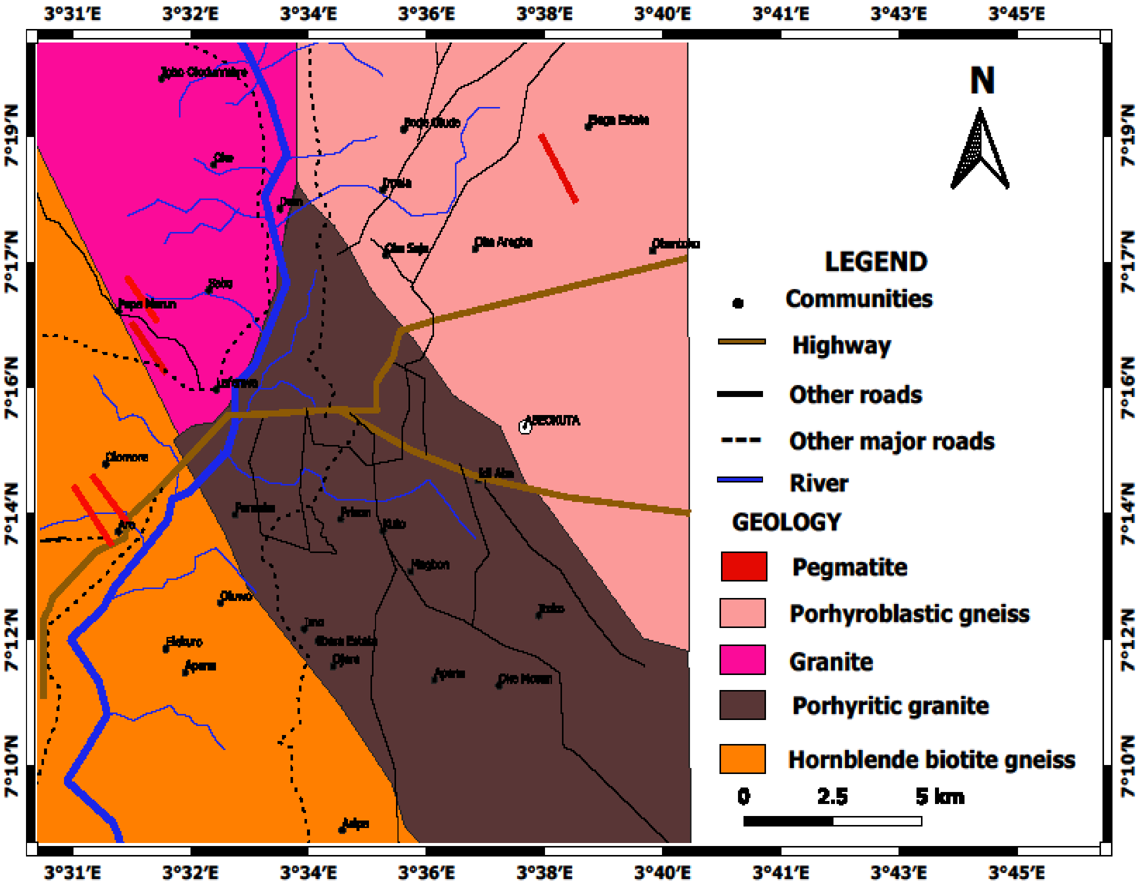

Fig. 3: Geological map of Abeokuta (Modified after Oloruntola and Adeyemi, 2014)

When fresh, such rocks have practically no porosity or permeability due to the interlocking crystal structure. The groundwater potential in crystalline rock terrains depends, therefore, on post-emplacement processes such as tectonism and weathering which could lead to the development of secondary porosity and permeability. The main aquifer in Abeokuta is the Basement aquifer where groundwater occurs in the weathered overburden and or the weathered/fractured Basement rocks. A major source of water in Abeokuta is surface water supply from Ogun River. This important source of water supply is not sufficient and does not meet the demand of the populace because the surface water has a very low output especially during the dry season when the evaporation rate is high (and precipitation is lower than annual average). Other sources of water are steams, dug wells and drilled boreholes. Streams occur naturally and some inhabitants especially in the suburbs still rely on them for drinking (Akinyemi *et al.*, 2011). A large number of people are dependent on the groundwater resource in the weathered regolith for basic water requirements and abstraction is largely through large diameter hand dug wells using a bucket tied to the end of a rope for withdrawing water. However, this poses problem during dry season because the required depth would not be reached due to the terrain and the cost of drilling borehole is very high. Where it is affordable, the rope-and-bucket arrangement is now being replaced in several households with boreholes with centrifugal pumps resulting in larger quantities of groundwater withdrawal. These boreholes may need to be drilled up to between 60 m and 80 m depth in order to ensure water supply even in the dry season. Yields are generally less than 2 m^3/day.

3.2.2 Groundwater Occurrence and Exploitation

As with other Basement aquifers, groundwater occurs in the weathered regolith and weathered/fractured Basement rocks. The thickness of the regolith varies between 20 m and 30 m while the weathered/fractured rocks extend to depths of up to 100 m. Groundwater exploitation is largely through large diameter hand dug wells using a bucket tied to the end of a rope for withdrawing water, or through drilled boreholes equipped with centrifugal pumps which are capable of withdrawing large volume of water. Average depth of boreholes in Abeokuta is about 80 m and cost of drilling including installation ranges between ₦800, 000 and ₦1 million.

3.2.3 Water Quality

Generally, groundwaters in most of the aquifers in Nigeria are fresh with low concentrations of total dissolved solids (< 500 mg L^{-1}). With respect to agricultural and irrigation purposes the groundwaters are excellent (Edet *et al.*, 2011). However, in major cities and rural communities of Nigeria, increased urbanization, improper waste disposal, intensive agricultural and industrial activities have increased threats of active groundwater pollution. There is difficulty in accessing documented research data on drinking water quality in Abeokuta metropolis. However, literature review of groundwater quality studies in Abeokuta and its environs between 2009 and 2021 (Ufoegbune *et al.* 2009, Adekunle *et al.*, 2013, Oloruntola and Adeyemi, 2014, Eseigbe *et al.* 2018, Falola *et al.*, 2021) indicates that the groundwater of Abeokuta is suitable for domestic and agricultural uses, though some treatment may be needed for industrial uses especially in cases of elevated iron concentrations. A summary of groundwater quality from literature review is presented in Table 1.

Table 1: Summary of groundwater quality in Abeokuta (Modified after Ufoegbune *et al.* 2009, Adekunle *et al.*, 2013, Oloruntola & Adeyemi, 2014, Eseigbe *et al.* 2018, and Falola *et al.*, 2021)

Parameter*	Well		Borehole		Mean	WHO GLV (2017)	NSDWQ MAL (2015)
	Min	Max	Min	Max			
pH	4.8	8.8	4.3	7.6	6.9	6.5-8.5	6.5-8.5
Temp (^{0}C)	26.0	29.2	30.0	37.0	27.6	Ambient	Ambient
EC(**µ**S cm^{-1})	35.3	2331	33.9	1149	863.9	1000	1000
TDS	30	1504	60	575	476.41	500	500
Turbidity (NTU)	0.37	2.21	0.63	2.20	1.25	5	5
Sodium	3.2	121	0.06	0.18	42.26	200	200
Potassium	1.2	126	0.35	0.61	14.73	12	-
Calcium	0.1	83.8			31.57	75	150
Magnesium	0.8	19.8			7.46	20	20
Chloride	9.1	222	4.5	28	70.52	200	250
Bicarbonate	34.3	369.8			169.81	250	200
Sulphate	1.19	82.3			23.94	200	100
Nitrate	0.8	60.8			17.14	50	50
Iron	0.29	0.63	0.19	0.36	0.39	0.3	0.3
Manganese	0.01	0.77			0.12	0.2	0.2
Zinc	0.05	0.84	0.24	0.47	0.50	3.0	3.0
Lead	0.10	0.18	0.04	0.16	0.097	0.01	0.01
Cadmium	0.01	0.08	0.00	0.06	0.54	0.003	0.003
Arsenic	0.001	0.009	0.00	0.00	0.003	0.01	0.01
Total coliform (cfu/100 ml)	220	250				10	10

*All units are in mg L^{-1} except pH or unless indicated
WHO GLV= World Health Organization Guideline Value (2017)
NSDWQ MAL= National Standards for Drinking Water Quality Maximum Allowable Limit

The results indicate that groundwater in Abeokuta has elevated iron content above the maximum allowable value. The high iron content in the water may be due to leaching from the lateritic top soil. While this may not affect the potability of the water because iron is essential in human body as it helps in the transmission of oxygen in blood, excess iron in water can cause red or brown stains in laundry and sanitary wares. However, higher zinc concentration in some shallow wells may give an undesirable taste to the water. A water softening system could be adopted to lower the content of zinc to make the water palatable for drinking. Cadmium and lead are also observed to be above the maximum allowable limit in many areas, Cadmium is noted for its renal toxicity due to its irreversible accumulation in the kidney. Lead is a strong neurotoxin in unborn, newborn and young children, leading to irreversible impairment of intelligence. Shallow wells were observed to have higher lead concentration than the deeper boreholes. Few areas have nitrate concentration greater than the maximum allowable limit. High nitrate concentration in water is seen as localized rather than regional occurrence and may be due to leaching of livestock waste as well as washing activities of the people. The presence of total coliform bacteria in water indicates microbial pollution, especially in the open, unprotected shallow wells. Since it is unlikely that bacterial contamination can come from the underground, it suggests that the contamination is due to human activities.

4.0 CONCLUSION AND RECOMMEDATION

With many of the surface water now polluted and impacted by the climate change, focus on the importance of groundwater as a drinking water source has increased. Groundwater is a vital natural resource for the reliable and economic provision of safe water supplies in both the urban and rural environment. The Ogun State Water Corporation supplies about 7.1% of water demand to Abeokuta from its two water treatment plants. This leaves a huge gap to be filled by groundwater abstraction. Thus, Abeokuta and its environs depend largely on the groundwater resources which occur in the weathered regolith and weathered/fractured basement complex rocks which underlie Abeokuta. Abstraction is through hand dug wells and drilled boreholes. Yields are generally low to moderate and the quality is generally good and fit for human consumption. Legislation for groundwater protection is absent in Nigeria and Ogun State in particular. Much of the water legislation in Nigeria is use-oriented without much focus on scientific research such as groundwater pollution or vulnerability. Nigeria is blessed with abundant water resources but the inability to harness, treat and make available potable water for use all over the country, accounts in part, for the poor economic development and social wellbeing within the country. The following recommendations are suggested for managing groundwater and protecting aquifers in Abeokuta:

i. Land use should be controlled and managed in terms of effluent discharge and waste management. This could be done by applying site-specific land use controls based on contaminant attenuation capacity of the strata overlying the aquifer instead of universal control measures. This is more cost-effective and will ensure acceptable trade-offs between competing interests.

ii. Scientific research-oriented, in addition to use-oriented legislation on groundwater management and aquifer protection should be enacted to ensure long-term sustainable use of groundwater in future generations.

REFERENCES

Adekunle**,** A.A**.,** Badejo, A.O. and Oyerinde, A.O. (2013). Pollution Studies on Ground Water Contamination: Water Quality of Abeokuta, Ogun State, South West Nigeria, *Journal of Environment and Earth Science*. *Vol. 3, No.5*, 2.

AfDB, (2008). African Ministers' Council on Water (AMCOW) and the African Development Bank (AfDB). Tunis, 28 January, 2008.

Akinyemi, O.D., Bello, R., Ayodeji, A.T., Akanbi, D.E., Ibine, M.M. and Popoola, J.A. (2011). Evaluation ofwater quality in Abeokuta, Southwest Nigeria, *International Journal of Water Resources and Environmental Engineering, Vol. 3(13), pp. 341-369.*

Ako B.D. (1979). Geophysical Prospecting for Groundwater in Parts of South-Western Nigeria. Unpublished PhD Thesis. Department of Geology, University of Ife, Ile-Ife, Nigeria p. 371

Charles J. (2011). Nigeria's Progress in Achieving Population Stabilization. National Planning Commission. Available at: www.gillespiefoundation.org/upload/Nigeria _Report_J_charls.pdf.

Edet, A., Nganje, T.N., Ukpong, A.J. and Ekwere, A.S. 2011. Groundwater Chemistry and Quality of Nigeria: A Status Review, *African Journal of Environmental Science and Technology. 5(13): 1152-1169.*

Eseigbe, A. P., Ibhadode, O., Ayoola, A. R. and Sosanolu, O. M. (2018). Experimental Determination of Drinking Water Quality in Abeokuta Metropolis, South-western Nigeria, *International Journal of Advances in Scientific Research and Engineering, Volume 4, Issue 12*.

Falola, T.O., Adetoro, I.O. and Idowu, O.A. (2021). Assessment of Groundwater Quality in Abeokuta North, Nigeria, *American Journal of Water Resources, vol. 9, no. 2*.

National Standards for Drinking Water Quality, NSDWQ (2015). Nigerian Standard for Drinking Water Quality. NIS 554:2015, Standards Organisation of Nigeria (SON).

Oloruntola M.O. and Adeyemi G.O. (2014). Geophysical and Hydrochemical Evaluation of Groundwater Potential and Character of Abeokuta Area, Southwestern Nigeria. *Journal of Geography and Geology; Vol. 6, No. 3*.

Ufoegbune, G.C., Lamidi, K.I., Awomeso, J.A., Eruola, A.O., Eruola, A.O., Idowu, O.A. and Adeofun, C.O. (2009). Hydro-geological Characteristics and Groundwater Quality Assessment in Some Selected Communities of Abeokuta, Southwest Nigeria. *Journal of Environmental Chemistry and Ecotoxicology, Vol. 1(1), pp. 010- 022.*

WHO (2017). Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum. Geneva: World Health Organization; 2017.

Paper 05

Performance Evaluation of Irrigation Water Delivery Structures in Kano River Irrigation Project (Phase I) Northwestern Nigeria

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ABSTRACT: Assessment of irrigation performance is essential while planning and drawing out management strategies for various irrigation schemes. However, in Nigeria, performance evaluations of irrigation projects are rarely conducted. Thus, few studies were carried out on the performance of the Kano River Irrigation Project (KRIP) phase 1 to ascertain its hydraulic adequacy, especially on structures such as canal regulators, sluices, and drop structures. Hence, this research is a field assessment of water delivery structures and evaluating canal adequacy in selected sectors of the KRIP. A survey of the study area was performed, and data were analyzed using QGIS and Civil 3D. From the results obtained, the existing water delivery structures were found to be in poor working conditions and inadequate to meet requirements with a poor structure index of 51%; the existing canals have significant sedimentation and scouring with some sections of the canals completely silted up or eroded deep enough to create ponding along the canals. A new design of the canals was proposed to meet the standards of the KRIP. Thus, the study has provided a more sustainable canal lining alternative, hence, anticipated to encourage scheme users and other stakeholders involved to improve water delivery performance in the KRIP.

Keywords: irrigation, performance, canal regulators, poor structure index, hydraulic adequacy

1.0 INTRODUCTION

Most Sub-Saharan African nations struggle with serious food and nutrition insecurity, particularly in rural regions (Elliot et al., 2022). According to Thomas et al. (2015), for many years, Africa has supported irrigated agriculture to ensure food security and raise rural residents' standards of life. Numerous studies have shown that irrigation schemes enhance African rural farmers food security and livelihoods. However, irrigation programs have performed poorly due to deficient infrastructure, despite their significant contribution to improving the livelihoods of rural African populations (Arcus, 2004).

The economies of the least developed nations in sub-Saharan Africa largely depend on agriculture, and many of these nations' irrigation potential is underdeveloped. Investment in water management infrastructure can help ensure the sustainability of these nations' agricultural output, subsequently increasing food security. (Hagos et al., 2010 and Djagbe et al., 2013). Irrigation and drainage improvements have greatly enhanced sub-Saharan Africa agricultural output (Djagbe et al., 2013). But this area also has a high irrigation system development project failure rate (Inocencio et al. 2007 and Djagbe et al. 2013).

Irrigation advancements have been and are anticipated to remain a significant part of the national development objectives of many developing nations, according to Thomas et al. (2015). They have been recognized as one of the main forces accelerating these nations' growth. This is not only due to irrigation's significance in ensuring and growing food supply but also because it serves as a tool for giving its rural people the opportunity for a decent life.

Despite the high priority irrigation enjoys in many developing countries in their development strategies and the significant portion of these countries limited financial resources invested in it, there has been an increase in concern and a steadily growing body of literature about the performance of existing irrigation systems in recent years. Many gravity-flow canal systems in developing nations operate below expectations (Asthana, 2022).

The Kano River Irrigation Project (KRIP) has made achieving self-sufficiency in operation and maintenance a strategic goal by focusing on irrigation facilities with relatively low investment costs, ease of construction, simplicity of operation, and maintenance. While certain sectors are doing well, several papers have noted that some sectors have fallen short of fulfilling their intended functions (Sangari, 2006; Tukur et al., 2013; Salisu et al., 2014).

Water allocation issues at KRIP are related to field-level water availability. Farmers near the bottom of the system complain they do not receive enough water, forcing them to use dry land irrigation, despite the water being regularly supplied into the main canal. Between the source and the point of application, water is lost, and it is necessary to determine the reasons for these losses to increase water availability. (Nthai, 2007).

Therefore, this study focuses on the functioning index of irrigation water delivery structures of KRIP Phase I.

2.0 MATERIALS AND METHODS

2.1 Study Area

Figure 1 depicts the KRIP Phase 1 in the Sudan Savannah Zone of Nigeria from longitude 8o 30' E to 9o 40'E and latitude 11o 30'N to 12o 03'N. It was initially intended to irrigate roughly 22,000ha, of which 13,227ha have been implemented as of 2008 and have been operational at some point. KRIP Phase 1 is divided by the River Shimar into East and West Branch. Water from the Tiga Dam is conveyed by (19km) long Main Canal up to Garun Babba village where the division works have been constructed (Hadejia Jama'are River Basin Development Authority Yearbook 1994). The project area has three distinct climatic seasons; warm rainy season June – September, cool dry season October – February and hot dry season March – May. Rainfall is highest in July and August with an average of 860 mm. Mean daily temperature ranges from 20 ^{o}C to 38 ^{o}C (Salisu *et al*., 2014).

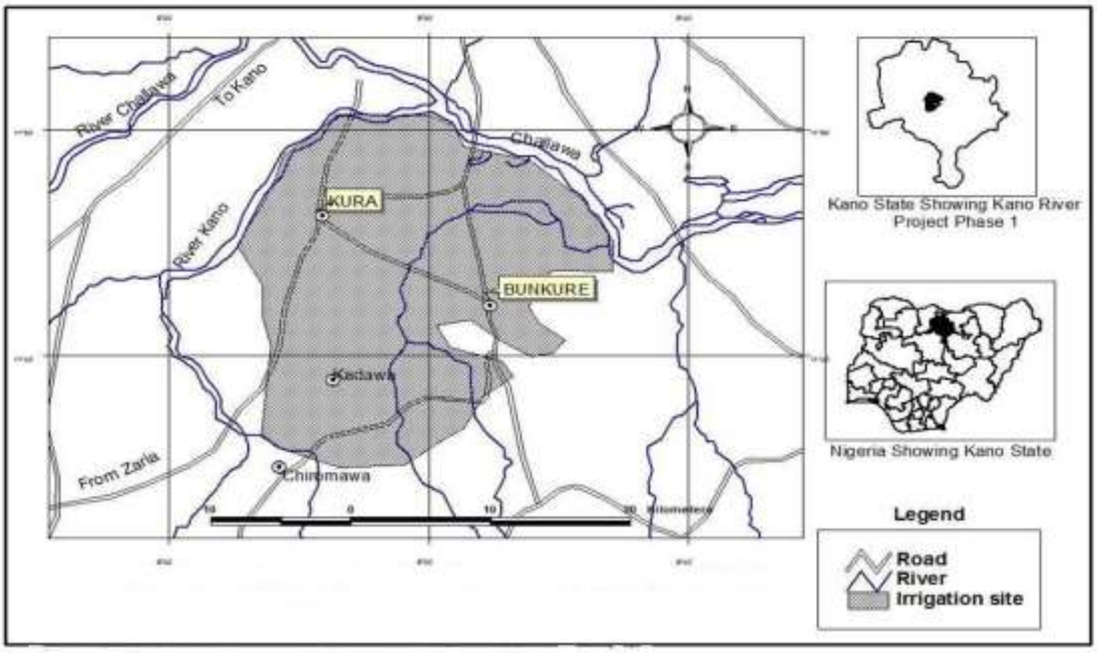

Figure 1. Kano River Irrigation Project Phase 1 (22, 000 ha).

2.2 Sampling and Site Selection

KRIP development started in the early 1970s with a planned area of 22,000 ha in Phase 1 of which 13,227 ha has been implemented in various stages till 2008 that has been functional at some point in time. The KRIP Phase I has 50 sectors planned with 44 developed each with a Distributary Canals (DCs) and Field Canals (FCs), besides the Main Canal (MCs). This study focuses on the Distributary Canals (DCs) and control structures along them within a sector boundary, simply because they are the major canals affected by the sedimentation problem and they supply the field canals with water that supplies the farms. A sample of five sectors was taken, 1 (Barnawa) from a small Gayere Branch Canal (GBC) bifurcation from the West Branch Canal (WBC), 1 (Kuluma) from the East Branch Canal (EBC) and 3 (Makwaro, Tsauni and Rakauna) from the much larger developed WBC area as shown in Figure 2.

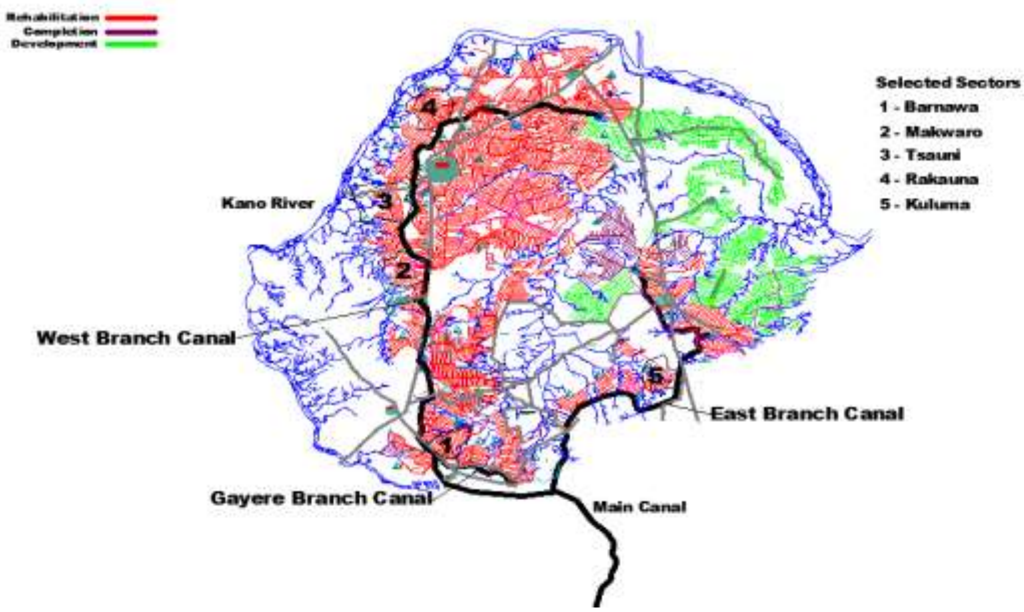

Figure 2. Kano River Irrigation Project Phase 1 (22, 000 ha) Showing Selected Sectors.

2.3 Types of Data

The types of data collected are irrigation water allowance, field size of the sectors from secondary sources and primary data was obtained through field survey identifying the structures in all the selected sectors.

Method of Data Collection

Field Network Survey

The purpose of the survey was to assess and evaluate the current condition of Distributary Canal and Control Structures in the sectors. The structures examined includes: stilling basin (SB), baffle module (BM), field turn-out (FTO), drop structure (DS), Begemman check gates (BG), spillways (SW). the observed structures are categorized into two groups as Functioning (F) and Not functioning (NF), respectively.

2.4 Method of Data Analysis

Water Delivery Structures Indicator.

According to Bos et al. (2005), performance indicator includes both a planned value and an actual value, allowing for assessing the degree of deviation. Additionally, it must include details that aid management in determining if the deviation is tolerable. As a result, indicators should, if possible, be stated as a ratio of the actual measured condition to the anticipated condition, hence,

$$Performance\ indicator\ level = \frac{Actual\ level\ of\ delivered\ resource}{Intended\ level\ of\ delivered\ resource} \qquad (1)$$

It is important to ensure that the indicators selected for a system will describe performance in respect of the objectives established for that system (Bos *et al*., 2005). Failure to take this into account may lead to managers being assessed in terms of activities that were not included in their initial brief.

Poor Structure Indicator that compares the poor and good structures of an irrigation system was used for the study. The International Water Management Institute (IWMI) designed and extensively field tested the chosen indicator. The comparison indicators were created to show broad linkages and patterns useful in illustrating the system status. For instance, when a given plan is operating well, or a significant intervention is required (Molden et al., 1998).

Functioning delivery structures are needed to keep the system in operational condition. For this to occur, the delivery structures must be functional as intended. Hence, functional performance can be quantified by the following ratio:

$$PSI_d = \frac{\sum N_p}{N_t}$$

(2)
Where;
PSI_d = Poor Structure Index of delivery structures
N_p = Number of poor structures (damaged)
N_t = Total number of structures

3.0 RESULTS AND DISCUSSION

3.1 Poor Structure Index (PSI)

This was calculated based on the concepts of equations (1) and (2). The result of the field survey was used in calculating the poor structure index (PSI) of the selected sectors as presented Table 1. From Table 1, it follows that, PSI of each sector was calculated as a ratio of 'number of structures under poor conditions to the total number of structures.

Table 1: Poor Structure Index of Selected Sectors

Sector Name	Total no. of structures	Condition		Poor Structure Index*
		Good	Poor	
Barnawa	21	11	10	0.48
Makwaro	15	6	9	0.60
Tsauni	13	7	6	0.46
Rakauna	39	25	14	0.36
Kuluma	31	9	22	0.71
TOTAL	**119**	**58**	**61**	**0.51**

*****Palmer, 1977, reported that the poor structure index of most irrigation schemes in United States of America fall in the range of < 1 to 20 %.

From Table 1, *Barnawa, Makwaro and Tsauni* sectors each has a distributary canal. However, *Barnawa sector* is divided into 12 number of fields served by 7 no. field turnouts. About 48% of the sector's conveyance and regulatory structures are in poor working condition. Similarly, *Makwaro sector* is allocated into 10 number of fields served by 6 no. field turnouts. About 60% of the sector's conveyance and regulatory structures are in poor working condition. Equally, *Tsauni sector* is distributed into 9 number of fields served by 5 no. field turnouts. About 46% of the sector's conveyance and regulatory structures are in poor working condition. While *Rakauna and Kuluma* sectors each has two (2) distributary canals. For the *Rakauna sector,* its area is divided into 25 number of fields served by 20 no. field turnouts. About 36% of the sector's conveyance and regulatory structures are in poor working condition. Portions of the canal are breached, and water cannot flow through the second distributary effectively. And then, *Kuluma sector* is divided into 27 number of fields served by 14 no. field turnouts. About 71% of the sector's conveyance and regulatory structures are in poor working condition. Hence, the portions of canals of these sectors are breached and silted, vegetative growth and poorly maintained, and water cannot flow to through several field turnouts due to lowered water level in the canal.

From the forgoing, it means that 52%, 54% and 66% of the conveyance and regulatory structures of the Barnawa, Tsauni and Rakauna sectors respectively are in good working condition. Therefore, in terms of structure condition index, the performances of these three sectors are better than Makwaro and Kuluma sectors. On average for the selected sectors 49% of the conveyance and regulatory structures are in good working condition. It is also observed that most of the clay lined canal sections have lost their shape leading to their inability to supply their required discharge and compliance with field turn-out structures.
Similar studies by Ijir (1994) found that the Wurno Irrigation Scheme in Nigeria had 89% of its structures in poor condition, rendering them inoperable. Thomas *et al*. (2015) also found that Vea, Doba, and Libga irrigation schemes in Ghana are structurally deficient, with poor structural indices ranging from 30% to 96%. Additionally, Palmer *et al*. (1991) observed that most irrigation schemes in the United States of America had inadequate structural indices that vary from 1 to 20%.

4.0 CONCLUSION

The study examined the functioning index of structures in the KRIP Phase I. The results of the study revealed that, all the five (5) irrigation sectors are infrastructurally deficient with an average Poor Structure Index of 51%, Thus, it is recommended that the water delivery structures in the KRIP should be rehabilitated to achieve good overall water delivery performance. Also, awareness creation and capacity building should be given to local water users and farmers on management of irrigation water and maintenance and its facilities.

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REFERENCES

Arcus, G. (2004). Principles, approaches and guidelines for participatory revitalization of smallholder irrigation schemes. Year 1 Progress Report, WRC Project No. K5//1463/4. Arcus Gibb, East London.

Asthana Anand N., (2022). Increasing production efficiency of irrigation systems through stakeholder participation. *Journal of the World water Council*: Water Policy Vol 24 No 6, 1061 doi: 10.2166/wp.2022.043. International Water Association.

Bos, M., Burton, M., & Molden, D. (2005). Irrigation and drainage performance assessment Practical Guidelines. CABI Publishing.

Djagba Justin F., Rodenberg Jonne, Zwart Sander J., Houndagba Cossi J., Kiepe Paul, (2013). Failure and success factors of irrigation system developments: a case study from the oueme and zou valleys in benin. wileyonlinelibrary.com DOI: 10.1002/ird.1794

Elliott Ronald Dossou-Yovo, Krishna Prasad Devkota, Komlavi Akpoti, Alexandre Danvi, Confidence Duku, Sander J. Zwart (2022). Thirty years of water management research for rice in sub-Saharan Africa: Achievement and perspectives, Field Crops Research, Volume 283, 2022, 108548, ISSN 0378-4290

Hadejia Jama-are River Basin Development Authority (1994) Yearbook.

Hagos F, Makombe G, Namara RE, Awulachew SB. (2010). Importance of irrigated agriculture to the Ethiopian economy: capturing the direct net benefits of irrigation. *Ethiopian Journal of Development Research* 32(1): 5–55.

Ijir, T. A. (1994): The Performance of Medium Scale Jointly Managed Irrigation Schemes in Sub-Saharan Africa: A Study of the Wurno Irrigation Scheme, Nigeria: University of Southampton, Faculty of Engineering and Applied Science, PhD Thesis.

Inocencio, A., Kikuchi, M., Tonosaki, M., Maruyama, A., Merrey, D., Sally, H., de Jong, I., (2007). Costs and performance of irrigation projects: A comparison of sub-Saharan Africa and other developing regions. Colombo, Sri Lanka: International Water Management Institute. 81 pp. (IWMI Research Report 109).

Molden, D., Sakthivadivel, R., Perry, C.J. and Fraiture, C. (1998). Indicators for Comparing Performance of Irrigated Agricultural Systems. International Water Management Institute: Research Report 20. Colombo, Sri Lanka.

Nthai, M. M. (2007). An evaluation of irrigation water supply infrastructure to improve conveyance efficiency and water availability at Dzindi Irrigation Scheme, Limpopo Province. Thesis, University of Pretoria, Faculty of Natural and Agricultural Sciences.

Palmer, J. D., Clemmens, A. and Dedrick, A. (1991). Field Survey on Irrigation Delivery Performance. Journal of Irrigation and Drainage Engineering. Vol. 117, No. 4, Pp. 567.

Salisu, A., Abdullahi, A. A., & Audu, M., (2014). Condition Survey of Drainage Facilities in Kore Sector Of Kano River Irrigation Project (KRIP) Phase I, Kano State, Nigeria. *International Journal of Engineering Research and Applications*. ISSN: 2248-9622, Vol. 4, Issue 6, June 2014, pp.107-109

Sangari, D. U. (2006). An Evaluation of Water and Land Uses in the Kano River Project, Phase I, Kano State. *Journal of Applied Science Environmental Management.*

Thomas, A. A., Felix, K. A., & Gordana, K.-B. (2015). Performance of Irrigation Water Delivery Structures in Six Schemes of Northern Ghana. *International Journal of Science, Engineering and Technology Research (IJSETR)*, Volume 4(Issue 9).

Tukur A. I., Olofin, E. A., & Mashi, S. A. (2013). Rate of Sediment Yield in the Conveyance Canals of Kano River Irrigation Project (Phase I) North-Western Nigeria. *Journal of Environment and Earth Science* Vol. 3, No.12, 2013

Paper 06

Geostatistical Modelling of Groundwater Quality Monitoring and Governance using GIS

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ABSTRACT: Groundwater sources are mostly used as drinking water in Nigeria utilized by private homeowners to meet increasing water demand for all purposes. The State Water Agencies have not been functional nationwide and cannot meet the 6th sustainable development goal, hence individuals resort to the construction of boreholes to meet their water needs. The groundwater quality of domestic boreholes in Benin City, Edo State was monitored to check the suitability of the sources for drinking purposes using ArcGIS 10.1 software and Global positioning system. Primary data was obtained by performing laboratory analysis on One Hundred (100) water samples collected randomly from various borehole locations. Twenty-eight physicochemical parameters were analyzed including some heavy metals such as Chromium, Lead, etc. The results of water quality parameters were compared with the standards. Eleven semivariogram models which include circular, exponential, J-Bessel, etc. were tested and fitted for each water quality parameter to measure spatial dependency and validate prediction errors. EC, TDS, HCO_3, Na, K, Ca. Mg, Cl, P, and NO_3 showed strong spatial dependency with the ratio of nugget to sill ($\frac{Cn}{C}$) < 25%. The kriging model has higher prediction accuracy and was employed for the prediction of the concentration level of water quality parameters of un-sampled borehole locations. The deterioration of groundwater quality was higher and more concentrated within the densely populated area of Benin City. The use of GIS in the assessment of water quality is essential for regular monitoring and protection of groundwater sources for human consumption and effective WASH.

Keywords: domestic boreholes, water quality, semivariogram, spatial variation

1.0 INTRODUCTION

Water and its quality is a very serious and vital issue for mankind due to its link with human health and welfare. It is one of the most valuable, and important essential resources. There is an abundance of it on the earth's surface but the quality as well as the quantity to serve its intended purpose is where the problem lies. The need for water supply has appreciated over the years due to human activities thus leading to scarcity of water in most parts of the world and thus, the problem of water pollution and contamination have also aggravated the situation (Sundara et al., 2010). In Benin City, water demand has increased as a result of the increase in population, urbanization, industrial and agricultural activities, etc. Thus, the quest for alternative sources to satisfy water demand has led to the indiscriminate construction of boreholes by individuals as a coping strategy without any concern for the quality of water abstracted. Secondly, only an estimated 30% of the inhabitants of Benin City have access to water supply from the state water board (public supply) which is also very unreliable and irregular. Therefore, Groundwater quality assessment is very important for the provision of water supply that ensures human safety. Geographical Information System (GIS) based spatial analysis is a tool that presents the distribution of water resources parameters geographically. Its application is useful in the study of groundwater quality distribution in Benin City. Spatial variability mapping of groundwater parameters is very necessary, especially in Benin City where borehole wells are the primary source of drinking water supply. It is also applicable to any City that requires a groundwater quality mapping to evaluate water potability. The output of groundwater quality mapping using GIS technology as was undertaken in this study will help to derive several specialized maps that depict borehole water quality as it presently exists within the City and the tool will be useful in monitoring water quality from place to place. This study will thus identify and show the most sensitive zones that may be contaminated or require immediate attention. It will also serve as a tool for cautioning against any potential environmental health problem.

2.0 MATERIALS AND METHODS

2.1 Sampling locations and water sampling

The boundary of the built-up area (land use) of Benin City was digitized and gridded at 2km intervals to determine sampling locations and to ensure coverage of the study area at a uniform spacing. The sampling points within each sub-area are the number of boreholes to be sampled for that area as summarized in Table 1

Figure 1 is the digitized map of Benin City showing the boundary areas as coded.

Table 1: Sampling Areas with the Number of Sampling Points

Sample Code	Road Boundary Area in Benin City	Estimated Area(Km^2)	Number of Sampling Borehole locations
A	Sapele – Airport road	34.84	12
B	Airport- Ekehuan road	29.10	10
C	Ekenhuan – Siluko road	30.79	12
D	Siluko – Benin Ore road	32.81	12
E	Benin Ore – Benin Auchi road	44.06	15
F	Benin Auchi – Benin Agbor road	15.06	12
G	Benin Agbor – Sakponba road	42.64	15
H	Sakponba – Sapele road	25.86	12
		Total = 100 sampling locations	

From Table 1, the total number of boreholes sampled was hundred (100). Using a handheld Garmin GPS 72 receiver, the GPS coordinates of the selected boreholes were determined for geo-referencing.

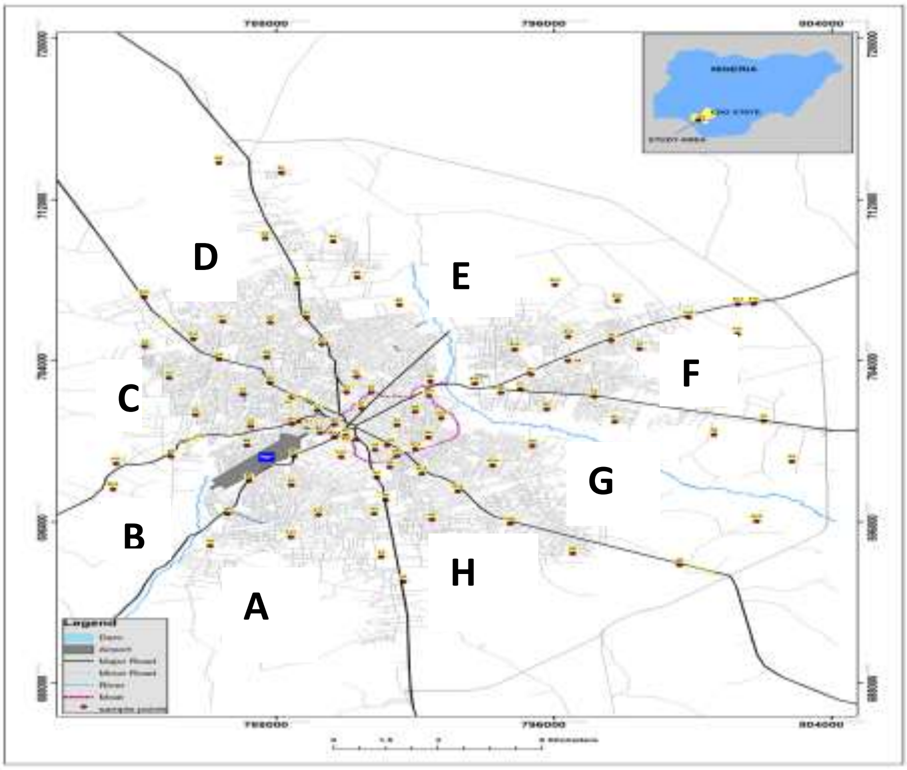

Figure 1. Digitized map of Benin City showing locations of sampled boreholes

2.2 Determination of water quality parameters

The laboratory used for the water quality analysis is MacGill Engineering and Technical Services located at No 234 Murtala Mohammed Way, Benin City. Water samples were transported to this laboratory daily after collection.

A total of twenty-eight (28) physicochemical parameters were analyzed for each sampled domestic borehole to provide a broad picture of the quality of water in the boreholes. The physicochemical parameters tested were pH, Electrical conductivity (EC), Total dissolved solids (TDS), and Dissolved Oxygen (DO). Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Bicarbonate (HCO_3), Sodium (Na), Potassium(K), Calcium (Ca), Magnesium (Mg), Chloride(Cl^-), Phosphorus (P), Ammonium(NH_4), Nitrite (NO_2), Nitrate (NO_3), Sulphate (SO_4), Iron (Fe), Manganese (Mn), Zinc (Zn), and Copper (Cu), Color, Turbidity, Total suspended solid (TSS), Chromium (Cr), Cadmium (Cd), Nickel (Ni) and Lead (Pb). Collection, preservation, and transportation of the water samples to the laboratory followed the standard guideline recommended by WHO (1996). The techniques, preparation of reagents, and procedures employed in the laboratory for the analysis and determination of all water quality parameters of groundwater samples collected followed the standard methods for examination of water and wastewater recommended by APHA, (1999).

2.3 Geostatistical analysis procedure.

Geostatistical analysis was performed using ArcGIS 10.1 software. The following procedures were employed:

a. Each location point (geo-reference point) was tied with the result of water quality parameters for that point in a Microsoft Excel sheet to form a database.
b. Using the geo-database creation function of the software, the data in Microsoft Excel was imported into ArcMap 10.1 by clicking the add data menu.
c. From the file menu, the XY coordinates of the sampled points were added to create the surface for water quality parameters.
d. On the Geostatistical Analyst toolbar, Geostatistical Analyst was clicked to explore data to examine the distribution of data using a histogram as shown in Figure 2. Trends were also examined using the trend analysis tool shown on the same Figure 2

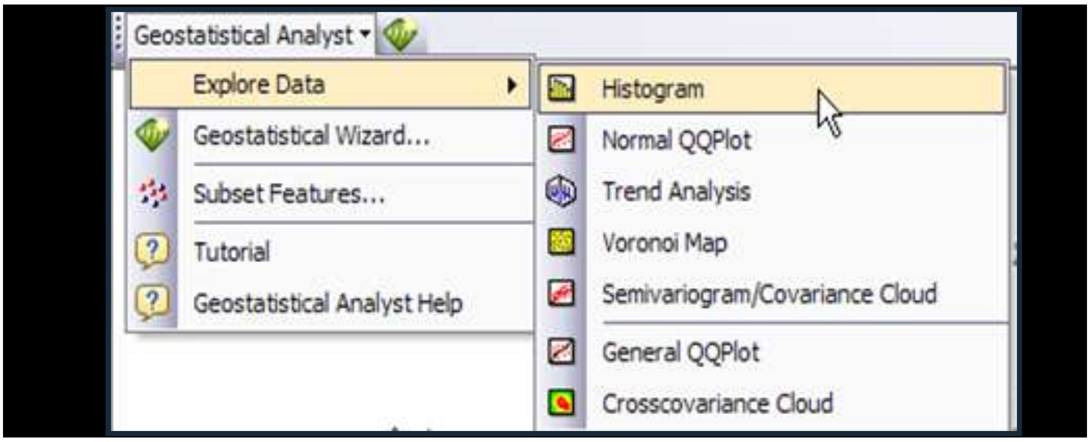

Figure 2: Geostatistical analyst toolbar in the ArcGIS 10.1 software.

e. On the Histogram dialog box, the Attribute arrow was clicked to select the water quality parameter to be examined. From the attribute arrow, other water quality parameters were selected subsequently and the distribution of each of the water quality parameters for all the samples was presented in a histogram. Histogram of each parameter was created to examine its normal distribution pattern. For samples that were not normally distributed, log transformations were applied by clicking the transformation box and selecting the type of transformation.
f. Trend Analysis box in Figure 2 was clicked to determine the trend in the data set. Each vertical stick in the trend analysis plot represents the locations and values (height) of each water quality parameter measurement. A best-fit line (a polynomial) was drawn through the projected points, showing trends in specific directions. If the line were flat (green and blue), there would be no trend. However, if there

is a trend it must be removed before creating a predicting surface using the kriging interpolation method.

g. Semivariogram fitting and spatial Dependency determination were done. Eleven (11) semivariogram models which include circular, hole effect, spherical, K-bessel, J-bessel, tetra spherical, pent aspherical, exponential, gaussian, rational quadratic, and stable were tested for each water quality parameter and through assessment of prediction errors; the best-fitted model was selected for each of the parameters. A fitted variogram has the nugget effect, the range, the sill, and the partial sill. Therefore, the ratio of the nugget semivariance to the sill semivariance ($\frac{Cn}{C}$) is a measure of spatial dependency of the measured quality. If the nugget percent is < 25%, there is a strong spatial dependency; between 25 – 75% is moderate spatial dependency and > 75% nugget percent shows weak spatial dependency (Essington, 2005; Liu, et al., 2006). The groundwater prediction maps of water quality parameters were produced using kriging interpolation techniques in ArcGIS 10.1 software.

3.0 RESULTS AND DISCUSSION

3.1 Statistical Presentation of Results of Physico Chemical Water Quality Parameters and Comparison with Standards.

A total of twenty-eight (28) physicochemical water quality parameters were analyzed for each borehole and compared with the World Health Organization (WHO, 2011) and the Nigerian Standard for Drinking Water Quality (NIS, 2015). The physicochemical parameters that were not detected in all the sampled boreholes were Color, Turbidity, Total suspended solids (TSS), Chromium (Cr), Cadmium (Cd), Nickel (Ni), and Lead (Pb). Table 2 is the statistical description of laboratory results of the water sample parameters detected.

Table 2: Groundwater Quality Statistics of physicochemical parameters of water samples and comparison with WHO and NSDWQ standards.

S/N	Parameter(mg/l)	Statistical description of obtained laboratory results of the water samples				WHO/ NSDWQ limit	Remark
		Range		Mean	SD		
		Min	Max				
1.	PH	3.4	6.3	4.50	0.59	6.5 – 8.5	Ok
2.	EC	46.22	714.13	236.61	194.20	1000	Ok
3.	TDS	25.88	399.91	132.50	108.76	500	Ok
4.	Dissolved Oxygen(DO)	1.90	10.20	5.14	2.65	5	Exceeded
5.	BOD_5	0.70	2.50	1.59	0.39	5	Ok
6.	COD	0.30	17.70	4.73	3.60	40	Ok
7.	Total Alkalinity (HCO_3)	3.10	92.20	28.25	25.01	100	Ok
8.	Sodium (Na)	1.40	36.10	12.34	9.18	200	Ok
9.	Potassium (K)	0.10	5.00	2.09	1.48	No guideline	-
10.	Calcium (Ca)	4.10	90.20	27.96	25.15	75	Exceeded
11.	Magnesium (Mg)	0.10	2.40	0.71	0.52	0.2	Exceeded
12.	Chlorine (Cl)	12.30	147.10	49.53	39.11	250	Ok
13.	Phosphorus(P)	0.02	0.98	0.32	0.29	5	Ok
14.	Ammonium (NH_4)	0.001	0.120	0.032	0.030	0.5	Ok
15.	Nitrite(NO_2)	0.001	0.843	0.066	0.105	0.2	Exceeded
16.	Nitrate (NO_3)	0.01	4.55	1.28	1.29	50	Ok
17.	Sulphate(SO_4)	0.11	8.120	1.66	1.96	100 - 400	Ok
18.	Iron(Fe)	0.09	0.97	0.42	0.24	0.1 – 0.3	Exceeded
19.	Manganese(Mn)	0.001	0.099	0.018	0.014	0.05 – 0.2	Ok
20.	Zinc (Zn)	0.005	0.228	0.071	0.047	3 - 5	Ok
21.	Copper(Cu)	0.001	0.020	0.009	0.005	1	ok

The Physico-chemical parameters that were not detected in all the sampled boreholes were Color, Turbidity, Total suspended solids (TSS), Chromium (Cr), Cadmium (Cd), Nickel (Ni), and Lead (Pb). Therefore, domestic boreholes in Benin City have no significant threat from heavy metals. Seventy -six percent (76%) of the physicochemical parameters analyzed were within the recommended limits for human consumption for all the samples. These parameters include Electrical conductivity (EC), Total dissolved solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Bicarbonate (HCO_3), Sodium (Na), Potassium(K), Chloride(Cl^-), Phosphorus (P), Ammonium(NH_4), Nitrate (NO_3), Sulphate (SO_4), Manganese (Mn), Zinc (Zn). Hence these parameters present no health threats to consumers. Twenty-four percent (24%) of the parameters which include DO, Ca, NO_2, Fe, and Mg exceeded the recommended value in some boreholes. Dissolved Oxygen (DO) exceeded standards in some samples. High DO levels speed up corrosion in water pipes. Corrosion in water pipes can increase the level of the contaminant in water (WHO, 2009; USEPA, 2009) Domestic boreholes face significant threats from iron and magnesium contamination. Iron is an essential element in human nutrition, but estimates of daily requirements depend on age, sex, and physiological status (WHO, 2008). However, Intake of high level of iron damages the liver, heart, and pancreas for individuals with mutated genes that abnormally absorb and accumulates iron in organs within the body (Wilkes Environmental Center, 2008; Dalton, 2013;) Consumption of high concentrations of magnesium in drinking water causes laxative effect and osmotic diarrhea. (USEPA, 2009). An elevated level of Nitrite in drinking water causes infant methemoglobinemia and is very unhealthy for pregnant women and livestock (Nas, 2009; Balakrishnan *et al.*, 2011, Gama, 2017)

3.2 Geostatistical Analysis and Spatial Variation Maps of Water Quality Parameters

The geostatistical analyst tool in ArcMap 10.1 was used to check for normality tests, trends, semivariogram fitting, and testing, cross-validate models, measure spatial dependency and generate maps. EC, TDS, HCO_3, Na, K, Mg, Cl, and P were the best-fitted models using the exponential model. A rational quadratic model was used for DO, Ca, and Zn. Out of the different kriging techniques, the ordinary kriging method was used in the study because of its simplicity and prediction accuracy in comparison to other kriging methods (Chang, 2014). The predicted concentration maps of the studied borehole parameters obtained by using the ordinary kriging interpolation method in ArcGIS 10.1 are presented in Figure 3 – Figure 18. Groundwater quality maps are useful in assessing the spatial variation and pollution level of each area (location) and they give insight into the most sensitive zones that may require immediate attention.

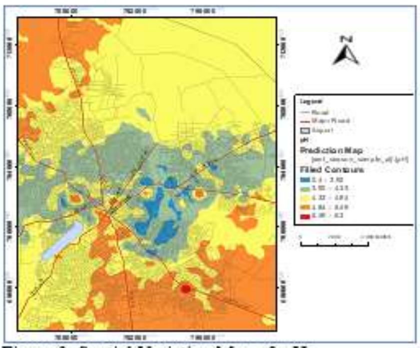

Figure 3: Spatial Variation Map of pH

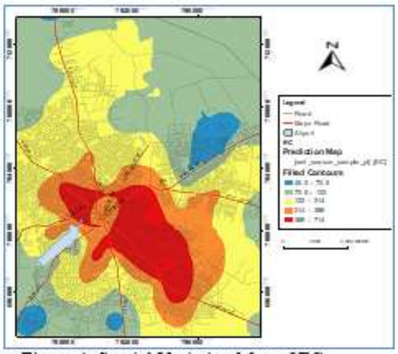

Figure 4: Spatial Variation Map of EC

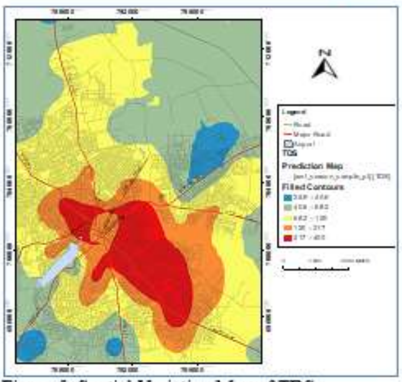

Figure 5: Spatial Variation Map of TDS.

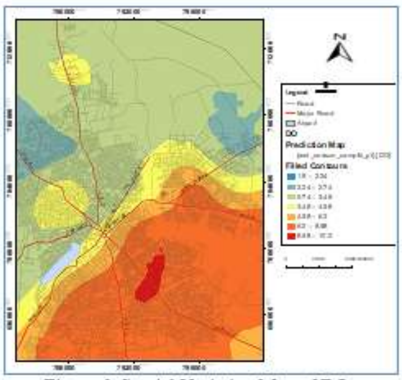

Figure 6: Spatial Variation Map of DO

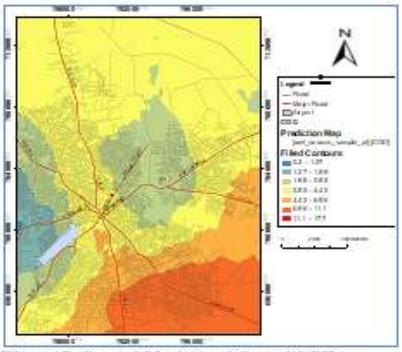

Figure 7: Spatial Variation Map of COD

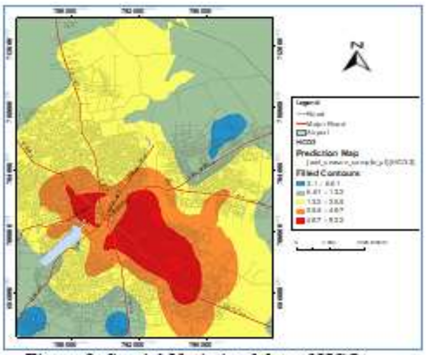

Figure 8: Spatial Variation Map of HCO_3

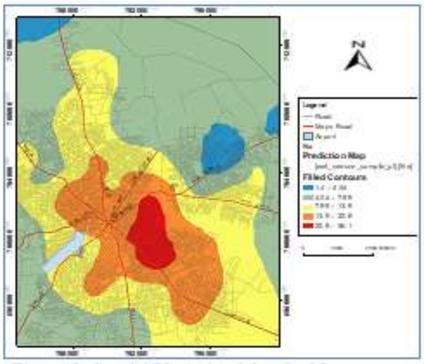

Figure 9: Spatial Variation Map for Na

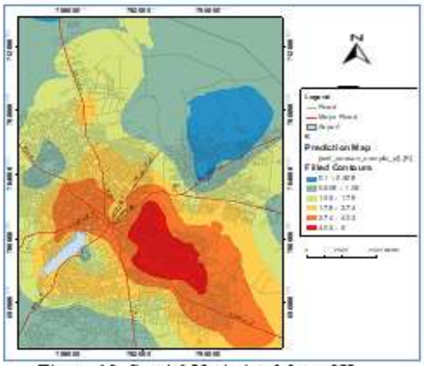

Figure 10: Spatial Variation Map of K

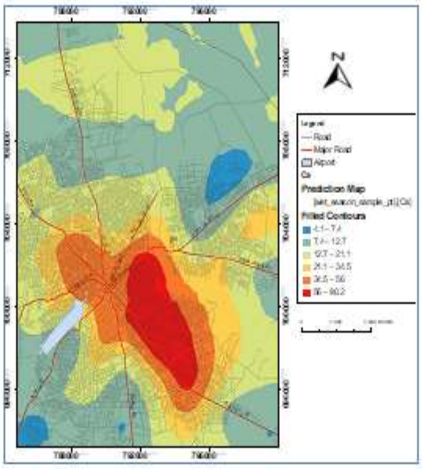

Figure 11: Spatial Variation Map of Ca

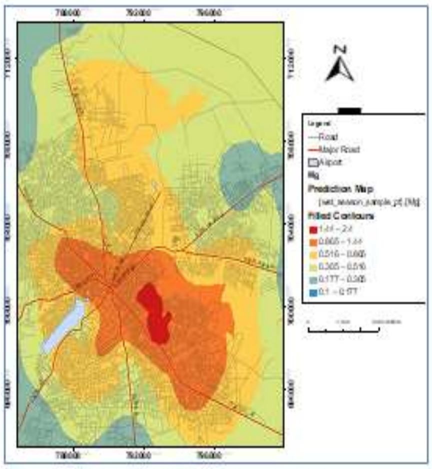

Figure 12: Spatial Variation Map of Mg

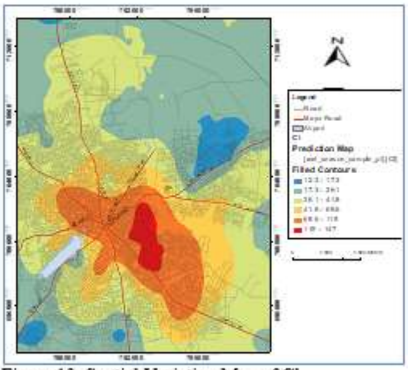

Figure 13: Spatial Variation Map of Cl

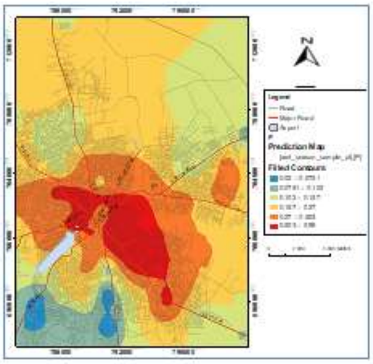

Figure 14: Spatial Variation Map of P

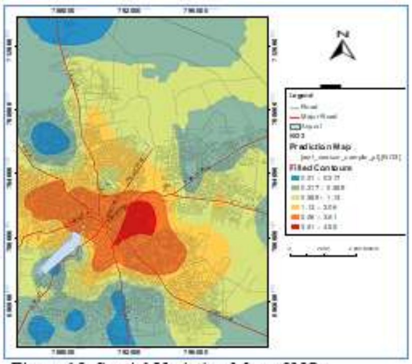

Figure 15: Spatial Variation Map of NO_3

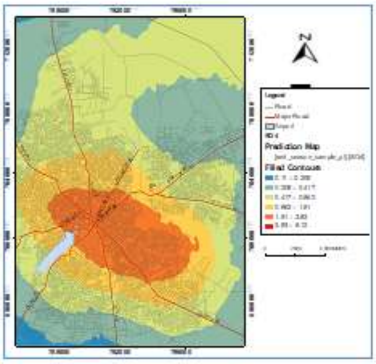

Figure 16: Spatial Variation Map of SO_4

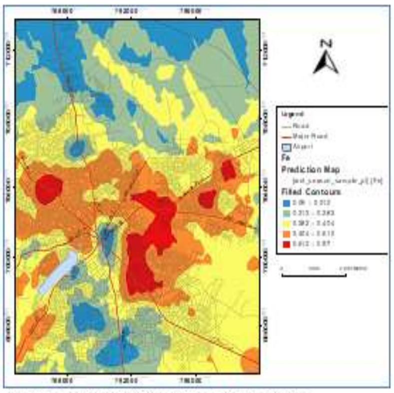

Figure 17: Spatial Variation Map of Fe

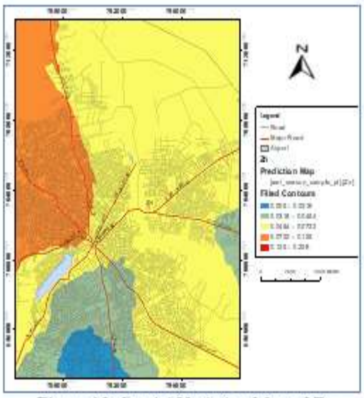

Figure 18: Spatial Variation Map of Zn

In Figure 3, the spatial distribution map of pH showed that the study area is generally acidic. Low values of pH were found mainly in Area G (Benin Agbor - Sakponba), followed by some parts of Area B, C, D, E, and F. Areas with less urbanization(far end of west North and south-east) had higher pH values ranging from 5.49 – 6.3. This may be due to less pollution of water bodies from man-made activities such as the release of domestic sewage and industrial effluents into water bodies. Built-up areas have more acidic concentrations than other areas due to the influence of human activities.

The recommended limit for EC is 1000 mg/l. The distribution map of EC Figure 4 showed that the concentration distribution was within the desirable standard for drinking. However, the central part of Benin City and Area G (Benin-Agbor-Sakponba) showed a concentration (388 – 714mg/l) more than the other areas. This may be due to the addition of substances from sewage, and surface runoff that accumulates at the downstream section of the river located in Area G. The contaminants percolate into the groundwater, especially during the rainy season.

The recommended limit for TDS is 500 mg/l. The spatial distribution map of TDS in Figure 5 had the same pattern as EC. It showed that the concentration level of TDS was quite high in central parts of Benin City with a higher concentration in Area G (Benin Agbor- Sakponba). This implies the entering of foreign matter into the groundwater (Narsimha et al., 2013) i.e. addition of substances through sewage and urban runoff

In Figure 6, the DO level in groundwater exceeded the limit in about 50% of the study area which includes areas A, H, G, and part of Area F. The desirable limit is set at 5mg/l. Other areas were within the desirable limit.

The spatial distribution map of COD in Figure 7 showed that the concentration level is within the desirable limit of 40mg/l. The COD concentration of groundwater poses no health risks.

The recommended limit for HCO_3 is 100 mg/l. The spatial distribution map of HCO_3 in Figure 8 exhibited the same pattern with TDS and EC. It showed that the concentration level of HCO_3 was quite high in central parts of Benin City with higher concentrations spreading down Area G (Benin Agbor- Sakponba Rd) and Area H(Sakponba - Sapele Rd). Higher HCO_3 during the wet season may be due to the action of CO_2 upon the basic material of soil and granitic rock (Vasanthavigar et al., 2010).

The desirable limit for sodium in drinking water is 200 mg/l. In all parts of the study area, as shown in Figure 9, the concentration levels of sodium were well below the benchmark limit. The high value of Na may be due to silicate weathering and dissolution of soil salts (Narsimha et al., 2013).

The spatial variation map of K in Figure 10 exhibited the same pattern as Na. Area G (Benin Agbor- Sakponba Rd) showed the highest concentration more than other parts of the study area. There is no guideline limit set for potassium. Concentrations of K normally found in drinking water are generally low and do not pose health concerns (WHO, 2007).

The desirable limit of calcium in drinking water is 75 mg/l. The spatial variation map of Ca in Figure 11 showed that groundwater of the southeastern parts (Area G) had a concentration level of calcium above the desirable limit. The high amount of Ca in the area may be attributed to geological formations encountered in the flow history (Narsimha et al., 2013). Higher Ca is also an indication of water hardness.

The Spatial variation map of Mg in Figure 12 revealed that the concentration of magnesium in domestic boreholes was more than the desirable limit (0.2mg/l) in all parts of the study area. The higher values are found in Area G and the center. The values decrease as it spreads out from the center. Magnesium appears to be in the same range in the northern part of the study area. Higher Mg is due to the dissolution of magnesium calcite, gypsums, and dolomite from source rock. It is an indication that domestic boreholes within those areas are generally hard.

The desirable limit of chloride in drinking water is 250 mg/l. The spatial variation maps of Cl in Figure 13 showed that the concentration of Cl within the study area was within the recommendable limit. Concentrations of chloride appear higher in the southeastern parts of the study area (Area G). High Chloride in that area may be due to pollution from chloride-rich effluents of sewage and municipal waste. Continuous monitoring is needed in this part of the study area.

The desirable limit of P for drinking purposes is 5mg/l. The spatial variation map of P in Figure 14 revealed that the concentration/ variation of the water quality parameter in the study area does not pose any problem. The tendency for P to adsorb to soil particles limits its movement in soil moisture and groundwater (Peavy et al., 1985).

The level of nitrate concentration in the groundwater of Benin City is well below the desirable limit set at 50mg/l as shown in Figure 15. Hence this parameter does not pose any health threat to the consumers. However, a higher amount of nitrate is an indication of potential pollution of agricultural-related contaminants. The recommended limit for SO_4 is 100 mg/l. There is no health threat about SO_4 in the study area as shown in Figure 16. Sulfate occurs naturally in drinking water.

The recommended limit for Fe is 0.1 mg/l. The spatial variation map of Fe in Figure 18 showed that the distribution concentration was above the desirable standard for human consumption within the study area. Therefore, Fe poses a significant health threat. It occurs naturally in soil, sediments, and groundwater and can be found in many types of rocks (WHO, 2008). In the dry season, the variation is not significant, which means that the distribution channel may be a source of iron contamination to water sources as well.

The allowable limit for Zn in drinking water is 3 mg/l. The spatial distribution map of Zn in Figure 18 revealed that the concentration level of Zn in the study area was within the desirable limit. Zinc concentration can be much higher as a result of the leaching of zinc from piping and fittings and the most corrosive waters are those of low pH and high carbon dioxide (WHO, 2017).

Conclusively, the maps generated by the ordinary kriging method showed the areas where the levels of groundwater concentrations are higher and above the desirable standards for drinking water quality. The maps identified the Central area, Area G (Benin Agbor – Sakponba Rd) and E (Benin Ore – Benin Auchi Rd) as the most sensitive area that needs protective measures and continuous monitoring. These two areas have the Ikpoba River cut across them. River accumulates the highest concentration of contaminants through surface runoff, and industrial and sewage discharge, which permeates to groundwater. Also, there is a regional groundwater flow from the east to west as a result of water finding its level (into the river) with rainfall as the most recharging source. Therefore, a lot of contaminants now tends to accumulate and infiltrate into the groundwater within area G and E. The centre of the study area is a built-up zone which also shows the impact of urbanization and other activities on groundwater quality. Variation Map through ArcGIS has shown these sensitive zones that are under threat and prone to health danger for serious monitoring and decision-making to ensure that the SDG 3rd goal of good health and well-being and 6th goal of clean water and sanitation is achieved.

4.0 CONCLUSION

The groundwater quality in Benin City is fit for human consumption based on sixteen parameters, however Dissolved Oxygen, Calcium, Iron, Magnesium and Nitrite exceeded the recommended limit set for human consumption and therefore minimal treatment is required to make the water sources suitable for human consumption. Semivariogram models fitted water quality parameters data and measured its spatial dependency. This made the kriging techniques effective in creating a continuous surface and produced spatial distributions of groundwater quality parameters within Benin City using measured values at known locations. Using GIS, concentrations of groundwater quality parameters maps (pH, EC, TDS, HCO_3, Na, K, Ca. Mg, Cl, P, NO_3, SO_4, and Fe) were produced. Areas G, E, and the central area of Benin City have higher concentrations and therefore, have been identified as the most sensitive zones prone to contamination. The use of GIS in the assessment of the water quality of domestic boreholes is essential in ensuring the safe use of the resource for human consumption and other purposes. ArcGIS can be used to integrate the laboratory analysis results of domestic boreholes with their geographical coordinates to take measures of safety for water consumption.

5.0 RECOMMENDATION

The borehole should be sited away from septic tanks to avoid fecal contamination. The government should establish a regulatory body to ensure proper spacing and site consideration. Iron and Magnesium correction units should be installed in homes to reduce the concentration level of Iron and magnesium in the water. Also, a Chlorinator or Violet unit should be installed to kill coliform bacteria and provide disinfected water for home use.

Commercial groundwater providers and Private homeowners should be registered and monitored to ensure the suitability of their water for human consumption. Just like medical health centers, there is a need for water laboratories and treatment centers to provide domestic water testing services and treatment where necessary. Enlightenment and awareness programs should be done continuously to educate the people. Government and stakeholders should make funds available for more research and enact laws that will improve groundwater quality for human health. This will help to ensure access to clean water and sanitation for all which is one of the most basic human needs for good health and well-being.

REFERENCES

APHA (1999): "Standard Methods for the Examination of Water and Wastewater", 20th edition. American Water Works Association, Water Environment Federation, Washington, DC.

Balakrishnan, P.; Saleem, A. and Mallikarjun, N.D. (2011): "Groundwater Quality Mapping Using Geographic Information Systems (GIS): A case study of Gulbarga City, Karnataka, India" *African Journal of Environmental Science and Technology. Vol. 5, No 12. pp 1069- 1084.*

Chang, K-T.: (2014) "Introduction to Geographic Information Systems" Seventh edition. McGraw-Hill Companies, Inc., 1221 Avenue, America, New York, NY 10020.

Dalton, J. (2013) "Groundwater News". Dales Water Services. www.dales.water.co.uk. Accessed on 28th July, 2023.

Essington, M.E. (2005): "Soil and Water Chemistry: An Integrative Approach" www.books.google.com.ng. e-library. Accessed on 28th July, 20203.

Gama (2017) "Groundwater Information Sheet" State Water Resources Control Board Division of Water Quality GAMA Program, Geo-Tracker. Accessed March, 2023.

Liu, D.; Wang, Z.; Zhang, B.; Song, K.; Li, X.; Li, J.; Li, F. and Duan, H. (2006) "Spatial Distribution of Soil organic carbon and Analysis of Related factors in croplands of the black soil region, Northeast China." Agriculture Ecosystem Environmental Journal, Volume 113, pp 73 – 81.

Nas, B. (2009): "Geostatistical Approach to Assessment of Spatial Distribution of Groundwater Quality" *Polish Journal of Environmental Studies, Vol. 18, No6. pp.1073-1082.*

NIS (2015) "Nigerian Standard for Drinking Water Quality" www.nigerian-standard-for-drinking-water-quality- NIS-554-2015, accessed on 28th July, 2023

Peavy, H. S., Rowe, D. R., and Tchobanoglaus, G. (1985). Environmental Engineering. International Edition, McGraw-Hill Book Co. Singapore. pp 49-56

Sundara Kumar, K.; Sundara Kumar, P.; Ratnakanth Babu, M.J. and Hanumantharao C. (2010): "Assessment and mapping of Groundwater quality using Geographical Information Systems", *International Journal of Engineering Science and Technology, Vol. 2(11)6035-6046,*

USEPA (2009) "Groundwater and Drinking water" www. Epa.gov. Accessed on 7th February 2023

Vasanthavigar, M.; Srinivasamoorthy, K.; Vijayaragavan, K.; Ganthi, R. R.; Chidambaram, S.; Anandhan, P.; Manivannan, R. and Vasudevan, S. (2010): "Application of Water Quality

Wilkes Environmental Centre (2008): Wilkes University Center for Environmental Quality, Environmental Engineering and Earth Sciences. www. Water research .com

World Health Organization (2003): "Manual of Basic Technique for a Health Laboratory" World Health Organization, 2nd edition, Geneva.

World Health Organization (2007): "Potassium in Drinking water" WHO/SDE/WSH/09.01/7 www.who. int/water_sanitation…/potassium.pdf. Accessed on 5th November, 2022.

World Health Organization (2008): "Guidelines for drinking water quality" electronic resource; Incorporation 1st and 2nd addenda v.1 Recommendation, 3rd edition, Geneva, 515

World Health Organization (2009): "Calcium and Magnesium in Drinking water, Public Health Significance" Printed in Spain.

World Health Organization (2011): "Guidelines for drinking water quality" Fourth edition.www. Unicef.org. Accessed on 23rd January 2023.

World Health Organization (2017): "Zinc in Drinking water" WHO/SDE/WSH/03.04/17

Paper 07 *Exploitation of Groundwater for Effective Water, Sanitation and Hygiene Governance in Nigeria*

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ABSTRACT: Groundwater exploitation remains a major source of water in most communities in Nigeria and it must be harnessed properly to promote water, sanitation and hygiene (WASH) practices and to eradicate environmental and public health-related problems. This paper discussed how groundwater can be exploited to strengthen the water, sanitation and hygiene in various communities in Nigeria. Challenges related to groundwater governance and water quality standards were examined. Findings revealed that significant investments have been made in the past to improve water, sanitation and hygiene but it has not yielded the required benefits. There is a need for infrastructure development and adequate policies to implement sustainable solutions. Innovative technology, sustainability strategies and appropriate tests should be conducted on the water to avert diseases and other health-related issues. The findings of this research can be used as a reference for similar cities in developing countries to adopt innovative solutions for better wash services, enabling the environment and safer cities. Adequate advocacies, smart WASH management technologies and the adoption of innovative strategies will enhance WASH in Nigeria. Groundwater is a viable source of water for toilets, hygiene in various buildings and other WASH activities in many communities in Nigeria. There is a need to set a new direction for research and capacity building for adequate water governance. Recommendations are presented to strengthen government policies and improve decision-making in water, sanitation and hygiene programmes.

Keywords: groundwater exploitation, water, sanitation, hygiene, water quality standards

1.0 INTRODUCTION

There are numerous ways to change the urban environment for the betterment of humanity. To prevent infections and other health-related problems, innovative technology, sustainability initiatives, and suitable tests on the water should be carried out. WASH in Nigeria will improve with adequate advocacy, clever WASH management technologies, and the implementation of novel tactics. Our most plentiful supply of freshwater is groundwater. Water promotes healthy ecosystems, agriculture, energy generation, sanitation, and environmentally friendly waste management. It also stimulates economic growth. It is impossible to overestimate the importance of water to industry, manufacturing, healthy living, and the prevention of infectious disease transmission. A lack or insufficient supply of water raises the danger of infectious diseases, bad industrialization, poor personal and community hygiene, poor food production, conflicts, human rights violations, and poverty. Water is an indication of life. 90% of mortality in children under five in underdeveloped countries is due to unclean water and subpar sanitation, with over a million deaths per year (WHO, 2019). For food production, agriculture, and industry, especially in developing nations, access to groundwater is essential. Nevertheless, natural causes and human actions consistently put this resource's sustainability in jeopardy. Groundwater quality is influenced by several factors, including overexploitation, geomorphic processes, hydrological mineralization, water-rock interactions, ion exchange and redox reactions, and human activities. Because a shortage of either can lead to several public health problems, water quality is just as important to sustaining basic human requirements as water availability. Water is a fundamental necessity that has huge ramifications for industrialization, development, food production, sanitation, and hygiene. By 2030, the Sustainable Development Goals (SDG) No. 6 aspires to meet all of humanity's water demands. Over 60 million Nigerians lack access to clean water despite the country having over 200 cubic kilometres of surface water and a sizable reservoir of untapped subsurface water. Conflicts and violence have also been brought on by the stress on water resources in some parts of Nigeria. For the environment, human health, and economic development, water is crucial. However, managing water resources properly is a big challenge for governments all over the world. The issues are numerous and complicated: billions of people still lack access to safe water and proper sanitation; there is growing competition for water among various purposes and users; and maintaining and enhancing water infrastructure in many countries requires large investments.

2.0 LITERATURE REVIEW

90% of mortality in children under five in underdeveloped countries is due to unclean water and subpar sanitation, with over a million deaths per year (WHO, 2019). By 2030, SDG's objective six intends to provide all home water demands, in particular. Despite the fundamental importance of water, a resource that is naturally abundant in the nation, Nigeria's socioeconomic development is still being hampered by its inadequate management (Odume and Slaughter, 2017; Salau, 2017; Independent, 2018; Oyebode et al, 2015). Many Nigerians have turned to self-help and unorganized, uncoordinated, and unsustainable subsurface water resource exploitation as a result of the country's inadequate water management and supply system (Akpor and Muchie, 2011). Over 60% of Nigerians with access to drinking water currently obtain it from underground sources, according to Omole (2013). In addition to hydrological concerns, he pointed out those funding, weak institutions, a lack of data management system, and poor execution of groundwater exploitation regulations all pose challenges to Nigeria's sustainable groundwater use. The degeneration of Nigeria's water supply and management has given rise to numerous private business initiatives. Access to a safe water supply has remained difficult for the majority of the population who live in poverty and rural areas. Obeta (2019) argues that it is unsustainable for the population's water demands to be met by for-profit commercial water ventures.

The government of Nigeria currently owns natural resources, and its relevant agencies regulate their exploitation (Ukpai et al., 2021), but water resources were deregulated to improve access to the water supply as a human right—a claim that tends to meet the needs of the expanding population. It should have been part of the deregulation for the public good to include a water policy that ensures competent water management regulatory frameworks are successfully implemented and enforced, but this seems problematic, especially since water managers with experts are no longer consulted before water development. Unplanned groundwater extraction may have further negative effects since geological conditions and other anthropogenic variables may have an impact on the water's quality. Many times, private individuals and enterprises are unable to cleanse water before making it usable for human consumption. According to studies by Cheri et al. (2014) and Olorunfemi et al. (2015), heavy metals, landfill and dumpsite leachates, industrialization, rate of urbanization, and geochemistry of the environment, all affect groundwater quality. These factors are also true for the majority of Nigeria's metropolitan districts. Two other significant problems influencing Nigeria's water resources are wetland degradation and climate change (Uluocha and Okeke, 2004; Coulibaly et al., 2018).

2.4 billion People utilize unimproved sanitation systems worldwide, with 695 million (or 28.96%) living in sub-Saharan Africa. Similarly, the region was home to 194 million people, or 30.41 per cent, of the 638 million people who shared sanitation that was otherwise upgraded. Additionally, 23% of people in sub-Saharan Africa continue to practice open defecation, compared to 13% globally in 2015 (UNICEF and WHO, 2015). As a result, it was not surprising that only three sub-Saharan African nations (Cape Verde, Reunion, and Seychelles) and 43 other nations (Sudan, South Sudan, Somalia, and Congo) were excluded from consideration for meeting the sanitation target because there was insufficient reliable data (UNICEF and WHO, 2015). This demonstrates how sub-Saharan Africa constitutes a significant drag on the attainment of the MDG sanitation target at the global level. Africa constitutes a significant drag on the attainment of the MDG sanitation target at the global level. According to Minh and Hung (2011), policymakers and the general public lack a proper understanding of the significance of improved sanitation solutions, which is another factor in the slow expansion of improved sanitation coverage in the world and developing countries in particular. They claimed that governments in underdeveloped nations do not recognize the link between better sanitation and economic growth or the source of increased welfare. Furthermore, cost-benefit analysis has not typically been used to support raising funding for sanitation programs.

3.0 METHODOLOGY

The methodology included a literature review and expert opinions. The study area is some part of Nigeria. The hydrology of Nigeria is dominated by the water bodies of the River Niger, River Benue, and Lake Chad. Nigeria's surface water production was projected to be around 214 billion cubic meters annually as of 2017 (Knoema, 2017), a figure that has mostly been consistent with data on the quantity and production of surface water in the nation since 1972. However, the entire yearly potential of Nigeria's renewable groundwater resources is estimated to be 155.8 billion cubic meters (FGN, 2014). Due to the various ways that climatic conditions show themselves around the country, the recharge potentials of both surface and groundwater vary. Due to high evapotranspiration and sparse rainfall in Northern Nigeria, recharging is lower than in the southern region. According to Tijaniet al. (2018), the North-East has the lowest groundwater recharge potential at 4.8 cm/year while the South-East has the most at 32.8 cm/year. The major rivers and bodies of surface water in Nigeria are depicted in Figure 1.

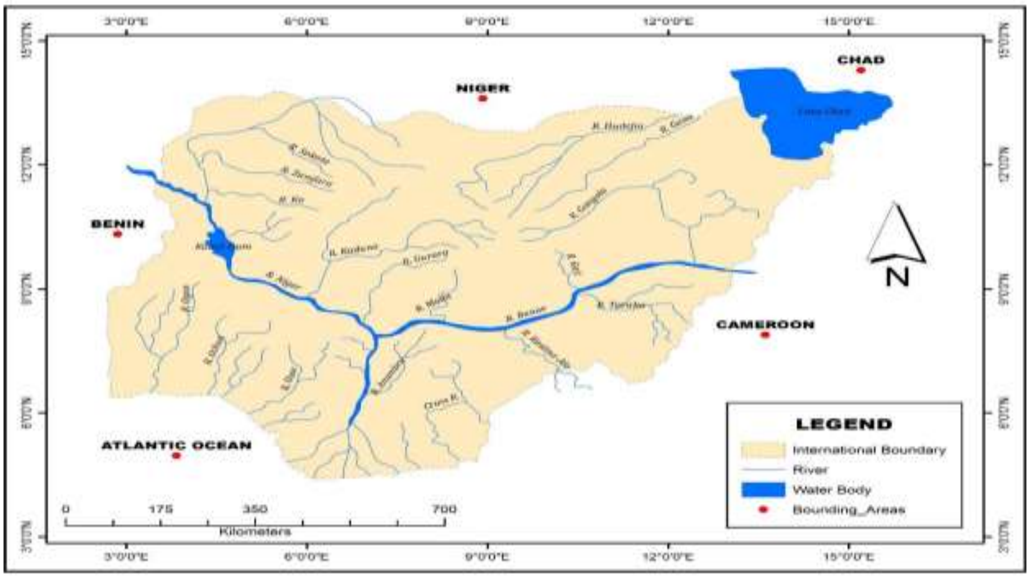

Figure 1: Hydrological Map of Nigeria

Nigeria has abundant water resources, as shown by the amount of rainfall, surface water deposits, and subterranean water storage (Ezeabasili et al., 2014; Idu, 2015), yet the gap between water supply and demand appears to be growing (Chukwu, 2015; Chukwu 2017). Both natural factors—such as the effects of climate change and hydrological extremes—and anthropogenic factors—such as the contamination of water bodies with industrial waste, oil spills, and the salinization of surface and groundwaters through irrigation and fertilizer use—threaten Nigeria's development of its water resources (Idu, 2015). Figure 2 indicates the percentage and pictorial image of Nigerians with a lack of water for WASH activities.

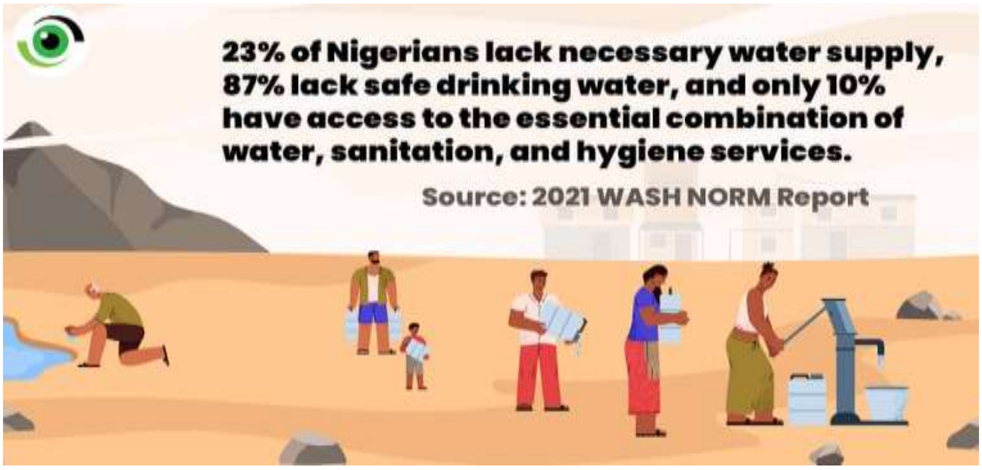

Figure 2; Percentage and pictorial image of Nigerians with a lack of water for WASH activities

Access to water generally for all economic use and clean drinking water is still a prevailing challenge across Nigeria. The Nigerian state has largely failed in its responsibility of providing potable water to the population, leaving about 2/3 or close to 70% of the population to resort to self-help in addressing their water needs (MICS, 2018). Figure 3 presents most activities, indicators and frameworks that need to be strengthened.

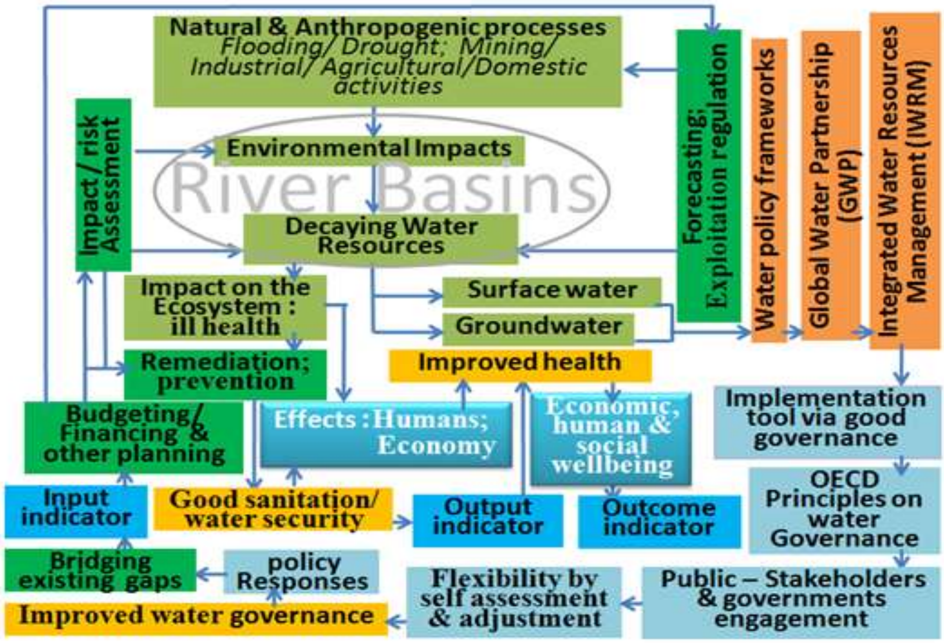

Figure 3: Activities, indicators and framework that need to be strengthened

Numerous stakeholders with competing interests and objectives participate in the management of water resources (Smith and Clausen, 2015). Even though the Global Water Partnership (GWP) was established to use Integrated Water Resource Management (IWRM) to resolve conflicts among stakeholders, implementation has not gone well, partly due to a lack of innovation in water governance. To create a framework for sound water governance, the Organization for Economic Co-operation and Development (OECD) rationalized several practices and principle frameworks (Figure 4) that create the prerequisites for effective, efficient, and inclusive water policies. As a result, the OECD Principles on Water Governance were created.

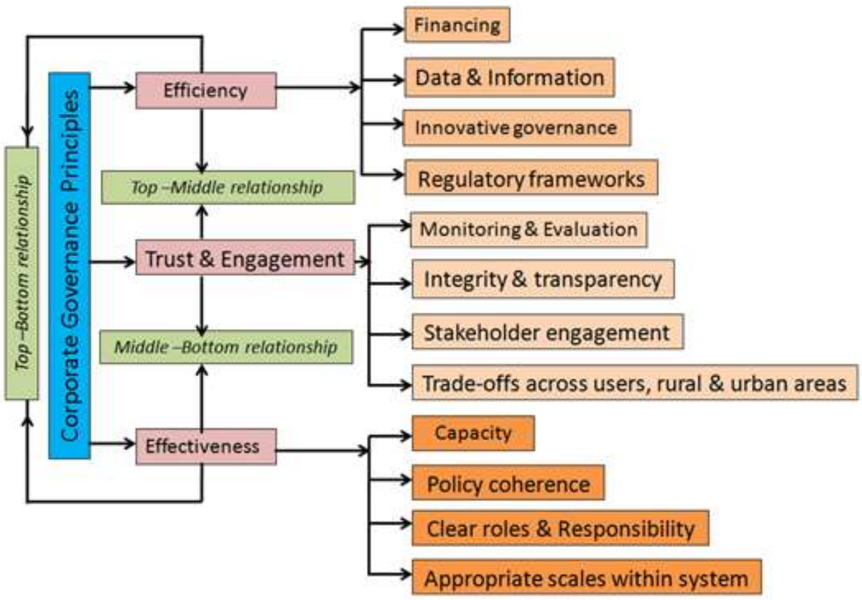

Figure 4: Practices and Principle Frameworks that provide conditions for effective, efficient, and inclusive water policies

Water and other natural resources have great promise in Nigeria. Different hydrological qualities in the northern and southern regions, which were influenced by climatic factors and geological settings, particularly mining, led to a variety of land uses. Both the land uses—primarily agricultural in the north and mining in the south—compromise the ecology and expose a large portion of humanity through the water supply. Due to cross-sectoral conflicts of interest, however, there is lax governance input in terms of ecological conservation services, which results in attitudes that amount to public ignorance of water policy. Figure 5 presents some areas where water can be exploited for WASH programmes.

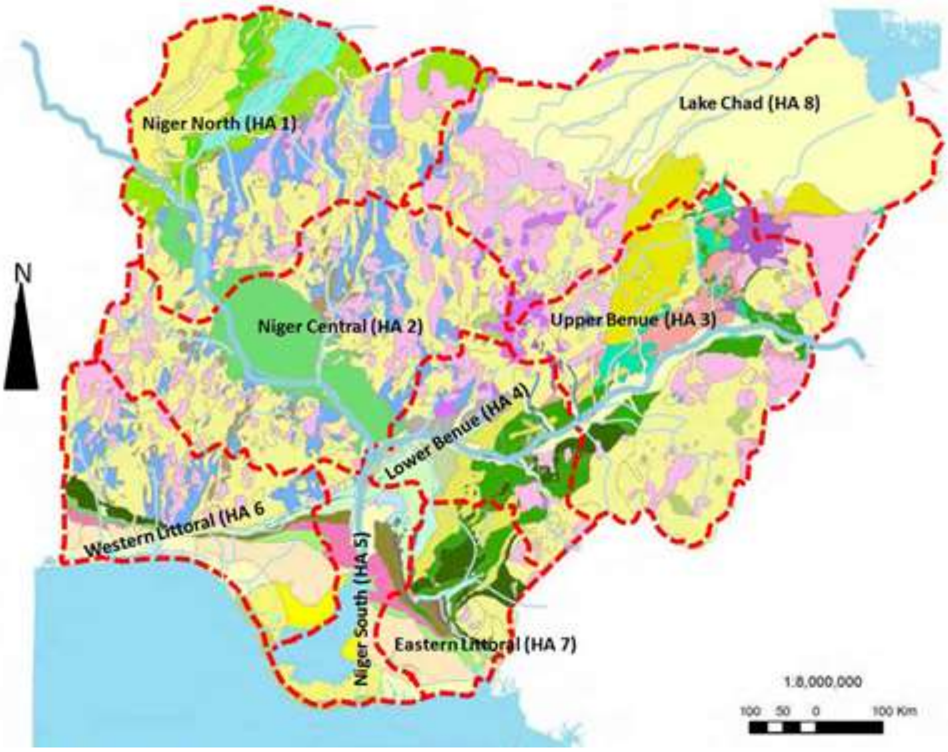

Figure 5: Some areas where water can be exploited for WASH programmes

The government has broad authority over property ownership, allowing it great control over resources like groundwater. The federal government has sole control over all surface and groundwater that affects at least two states under the 1993 Water Resource Decree. The ruling does, however, also permit access to and household use of the water by the populace. It also permits those who have the right to occupy a property to use and exploit the groundwater beneath it (FGN, 1993). In Nigeria, the Land Use Act serves as the primary legislative framework for the exploitation of water resources (FGN, 2004a). Figure 6 presents a typical manually drawn borehole for a community.

Figure 6: Manually drawn borehole for a community

Despite various efforts, 208 million people in Africa still practised open defecation in 2020. Figure 7 presents countries in Africa with the largest number of people practising open defecation in 2020. Figure 8 presents aspects where we can secure sustainable water for all

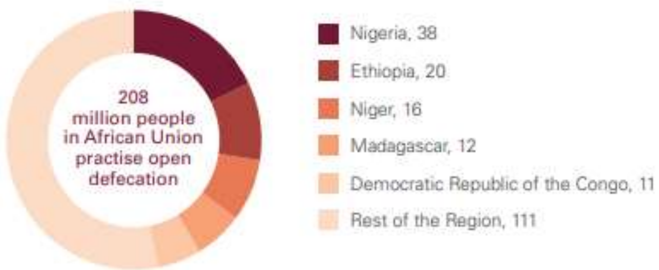

Figure 7: Countries in Africa with the largest number of people practising open defecation in 2020

Figure 8: Aspects where we can secure sustainable water for all

Water, sanitation, and hygiene (WASH) in a health care facility denote the provision of water, regular sanitation, health care waste management, hygiene, environmental cleaning, and services in all parts of the health facility. Figure 9 presents multiple benefits of adequate WASH in Primary Health Care Facilities. Figure 10 indicates an example of washing hands for hygienic activities in schools.

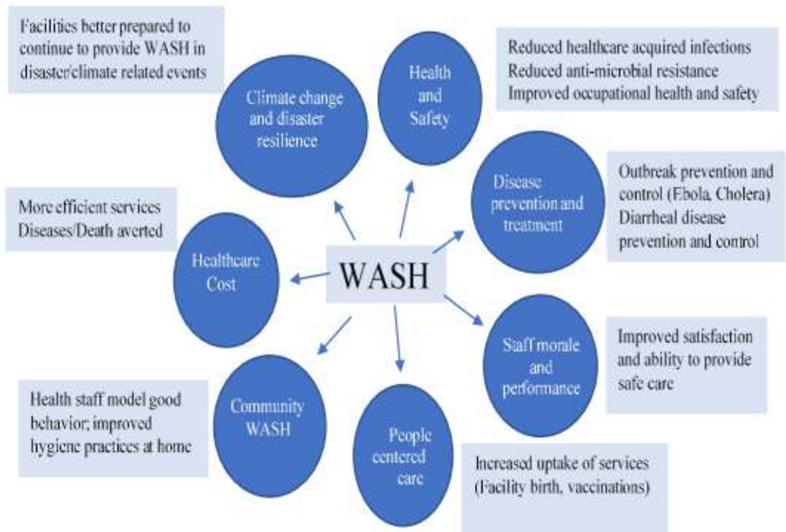

Figure 9: Multiple benefits of adequate WASH in Primary Health Care Facilities
Source: (WHO, 2019)

Figure 10: Washing hands for hygienic activities in schools

In Africa, there are large disparities in access to basic hygiene services between and within countries. Figure 11 presents WASH's Contributions to UNICEF's Key Outcomes for Children, Across the Life Course. Figure 12 indicates mitigation measures, standardization and Enforcement that can assist WASH activities.

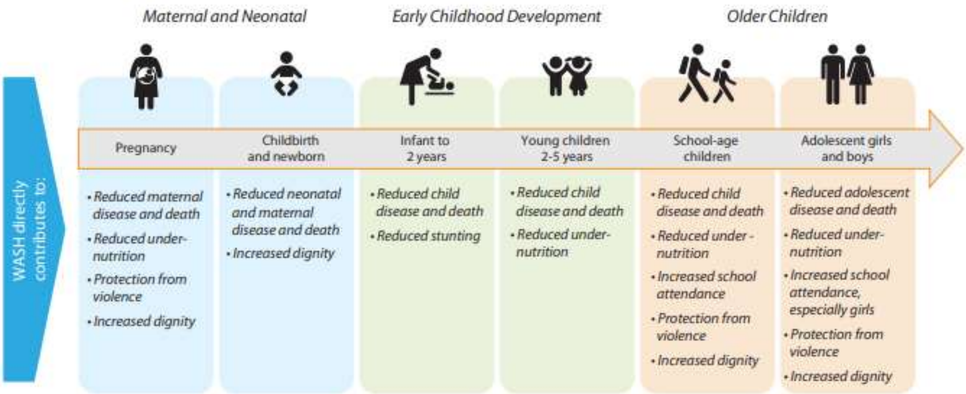

Figure 11: WASH Contributions to UNICEF's Key Outcomes for Children, Across the Life Course

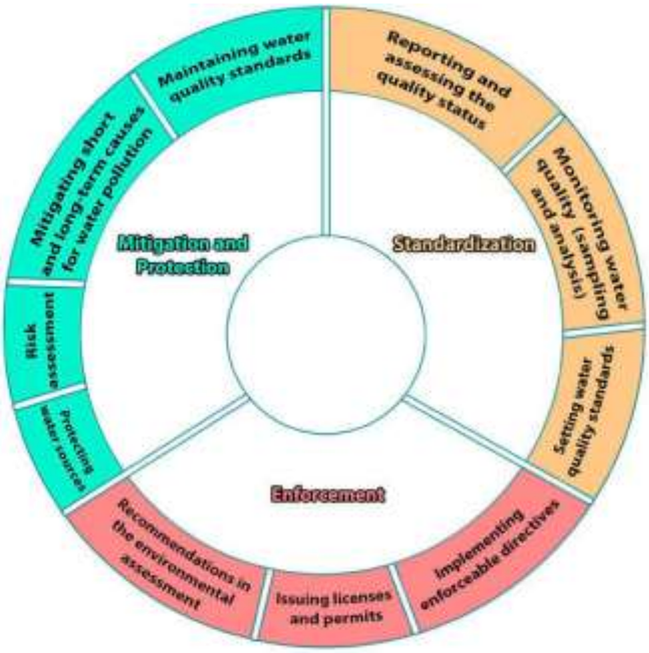

Figure 12: Mitigation measures, standardization and Enforcement for WASH

4.0 HOW GROUNDWATER CAN BE EXPLOITED FOR SUSTAINABLE DEVELOPMENT AND EFFECTIVE WASH

The following will assist in how groundwater can be exploited for sustainable development and effective WASH and management of water resources for health and wealth in Nigeria:

i. Strategic Policies and Public-private interventions: Coherent policies, robust political oversight, Public-Private Partnership, enormous investment in water technology and cutting-edge innovation can be used to achieve effective WASH programmes

ii. Integrated Water Resources Management (IWRM): Integrated Water Resources Management is a holistic approach to managing water resources sustainably. It involves the coordinated development and management of water, land, and related resources, to maximize economic and social welfare without compromising the sustainability of vital ecosystems. IWRM includes policies, strategies, and actions that promote sustainable water use, conservation, and protection.

iii. Water Conservation: Water conservation is an important aspect of sustainable water resources management. It involves reducing the amount of water used in domestic, agricultural, and industrial activities through the adoption of water-efficient technologies and practices. This can include rainwater harvesting, the use of low-flow toilets, faucets and showerheads, and water recycling and reuse.

iv. Water Quality Management: Water quality management is essential for ensuring that water resources are safe and healthy for human consumption and other uses. This involves the development and implementation of policies and strategies to control pollution sources and protect water quality. It also involves the monitoring and testing of water quality to ensure that it meets regulatory standards.

v. Community Participation: Community participation is crucial in achieving sustainable water resources management. This involves engaging communities in water management decision-making processes, as well as educating them on water conservation and sanitation practices. Community participation helps to foster a sense of ownership and responsibility among individuals and communities, which can lead to better management of water resources.

vi. Capacity Building: Capacity building is essential for ensuring that stakeholders have the knowledge, skills, and tools necessary to manage water resources sustainably. This includes training and education programs for water resource managers, policymakers, and other stakeholders. Capacity building can also include the development of monitoring and evaluation systems to track progress towards sustainable water resource management.

5.0 CONCLUSION

In many communities in Nigeria, groundwater is a reliable source of water for toilets, cleanliness in different buildings, and other WASH activities. To implement sustainable solutions, there is a requirement for infrastructure development and suitable policies. Exploiting groundwater is a crucial part of the water, sanitation, and hygiene (WASH) sector.
Groundwater is our most abundant source of freshwater. It supports our drinking water supplies, sanitation systems, farming, industry and ecosystems. As climate change worsens and populations grow, groundwater is vital for our survival. It supports farming, industry, ecosystems, sanitization systems, and drinking water sources. Groundwater is crucial for human survival as population growth and climate change increase. In many communities in Nigeria, groundwater is a reliable source of water for toilets, cleanliness in different buildings, and other WASH activities. Due to the disparities in water supplies and infrastructure, Nigeria's rural-urban gap has widened with the growth of the country's water infrastructure. The third plan sought to "ensure that no community of 20,000 people or more shall be without essential services" and supported integrated rural-urban development.

A significant issue around the world is the lack of access to sanitary facilities. Septic systems, pit latrines, and other sanitation facilities can all be designed using tools that water engineers give to manage safe and efficient sanitation systems. Nigeria is one of many countries in the globe that experience water scarcity and poor water quality, which can make it challenging to plan and operate WASH systems. Water engineers offer instruments for evaluating the quality and quantity of water as well as for designing and managing water supply and treatment systems that satiate the needs of communities. Options for infrastructure development must continue to be adaptable to a future with unknown trends in population expansion, economic needs, and climate change.

There is widespread agreement that building up water infrastructure is essential for achieving the Sustainable Development Goals (SDGs). For Nigeria's health and prosperity, it is essential to manage water resources effectively and sustainably. To do this, the nation must develop an integrated strategy for managing its water resources, one that incorporates community involvement, water quality management, water conservation, and capacity building. Nigeria can successfully manage its water resources to increase the well-being and prosperity of its people with the help of these policies. Developing water infrastructure is essential for achieving sustainable development, particularly for energy generation, agricultural growth, sanitation, and water delivery. Failure of water projects poses a serious problem for WASH in Nigeria. For instance, due to the overwhelming number of unsuccessful water projects, the principles of functionality and sustainability are under scrutiny in the rural water supply sector. The effects of WASH efforts have been severe.

6.0 RECOMMENDATIONS

The following recommendation will assist exploitation of groundwater for effective water, sanitation and hygiene governance in Nigeria:

i. The government's plan should be a comprehensive one putting into consideration both the rural and urban population growth index.
ii. A synergy between researchers, the private sector, professionals and government at all levels can facilitate more sustainable water resources development by drawing on existing financial, technical, and regulatory knowledge and opportunities at local, regional, and international levels.
iii. The use of groundwater for WASH, reservoirs, and other water infrastructure in Nigeria needs to be adequately documented and monitored.
iv. There is a need to educate the public about proper sanitation practices, find affordable remedies, and install latrines and toilets that flush into a sewer or a secure enclosure.
v. .Facility inspectors should ensure proper water and sanitation infrastructure are provided when buildings are constructed. A lot of landlords fail to provide adequate water and sanitation facilities when constructing houses or shops, especially in the rural area.
vi. Public education and information sharing is key to any strategy on achieving improve WASH services. Efforts should be made by WASH agencies to disseminate relevant information on the consequences and benefits of WASH and how to achieve adequate services, by using improved sources of drinking water, sanitation and hygiene practices to the general public.
vii. Corruption in the WASH sector must be tackled to make any meaningful progress in WASH services in Nigeria
viii. The Nigerian government needs to invest more in water resources management by providing adequate funding for the implementation of policies and programs. This will enable the government to develop and maintain infrastructure for water supply and sanitation, as well as to establish effective water quality management systems.
ix. It is important to speed up and scale up innovative approaches through favourable legislation, the application of instruments like artificial intelligence, and the modification of ideas to local conditions.
x. Effective alternatives to conventional sanitation and hygiene practices include participatory planning, innovative financing methods, water conservation and reuse, the establishment of laws and regulations that serve as the cornerstone of efficient WASH strategies, and a move away from conventional sewer systems toward decentralized/small-scale systems.
xi. The introduction of best practice solutions for water preservation in areas where the water is scarce, and the ranking of water efficiency as extremely important across activities
xii. Current national recommendations for environmental health in healthcare facilities should include effective governance and management for WASH at all levels.

REFERENCES

Akpor, O.B. and Muchie, M. (2011). Challenges in meeting the MDGs: The Nigerian drinking water supply and distribution sector. Journal of Environmental Science and Technology, 4 (5), 480-489.

Chukwu, K. E. (2015). Water supply management policy in Nigeria: challenges in the wetland area of Niger Delta. European Scientific Journal, 11(26), 303-323.

Chukwu, K. E. (2017). Pollution of surface water resources in Nigeria. International Journal of Academic Research in Environment and Geography, 4(1), 77–92.

Coulibaly N., Coulibaly, T. J. H., Mpakama, Z. andSavané, I. (2018). The impact of climate change on water resource availability in a transboundary basin in West Africa: the case of Sassandra. Hydrology, 5(12), 1-13.

Ezeabasili, A. C. C., Okoro B. U., andEzeabasili, A. I. (2014). Water resources: management and strategies in Nigeria. An International Journal of Science and Technology, 3(1), 35-54.

Federal Government of Nigeria [FGN] (2004a). Land Use Act. Retrieved April 11, 2020, from: https://www.lawyard.ng/wp-content/uploads/2015/11/LAND-USE-ACT2004.pdf

Federal Government of Nigeria [FGN](1993). Nigeria: water resources decree 1993. Retrieved on April 11, 2020, From: http://www.ielrc.org/content/e9302.pdf

Federal Republic of Nigeria [FGN] (2014). The project for review and update of Nigeria's national water resources master plan, volume 5 supporting report. Retrieved from: https://openjicareport.jica.go.jp/pdf/12146569.pdf

GWP (2000). Integrated Water Resources Management (IWRM). Global Water Partnership (GWP) Technical Advisory Committee (TAC), Sweden, background paper No. 4, p. 68.

Idu, A. J. (2015). Threats to water resources development in Nigeria. Journal of Geology and Geophysics, 4(3), 1-10. doi:10.4172/2329-6755.1000205

Knoema (2017). Nigeria-volume of surface water produced internally. Retrieved May 5, 2020, from https://knoema.com/atlas/Nigeria/Volume-of-surface-water-produced

Obeta, M. C. (2019). Private for-profit rural water supply in Nigeria: policy constraints and options for improved performance. Journal of Water and Land Development, 41(4-6), 101-110.

Ocheri, M. I, Odoma L.A. and Umar, N.D. (2014). Groundwater quality in Nigerian urban areas: a review. Journal of Science Frontier Research: H Environment and Earth Science, 14(3), 34-46.

Odume, N. and Slaughter, A. (September 5, 2017). How Nigeria is wasting its rich water resources. The Conversation. Retrieved from: http://theconversation.com/how-nigeria-is-wasting-its-rich-waterresources-83110

Olorunfemi, D., Efechuku, U. and Esuana, J. (2015). Toxicological evaluation of drinking water sources in some rural communities in southern Nigeria after microfiltration treatment. Polish Journal of Environmental Studies, 24(3):1205–1212. doi: https://doi.org/10.15244/pjoes/34672

Omole, D. O. (2013). Sustainable groundwater exploitation in Nigeria. Journal of Water Resources and Ocean Science, 2(2), 9-14. doi: 10.11648/j.wros.20130202.11

Oyebode, O. J, Adebayo, V. B., and Oyegoke, S. O. (2015). Water and Development Challenges in Nigeria. International Journal of Scientific and Engineering Research, 6(8), 1145- 1160.

Salau, S. (July 11, 2017). The government urged to maximize the economic benefits of water resources. The Guardian. Retrieved April 28, 2020, from https://guardian.ng/business-services/government-urged-to-maximiseeconomic-benefits-of-water-resources/

Smith M. and Clausen T. J. (2015) Integrated Water Resource Management: A New Way Forward: A Discussion Paper of the World Water Council Task Force on IWRM, 21p

Tijani, M., Crane, E., Upton, K., Ó Dochartaigh, B.É. and Bellwood-Howard, I. (2018). Africa Groundwater Atlas: Hydrogeology of Nigeria. British Geological Survey. Retrieved from: http://earthwise.bgs.ac.uk/index.php/Hydrogeology_of_Nigeria

Uluocha, N.O. and Okeke, I.C. (2004). Implications of wetlands degradation for water resources management: Lessons from Nigeria. GeoJournal, 61(2), 151-154.

Minh, H. V and Hung, N. V (2011) Economic Aspects of Sanitation in Developing Countries, Environmental Health Insights, 5: 63-70

UNICEF/WHO (2015) Progress on Sanitation and Drinking Water2015 Update and MDG Assessment,www.wssinfo.org/fileadmin/user…/JMP- Update-report2015_English.pdf (Accessed November 20, 2017) 28. USAID (2017) West Africa Water Supply, Sanitation.

Paper 08

Open Defecation Practices in Nigeria: A Review on Effects, Challenges and Mitigating Approaches

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ABSTRACT: Open defecation (OD) is an abolished practice globally, due to its several direct and indirect negative consequences on the public health, environment and socio-economic development. Nigeria is ranked third in OD practices with over 20% of the population being indulge in it. This study reviews the various effects and challenges to open defecation free in Nigeria, The report aims to help understand the magnitude of the impacts and challenges of OD practising free in Nigeria, towards proper planning and achieving the nation's 2025 target of ensuring OD free Nation. The paper identified and discussed on the public health, psychosocial, economic and environmental impacts of OD in Nigeria, furthermore it was revealed that inadequate sanitation facilities, lack of knowledge, poor attitudes, poverty, inadequate water supply and lack of functional legal system are the major challenges to the prevalence and continues OD practices in Nigeria, the study concludes that addressing the underlying issues of poverty, cultural norms and maintenance culture of public infrastructures of water supply, sanitation and hygiene will significantly curb OD practice in Nigeria, helping the Country to achieve its 2025 target of ensuring OD free Nation.

Keywords: open defecation; sanitation; facilities; public health; hygiene

1.0 INTRODUCTION

Provision of adequate toilets and sanitation facilities is integral to health and human development, and one of the key elements of the WASH sector (Water sanitation and hygiene). Sanitation is one of the critical issues to be addressed in the United Nations sustainable development goals which is to ensure access to sanitation for all by 2030. However, across the globe about 1 billion people lack access to basic toilets facilities (WHO/UNICEF (2017). the situation thus has inevitably exposed people and communities to the improper practices of disposing human faces in water ways, surface waters, open fields and trenches, better known as open defecation (UNICEF, 2018). Open defecation is an abolished practice globally, due to its several direct and indirect negative consequences on the public health, environment, economic and social impacts particularly to women (Saleem et al. 2019, Okuku, 2020) and children (Okuku, 2020) in low-income communities in developing countries. It is predominantly a rural based practice where culture, tradition, and morals are significant factors. However, a large number of people in the urban regions are also affected due to many challenges related to sanitation services.

Nigeria is among top countries globally with high level of open defecation (OD) practices, the country ranks third in OD practices with over 20% of the population being involve in it, and perhaps the practice continues to persist both in urban and rural environment despite it negative impacts (Ngwu, 2017, UNICEF, 2017). However, several measures have been deployed over the years to make Nigeria OD free, but this still remain a nightmare, as today 47 million Nigerians practices OD. Recently the country flag up a major campaign towards attaining free Open defecation nationwide by 2030, this is in line with the UN Sustainable Development Goal (SDG 6), which is to ensure access to sanitation for all. The Federal Government of Nigeria in its efforts for attaining ODF, has set a far more ambitious commitment to end open defecation in the country by 2025 through the formulation of a National Road Map (FMWR 2016a) and establishment of the Partnership for Expanded Water Supply, Sanitation and Hygiene [PEWASH] (FGN 2016). Notwithstanding, a state of emergency was declared on the water supply, sanitation and hygiene (WASH) sector on 8 November 2018 (Premium Times 2018), while an executive order 009 targeted towards making Nigeria open-defecation-free by 2025 was signed on 20 November 2019 to show more commitments. These policy directions, suggest that Nigeria is committed to ending open defecation by 2025. This reports therefore present a review on the various effects of OD practices in Nigeria, various challenges to stopping the practices by individuals and organizations (highlighting the barriers to attaining open defecation free in Nigeria), and also recommended some technical approach towards making Nigeria free OD and achieving the UN SDG target. The report aims to help understand the magnitude of the impacts of OD practices in Nigeria, and the major hurdles why the OD situation remains unchanged despite several efforts, so as to pave way for proper planning towards achieving the 2025 target.

2.0 EFFECTS OF OPEN DEFECTION PRACTICES

Public Health Impacts: open defecation primarily comes with many negative impacts on the health status of people, it has been estimated that 842,000 deaths globally are related open defecation related diseases (Gbadegesin et al. 2020). it is one the major causative routes of typhoid, hepatitis, cholera, polio and diarrhoea which claims hundreds of thousands of children's lives every year, Diarrhoea is the leading cause death in children under five years, with more than 88 per cent of diarrhoea in children attributable to OD which also makes them vulnerable to stunting (Dean, and Arabinda Ghosh; 2013) and malnutrition; due to persistent diarhoea and loss of appetite, hence they absorb fewer nutrients from their food leading to malnutrition (PRB, 2014) and therefore, it is not surprising that Nigeria has found it very difficult to eliminate polio in spite years of relentless efforts. (Punch, 2018). In addition, available evidence shows that a gram of faeces contains about one million bacteria, 10 million viruses and one thousand parasite cysts. Furthermore, children 's faeces is said to contain more bacteria than adults'(UNICEF, 2018). Defecation into especially water ways and water bodies consequently interfere with the quality and contaminate drinking water supply systems (either municipal surface water or ground water) with such as *Escherichia coli*, faecal *streptococci*, *Salmonella typhi* leading to waterborne illness (Okullo et al. 2017). on the other hand some are ingested into the body directly through faecal oral route, mostly by infants and children (Bawakunle et al. 2017; Islam et al. 2017).

Psychosocial impacts: The practice of open defecation often results in a number of psychosocial issues, such as increased risk of sexual exploitation, mental stress (Samuel and Ezeah, 2020), threat to women's privacy and dignity, safety and security, etc. Women are the most vulnerable group affected by the social impacts due to poor or unavailability of decent toilets, research findings showed that open defecation expose women to sexual harassment and rape and even death. This occurs as the defecation practice usually occurs in remote and relatively dark and quiet environment such as backyards, bush and mostly in the night (Adepoju, 2019). Furthermore, having to defecate openly infringes on human safety and dignity. This holds particularly true for women and girls, who loose privacy and face shame having to defecate in public, or – after painfully holding their bladder and bowels all day – risk attack by waiting until night falls. Where toilets do exist, additional inequalities present in usability. Toilets generally remain inadequate for populations with special needs, such as the disabled and elderly, and women and girls requiring facilities to manage menstrual hygiene.

Economic impacts: Indirectly open defecation has tremendous effects on the economy of the country. Nigeria loses related to open defecation practices accounts for 455 billion annually, for example, on tourism as income generating practices; open defecation pollutes beaches in Lagos and other Nigerian coastal cities thereby decreasing their potentials to attract local and international tourists (Abubakar and Dano, 2018). Economically open defecation reduces the human capital of a country's workforce and inhibits people's physical and cognitive development (Mara, 2017). Care givers and parents have to bear the task of taking care of the sick children thereby loosing hours of labor productivity time and also income and long hours and finances are devoted towards taking care of the sick (WSP, 2012). Open defecation also has Impacts on agriculture economic productivity; It has been found that some of the bacteria present in faeces may reduce seed germination, which in turn, reduce agricultural productivity (Singh et al. 2007) consequently leading to economic loss.

Impacts on the Environment: In addition to its impact on public health, economy and psychosocial. The environment also suffers as a result of open defecation because it introduces toxins and bacteria into the ecosystem in amounts that it cannot handle or break down at a time. This leads to build up of filth. Also, the load of microbes can become so great that in the end, they end up in aquatic systems thereby causing harm to aquatic life. At the same time, it can contribute to the formation of algal blooms that form disgusting scum on the surface of the water ways which disturb aquatic life underneath the water by preventing oxygen and light diffusion into the water (Aboje, 2018). Heaps of human faeces or just the sight of it cause eyesore and nauseate anyone who is close. The stink emanating from the refuse is also highly unappealing and pollutes the surrounding air. Such places also attract large swarms that make the area completely unattractive for the eye.

3.0 CHALLENGES/CAUSES OF OPEN DEFECATION IN NIGERIA

Inadequate and unsustainable toilet facilities; this is the primary cause of open defecation, when adequate toilets and sanitation are unavailable or inadequate, the practice of open defecation is inevitable. The Nigeria National Demographic and Health Survey revealed that that only 31.5% of households in the Nigeria have an improved toilet facility (Abubakar, et al. 2017), accordingly the prevalence to OD was found to be more severe in the rural than the urban areas, and regionally, North central had the highest (50%), while North West recorded lowest figure (14.3%)(Unicef,2017), undoubtedly these socio-demographic figures indicates high tendencies for the prevalence of OD practices, where people have no alternative than to defecate into water ways and water bodies, it has been found that lack of proper toilets has often let to the indulgence in the practice of open defecation, according to investigation by various researchers it is has revealed that in Nigeria this menace has been critical to especially the public places such as markets (Eremutha *et al.*, 2016) and schools (Hothur *et al.*, 2019; Philip and Ajayi, 2018). A study conducted by RandymayEja et al. 2020 in various places across the states of Cross River and Akwa Ibom revealed that poor toilets and sanitation coverage has shown a great potential for open defecation practices, according to the study Akwa Ibom state has only 38.10% improved sanitation coverage, thus indicating open defection as an alternative. On the other hand, toilets facilities available are poorly maintained and lacks absolute hygiene integrity, and are mostly shared among many users (Philip and Ajayi, 2018) without segregation for women, thus, it could be discouraging, unsuitable and unconducive for users leading to the alternative such as open defaecation.

Poor Knowledge, attitudes and practices towards sanitation: attitudes and practices towards sanitation is one the challenges towards provision of sustainable WASH facilities in developing countries, Lack of WASH knowledge, unhygienic practices and poor attitudes towards sanitation facilities often times are significant factors to the prevalence of open defecation practices in communities. It has been reported that OD is deeply rooted in the tradition and culture of some Nigerian rural communities and requires eradicating it through behavioural change because simply supporting building latrines alone may not be sufficient (Ngwu, 2017; Gentler, 2015). Also a number of people particularly in rural areas find pleasure in defecating into their drinking water bodies (Ngwu, 2017), this indicates that there is a direct positive correlation between behaviours and open defecation practices and its health implications (WHO, 201l; Eneji, 2015), Therefore It is not enough to provide clean and safe toilets. There is also a need to change behaviours as a means to bridge the gap between building latrines and their proper use.

Low financial capacity: It was found that the richest households in Nigeria are the least to exercise OD (1%), followed by the richer households (5.6%); and the middle class; the poorer and poorest aggregated, represents the over three quarters (79%) of those households who exercise OD in Nigeria (Mara, 2017). Indeed poverty has often being a major barrier to accessing and maintaining sanitation facilities (Osumanu et al. 2019), where communities well perceive the importance of sanitation as well as its negative consequences and danger involved in improper human faces disposal, but lack of fund to provide such has been their major obstacle studies by various researchers across the country revealed that the major challenge of communities towards abstaining from open defection was lack of fund to provide a decent toilets in their houses which corroborates the findings by Sridhar et al. 2020 in Kaduna State and Miner et al. 2016 in Plateau State, Where communities suffer general WASH challenges due to poverty. In other studies, in South Africa, a unit increase in the income of respondents could lead to 0.1% decrease in the odds of indulging OD, thus supporting the findings in Nigeria.

Lack of adequate water supply: availability of adequate water is prerequisite to toilet construction, lack of adequate water is critical to averting open defecation practice in Nigeria, a study by Philip and Ajayi (2018) concluded that tertiary institution students in Nigeria indulgence in open defecation was due to insufficient water supply to flush toilets and conduct other sanitation services. According to the same study, the amount of freshwater required to realise Nigeria's open-defecation-free status by 2025 amounted to between 1.0 and 1.10 $\times 10^9$ m^3. This represents between 0.27 and 0.29% of Nigeria's total water resources potential estimated at 375.1×10^9 m^3/year. Although this requirement is not huge compared with the estimated total water resources potential, even at periods of high demands, especially during the dry periods when freshwater shortages are expected. It will require considerable investments in water storage, distribution and maintenance systems.

Lack enforcement factor/functional legal mechanism: although there is an existing law to penalise OD defenders as enacted by the National assembly of the federal republic of Nigeria (NAFRN, 2007), However there is poor performance by relevant authorities mandated with the responsibility of enforcing and prosecuting the defaulters, it has been observed by many researchers that lack of proper monitoring and supervision by concern authorities have let to people defying rules and regulation on environmental protection including defecation in open spaces and into water bodies. A study by Oluwole and Oluwaseun (2016) observed that lack of enforcement environmental sanitation law in Oshogbo, Nigeria, has resulted to poor sanitation condition amongst people.

4.0 APPROACHES TO OPEN DEFECATION FREE NIGERIA

***Provision of water and sanitation infrastructures*:** Huge investment has been made in the provision of water supply and toilet facilities by government and non-government actors across the Nation especially at public places such as Schools, Markets, Motor Parks, Airports, Cinemas, Stadia, Hospitals, etc. Despite these investments, operation and maintenance of these facilities are becoming a herculean task thereby creating a wide gap in the infrastructural requirement in Nigeria for attaining of open defecation free status.

***Government policies and strategies*:** The Nigerian government in its effort to end open defecation have come up with a number of policy framework over the years, such as being a signatory to the UN SDGs, establishment of a roadmap to ODF by 2025, signing of executive order 009 and subsequent declaration of state of emergency in the water and sanitation sector (Premium Times 2018).

***Financial assistant to enable latrine ownership*:** The principle of credit financing in terms of subsidy was considered in assisting households to construct home toilets. In this regard, there is a need to develop appropriate finance mechanisms, through partnerships with Municipal authorities and local financial institutions that ensure financial discipline and ability to recover the cost of investment.

***Behavioural change and communication (BBC)*:** in sensitize the public on the inherent health and environmental risks associated with open defaecation, the BCC approach was adopted, this approach involves the mobilization and training of community members to communicate campaign messages for behaviour change via household visits, meetings, rallies, telecommunication, social media, etc. (Gross & Gunther,2014; Mara, 2017; and Abubakar, 2018). Religious and traditional bodies within the community may also be effective vehicles for channelling such messages (Osumanu et al. 2019). The BCC programme should be extended to primary schools and informal schools, market places, motor parks and even secondary schools where people may lack the knowledge of health and environmental risks associated with open defaecation (Abubakar, 2018). The benefits of BCC programme are evident since it has been effective in reducing OD and sustaining the gains achieved in getting communities OD free without slipping back to OD. (Desai et al 2015). BCC strategy helps to address the negative behaviour and attitude associated with the practice of open defecation in rural part of Nigeria. Particularly, BCC is necessary at the individual level of the change process through the application of relevant change theories to motivate the individual to change from defecating openly and encourage the use of modern alternatives (Ngwu, 2017).

***Community led total sanitation*:** Community-Led Total Sanitation (CLTS) refers to an innovative way of motivating communities to take self-driven initiatives for the total eradication of open defecation (OD). By this communities are encouraged to carry out self-appraisal and evaluation regarding OD and initiate actions towards the achievement of open defecation free (ODF) status. The key idea in CLTS is recognizing the fact that mere provision of toilets doesn't translate to their use, neither can it result in improved sanitation and hygiene (IDS, 2018)**.** Between 2004 and 2006 Water Aid ran pilot CLTS in 9 communities of Benue state, Nigeria. This was kick-started with a visit of some Nigeria stakeholders to Bangladesh, after which a model was designed using the Bangladeshi concept as a guide. Water Aid and its LGA and NGO partners implemented the pilot project with promising results –there was sudden increase in latrine construction and an improved hygiene practices in focal communities. Though the pilot recorded remarkable degree of success it had its own challenges. Hence, the lessons learnt from the pilot were used for modifications in strategy and consequent expansion of the CLTS approach into the then Water Aid's joint programme with UNICEF in 24 communities of 12 LGAs in Benue, Enugu, Ekiti and Jigawa states (Unicef Nigeria,2018). As of July, 2014 CLTS has been initiated in all 36 States and FCT. Triggering has taken place in 19,467 communities of which 9,728 (around 50%) were declared ODF. Of this 3,276 (close to 34%) have been certified (FMWR 2016a).

5.0 CONCLUSION

The persistence of OD practice despite tremendous efforts by the Federal, state and local governments and their development partners, underscores the significance of the problem in Nigeria. Hence, the call for continued efforts by all stakeholders for more robust innovations to address the underlying issues of poverty, cultural norms and lack/ poor maintenance culture of public infrastructure for water supply, sanitation and hygiene. Again, proactive response measures targeted at proffering solutions that suits the different patterns of OD should be deployed. There should be more multi-sectoral synergy among all key stakeholders in the sector.

5.1 RECOMMENDATIONS

i. To achieve OD, there is a need to ensure that there are enough toilets and sufficient water to enhance sanitation services through massive investment in new infrastructure, rehabilitation of existing ones and sustainable operation maintenance.
ii. Government should establish incentives for people to build their own toilets by providing subsidies and putting up public toilets in strategic locations.
iii. Creating government programs that encourage sanitation and personal hygiene is also very important, individuals must be involved and forced to take up the responsibility of enhancing their hygiene as well as overall health. Through such programs, people can get to learn the importance of their environments and work towards ensuring that they do not harm themselves by partaking in open defecation, this

eventually reduces healthcare burdens on the government and lessens the number of those who practice open defecation as it will be seen as a terrible activity.

iv. Strict enforcement of existing sanitation laws and prosecution of offenders is critical. In the other hand estate developers should be monitored under the law to provide enough toilet facilities that commensurate with number of expected occupants before their building plan is approved.

v. Another platform that needs to be addressed is the negative cultural association that people have with toilets. The people should be informed through religious and traditional leaders and given civic education to enable them break away from their cultural beliefs on issues such as the fact that toilets are safe to use. In other words, cultural norms and beliefs must be changed over time through education and awareness creation. With time, people can become informed and drop the beliefs or at least adjust and make concessions about the ones that are most destructive.

vi. Therefore sanitation marketing should be encouraged through supporting interested entrepreneurs with low or non interest loan facilities to drive the infrastructural investment.

REFERENCES

Aboje F. (2018). Public Health in Nigeria, Threatened by Open Defecation Environment and Health.

Abubakar I R. (2017). Access to Sanitation Facilities among Nigerian Households: Determinants and Sustainability Implications, *Sustainability* 9, 547, doi:10.3390/su9040547

Abubakar, I. R. & Dano U. L. (2018). Socioeconomic challenges and opportunities of urbanization in Nigeria. In Urbanization and Its Impact on Socio-Economic Growth in Developing Regions 219- 240.

Adepoju, P. 2019. Water and sanitation: Why Nigeria's campaign to end open defecation is failing. https://www.devex.com/news/why-nigeria-s-campaign-to-end-open-defecation-is-failing-95448

Ajayi, O O and Philip K L. 2018. Assessment of Open Defecation and Prevalence of Soil Transmitted Helminthes among a Tertiary Institution Students in Nigeria. *International Journal of Environment, Agriculture and Biotechnology 3(6): 2185-2191* http://dx.doi.org/10.22161/ijeab/3.6.32.

Bawankule, R., Signh, A., Kumar, K., Pedgaonkar, S. 2017 Disposal of children's and its association with childhood diarrhea in India. *BMC Public Health* 17:12. https://doi.org/10.1186/s12889-016-3948-2

Dean S, Ghosh, A. 2013. Open Defecation and Childhood Stunting in India: An Ecological Analysis of New Data from 112 Districts. *PLoS ONE*

Desai, R., McFarlane, C., & Graham, S. (2015). The politics of open defecation: informality, body, and infrastructure in Mumbai. Antipode, 47(1): 98-120

Eremutha FA, TaiwoHB, Sridhar MKC, Olufemi OA. 2016. Evaluation of sanitary condition in Kuje market in Abuja, Nigeria with diverse cultural practices and provision of a dry ecological toilet system. *Sociology and Anthropology*, 4(1): 1011-1-19.

FGN 2016, Partnership for Expanded Water Supply, Sanitation & Hygiene (PEWASH): Programmed Strategy (2016– 2030). FMWR, Abuja.

FMWR 2016a. Making Nigeria Open-Defecation-Free by 2025 – A National Road Map. FMWR, Abuja.

FMWR 2016b. National Water Resources Policy. FMWR, Abuja.

Gbadegesin, O. A. and Akintola, S. O. (2020). A Legal Approach to Winning the 'Wash' War in Nigeria. European Journal of Environment and Public Health, 4(2), em0043. https://doi.org/10.29333/ejeph/8237

Hothur, R. Arepalli, S. and DoddojuVeera, A B. 2019. A KAP study on water, sanitation and hygiene among residents of Parla Village, Kurnool district, AndraPradesh. *International Journal of Community Medicine and Public Health*, 6(5): 2081-2085.

IDS. (2018). Community-Led Total Sanitation Approach. CLTS Knowledge Hub. Institute of Development Studies (IDS). http://www.communityledtotalsanitation.org/page/cltsapproach (Accessed on 14/02/2021

Islam M, Ercumen A, Ashraf S Rahman M, Shoab AK, Luby SP. 2018. Unsafe diposal of faecec of children 3 years among households with latrine access in rural Bangladesh: Association with houdrhold characteristics, fly presence and child diarrhea. *PLos ONE 23(4)*. https://doi.org/10.1371/journal.pone. 0195218/

Mara, D. (2017). The elimination of open defecation and its adverse health effects: a moral imperative for governments and development professionals. *Journal of Water, Sanitation and Hygiene for Development*, *7*(1), 1-12.

National Assembly of Federal Republic of Nigeria. National Environmental Standards and Regulations Enforcement Agency (Establishment) ACT 2007, No. 25 [online]. NAFRN; 2007. Available: https://nass.gov.ng/document/download/58 21 [Accessed 01/03/2021].

Ngwu, U. I. (2017). The Practice of Open Defecation in Rural Communities in Nigeria: A Call for Social and Behaviour Change Communication Intervention, International Journal of Communication Research, 7 (3): 201 – 206.

Okuku, M O. 2020. Policy Brief: Ending Open Defecation in Nigeria. *International Journal of TROPICAL DISEASE & Health* 41(19): 47-54, Article no. IJTDH.62861

Okullo, JO, Moturi WN, Morara GO. 2017. Open defacation and its effects on the bacteriological quality of drinking water sources inisiolo country, Kenya. *Environmental Health Insights,* 11: 1-8. DOI: 10.1177/11786302177.

Oluwole D, Oluwaseun O. 2016. Environmental sanitation practices in Osogbo, Nigeria: An assessment of residents' sprucing-up of their living environment, Economic and Environmental Studies Opole University, Faculty of Economics, Opole, 16, (4): 699-716.

Osumanu, I. K. Enoch, A. K, Frank A. 2019. Determinants of Open Defecation in the Wa Municipality of Ghana: Empirical Findings Highlighting Sociocultural and Economic Dynamics among Households. *Hindawi Journal of Environmental and Public Health* Volume 2019, Article ID 3075840. https://doi.org/10.1155/2019/3075840

PRB (Population Reference Bureau). 2014. Water, Sanitation, Hygiene, and Malnutrition in India Retrived from: https://www.prb.org/india-sanitation-malnutrition/, accessed [20/3/2021]

Premium Times 2018. Buhari Declares State of Emergency on Water, Sanitation. Available from: www.premiumtimesng.com/news/headlines/294741-buhari-declares-state-of-emergency-on-water-sanitation.html (accessed 20 March, 2021).

Punch Newspaper. Open defecation: Nigeria's sanitation challenges. (April 22, 2018). https://punchng.com/open-defecation-nigeriassanitation-challenges/ (Accessed on 21/03/2021)

Randymay Eja Kalu, Kimboline Donatus Etim, Okon Aniekanabasi Jonathan and Matthew Egbobor Eja. (2019). Open Defecation Profile of Rural Communities in Cross River and Akwa Ibom States of the Niger Delta, Nigeria. Internationa Journal of Current Microbiology and Applied Science 8(12): 2332-2340. https://doi.org/10.20546/ijcmas.2019.812.275

Saleem, M., Burdett, T. & Heaslip, V. Health and social impacts of open defecation on women: a systematic review. *BMC Public Health* **19,** 158 (2019).

Samuel O, Ezeah, P O. 2020. Socio-Economic Status and Health Shocks; Analysis of Coping Strategies Among Internally Displaced Persons (IDPs) Households in Abuja Nigeria. *Research Square*, 1-15.

Singh BR, Kumar A, Agrawal S, Verma A. 2007. Effect of Salmonella enterica subspecies enterica serovar, Typhimurium and Serratia fonticola on germination of seeds of common crops. *The Journal of Infection in Developing Countries*, 1(1):67-71.

Sridhar, M. K. C., Okareh, O. T., and Mustapha, M.Assessment of Knowledge, Attitudes, and Practices on Water, Sanitation, and Hygiene in Some Selected LGAs in Kaduna State, Northwestern Nigeria. *Journal of Environmental and Public Health*, Volume 2020, Article ID 6532512

Unicef India (2018). Eliminate Open Defecation - Eliminate Open Defecation. http://unicef.in/Whatwedo/11/Eliminate-Open-Defecation (Accessed on 19/03/2021).

Unicef Nigeria (2018). Case Study: Community-Led Total Sanitation in Nigeria. https://www.unicef.org/wcaro/ WCARO_Nigeria_CLTSCase-studies.pdf (Accessed on 23/02/2021)

Unicef, India. Eliminate Open Defecation - Eliminate Open Defecation. http://unicef.in/Whatwedo/11/Eliminate- OpenDefecation (Accessed on 29/03/2021).

UNICEF. (2018). Water. Sanitation and Hygiene. Available at: https://www.unicef.org/nigeria/water-sanitation-andhygiene

UNICEF/WHO (2017). Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. Geneva: World Health Organization.

Water and Sanitation Program Nigeria. Economic Impacts of Poor Sanitation in Africa: Nigeria loses NGN455 billion annually due to poor sanitation [online]. WSP; 2012. Available:http://documents.worldbank.org/curated/en/855961468297356898/pdf/681260WSP0ESI0000Box367907B0PUBLIC0.pdf[Accessed 25/03/2021].

WHO/UNICEF (2017). Joint Monitoring Programme. Progress on Sanitation and Drinking Water—2017 Update and SDG Baseline; World Health Organization: Geneva, Switzerland.

Paper 09 *Assessment of Water Quality of a Mined Quarry Pit in Edo State (A Case Study of Freedom Group of Companies Ikpeshi)*

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ABSTRACT: It is a known fact that the Open pit created after quarrying activities had taken place will begin to retain water accumulated both from surface running water and the one that flow from aquifer. Also, mining activities can cause the release of industrial waste through smelting of mineral ore, incineration of fossil fuels, use of mineral loaded water for irrigation and chemical based pesticides and fertilizers. This study aims at examining the water accumulated in the mine-out pit of Freedom Quarry, Ikpeshi, Edo and detects whether it can be put into other uses. Seven labelled plastic bottle, narrow necked were used to take water samples from different location, at the mined-out pit(QWS1-4), nearby borehole(BHW1) and river(RWS1-3) water. Following the World Health Organization (WHO) standard, laboratory tests were carried out on: pH, turbidity, color, conductivity, hardness, coliform count and dissolved chemicals. The pH(4.90-8.40) values range from acidic to alkaline; the conductivity(182.1- 498µs/cm) indicates that the samples are of moderately good conductors of electricity, hardness(52.60-172.30, soft to very hard, magnesium(1.26 – 7.72mg/l) is very low, calcium(5.21–21.40mg/l) is of high concentration, iron(0.10-0.18mg/l) content is okay, turbidity (1.16–8.73NTU) is suitable, zinc(0.04-0.08mg/l) is suitable, the total dissolved solid(94–262 mg/l) is okay and the presence of coliform count(0-12) indicates that the water has been contaminated with the faecal material and not allowed according to WHO. In conclusion, the water accumulated in the mined-out pit and its vicinity are found to be contaminated and needed to be treated before it can be employed for domestic and agricultural purposes.

Keywords: quarrying, Pit, turbidity, hardness, coliform

1.0 INTRODUCTION

In human living and environment, there is always a link between the ways by which various activities take place and water pollution of the habitat as a result of waste released through mining activity: smelting of mineral ore, incineration of fossil fuels particularly coal or petroleum and waste from mineral processing are some of the process that can cause pollution of the territorial water.

Human activities had being one of the root cause of water pollution in the environment (De Giudici *et al*., 2019). When the natural composition of water is altered and degraded, the next phase is to redeem it back to a state of usefulness (Skousen, *et al*., 2019). The phenomenon of environmental pollution and alteration of water nature by influence of other ion based dissolved substances or infusion of inorganic hazardous compounds are becoming a usual occurrence in most part of the developing world (Egboka *et al*., 1989).

It is established that the effect of temperature caused by heat energy to an extent is responsible for the water pollution plus the dissolution of soluble ions and molecules, such as Arsenic, Cadmium, Zinc, Lead, Chromium, and Manganese which are term poisonous elements. When these elements are found in water in such quantity that is above permissible limit established by the World Health Organization (WHO), UNDP and standard organization in Nigeria such as NAFDAC, could cause a negative impact on human health especially the effect on the Central Nervous System (Oteze, 1981; WHO, 2021)).

Mining comprises activities involving the production of minerals and quarry stones, which can lead to the production of some dissolved solutes and solvents; when the dissolved solutes and solvents permeate the water in human bodies they alter the natural state of the universal solvent within the body and render it toxic, thiswould invariable have environmental and health impacts. The permeation of the creeps of this material or its ions into the water necessitate the thought of assessing water quality of mined quarry, borehole water nearby and river water around the site. Water at quarry pit is polluted if the tailing is located where heavy metal such Pb and wastes can easily be diffuse through underground water into the mined out pit (Wolkersdorfer, 2014; Patrick *et al*., 2021).

Moreover, the type of pollution found in water in a mined out open pit can be influenced by the type of rock or ore in the environment. Saline water contained in rock formations increases the concentration of chloride in freshwater bodies, causing quality detriment and toxicity to their communities (Elphick *et al.* 2011; Diego *et al*., 2023). Sulfide ores dissolved in mine water leads to the formation of acid mine drainage, which results in an abundance of iron and sulfate ions and the mobilization of potentially toxic metals (Acharya and Kharel, 2020; Zhang *et al*., 2021). The precipitation of hydrous ferric oxides tends to clog riverbeds, generating negative effects on the flora and fauna (Sobolewski and Sobolewski, 2022)

There have been several method applied for the treatment of polluted mine water such as Wetland treatment method; this can be applied to the purification of water accumulated inside the mined out area of Quarry pit. If mine water contains contaminants such as hydrolysable metals (Al, Fe, Mn), metals typically associated with mining activities (Ag, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, U, V, Zn), metalloids (e.g. As, Sb, Se), and other pollutants (e.g., cyanide, ammonia), a designed is made to artificially emulate natural wetlands by creating a near-natural and densely vegetated aquatic environment for its treatment (Joscha *et al*., 2021).

Also, Passive treatment are systems that rely on natural ameliorative processes that are eased by providing an appropriate environment for those processes, which include neutralization of acidity by limestone, aerobic oxidation of ammonia, iron and manganese, anaerobic reduction of ferric iron, selenium, nitrate, and sulfate, precipitation of metals as sulfide minerals, settling of precipitated contaminants, and various adsorption, co-precipitation, and ion exchange reactions. Several of these processes are catalyzed by bacterial activity (Kleinmann *et al*., 2021; Skousen *et al.*, 2017). The methods for the removal or inactivation of microbial pathogens, include chemical disinfection, filtration, flocculation/disinfection and heat. Boiling is heat method which is highly effective, killing human pathogens even in turbid water and at high altitude. But boiling involves the high-cost use of carbon-based fuel sources and does not provide any residual protection (WHO, 2015). World Health Organization (WHO) has given guidelines for drinking-water quality for human health condition which when mine water is treated are useful to obtain standard. Standards are varieties of formats in form of regulations, standards, specifications, laws, decrees, requirements and norms put together by Countries and territories to control the drinking-water quality (WHO, 2021) and for poultry and other agricultural uses (CCME, 2005).

2.0 METHODOLOGY

Four samples of water were taken from Quarry pit water (QW), one from Borehole water (BHW) in the Quarry vicinity and three from the nearby River. Plastic bottles narrow necked and rinsed with sodium thiosulfate were utilized for the collection of water samples within the three zones. The bottles containing the samples were corked tightly and labeled with inscription of location numbers and were immediately placed in a lightproof insulated box containing melting ice and the samples were taken to the laboratory for analysis within six to eight hours. Bacteriological, physical and chemical analysis were done and results were obtained which were compared to World Health Organization standard (WHO, 1994).

Multiple-tube method which is based on an indirect assessment of microbial density in the water sample by reference to statistical tables to determine the most probable number of microorganisms present in the original sample was used. Appropriate volumes of water are added aseptically to tubes or other vessels containing sterile nutrient medium of a concentration that will ensure the mixture corresponds to single-strength medium. 10 ml of sample was added to 10 ml of double-strength medium. The tube contains a small inverted glass tube (Durham tube) to facilitate the detection of gas production. Growth in the medium is confirmed by visible turbidity and/or a color change. Tubes are incubated without resuscitation, and the number of positive reactions is recorded after 48 hours.

Photocolorimetry was used for the determination of chlorine by means of N,N-diethyl-p-phenylenediamine (DPD). Color was generated following the addition of DPD to the water sample and is matched against standard colored discs. The result is expressed as mg/litre of free residual chlorine.

In order to determine the turbidity of the water samples, water was slowly added to the turbidity tube, taking care not to form bubbles. Fill until the mark at the bottom of the tube just disappears. Read the turbidity from the scale marked on the side of the tube. The value is that corresponding to the line nearest to the level of the water in the tube.

The determination of pH of the water samples collected involved using a pH meter of M-Tester 1, buffer solutions of pH 4.0 and 10.0 and beaker. The pH meter electrode was rinsed with distilled water. 200 ml of water sample in a clean 200 ml capacity beaker was used. Then, the electrode end of the pH meter was introduced into the sample of water and pH measurement taken thereafter. Both the pH meter electrode simultaneously with the sample were rinsed with water. All the pH values were recorded and tabulated in the results section.

An electrical conductivity meter (P 65) with 0.01M NaCl solution was applied during the determination of the Electrical Conductivity of the Water Sample. The conductivity meter was calibrated. The conductivity meter probe was rinsed with clean water, followed by the water sample itself. About 200 ml of the water sample was poured into a clean beaker. The probe of the meter was then inserted into the sample in the beaker, thereafter press the READ button and then wait for an equilibrium state reading. The EC value was recorded.

The determination of Phosphate in the various water samples involved the use of HACH DR 2000, 20 ml pipette, hot plate, 100 ml volumetric flask, 50 ml cuvete, 300 ml round bottom flask were required to carry out the experiment with the following chemical reagent: Ascorbic acid (25% w/v) solution, ammonium molybdate-antimonyl solution 250 mg/l of phosphate standard stock solution, a solution of Pecchloric acd, KOH solution 6 Molar and Phenolphtalin indicator. An oxidation method using oxidation state/number approach where the state keeps track of electrons gained when a substance is reduced and the electron lost when a substance is oxidized. Multi tube test (APHA 9222A) including method based upon reaction of the nitrate ion with brucine sulphate in a 13 N sulfuric acid solution at a temperature of 100ºC. The color of the resulting complex is measured at 410 nm.

3.0 RESULTS AND DISCUSSIONS

Table 1 shows the physical and chemical properties of the water taken from the quarry pit water samples (QWS1-4), borehole water (BHW1) and the nearby river water samples (RWS1-3). The results of QWS1-4 shows that pH is about 5.0 which showed that it is moderately acidic, it is an important operational parameter, particularly in terms of the effectiveness of chlorination or the optimization of coagulation(WHO, 2022). It can be an important factor in corrosion of metals in distribution systems and plumbing; the conductivity is within 458 – 498 μ_s/cm, a measure of the inorganic ion content of water and is not of direct concern for health, but high conductivity may be an indicator of acceptability in high total dissolved solids (TDS) waters, and sudden changes can be an indicator of pollution or ingress into distribution; turbidity ranges from 1.16 to 1.57 NTU, which is within the suitable limit (Table 1 and 2), it is also an important operational parameter as an indicator of the efficiency and is an indicator of the removal of microorganisms in filtration. High turbidity at 4 NTU (nephelometric turbidity unit) and above can be seen by consumers and may be unacceptable at the tap.

Calcium (Ca) ranges from 7.52 to 20.03 mg/l and its at high in comparison to WHO (Table 3). Calcium is the most abundant metal in the human body and main constituent of bones and teeth with key metabolic functions. However, excessive calcium could be very toxic to aquatic organisms. Magnesium value is from 1.82 to 7.72 mg/l which is low according to the WHO standard and when it is too high can renders the environment hostile for the survival of man by polluting the soil and water bodies in the surrounding environment. However, due to low hardness of these minerals, they tend to be easily dissolved by water (precipitation) thereby infiltrating into the surface and groundwater and rendering it unfit for drinking. Furthermore, Chloride, Phosphate and nitrate values are respectively in the following ranges 53.84 -92.05mg/l; 0.08 to 016 mg/l and 0.01 and 0.08 mg/l. All these showed the presence of negative ion in the water and high nitrate concentrations that is well above the WHO guideline value can give rise to blue-baby syndrome in bottle-fed infants, particularly where there is endemic diarrhoea in infants. The range of total hardness is from 71.05 to 172.30 and the total dissolved solids is from 120 to 254 (WHO, 2016). Coliform count ranges from 1 to 3 (Table 2). The values show that the water is from moderately hard to hard one and the water is not suitable for consumption due to the presence of coliform (Table 2, 3 and 4).

Table 1: Physical and chemical characteristics of the water samples

Sample code	pH	Conductivity (μS/cm)	Color (TCU)	Turbidity (NTU)	Ca mg/L	Mg mg/L	Chloride (mg/L)	Phosphate mg/L	Nitrate mg/L
Maximum Permitted Level(SON, 2015)	6.5-8.5	1000	15	5	0.07	20	250		50
QWS1	5.02	498	0	1.43	20.03	7.72	92.05	0.16	0.08
QWS2	5.20	458	1	1.57	10.56	3.44	63.14	0.08	0.04
QWS3	5.1	478	0	1.38	14.43	4.54	74.24	0.12	0.03
QWS4	4.9	468	0	1.16	7.52	1.83	53.84	0.14	0.01
BHW1	7.81	182.1	0	1.72	5.21	1.40	32.00	0.95	0.02
RWS1	8.32	366	1	2.31	15.62	4.88	81.05	0.20	0.04
RWS2	8.35	356	1	4.16	21.40	1.26	79.20	0.05	0.03
RWS3	8.40	376	1	8.73	6.60	2.72	77.10	0.25	0.02

Also, the results from the borehole water is soft with hardness value of 52.60 mg/l but with contamination of coliform value of 5 mg/l which is not allowed according to WHO standard (Osiyoku, 2023), while river water in the vicinity of the quarry pit showed that the water are contaminated with the coliform value of 12 and the water is hard with hardness value of 121.38 (Table 2, 3 and 4)

Table 2: Physico-chemical and pathogenic tests of water samples

Sample Code	Total Hardness (mg/L)	Bi carbonate	Iron (Fe) (mg/L)	Zinc (Zn) (mg/L)	Coliform Count (cfu/mL)	Total dissolved Solids (mg/L)
Maximum Permitted Level (SON, 2015	150		0.3	3	10	500
QWS1	172.30	56.35	0.12	0.06	3	254
QWS2	98.20	32.74	0.14	0.08	3	134
QWS3	109.9	36.55	0.18	0.06	1	185
QWS4	71.05	22.74	0.11	0.04	1	120
BHW1	52.60	22.53	0.11	0.04	5	94
RWS1	111.82	40.00	0.14	0.07	12	188
RWS2	121.38	53.52	0.10	0.06	7	232
RWS3	101.27	50.42	0.11	0.06	0	262

Table 3: Comparison of the obtained values with the World Health Organization Standard (WHO, 1994)

Parameters	Higher Desirable (mg/l)	Maximum Permissible Level (mg/l)	Range of values from analysis (mg/l)	Remarks
pH	7.0-8.9	6.5-9.5	4.90-8.40	It is acidic to Alkaline
Conductivity	900 (µs/cm)	1200 (µs/cm)	182.1 – 498	
Total Hardness	100	100	52.60 – 172.30	Soft to Very Hard
Magnesium	20	20	1.26 – 7.72	Highly low
Calcium	0.01	0.07	5.21 – 21.40	At High Concentration
Iron	1.0	3.0	0.10 – 0.18	Okay
Turbidity	5.0	5.0	1.16 – 8.73	Suitable
Zinc	0.01	3.0	0.04-0.08	Suitable
Total Coliform	Not allowed	Not allowed	0 – 12	Not suitable
Total dissolved Solid (Mg/L)		500	94 - 262	Okay

Table 4. Water classification according to its hardness

Hardness (mg/l)	Types of Hardness
0 – 60	Soft water
61 – 120	Moderately hard water
121 – 180	Hard water
Greater than 180	Very hard water

4.0 CONCLUSIONS AND RECOMMENDATIONS

The results obtained from this investigation showed that the turbidity (1.16 – 8.73 NTU), total dissolved solids (94 – 262 mg/l), are sort of high in some samples. The pH (4.90-8.40) of the samples of water taken 4.9 to 8.40 which interprets that pH is generally acidic to alkaline and the measurement of electrical conductivity ranges from 182.1 to 498 µs/cm which depicts the samples are good or moderate good conductors of electricity. The result of Total Hardness of the sample ranges from 52.60 to 172.30 which depicts that the hardness is within soft water, moderately hard water and very hard water. The presence of coliform count (0-12) bacterial from the water sample collected indicates that the water has been contaminated with the faecal material of human.

Phosphate (0.05 to 0.95 mg/l), Chloride (32.00-92.05mg/l), Nitrate (0.01-0.08mg/l), Zinc (0.04-0.08 mg/l), magnesium (1.26 – 7.72 mg/l), calcium (5.21 – 21.40 mg/l) and iron (0.10-0.18 mg/l) existed in considerable concentration which are usually within the average nominal values as to be compared to the World Health Organization limit values. The color of samples examined is within the range of hazed unit measurement.

Therefore, it is recommended that the water accumulated in the mined-out pit of Freedom Quarry site should be treated before it can be used for domestic and agricultural purposes.

REFERENCES

Acharya BS, Kharel G (2020) Acid mine drainage from coal miningin the United States-an overview. J Hydrol 588:125061. https://doi.org/ 10. 1016/j. jhydr ol. 2020. 125061

CCME (2005). Canadian Council of Ministers of the Environment.

De Giudici G, Medas D, Cidu R, Lattanzi P, Rigonat N, Frau I, Podda F, Marras PA, Dore E, Frau F, Rimondi V, Runkel RL, Wanty RB, Kimball B (2019) Assessment of origin and fate of contaminants along mining- affected Rio Montevecchio (SW Sardinia, Italy): a hydrologic-tracer and environmental mineralogy study. Appl Geochem 109:104420

Diego Bedoya-Gonzalez1, Timo Kessler, Thomas Rinder, Sylke Hilberg, Zsuzsanna Szabo-Krausz and Maria-Theresia Schafmeister (2023). A Multiple Interactive Continua Model (MINC) to simulate reactive mass transport in a Post-Mining Coal zone: A case study of the Ibbenbüren Westfield. Mine Water and the Environment. 42:266–292 https://doi.org/10.1007/s10230-023-00938-2

Egboka, B. C. E., Nwankwo, G. I,, Orajaka, I. P. and Jiofor, A, O. (1989) Guidelines for drinking Water Quality (World Water) Illinois Groundwater Pollution.

Elphick JRF, Bergh KD, Bailey HC (2011) Chronic toxicity of chlorideto freshwater species: effects of hardness and implications for water quality guidelines. Environ Toxicol Chem 30:239-246. https:// doi. org/ 10. 1002/ etc. 365

Ezenabor, B. O. (1991) Pollution of Water whatever description is actionable Riparian Right.

Joscha Opitz, Matthias Alte, Martin Bauer and Stefan Peiffer (2021). The Role of Macrophytes in Constructed Surface-flow Wetlands for Mine Water Treatment: A Review. Mine Water and the Environment. 40:587– 605, https://doi.org/10.1007/s10230-021-00779-x

Kleinmann B, Skousen J, Wildeman T, Hedin B, Nairn B and Gusek J. (2021). The early development of passive treatment systems for mining-influenced water: a North American perspective. Mine Water Environ 40:818- 830. https:// doi. org/ 10. 1007/ s10230- 021- 00817-8

Kleinmann R., Sobolewski A. and Skousen J. (2023). The evolving nature of Semi-passive Mine Water Treatment. Mine Water and the Environment (2023) 42:170–177 https://doi.org/10.1007/s10230-023-00922-w

Nigerian Industrial Standard NIS-554-2015 (2015). Nigerian Standard for Drinking Water Quality (ICS 13.060.20). Standard Organization of Nigeria (SON): 17 – 21.

Offodile, M. E. (1992). An Approach to Groundwater Study and Development in Nigeria. Mecon Geology and Engineering Services Ltd, Jos.

Osiyoku D. A., Ifelola E. O., Umoru T. A. (2023). Impact of Quarrying activities on the water quality in Ikpeshi, Akoko-Edo, Edo State, Nigeria. IRE Journals. 6 (11): 309 – 314.

Oteze, G. E. (1981) Water Resources in Nigeria Environment. Vol. 3, Springer, Berlin Heidelberg, 177 – 184.

World Health Organization (1984) International Standard for Drinking Water. 8th Edition, Geneva, 53p.

Patrick Byrne, Alan Yendell, Ilaria Frau and Aaron M. L. Todd (2021). Identification and Prioritisation of Mine Pollution Sources in a Temperate Watershed Using Tracer Injection and Synoptic Sampling. Mine Water and the Environment. 40:980–993 (https://doi.org/10.1007/s10230-021-00792-0).

Sobolewski A, Sobolewski N (2022) Holistic design of wetlands formine water treatment and biodiversity: a case study. Mine WaterEnviron 41:292-299

Skousen J G, Ziemkiewicz PF, McDonald LM (2019). Acid mine drainage formation, control and treatment: approaches and strategies. Extr Ind Soc 6(1):241–249. https:// doi. org/ 10. 1016/j. exis. 2018.09. 008

Skousen J, Zipper CE, Rose A, Ziemkiewicz PF, Nairn R, McDonald LM and Kleinmann R. L. (2017). Review of passive systems for acid mine drainage treatment. Mine Water Environ 36:133-153. https:// doi. org/ 10.1007/ s10230- 016- 0417-1

WHO (2015). Guidelines for drinking-water quality. Fourth Edition. http://www.who.int//water_sanitation_health/publications/2011/dwq_guidelines/en/

WHO (2016). Protecting surface water for health identifying, assessing and managing drinking-water quality risks in surface-water catchments. ISBN 978 92 4 151612 9

WHO (2021). A global overview of national regulations and standards for drinking-water quality, second edition. ISBN 978-92-4-002364-2 (https://creativecommons.org/licences/by-nc-sa/3.0/igo)

WHO (2022). Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. ISBN 978-92-4-004506-4: 167-169

Wolkersdorfer C. (2014) Water management at abandoned flooded underground mines. Springer, Berlin.

Zhang J, Chen L, Hou X, Lin M, Ren X, Li J, Zhang M, Zheng X(2021) Multi-isotopes and hydrochemistry combined to reveal themajor factors affecting carboniferous groundwater evolution in the Huaibei coalfield, North China. Sci Total Environ 791:148420. https:// doi. org/ 10. 1016/j. scito tenv. 2021. 148420

Paper 10 *Evaluation of Temporal Variation in Groundwater Quality in Iwo Local Government Area, Nigeria*

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ABSTRACT: The research was conducted in Iwo Local Government Area, Osun State, Nigeria, to evaluate the various groundwater resources and to generate temporal differences between the dry and rainy seasons. The physicochemical and heavy metal characteristics were measured throughout one year, including both rainy and dry seasons. Temperature, turbidity, pH, electrical conductivity, total suspended solids, total dissolved solids, total alkalinity, total hardness, chloride, sulphate, nitrate, phosphate, magnesium, and calcium were all measured. The atomic absorption spectrophotometer (AAS) was used to analyse heavy metals, and the most probable number (MPN) of counting coliforms was used for microbiological examination. Total hardness, cadmium, calcium, sulphate, and phosphate were the groundwater quality metrics, with mean values exceeding the acceptable criteria for both seasons. The tested water's physical, chemical, and microbiological features during the rainy and dry seasons were analysed using principal component analysis (PCA), which yielded six main components with eigenvalues larger than one. Principal Components (Rainy, Dry): Chromium (.913, .857); manganese (.867, .849); iron (.827, .802); zinc (.848, .787); turbidity (.930, .865); and pH (.947, .905) were the groundwater quality metrics that were very significant, with factor loadings greater than 75% throughout the season. The study suggests that frequent monitoring programmes to assess the groundwater quality in the study area need to be enforced to prevent groundwater degradation due to heavy metals.

Keywords: evaluation, temporal variation, groundwater quality, principal component analysis, Iwo local government area

1.0 INTRODUCTION

Natural processes and human interferences both influence the quality and quantity of river water; the latter is one of the critical causes of environmental concerns that modify the hydrochemistry of our river and aquifer systems. Rivers are incredibly varied on both a spatial and temporal scale, and river water quality and quantity variations are examined extensively worldwide. In the recent decade, there has been a widespread deterioration in the water quality of inland aquatic systems (Olajire and Imeokparia, 2001; Heberer, 2002; Mara, 2003; Vié *et al.*, 2009; Murray *et al.*, 2010) and freshwater systems, which make up a massive number of inland waterways, play a vital role in the assimilation and transportation of contaminants from a variety of sources (Vutukuru, 2003; Vié *et al.*, 2009, Adeogun *et al.*, 2011). Inadequate potable water supplies and rapid population growth in emerging countries like Nigeria have put a strain on groundwater supplies. Unfortunately, such countries' rapid development has resulted in significant groundwater contamination (Mahapatra *et al.*, 2012). Several investigations with hazardous characteristics and microbiological contaminations have identified some of these issues of groundwater sources.

Given the world's finite supply of fresh water (Chinhanga, 2010) and the involvement of anthropogenic activities in the decrease of water quality, the protection of the integrity of water resources has been prioritised in the twenty-first century (USEPA, 2007; Wei *et al.*, 2008). This, however, cannot be accomplished without a spatiotemporal assessment of the water and sediment quality in the aquatic systems under consideration. Numerous studies have identified pollution sources and the possible effects of natural processes and anthropogenic activities on spatiotemporal water quality fluctuations (Pati *et al.*, 2014; Bu *et al.*, 2014). Long-term surveys and water quality monitoring programmes are an excellent approach to understanding river hydrochemistry and pollution due to spatial and temporal variations in water chemistry. Still, they produce large sets of data, making interpretation of latent meaningful information difficult (Shrestha and Kazama 2007). It is almost necessary to use multivariate techniques and data reduction to attain a decent outcome. Using multivariate statistical approaches, multidimensional measurements can be interpreted using multivariate statistical methods. Cluster analysis (CA), principal component analysis (PCA), and factor analysis (FA) have all been used successfully to analyse and interpret water quality data sets, assess water quality, understand temporal/spatial variations, and identify latent pollution sources in river water (Kumarasamy *et al.* 2014; Pati *et al.* 2014; Thareja 2014; Mavukkandy *et al.* 2014; Wang *et al.* 2014).

Zhang *et al.* (2011) investigated the geographical and temporal variability in water quality in the Southwest New Territories and Kowloon, Hong Kong. Garizi *et al.* (2011) used multivariate statistical approaches to investigate the seasonal fluctuations of surface water in the Chehelchay watershed in northeast Iran. Vieira *et al.* (2012) investigated the spatial variability of surface water in the Lis River Basin, Portugal. Most of the research has only looked at river reaches in rural, urban, and industrial settings, indicating the effects of land use, urbanisation, and trophic changes. Only a few of these investigations have been natural river systems and groundwater sources. Identifying the water pollution factors and sources of clusters and groups described by cluster analysis has been the subject of only a few research. Researchers have used multivariate statistical approaches such as CA, PCA/FA, and discriminant analysis (DA) to analyze and understand spatiotemporal fluctuations in water quality in the Xiangxi River, China (14 parameters at 12 sites) with a 5-year continuous monitoring data set.

The research goal was to use multivariate statistical analysis to assess the variability of physicochemical and biological variables that cause temporal fluctuation in the groundwater resources of in Iwo Local Government Area (LGA), Osun State, Southwestern Nigeria. Groundwater quality studies in the Iwo LGA have shown the importance of conducting frequent groundwater quality assessments. During site investigations, consumers in the Iwo LGA described various groundwater sources as having a foul taste and aroma. Because of natural and anthropogenic processes, it's crucial to comprehend the nature and chemistry of groundwater oscillations. This type of research is projected to impact proponents' groundwater development initiatives, especially in developing countries, and will emphasise the need for enhanced efforts to rectify various types of imbalances.

2.0 MATERIALS AND METHODS

2.1 Study Area

Iwo is an LGA in the state of Osun. The five parts of the land are Isale Oba, Molete, Oke Adan, Gidigbo, and Oke Oba. This is further divided into 15 political wards. The urban district of Iwo town is located between the latitudes of 07°38' N and 07°40' N, and the longitudes of 004°09' E and 004°11' E.

Iwo is a 245-square-kilometer town, and the research area is surrounded by Aiyedire and Ola Oluwa in Osun State. Iwo's borders also encompass Lagelu, Akinyele, Afijio, and Oyo East in Oyo State, as seen in Figure 1. The Oba and Aiba rivers pass through the study area, with the Aiba River in the north-eastern corner.

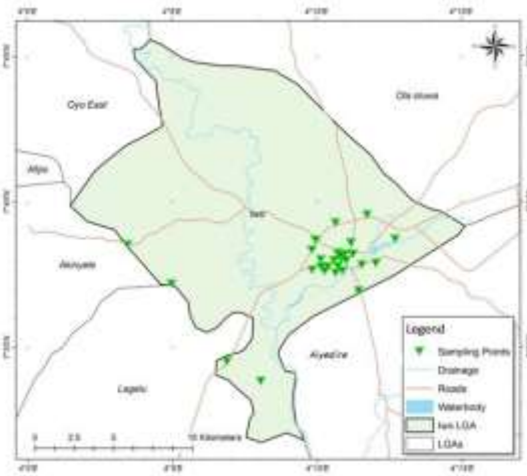

Figure 1. Map of the Study Area

The Aiba water reservoir is the town's principal source of drinkable water. Unfortunately, due to inadequate management and a rise in the area's population, the area's drinking water supply has become insufficient. As a result, the town's underground water supplies were tapped.

The annual rainfall in Nigeria's southern region ranges from 150 to 300cm. Maximum ambient temperatures range from 33.84 degrees Celsius in February to 28.8 degrees Celsius in August, with minimum temperatures ranging from 25.18 degrees Celsius in March to 23.0 degrees Celsius in August.

2.2 Collection of samples

As shown in Table 1, water samples were obtained from 30 distinct places and sources. The sampling was focused on the population that relies on groundwater for drinking. Using hand-held Global Positioning System (GPS) technology, groundwater sources were stratified and randomly located. The majority of wells in urban areas were lined, but wells were unlined and operated by hand pumps in rural areas. Each well's location was recorded using a hand-held GPS.

Table 1. Locations from where water samples are collected and corresponding water sources

S/N	Location	Water Source
1	Oke –ola	Motorized Borehole
2	Palace road	Lined Well
3	Akinfenwa	Lined Well
4	Old barrack	Motorized Borehole
5	Hospital Gate	Lined Well
6	MOT junction	Motorized Borehole
7	Orikan Compd.	Lined Well
8	Oke odo	Lined Well
9	Moseru Compd.	Lined Well
10	Oja Oba	Lined Well
11	Oriolowo	Motorized Borehole
12	Gaa - Fulani	Hand Pump Well
13	Molete ward 3	Lined well
14	Saabo	Lined Well
15	Omosan Compd.	Unlined Well
16	Jagun Ilu Compd.	Unlined Well
17	Ponkuku compd.	Motorized Borehole
18	Lakata Compd.	Unlined well
19	KLM, Feesu	Motorized Borehole
20	Itesiwaju, Odoori	Motorized Borehole
21	Aipate	Lined Well
22	Owoeye Bus Stop	Motorized Borehole
23	Abanise	Motorized Borehole
24	Oke bode	Lined Well
25	Adeeke	Lined Well
26	Laito	Motorized Borehole
27	Agberire	Hand Pump Borehole
28	Alagbon	Hand Pump Borehole
29	Papa	Hand Pump Borehole
30	Mojibere Village	Unlined Well

The sample was carried out twice: once during the rainy season (October) and again during the dry season (November) (January). There was a lot of rain in October and November, and January was bitterly cold. The samples were collected using a plastic bucket from the tap of hand pump wells, boreholes, and shallow wells. Some experimental values were recorded on the spot, while others were recorded in the lab using three replicates and standard procedures.

Before sampling, all glassware and sample bottles were cleaned with liquid detergents and washed with distilled water. The plastic bottles used for sampling were labelled according to political wards and then rinsed three times on-site with the groundwater sampled to avoid any mistakes. A two-litre water sample was taken for physical and chemical analysis, while a microbiological sample was taken from a tiny, autoclaved glassware sample. The samples were kept in the refrigerator for 5 hours before analysis (Jeje and Oladepo, 2014). This was done to preserve the physical, chemical, and microbiological properties.

2.2 Measurement of Physicochemical Parameters

Temperature, turbidity, pH, electrical conductivity, total suspended solids, total dissolved solids, total alkalinity, total hardness, chloride, sulphate, nitrate, phosphate, magnesium, calcium, iron, zinc, lead, manganese, cadmium, chromium, and total coliform were all measured for the water samples collected. All of the tests were done in accordance with Olutona *et al.* (2012) and Ogunbode and Ifabiyi's research (2014).

Water samples were tested for hydrogen ion concentration (pH), temperature, and electrical conductivity using a pH metre, a thermometer, and a platinum electrode conductivity metre (EC). The total dissolved solids were calculated using a total dissolved solid metre (TDS). Standard silver nitrate titration was used to determine the amount of chloride (Cl^-). After digestion with concentrated sulfuric acid, the water samples' phosphate content (PO_4^{3-}) was determined using a colorimetric approach. The sulphate concentration was determined using the turbidimetric technique and a spectrophotometer (SO_4^{2-}). The hardness (TH) was determined using the conventional Ethylene Diamine Tetra Acid (EDTA) titration method, which was buffered at pH 10. The complexometric titration method, which involves titrating the water sample with a predetermined concentration and volume of EDTA, quantifies the quantity of calcium (Ca) in water hardness.

The presence of magnesium was determined using the difference between total and calcium hardness expressed as $CaCO_3$ equivalent (Mg). The water samples' alkalinity (T. Al.) was determined by titrating 100 ml of each sample with 0.2 N sulphuric acid solution and using phenolphthalein and mixed indicators. TSS was measured by gravimetric analysis, which involved heating the sample in an oven and then chilling it in a desiccator. Turbidity (Turb.) was determined using an electronic turbidimeter with scattered-light detectors. A UV-VIS spectrophotometer was used to assess nitrate concentration (NO_{3-}). Total coliform (TCC) was extracted from water samples using the membrane-filtration method (microbiological analysis).

2.4 Analysis of Heavy Metals

The groundwater samples were analyzed with PG990 AAS for finding the presence of lead, chromium, cadmium, manganese, zinc, and iron utilizing flame atomization, an air-acetylene flame, and a single element hollow cathode lamp while following standard equipment procedures. 100 mL of collected water was digested with 10 mL of pure nitric acid to acquire exact results. The solution was boiled for 30 minutes, then cooled before being transferred to a 100 ml beaker that had been filled halfway with distilled water.

2.5 Temporal variation

The laboratory results of groundwater quality parameters determined in the laboratory were normalised by determining the average values of the experimental values. The standardised data were subjected to PCA. PCA was performed on 21 parameters at 30 different sample locations over two seasons to identify the critical seasonal water quality characteristics. By multiplying the original correlated variables by the eigenvector, the principal components (PC) were calculated.

The eigenvector, a series of coefficients called loadings, was generated from the correlation matrix of original variables. PC that account for variance more than 1 (eigenvalue – one criterion) was considered significant. This is because a PC with an eigenvalue greater than unity holds more information than a single original variable, ensuring dimensionality reduction. New PC axes were rotated using varimax to increase variance among the variables under each component while also improving its interpretation.

The extent of the original variable in the form of PC-coefficient into several PCs is shown by component loading. Loading was classified as 'strong', 'moderate' and 'weak' with absolute loading values of > 0.75, 0.75-0.5, and 0.5 – 0.3, respectively. A key parameter contributing to seasonal fluctuations in groundwater water quality was judged to be a water quality metric with a substantial correlation coefficient value (> 75%). In equation 1, the PC is stated as follows:

$$Z_{ij} = PC_{i1}X_{1j} + PC_{i2}X_{2j} + \ldots\ldots + PC_{im}X_{mj} \quad (1)$$

where, Z is the component score, PC is the component loading, X is the measured value of the variable, i is the component number, j is the sample number, and m is the total number of variables.

3.0 RESULTS AND DISCUSSION

3.1 Physical, chemical, and microbiological parameters of groundwater

The results of physical, chemical, and microbiological aspects of groundwater quality during rainy and dry seasons are shown in Tables 2.

Table 2. Groundwater parameters mean against WHO values for rainy and dry seasons

SN	Parameter	Rainy Season		Dry Season	
		WHO Std.	Mean Value	WHO Std.	Mean Value
1	pH (-)	6.5 – 8.5	7.07	6.5 – 8.5	7.16
2	Temp (°C)	25	27.48	25	16.20
3	EC (μS/cm)	1000	568.60	1000	504.97
4	TDS (mg/l)	500	330.57	500	308.30
5	T. Al. (mg/l)	200	120.57	200	141.43
6	TSS (mg/l)	250	180.00	250	190.00
7	Turb. (NTU)	5	3.90	5	3.03
8	TH (mg/l)	150	252.93	150	299.63
9	Ca (mg/l)	75	98.27	75	115.83
10	Mg (mg/l)	50	1.91	50	2.32
11	Cl (mg/l)	250	67.13	250	68.44
12	NO_3^- (mg/l)	50	52.16	50	48.29
13	SO_4^{2-} (mg/l)	250	305.12	250	285.70
14	PO_4^{3-} (mg/l)	0.05	1.76	0.05	1.71
15	Fe (mg/l)	0.3	0.16	0.3	0.19
16	Pb (mg/l)	0.01	0.01	0.01	0.01
17	Mn (mg/l)	0.05	0.03	0.05	0.03
18	Zn (mg/l)	3.0	0.03	3.0	0.03
19	Cd (mg/l)	0.003	0.02	0.003	0.02
20	Cr (mg/l)	0.05	0.03	0.05	0.03
21	TCC (cfu/ml) x 10^{-4}	10	22.67	10	6.63

The mean values of the groundwater quality parameters in the research region were compared to the World Health Organization's (WHO) standard values. According to the findings, 13 of the 21 groundwater characteristics were below the normal values for the rainy season. Calcium, cadmium, total hardness, temperature, sulphate, total coliform, phosphate, and nitrate were the eight metrics that exceeded the standard levels. Calcium, cadmium, total hardness, sulphate, and phosphate were also over the standard ranges for the dry season.

3.2 Temporal variations

PCA reduced the 21 variables to six main components for both the rainy and dry seasons. These six factors accounted for the variables that substantially impacted the overall variation in groundwater quality. The six principal rainy season components accounted for 76.15% of the cumulative fluctuations, and the dry season's six PCs accounted for 74.56% of the cumulative fluctuations.

3.3 Evaluation of groundwater quality parameters for rainy season

The physical, chemical, and microbiological characteristics of tested water during the rainy season in the Iwo LGA were analysed using PCA, which yielded six PCs. These six variables accounted for 76.154% of the total variation in water quality. The resulting eigenvalues were sorted in descending order. The cumulative percentage variance of the six components for the rainy season with eigenvalues greater than one were considered significant, as reported in Table 3 and represented in Figure 2 a.

Table 3. Total variance for rainy season

PC	Eigen values	Variance	Cum. %	Rotated	Variance	Cum.%
1	**5.419**	25.804	25.804	4.493	21.394	**21.394**
2	**3.275**	15.595	41.399	2.685	12.787	**34.182**
3	**2.623**	12.488	53.887	2.509	11.949	**46.131**
4	**1.777**	8.462	62.349	2.447	11.650	**57.782**
5	**1.639**	7.803	70.152	2.072	9.869	**67.650**
6	**1.260**	6.002	76.154	1.786	8.504	**76.154**
7	.998	4.755	80.909			
8	.821	3.911	84.819			
9	.738	3.517	88.336			
10	.668	3.182	91.518			
11	.473	2.251	93.769			
12	.350	1.668	95.438			
13	.268	1.279	96.716			
14	.191	.911	97.627			
15	.185	.882	98.509			
16	.137	.650	99.159			
17	.070	.333	99.492			
18	.060	.284	99.776			
19	.029	.136	99.912			
20	.019	.088	100.000			
21	7.852E-007	3.739E-006	100.000			

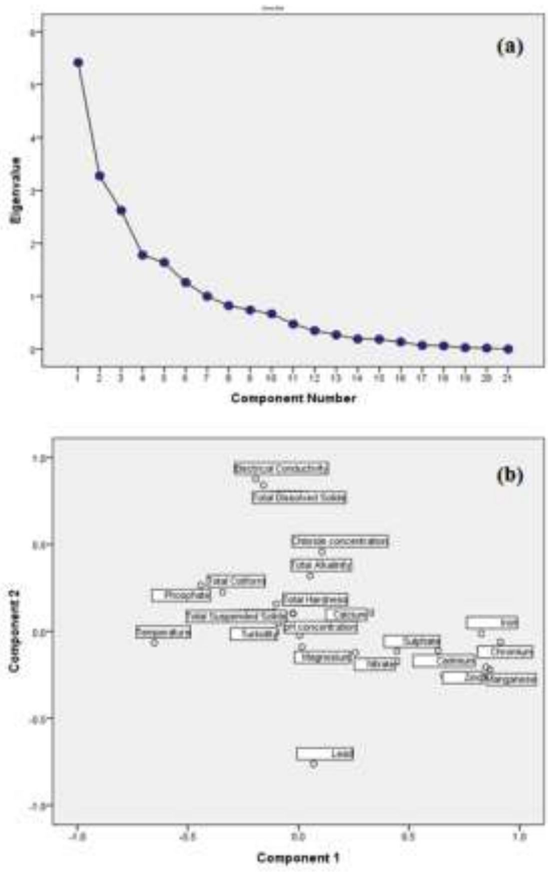

Figure 2. Evaluation of rainy season (a) Scree plot for the rainy season (b) Factor loading plot between components 1 and 2 for the rainy season

The first PC accounted for 21.394% of the overall variation, whereas the second PC accounted for 12.787%. The factor loading charts for the first and second PCs are shown in Figure 2 b. The third, fourth, fifth, and sixth PCs were responsible for 11.949%, 11.650%, 9.869%, and 8.504% of the overall variation.

The factor loadings for the six critical PCs calculated against the groundwater quality measures are provided in Table 4. In the study region, parameters with factor loadings of more than 75% were considered highly significant. Chromium, manganese, zinc, and iron make up the first primary component, with factor loadings of 91.3%, 86.7%, 84.8%, and 82.7%, respectively. This indicated contamination from natural groundwater-rock interactions and some anthropogenic activities such as leaching from trash dump sites.

Table 4. Rotated component matrix for rainy season

Parameters	Components					
	1	2	3	4	5	6
Chromium	**.913**	-.060	.021	-.005	-.070	.146
Manganese	**.867**	-.219	-.029	-.017	-.144	.091
Zinc	**.848**	-.205	-.046	-.047	.238	.033
Iron	**.827**	-.013	.062	.015	.035	-.085
Temperature	-.652	-.065	.083	.378	-.141	-.153
Cadmium	.632	-.110	.419	-.106	-.244	.222
Elect. Cond.	-.193	**.876**	.191	.168	.011	-.101
Total D Solid	-.158	**.841**	.123	.154	.040	-.078
Lead	.069	**-.762**	.147	.062	-.075	-.163
T. Hardness	-.024	.103	**.883**	-.129	.280	.035
Calcium	-.025	.105	**.879**	-.138	.278	.052
Phosphate	-.442	.266	-.483	-.293	.190	-.021
Turbidity	-.091	.047	-.062	**.930**	-.007	-.045
Total S Solid	-.101	.158	-.127	**.846**	.139	.083
Chloride	.107	.458	-.123	.547	-.488	-.164
pH	.005	-.023	.190	.080	**.947**	.058
T. Alkalinity	.053	.320	.404	.020	.686	.015
Nitrate	.258	-.122	.174	.163	.196	.722
Sulphate	.446	-.114	.263	.022	.082	.648
Magnesium	.015	-.090	.092	.331	.042	-.606
T. Coliform	-.343	.226	-.343	.300	-.195	.529

The second PC includes electrical conductivity, total dissolved solids, and lead, with factor loadings of 87.6%, 84.1%, and 76.2%, respectively. This showed pollution because of natural processes. The third PCs were total hardness and calcium, which had factor loadings of 88.3% and 87.9%, respectively.

Turbidity and total suspended solids were the fourth PC, with factor loadings of 93.0% and 84.6%, respectively. The pH was the sole enormously significant parameter in the fifth PC, with factor loadings of 94.8% indicating contamination from the natural sources. Even though the eigenvalue of the sixth component was more than one, as shown in Figure 2 a, it had no groundwater parameters with factor loading greater than 75%.

3.4 Evaluation of groundwater quality parameters for dry season

The PCA of the physical, chemical, and microbiological characteristics of measured water during the dry season in the Iwo LGA yielded six PCs. These six components accounted for 74.556% of the total variation in water quality. The calculated eigenvalues were ordered in descending order. The cumulative percentage variance of the six components for the dry season with eigenvalues greater than one was judged significant and are reported in Table 5 and illustrated in Figure 3a.

Table 5. Total variance for dry season

PC	Eigen values	Variance	Cum. %	Rotated	Variance	Cum.%
1	**4.578**	21.800	21.800	4.048	19.275	**19.275**
2	**3.720**	17.715	39.515	3.406	16.219	**35.495**
3	**2.705**	12.881	52.395	2.486	11.839	**47.334**
4	**1.753**	8.348	60.743	2.034	9.685	**57.019**
5	**1.564**	7.445	68.188	1.870	8.903	**65.922**
6	**1.337**	6.368	74.556	1.813	8.634	**74.556**
7	.999	4.758	79.314			
8	.936	4.458	83.772			
9	.700	3.334	87.106			
10	.593	2.823	89.929			
11	.522	2.483	92.412			
12	.377	1.795	94.207			
13	.354	1.685	95.892			
14	.261	1.241	97.133			
15	.211	1.002	98.135			
16	.167	.797	98.932			
17	.123	.584	99.517			
18	.072	.344	99.861			
19	.027	.127	99.987			
20	.002	.010	99.998			
21	.000	.002	100.000			

The first PC accounted for 19.275% of the overall variation, whereas the second PC accounted for 16.219%. The factor loading charts for the first and second PCs are shown in Figure 3 b. The third, fourth, fifth, and sixth PCs were responsible for 11.839%, 9.685%, 8.903%, and 8.504 8.634% of the overall variation.

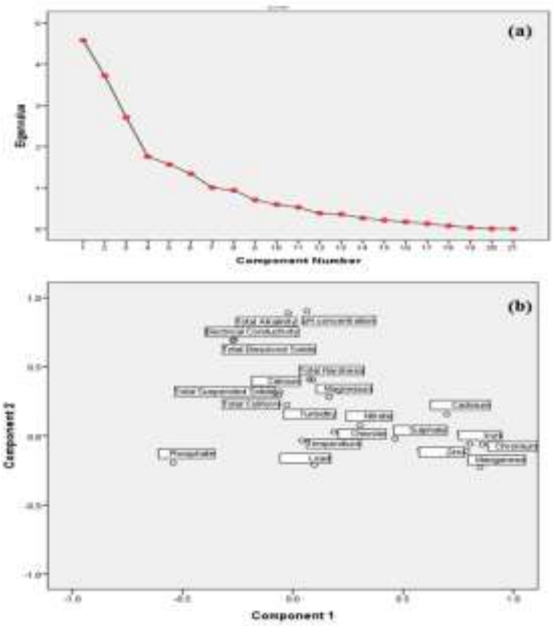

Figure 3. Evaluation for dry season (a) Scree plot for dry season (b) Factor loading plot between components 1 and 2 for the dry season

The six significant PCs tabulated against the groundwater quality parameters gave factor loadings, as shown in Table 6. The parameters with factor loadings above 75% were considered strongly significant in the study area. The first PC included chromium, manganese, iron, and zinc with factor loadings of 85.7%, 84.9%, 80.2%, and 78.7%, respectively. This indicated contamination due to groundwater's natural interactions with rocks and anthropogenic activities such as leachate from refuse dumpsites.

Table 6. Rotated component matrix for dry season

Parameters	Components					
	1	2	3	4	5	6
Chromium	**.857**	-.062	.099	-.044	.112	.189
Manganese	**.849**	-.226	.017	-.045	.045	.029
Iron	**.802**	-.060	-.093	.097	.273	-.032
Zinc	**.787**	-.108	-.052	-.050	-.017	.040
Cadmium	.697	.157	-.107	.146	-.272	.061
Phosphate	-.543	-.196	.103	.270	.101	-.103
pH	.064	**.905**	.161	-.037	-.035	.041
T. Alkalinity	-.021	**.889**	-.042	-.048	-.041	-.055
Elect. Cond.	-.265	.695	.041	.252	.474	.066
Total D. Solid	-.274	.692	.036	.290	.495	.066
Turbidity	-.028	.225	**.865**	.250	-.150	.072
Total S. Solid	-.059	.320	.739	.046	.161	.053
T. Hardness	.090	.405	-.729	.373	-.196	.154
Calcium	.075	.408	-.726	.403	-.188	.154
Temperature	.041	-.033	-.093	**.855**	-.113	.029
Lead	.097	-.209	-.081	-.695	-.398	-.009
Chloride	.186	.030	.138	.004	**.824**	-.118
T. Coliform	-.064	.294	.011	-.239	.436	.694
Nitrate	.304	.076	-.048	-.067	-.095	.685
Sulphate	.463	-.020	-.106	.173	-.211	.622
Magnesium	.163	.281	-.102	-.319	.084	-.582

pH and total alkalinity were the second most critical PCs, with factor loadings of 90.5% and 88.9%, respectively. Turbidity was the third PC, with a factor loading of 86.5%.

The temperature was the fourth main component, with a factor loading of 85.5%. The fifth main component revealed chloride as the only highly significant parameter, with a factor loading of 82.4%. This showed contamination as a result of anthropogenic activity. Although the eigenvalue of the sixth component was more than one, as shown in Figure 3 a, it had no groundwater parameters with factor loading greater than 75%.

3.5 Temporal variations of parameters for both rainy and dry seasons

Table 7 shows the vital groundwater parameters in the research area under study during rainy, dry, and entire seasons. Chromium, manganese, iron, zinc, turbidity, and pH were the groundwater quality characteristics that were very significant throughout the season, as shown in Table 7.

Table 7. Significant groundwater parameters in Iwo LGA

SN	Rainy Season	Dry Season	Rainy and Dry Seasons
1	Chromium	Chromium	Chromium
2	Manganese	Manganese	Manganese
3	Zinc	Iron	Iron
4	Iron	Zinc	Zinc
5	Electrical conductivity	pH	pH
6	Total dissolved solids	Total alkalinity	Turbidity
7	Lead	Turbidity	
8	Total hardness	Temperature	
9	Turbidity	Chloride	
10	Total suspended solids		
11	pH		
12	Calcium		

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4.0 CONCLUSION

The groundwater sources from the Iwo LGA were sampled and tested in the lab using standard methods, and the results were analyzed using PCA. The findings resulted in a conscious understanding of groundwater quality in the Iwo LGA and sufficient information. These results were compared to the WHO's acceptable levels. For both seasons, total hardness, calcium, cadmium, sulphate, and phosphate were the groundwater quality metrics with mean values above the standard norms.

The physical, chemical, and microbiological features of tested water during the wet and dry seasons were analysed using PCA, which yielded six main components with eigenvalues larger than one. Chromium, manganese, iron, zinc, turbidity, and pH were the groundwater quality metrics that were very significant, with factor loadings greater than 75% throughout the season.

To protect the public health of the Iwo LGA, the study advised that physical, chemical, and microbial analyses of groundwater in the Iwo LGA be performed regularly. The study also suggests frequent monitoring programmes to find the influence of fertilisers on groundwater quality in the study area to prevent groundwater degradation. Special projects should be created for early detection of excessive heavy metals and groundwater treatment in some locations for healthy living.

REFERENCES

Adeogun, A. O., Chukwuka, A. V., & Ibor, O. R. (2011). Impact of abattoir and saw-mill effluents on water quality of upper Ogun River (Abeokuta). *American Journal of Environmental Sciences, 7(6), 525*.

Bu, H., Meng, W., & Zhang, Y. (2014). Spatial and seasonal characteristics of river water chemistry in the Taizi River in Northeast China. *Environmental monitoring and assessment, 186(6), 3619-3632*.

Chinhanga, J. R. (2010). Impact of industrial effluent from an iron and steel company on the physico-chemical quality of Kwekwe River water in Zimbabwe. *International Journal of Engineering, Science and Technology*, *2*(7).

Garizi, A. Z., Sheikh, V., & Sadoddin, A. (2011). Assessment of seasonal variations of chemical characteristics in surface water using multivariate statistical methods. *International Journal of Environmental Science & Technology*, *8(3), 581-592.*

Heberer, T. (2002). Occurrence, fate, and removal of pharmaceutical residues in the aquatic environment: a review of recent research data. *Toxicology letters*, *131(1-2), 5-17*.

Jeje, J. O., and Oladepo, K. T. (2014). 'Water supply technologies : momentous effects on sanitation systems in Nigeria'. *International Journal of Civil and Environmental Research, 1(4), 141–151*.

Kumarasamy, P., James, R. A., Dahms, H. U., Byeon, C. W., & Ramesh, R. (2014). Multivariate water quality assessment from the Tamiraparani river basin, Southern India. *Environmental earth sciences, 71(5), 2441-2451*.

Mahapatra, S. S., Sahu, M., Patel, R. K., & Panda, B. N. (2012). Prediction of water quality using principal component analysis. *Water Quality, Exposure and Health*, *4*(2), *93-104*.

Mara, D. (2003). *Domestic wastewater treatment in developing countries*. Routledge.

Mavukkandy, M. O., Karmakar, S., & Harikumar, P. S. (2014). Assessment and rationalization of water quality monitoring network: a multivariate statistical approach to the Kabbini River (India). *Environmental Science and Pollution Research*, *21*(17), *10045-10066*.

Murray, K. E., Thomas, S. M., & Bodour, A. A. (2010). Prioritizing research for trace pollutants and emerging contaminants in the freshwater environment. *Environmental pollution*, *158*(12), 3462-3471.

Ogunbode, T. O., and Ifabiyi, P. I. (2014). 'Determinants of domestic water consumption in a growing urban centre in Osun State, Nigeria'. *Academic Journals*, *8*, *247–255.* https://doi.org/10.5897/AJEST2013.1627

Olajire, A. A., & Imeokparia, F. E. (2001). Water quality assessment of Osun River: studies on inorganic nutrients. *Environmental monitoring and assessment*, *69(1), 17-28*.

Olutona, G. O., Akintunde, E. A., and Otolorin, J. A. (2012). 'Physico-chemical quality assessment of shallow well- waters in Iwo, Southwestern Nigeria'. *Journal of Environmental Science and Water Resources*, *1*(6), *127–132*.

Pati, S., Dash, M. K., Mukherjee, C. K., Dash, B., & Pokhrel, S. (2014). Assessment of water quality using multivariate statistical techniques in the coastal region of Visakhapatnam, India. *Environmental monitoring and assessment*, *186*(10), *6385-6402*.

Shrestha, S., & Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji River basin, Japan. *Environmental Modelling & Software*, *22(4), 464-475*.

Thareja, S. (2014). An assessment of physico-chemical parameters of Ganga water using multivariate analysis. In *Chemistry: The Key to our Sustainable Future* (pp. 293-309). Springer, Dordrecht.

USEPA, 2007. Recent recommended water quality criteria. United States Environmental ProtectionAgency, http:// www.epa.gov/waterscience/criteria/wqcriteria.html

Vié, J. C., Hilton-Taylor, C., & Stuart, S. N. (Eds.). (2009). *Wildlife in a changing world: an analysis of the 2008 IUCN Red List of threatened species*. IUCN.

Vieira, J. S., Pires, J. C., Martins, F. G., Vilar, V. J., Boaventura, R. A., & Botelho, C. M. (2012). Surface water quality assessment of Lis River using multivariate statistical methods. *Water, Air, & Soil Pollution*, *223*(9), *5549-5561*.

Vutukuru, S. S. (2003). Chromium induced alterations in some biochemical profiles of the Indian major carp, Labeo rohita (Hamilton). *Bulletin of environmental contamination and toxicology*, *70*(1), *0118-0123*.

Wang, H. D., Wang, Y., & Lin, Z. (2007). The control and damage of organic pollutant in Songhua River to the ecological environment. *Environmental Science and Management*, *32*(6), 67-69.

Wei, S., Wang, Y. J. C. W., Lam, J. C., Zheng, G. J., So, M. K., Yueng, L. W., ... & Lam, P. K. (2008). Historical trends of organic pollutants in sediment cores from Hong Kong. *Marine pollution bulletin*, *57*(6-12), *758-766*.

Zhang, X., Wang, Q., Liu, Y., Wu, J., & Yu, M. (2011). Application of multivariate statistical techniques in the assessment of water quality in the Southwest New Territories and Kowloon, Hong Kong. *Environmental monitoring and assessment*, *173*(1), *17-27*.

Paper 11 Strategies for Effective Implementation of Water, Sanitation and Hygiene Programmes in Nigeria

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ABSTRACT: Effective implementation of water, sanitation and hygiene (WASH) programmes is critical to improving access to safe water and sanitation and promoting better health and well-being for various communities in Nigeria. This paper examined strategies for effective implementation of water, sanitation and hygiene programmes in Nigeria. The methodology employed involves in-depth research into WASH initiatives in Nigeria, professional judgments, and literature reviews. Challenges facing the proper implementation of WASH programmes in Nigeria were itemized. Equipment that can aid in the implementation of WASH programmes was also identified. The effective implementation of WASH programmes in Nigeria requires a multi-faceted approach that addresses both the physical infrastructure and the social and cultural factors that can impact access to and use of WASH services. One key strategy is to prioritize community engagement and participation. It is important to recognize the fact that effective implementation of WASH programs requires sustained political commitment and funding. The role of technology and rethinking strategies in WASH programmes cannot be undermined. The WASH works on long-term prevention and control measures for improving health, reducing poverty, and improving socio-economic development as well as responding to global emergencies and outbreaks of life-threatening illnesses. This will also support the achievement of the Sustainable Development Goals.

Keywords: effective implementation, sustainable development goals, hygiene, socio-economic development, rethinking strategies

1.0 INTRODUCTION

Water, sanitation and hygiene (WASH) systems are essential for promoting public health, ensuring access to safe drinking water, providing safe sanitation facilities, and promoting good hygiene practices. However, designing and managing WASH systems can be challenging due to water scarcity, poor water quality, sanitation challenges, hygiene practices, and disaster risk reduction. The potential of actors to participate in future actions and experiments should therefore be taken into account when choosing research participants for WASH initiatives. Additionally, the process should give actors the chance to learn, develop their capacities, and access resources (Silvestri et al. 2018). Various sector-wide measures have been developed over the years to organize the sector into a coherent whole. The National Water Supply and Sanitation Policy, which is currently in effect, the Water Resources Policy, which covers the entire sector, the Water Law, the Water Resources Management Strategy, and the National (Environmental) Sanitation Policy, which is in the advanced stages of preparation, are among these. Nigeria has made significant strides in creating policies and strategies for delivering water supply and sanitation services, but there are significant obstacles in the way of actually putting them into practice. As a result, over 110 million people lacked access to better sanitation in 2013 and around 70 million people out of a population of 171 million did not have access to safe drinking water (UNICEF, 2016). The benefits of improved water supply have important socio-economic benefits. Water can be used for a variety of productive uses, generating important sources of income (cash and non-cash) for households. Improved water supply does not automatically lead to poverty alleviation. To maximize water-related benefits, interventions in other areas or sectors may be required.

2.0 LITERATURE REVIEW

Sanitation is a critical issue in many countries around the world including Nigeria. Improving WASH is essential for promoting good health and improving the overall quality of life. Water is necessary for life and affects a country's entire socioeconomic growth (Nwankwoala, 2011). In Nigeria, there are various and intricate issues with cleanliness and water supply (Ademiluyi and Odugbesan, 2008). The most economical preventive measure for reducing the burden of illness linked to diarrhoea and under-five mortality in the nation may be improving WASH in communal housing. According to Okoh and Alex-Hart (2014) and Agbolade et al. (2015), caregivers in Nigeria typically have a low level of understanding about proper WASH practices and engage in incorrect behaviour when it comes to managing several elements of childhood diarrhoea at home. Each year, the UN High-Level Political Forum (HLPF) on Sustainable Development collaborates with numerous international stakeholders to achieve a variety of sustainable development goals. The HLPF concentrated on seven objectives in 2017 that would end poverty and advance prosperity in a world that was changing. Sustainable Development Goal (SDG) three, "good health and well-being," was one of these seven objectives (UN, 2017). The lack of safe water, sanitation, and hygiene services (WASH) is a significant risk factor for infectious diseases like diarrhoea and death from these diseases, according to the SDG progress report (2017) for SDG 3 (UN, 2018; Yaya et al., 2018).

Furthermore, private sector participation in the water sector is a topical and growing issue (Hardoy et al, 2000). However, the advanced countries' model of privatization mustn't be foisted on developing countries, where effective regulation may be difficult to achieve. In the prevention and control of disease, particularly those connected to water and sanitation, water sanitation and hygiene practices play a significant role in environmental public health. Water has a significant role in the transmission of many diseases among people. To ensure human health, survival, and community growth, water sanitation and hygiene are crucial. Water Sanitation and Hygiene require immediate and adequate attention and its impacts and mitigation should be given strategic consideration of WASH in Nigeria. (Oyebode, 2021). Freshwater scarcity and abuse are severe and growing challenges to environmental preservation and sustainable development (Refsgaard and Abbott, 1990).

Water is necessary for life support and affects a country's entire socioeconomic development. In Nigeria, numerous programs to improve the country's water supply and sanitary conditions have been implemented by various administrations. Without enough local support and accountability, public empowerment and involvement may not be empowering, scalable, or sustainable. According to Silvestri et al. (2018), "systemic ways to understand the complexity of the problems at hand and to propose innovative governance approaches" are necessary for the sustainability of WASH services. Another issue in the WASH setting is unequal access to education (Silvestri et al. 2018). A crucial educational strategy that might address sustainability in WASH awareness and services within the community is to increase the capacity of prospective change agents.

Poor sanitation and hygiene practices hurt people's health and socioeconomic well-being, with children bearing the brunt of this cost in terms of deaths, missed school days, illnesses, malnutrition, and poverty. The aforementioned is brought on by the spread of bacteria, viruses, and parasites that are present in human excreta and that would otherwise contaminate soil, water, and food (WHO, 2008).

Urban and rural development are both centred on having access to a sufficient and secure water supply. Any country's development of its water supply and sanitation system is an ongoing, long-term process that calls for meticulous planning and execution aimed at enhancing living circumstances (Babalola, 1990, 1997). Rural communities in Nigeria that are relevant to the water and sanitation sector often have populations under 5,000 and lack paved roads, electricity, and piped water. According to MICS (1999), the national standard for water use in rural areas is now 30 L per person per day, with 48 and 44% of people having access to clean water and toilets.

Within 250 meters of the neighbourhood, 30 L per capita per day of safe water must be delivered, servicing between 250 and 500 people at each water station. Safe water must also meet the National Drinking Water Quality for Nigeria. Water availability in Nigeria is insufficient compared to demand, as it is in the majority of sub-Saharan Africa. According to MacDonald et al. (2005), treated and untreated piped water from groundwater sources, shallow boreholes, wells with ponds, springs, lakes, rivers, and streams are the primary sources of water for households.

3.0 METHODOLOGY

The methodology employed involves in-depth research into WASH initiatives in Nigeria, professional judgments, and literature reviews. Focus groups and discrete observations from deliberately chosen communities in Nigeria were used. Figure 1 presents the conceptual framework of the National Rural Water Supply and Sanitation Programme in Nigeria. Table 1 presents the components of the water and sanitation problem in Nigeria.

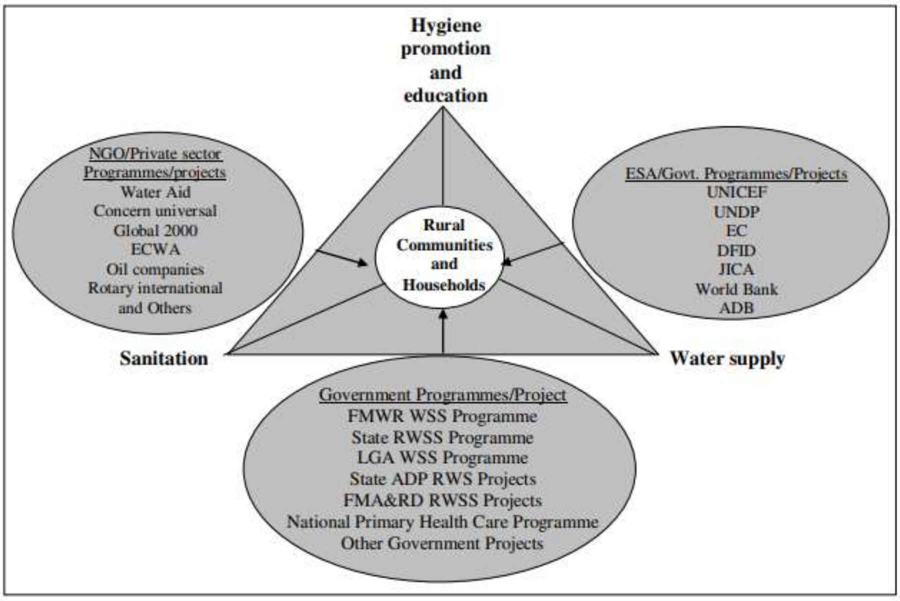

Figure 1: Conceptual Framework of the National Rural Water Supply and Sanitation Programme in Nigeria

Table 1: Components of the water and sanitation problem in Nigeria

ASPECT	IMMEDIATE PROBLEM	CONSEQUENCES
Water Supply	Distant sources	Much expenditure of time and energy (especially by women) Low levels of water consumption, resulting in water-washed disease
	Unreliable sources (drought-prone, or poorly engineered or managed)	Time spent queueing of seeking alternative sources
	Poor quality (faecally contaminated) sources	Water-borne disease
Excreta disposal	Lack of safe facilities for disposal of human faeces	Contamination of soil, surface water and ground water
	Little privacy for defaecation, and lack of water for anal cleansing and hand-washing	Defaecation (by men) in open, often near water (e.g. canal side of river banks); hardship for women for whom public defaecation is unacceptable
Wastewater disposal	Engineered facilities for treatment or safe disposal rarely exist	Indiscriminate disposal leads to environmental contamination, insect habitat creation, and/or unsafe re-use downstream

The limited effects of community water and sanitation programs in Nigeria, as well as many other developing nations, are a widespread phenomenon. This is because many of these programs are poorly designed and are abandoned early due to a variety of institutional, institutional, and economic constraints. According to conventional knowledge, sustainability is unlikely to be achieved without community involvement (Narayan, 1995; Oyesiku, 1998).

Water is a basic requirement with far-reaching consequences for sanitation and hygiene, agricultural and food production, industrialization, and development. Sustainable development and effective management of water resources are critical for the health and wealth of any nation, including Nigeria. Nigeria is blessed with abundant water resources, but the country faces challenges in managing these resources sustainably. Figure 2 presents a hydrological Map of Nigeria

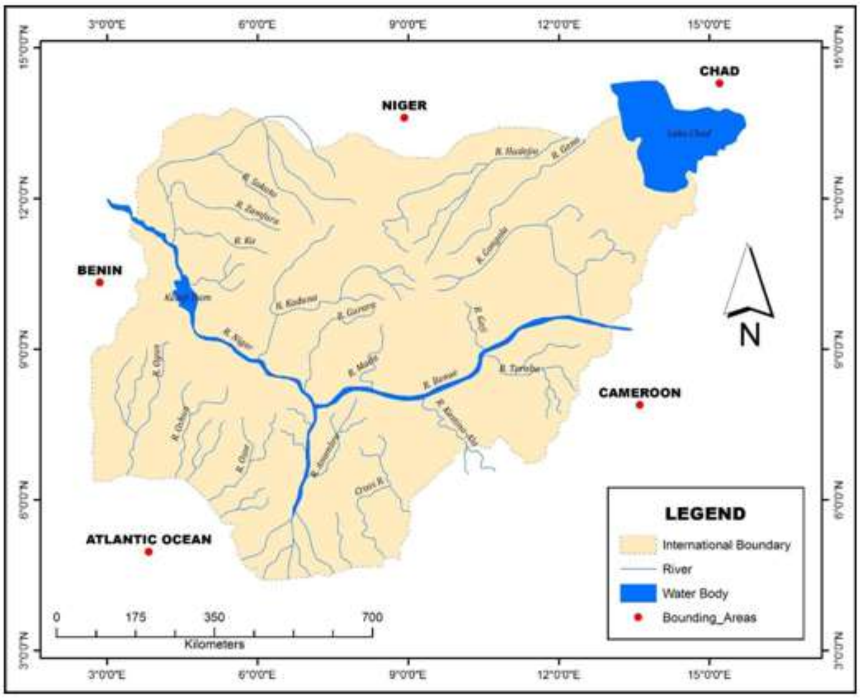

Figure 2: Hydrological Map of Nigeria

The funding for water resource development in Nigeria is insufficient to meet the country's aspirations and stated objectives, as the current average annual national commitment of 86 billion Naira ($220 million) falls short of the annual investment requirement of 974 billion Naira ($2.5 billion) required to meet the SDG target by 2030. Following the Millennium Development Goals (MDGs) and President Goodluck Jonathan's promise in 2010, 75% of the population should have access to clean drinking water by 2015 (Egbinola 2017). Regrettably, in 2011, the year after the promise by President Goodluck Jonathan reduced the financial allocation to the Ministry of Water Resources by almost half. Since then, the financial allocation for water resource development has followed a similar pattern of inconsistency, with the lowest allocation in the fiscal year 2015, compared to allocations in all other fiscal years between 2010 and 2020, as shown in Table 2. Table 1 presents Budgetary Allocation for Water Resources Development in Nigeria.

Table 1: Budgetary Allocation for Water Resources Development in Nigeria

Year	**Budget (₦)**	**Budget for Water Resource Development**	**Percentage of Budget**
2010	4.4tn	112bn	2.5%
2011	4.2tn	62bn	1.4%
2012	4.7tn	39bn	0.8%
2013	4.9tn	88bn	1.7%
2014	4.9tn	51bn	1.0%
2015	4.4tn	13bn	0.02%
2016	6.0tn	53bn	0.8%
2017	7.4tn	111bn	1.5%
2018	9.1tn	155bn	1.7%
2019	8.9tn	73bn	0.8%
2020	10.5tn	100bn	0.9%

Source: Compiled by authors from Nigeria Budget Office

Table 1 depicts the evolution of national financing for water resource development. It also illustrates the level of commitment of governments to the development of water resources in terms of financing since 2010. Since 2010, the greatest proportion of the national budget committed to subsidizing water resource development has been 2.5% of the entire budget. In 2011, it was 1.4%, 0.8% in 2012, 1.7% in 2013, and 1.0 in 2014. The proportion of the national budget allotted to water resource development plummeted to 0.02% in the first year of President Muhammadu Buhari's first term. In the three years that followed, it gradually increased to 0.8%, 1.5%, and 1.7%, respectively. The proportion of the budget allocated to water resource development in 2019 and 2020 has not indicated that the government plans to emphasize the sector. 73 billion Naira (0.8%) of a total budget of 8.9 trillion Naira in 2019, and 100 billion Naira (0.9%) of a total budget of 10.5 trillion Naira in 2020, indicated no major positive shift in government priorities of the industry.

4.0 CHALLENGES

Challenges facing the proper implementation of WASH programmes in Nigeria are the following:

i. Inadequate data and information resulting from a weak monitoring system poses high risks to decision-making and planning and urgently need to be addressed through the formalization of an effective national hydrological monitoring centre
ii. Lack of funding: Implementing WASH solutions can be expensive, and many communities in low- and middle-income countries may not have the resources to pay for the necessary infrastructure and ongoing maintenance costs.
iii. Lack of accountability and transparency in complying with existing standards for quality and wastewater treatment, in particular when governments cannot monitor their performance and civil society is not fully engaged to hold them accountable.
iv. Limited access to technology and expertise: Some communities may lack access to the technology and expertise needed to implement and maintain WASH solutions effectively. This can include a lack of access to specialized equipment and materials, as well as a lack of trained personnel to operate and maintain WASH infrastructure.
v. Cultural and social barriers: Cultural and social factors can also be a barrier to implementing WASH solutions. For example, some communities may not see the value in investing in sanitation or hygiene practices or may have cultural practices that make it difficult to implement certain types of solutions.
vi. Political instability and conflict: Political instability and conflict can also hinder the implementation of WASH solutions, as they can disrupt supply chains, damage infrastructure, and limit access to funding and expertise.
vii. Environmental challenges: Environmental challenges, such as droughts, floods, and water scarcity, can also make it difficult to implement WASH solutions effectively. These challenges can affect the availability and quality of water resources and can make it difficult to construct and maintain infrastructure.
viii. Lack of coordination: Lack of coordination between different stakeholders, including government agencies, non-governmental organizations, and community members, can also be a barrier to implementing WASH solutions effectively. Without coordination and collaboration, it can be difficult to ensure that resources are used effectively and that solutions are sustainable and equitable.

4.0 STRATEGIES FOR IMPROVING WASH SYSTEMS

Overall, improving WASH systems requires a coordinated approach that takes into account social, economic, political, and environmental factors. By implementing these strategies, it is possible to improve access to safe water, sanitation, and hygiene, promote public health, and ensure the sustainability and equity of WASH systems over the long term. The Strategic Framework presented in Figure 1 and elaborated below, sets out a vision, objectives and principles to guide our programming approaches and results areas, which will be used by UNICEF country offices to determine context-specific interventions. Figure 3 presents UNICEF 2016–2030 WASH Strategic Framework.

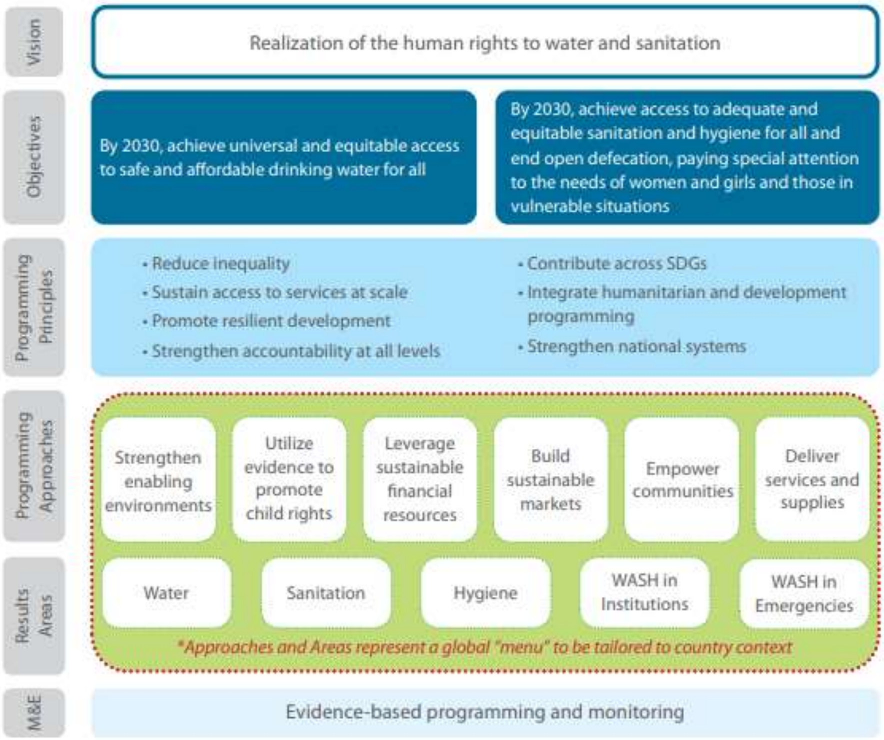

Figure 3: UNICEF 2016–2030 WASH Strategic Framework

This Strategy provides guidance on which approaches could be used in different contexts, leaving discretion to UNICEF's country offices to work with governments to decide on the most effective programmatic focus. Figure 4 presents a snapshot of UNICEF's Strategy for WASH (2016-2030)

Figure 4: UNICEF's Strategy for WASH (2016-2030): A Snapshot

In a variety of crises and complicated humanitarian situations brought on by conflict, forced migration, disease outbreaks, public health emergencies, acute and chronic malnutrition, and natural disasters, quick and effective WASH initiatives are essential for saving children's lives. As it offers the primary incentives for acts that either support or hinder sustainability, the interrelationship between these three broad groups of players is essential to how services are given and sustained. A regulatory function promotes the accomplishment of agreed-upon duties and responsibilities by establishing systems for control and oversight of these interrelationships. Regulation generally fosters good governance and safeguards the rights of consumers to better services. Accountability in this context refers to systems of controls that hold organizations in the public and private sectors accountable for their deeds and ensure that sanctions can be used against subpar performance, unlawful behaviour, and/or power abuses. Users can request services from policymakers as citizens, and policymakers can affect users' behaviour. Figure 5 presents the accountability framework for sustainable services.

Figure 5: The Accountability Framework for Sustainable Services

UNICEF will define its support based on the specific context of sanitation in communities. As illustrated in Figure 9, programmes will stress demand creation in communities where open defecation is still common; and improve supply in communities where open defecation is low but there are high proportions of unimproved latrines (i.e. where demand exists but the availability of affordable and aspirational sanitation solutions are limited), and promote innovative financing solutions in communities where basic sanitation coverage is high, but some households (often the poorest and marginalized) have yet to be reached. Where communities face space limitations, land tenure issues, high water tables, climate vulnerability, or other geophysical hazards, the response will be designed to meet these challenges. Figure 6 presents UNICEF's Strategy for Water, Sanitation and Hygiene (2016-2030).

Figure 6: UNICEF's Strategy for Water, Sanitation and Hygiene (2016-2030)

There are several ways to improve WASH systems, they include:

i. Full involvement of communities in all stages of programme implementation and management is the correct pragmatic approach for the present. However, this approach does not divest Governments and NGOs of their responsibility for continuing and evolving support of the programmes which they promote.

ii. New models of institutional, financial, contractual, and legal relationships between communities and back-stopping agencies should be sought. Permanence and improvement of service should be the goals. A short-term "project" mentality on the part of funding organizations should be eschewed in favour of long-term and evolving commitment to developing country partners.

iii. Greater emphasis should be placed on institutional support (re-training, resourcing, and reform) of Government and non-government back-stopping organizations.

iv. Effective information management, monitoring and evaluation are crucial for the successful management and regulation of water resources or water services as they creates the platform to initiate interventions/actions, understand trends, adapt management plans appropriately or plan effectively for the future

v. Ensure that sufficient revenue is received through tariffs and grants to operate, maintain and improve the water supply and sanitation system. The tariff structure must allow for cross-subsidization for the indigent and the building of a reserve for periods of drought.

vi. WASH services require strong national policies, financial systems, and monitoring to be sustainable, resilient and accountable.

vii. Government budgets for financing WASH, especially WASH infrastructure, and for expanding services to those in need remain low. Private sector investment is also insufficient, given the lack of legal frameworks, associated risks, and low returns in the water and sanitation business. As a result, one of the greatest barriers to achieving WASH-related targets is the large spending gap.

viii. Without strong governance, neither government stakeholders nor donors and development partners can be held accountable.

5.0 CONCLUSION

One cannot exaggerate the importance of a comprehensive education program that makes use of a variety of mass media, interpersonal communication methods, and social occasions (including holidays, market days, and literacy classes). Potable water supply and proper sanitation for the rural population need to get immediate attention if health is to be prioritized. To support student's rights to a healthy environment and clean water, sanitation, and hygiene (WASH) in educational institutions, this intervention is widely acknowledged as being essential. Poor WASH conditions have an impact on household food security, rural livelihood sustainability, health, and people's general well-being because access to water is still essential for achieving sanitation and hygiene in rural settlements.

Furthermore, promoting community-led WASH efforts in rural areas requires that poverty alleviation initiatives that would ensure improved income generation and enhanced social capital are given priority attention by the government in rural development. This will enhance the rural population's capacity to form self-help groups and embark on community-led micro-projects that can have far-reaching impacts on their well-being before external support reaches them. The majority of water and sanitation initiatives in metropolitan Nigerian slum areas are carried out using the self-supply option. This is described as a household or small group of households improving WASH goods, such as water and sanitation structures, incrementally and paying for it out of their resources. Bridging the gap that exists in the provision of adequate WASH services is the right step towards achieving sustainable access for all, to improved WASH services by the year 2030.

The benefits from adequate provision of WASH services such as those implied by the MDGs and SDGs for water supply and sanitation are huge and far outstrip their costs. When it comes to funding, building, and administering WASH infrastructure, the private sector is essential. Adopting novel financing strategies, such as public-private partnerships, can aid in the mobilization of additional funding for the WASH sector. Additionally, involving the business and private sector in the delivery of WASH services and creating an environment that encourages private sector participation will aid in building a solid institutional framework. The government should give rural areas in Nigeria priority when providing WASH services and make sure that initiatives are catered to their particular needs and conditions because rural people in Nigeria experience considerable barriers to getting WASH services. To encourage better hygiene habits and ensure that WASH efforts are sustainable, behaviour modification is essential. Therefore, the government ought to fund behaviour modification efforts that encourage better hygiene and sanitation practices.

6.0 RECOMMENDATIONS

Proper coordination, involvement of water experts and collective efforts of the government, individuals and private sectors will yield tremendous benefits.

i. Public education and information sharing is key to any strategy on achieving improve WASH services. Efforts should be made by WASH agencies to disseminate relevant information on the consequences and

benefits of WASH and how to achieve adequate services, by using improved sources of drinking water, sanitation and hygiene practices to the general public.
ii. Corruption in the WASH sector must be tackled to make any meaningful progress in WASH services in Nigeria
iii. Governments' inability (largely because of lack of resources) to maintain water and sanitation infrastructure has been the major factor leading to the promotion of community participation in development programmes.
iv. Continuous support for community participation, and specifically institutional, legal, and contractual links between communities, Governments and NGOs need to be developed.

REFERENCES

Ademiluyi, I. A., and Odugbesan, J. A. (2008). Sustainability and impact of community water supply and sanitation programmes in Nigeria: An overview. *African Journal of Agricultural Research*, *3*(12), 811-817.

Agbolade, M.O.; Dipeolu, I.O.; Ajuwon, A.J. Knowledge and use of oral rehydration therapy among mothers of under-five children in a military barrack in Ibadan, Nigeria. *Afr. J. Biomed. Res.* 2015, *18*, 7–15.

Babalola J.O (1990). Coping with water supply demands and growth in the 1990s. Water Resour. J. Nig. Assoc. Hydrogeol. (NAH), 2(1): 26 - 30.

Babalola J.O (1997). Rural Water Supply: Issues, Problems and Prospects. Water Resources J. Nig. Assoc. Hydrogeologists (NAH), 8(1): 19 -25

Hardoy H, Schusterman R (2000). New models for the Privatization of Water and Sanitation for the Urban Poor. J. Environ. Urbanization 12 (2): 63-75

MacDonald AM, Davies J, Calow RC, Chilton PJ (2005). Developing Groundwater: A guide for rural water supply. ITDG Publishing, Rugby, UK.

MICS (1999). Multiple Indicator Cluster Survey, WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation.

Narayan D (1995). The Contribution of People's Participation: Evidence from 121 Rural Water Supply Projects. Environmentally Sustainable Development Occasional Paper Series, No 1, World Bank, Washington DC, USA

Nwankwoala, H. O. (2011). Localizing the strategy for achieving rural water supply and sanitation in Nigeria. *African Journal of Environmental Science and Technology*, *5*(13), 1170 1176.

Okoh, B.A.N.; Alex-Hart, B.A. Home management of diarrhoea by caregivers presenting at the diarrhoea training unit of a tertiary hospital in southern Nigeria. *Br. J. Med. Med. Res.* 2014, *4*, 5524–5540.

Oyesiku O. O. (1998). Modern Urban and Regional Planning Law and Administration in Nigeria, Kraft Books Limited, Ibadan.

Refsgaard, J. C., and Abbott, M. B. (1990). The role of distributed hydrological modelling in water resources management. In *Distributed hydrological modelling* (pp. 1-16). Springer,

Dordrecht.Sentis, I. P. (2010). Hydrological Approach to Soil and Water Conservation. *International Centre for Theoretical Physics*, *1*, 1–25.

UNICEF (2016). Water sanitation and hygiene: the situation. Retrieved from https:// www.unicef.org/nigeria/wes.html)

United Nations. High-Level Political Forum on Sustainable Development. 2017. Available online: https://sustainabledevelopment.un.org/hlpf (accessed on 15 November 2017).

United Nations. Report of the Secretary-General, 'Progress towards the Sustainable Development Goals. Progress of Goal 3 in 2017. Available online: https://sustainabledevelopment.un.org/sdg3 (accessed on 14 January 2018).

Yaya, S., Hudani, A., Udenigwe, O., Shah, V., Ekholuenetale, M., and Bishwajit, G. (2018). Improving water, sanitation and hygiene practices, and housing quality to prevent diarrhea among under-five children in Nigeria. *Tropical medicine and infectious disease*, *3*(2), 41.

Paper 12 Geo-Resistivity Investigation for the Assessment of Groundwater Aquifer Protective Capacity: A Case Study of the Federal Polytechnic Ado-Ekiti, Nigeria

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ABSRACT: Anthropogenic activities by students around Abuja Hostel within Federal Polytechnic Ado Ekiti have necessitated a geophysical assessment. This is to unveil the rate of aquifer protective capacity of the study area against the effects of contaminants and the expected long-term impacts on the groundwater system. Eighteen (18) Vertical Electrical Sounding (VES) points were probed across the study area. The measured resistivity data were interpreted with computer software packages, which gave the resistivity, depth, and thickness for each layer while maps were generated. Dar-Zarrouk parameter (Total Longitudinal Unit Conductance, S) of the earth materials overlying the aquifer was computed. The VES result revealed a lithological sequence of topsoil/lateritic soil, sandy clay, partially weathered/fractured basement layer and the bedrock. KH curve type (20%) and HA curve type (80%) were obtained in the study area. The isopach map of overburden discriminated between zones of thick and thin overburden. Aquifer overburden thickness of between 15 m and 32 m occurred in about 67% of the area which thus suggests that the thick layer act as a seal, thus protecting the major aquiferous units. The estimated total longitudinal conductance ranges from 0.0878 – 0.9343 mhos indicating a poor to moderate protective capacity rating across the study area. The interpreted results of the overburden layer show 6% good, 61% moderate, 22% weak and 11% poor aquifer protective capacity. These show that aquifers in the study area have predominantly moderate aquifer protective capacity with lenses of weak – poor protective capacity. The moderate value of the protective capacity is a result of the presence of a reasonable amount of clay as an overburdened impermeable material in the study area, thereby retarding the percolation of contaminants into the aquifer.

Keywords: aquifer, contaminants, resistivity, longitudinal unit conductance, overburden

1.0 INTRODUCTION

The focus on groundwater has largely switched in recent years from the issue of sourcing to concerns about groundwater quality and protection. Since groundwater supplies drinking water to billions of people worldwide, its security is of the utmost significance. In Nigeria, groundwater is a significant, natural, and healthy resource that delivers supplies of drinking water. Groundwater is used by many people, yet it can become contaminated by things close to the surface. Within metropolitan areas, contamination of the hydro-geologic system has become a frequent occurrence. Both naturally occurring processes and acts that may be explicitly linked to human activity (anthropogenic activities) affect the quality of groundwater. The environment of the groundwater is under attack from an ever-increasing amount of toxins as a result of our consumerist way of life. According to studies, a high rate of urbanization, industrialization, and other human activities during the last century led to the discharge of poisonous material into the earth, which then filtered into the aquifer. The Precambrian Basement Complex's aquifers often exist at shallow depths, making them susceptible to surface or near-surface contaminants (Olateju *et al.,* 2018). Natural processes, nonpoint agricultural and urban runoff, waste disposal methods, spills, leaks, and other unintentional or intentional discharges can all compromise groundwater's potability. The permeability, porosity, and overburden thickness of geologic formations all affect the rate of groundwater contamination. The ability of polluting influents to escape into the subsurface to contaminate groundwater, make the soil corrosive, and form a polluting plume that extends hundreds of meters is increased when the underlying geologic material is unconsolidated and uncompacted, such as coarse sand (Keswick *et al.,* 1982). To some extent, however, the physical environment may shield groundwater from the effects of nature, particularly when it comes to toxins that penetrate the subsurface zone. The earth medium filters percolating fluid naturally; this function is a measure of the earth medium's protective capacity (Olorunfemi *et al.,* 1999). The ability of the overburden unit to delay and filter penetrating ground contaminating fluid into the aquiferous unit is known as aquifer protective capacity (APC)

(Onyenweife *et al.,* 2020). Clay composition and overburden thickness have this kind of protecting potential. The total overburden thickness can offer protection by decreasing the time it takes for contaminants to infiltrate into the groundwater, whereas a high clay content prevents smooth motion and is typically characterized by low hydraulic conductivity and resistivity values, and consequently low longitudinal conductance. Overburden protective capability was defined by Omoyoloye *et al.*, (2008) as the ratio of overburden thickness to resistivity. The protective capacity is thought to be proportional to the longitudinal unit conductance in mhos, meaning that the more the overburden's longitudinal conductance, the more protective its capacity. The overburden protection capacity of a region can be evaluated using the absolute longitudinal conductance. (Olajide *et al.*, 2020).

Henriet (1976) demonstrated that the combination of layer resistivity and thickness in the Dar Zarrouk parameters S (longitudinal conductance) and T (transverse resistance) may be of direct use in aquifer protection studies and for the evaluation of hydrologic properties of aquifer. According to Olorunfemi *et al.,* (1999), Alabi *et al.,* (2021), Oladapo *et al.,* (2004), and Atakpo and Ayolabi (2009), the protective capacity is thought to be proportional to the longitudinal unit conductance in mhos. Electrical resistivity prospecting can be used to offer information about the lithology, stratigraphic sequence, overburden thickness, and hydro-geological features of the underlying material. Vertical Electrical Sounding (VES) is frequently used for groundwater investigation within the basement complex rocks of Africa. The delineation of subsurface geological sequence, geological structures and features of interest, aquifer units, types, and depth extent have all been accomplished using this method in nearly all geological terrains (Oladapo *et al.,* 2004; Ako *et al.,* 2005; Lashkaripour *et al.,* 2003; Kayode and Olawale, 2021). In Nigeria, some recent studies (Olajide *et al.,* 2020; Olateju *et al.,* 2018; Adeniji *et al.,* 2014; George *et al.,* 2014) used the electrical resistivity approach to delineate groundwater potential and investigate aquifer protective capacity. Abiola *et al.,* (2009) studied the groundwater potential and aquifer protective capacity of overburden units in Ado Ekiti and delineated three groundwater potential zones (high, medium, and low) and aquifer protective capacity (good, moderate, weak, and poor) in the study area. Olateju *et al.,* (2018) evaluated groundwater and aquifer protection capacity at the Olabisi Onabanjo University campus using the resistivity method. The result showed that the area is underlain by 3-5 layers (the topsoil, clay/clayey sand/sand/laterite, fractured basement, and the fresh basement), the reflection coefficient range is between 0.62 and 0.98 while the protective capacity range is between 0.03 and 0.28 (poor to moderate). Groundwater potential of the area were classified as high, medium and low.

The Federal Polytechnic Ado Ekiti is a fast-growing institution. It lies within the Precambrian Basement terrain of Nigeria. The continuous student activities around hostels within the campus emphasize the need for urgent intervention to groundwater pollution. Improper wastes disposal, open defecation, engine oil spillage among others are human activities being practiced around the study area (Abuja Hostel) and especially closed to an existing borehole supplying water to the hostel. These contaminated wastes might pose a serious threat to the health of the students living in the hostel due to their bulk and susceptibility to groundwater pollution.

Consequently, a detailed geoelectric survey of the study area was carried out to ascertain the geoelectric parameters (resistivities and thicknesses) of subsurface layers and their hydrogeological properties. The study is also aimed at evaluating the aquifer protective capacity (insulation from pollution) of the overlying formations.

2.0 STUDY LOCATION AND GEOLOGY

The study area is located within Latitude 839500 and 839750 and Longitude 753950 and 754100 in Universal Traverse Mercator (UTM), Ado-Ekiti, southwestern Nigeria. It is within the Federal Polytechnic Ado-Ekiti, along Ijan-Ekiti road. The geology of the study area falls within the Basement Complex of South-western Nigeria dominated by the crystalline rocks. The rock sequence in the area includes granitic rocks, charnockitic rocks, gneisses and migmatites. The gneissic rocks in this area form the country rock into which the granitic and charnockitic rocks intruded. They occur as low-lying exposures. Xenoliths of these units are frequently found in the granitic and charnockitic bodies (Olanrewaju, 1987).

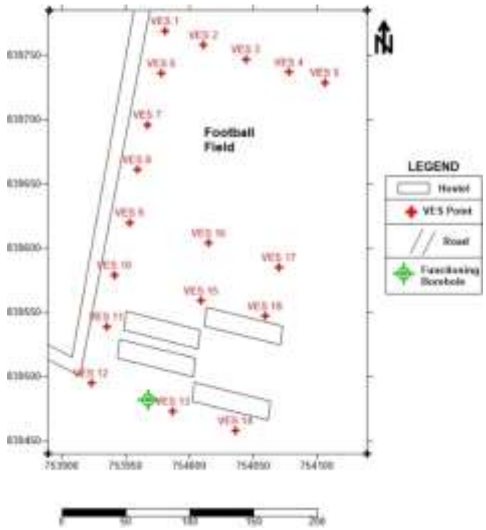

Figure 1: Base map of the study area showing VES points

3.0 MATERIALS AND METHODS

In this study, the Schlumberger array was performed using the vertical electrical sounding field procedure to assess the electrical resistivity of the subsurface and the thickness of the aquifer.

A total of eighteen (18) VES points were occupied along five (5) traverses for data acquisition (Fig. 1). The electrical resistivity of the area was measured using Campus Ohmega Terrameter. The apparent resistivity (ρa) values were obtained as the product of the resistance read from the resistivity meter and its corresponding geometric factor calculated. These were then plotted against their corresponding half current electrode spacing (AB/2) on a bi-logarithm paper. The plotted field curves were therefore interpreted manually by partial curve matching using different master curves. The geoelectric parameters from the partial curve matching interpretation then served as an input model for computer-assisted iteration. Computer modelling software (WINRESIST) was used to generate data for the estimated model.

The aquifer protective capacity (S) of the study area was calculated based on the values of the longitudinal unit conductance of the overburden rock units in the area. The longitudinal layer conductance (S) of the overburden at each station was obtained from equation (1) (after Henriet, 1976):

$$S_T = \sum_{i=1}^{n} \frac{hi}{\rho i}$$

Where S_T is the total longitudinal conductance, Σ is summation sign, *hi* is the saturated thickness of each layer, *ρi* is the true resistivity of each layer and n is the number of layers.

Using modified Oladapo and Akintorinwa (2007) classification, the results of longitudinal conductance was used to classify areas into good, moderate, weak and poor protective capacity (Table 1).

Table 1. *Modified longitudinal conductance/protective capacity rating*

Longitudinal Conductance (Mhos)	Protective Capacity Rating
>10	Excellent
5–10	Very good
0.8–4.9	Good
0.2–0.79	Moderate
0.1–0.19	Weak
<0.1	Poor

(Oladapo and Akintorinwa, 2007).

4.0 RESULTS AND DISCUSSION

4.1 Vertical Electrical Sounding (VES)

The curve types identified are majorly HA and KH (Figure 3a and 3b). The most predominant curve type within the study area is HA-type having a percentage frequency of 80 % while HA-type having 20 %. The type curves show that the lithologic sequences delineated are four geo-electric layers. The HA and KH-type curve are typical of the weathered/fractured (unconfined) aquifer type wherein a fractured zone underlies the weathered zone directly.

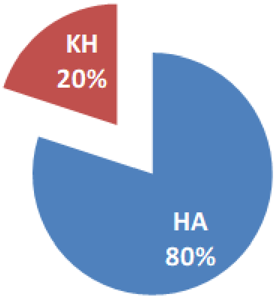

Figure 2: VES Curves Distribution

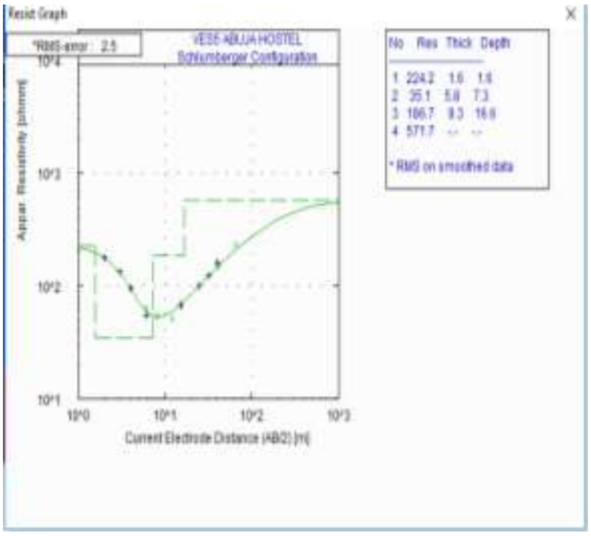

Figure 3a: Typical HA iterated curve in the study area

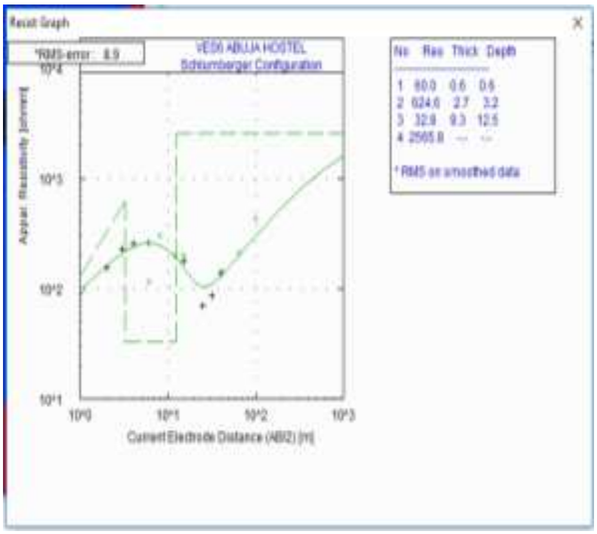

Figure 3b: Typical KH iterated curve in the study area

4.2 Geo-Electric Sequences

Results were analyzed to delineate the lithology of the study area. 2-D geoelectric sections were drawn in N-S and W-E directions. The resistivity values and depths obtained after iteration were used to interpret the lithology of the study area which revealed four subsurface layers: the top-soil, the sandy clay layer, partially weathered/fractured basement and the fresh basement. The topsoil constitutes the first layer with resistivity which varies from 60 ohm-m to 637 ohm-m and thickness range of 0.8 - 2.0m. The predominant composition of the top soil is lateritic clay, sandy clay and clayey sand. Underlying the first layer is the sandy clay lithologic layer with resistivity range of 11 ohm-m to 1,110 ohm-m and thickness range of 1 to 8m, which indicated that the material composition is sandy clay, clayey sand and clay. The third lithologic layer correspond to weathered/fractured basement with resistivity value ranging from 11 ohm-m to 460 ohm-m and thickness of 6 to 32m. This unit is indicative of high degree of fracture and/or water saturation. The fourth layer has the resistivity ranging from 144 ohm-m to 5533 ohm-m. This represents the bedrock. The resistivity values obtained indicated groundwater occurrence is predominant in the weathered/fractured zones. Geoelectric sections in north-south and east-west directions were shown in Figure 4a and 4b.

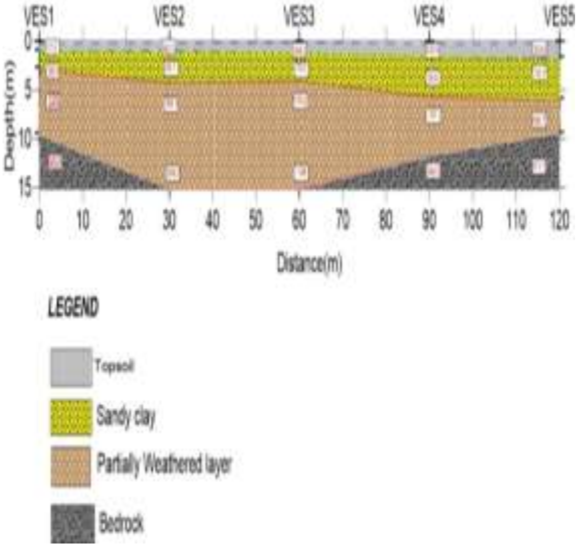

Figure 4a: Geo-electric section along Traverse 1 (E-W) in the Study Area

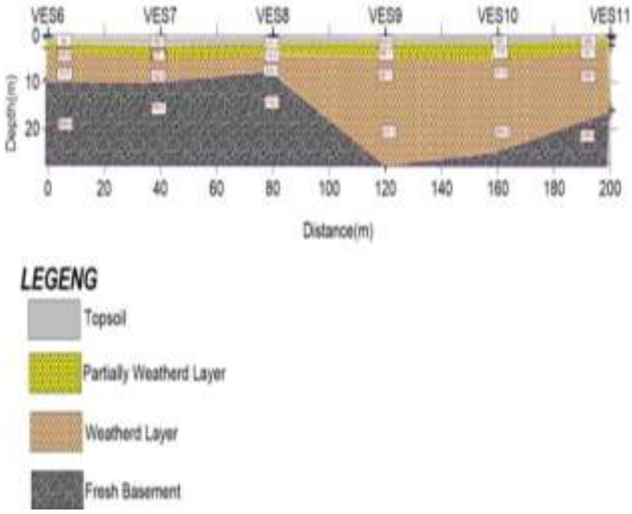

Figure 4b: Geo-electric section along Traverse 2 (N-S) in the Study Area

4.3 Aquifer Protective Capacity Evaluation

The nature of the materials that overlain the mapped aquifers were evaluated using the layer parameters (i.e. resistivity and thickness) to determine its capacity to prevent infiltration of unwanted fluids into the aquifer. The ability of geologic materials overlying an aquifer to retard and filter percolating ground surface polluting fluids is a measure of its protective capacity. Table 2 presents the summary of the computation of total longitudinal conductance, S and overburden protective capacity rating at all the VES stations.

The longitudinal conductance values obtained showed that aquifers in the study area are predominantly moderately protected with lenses of weak – poor protective capacity except for VES 18 that is adequately protected. The moderate value of the protective capacity is as a result of the presence of average amount of clay as an overburden impermeable material in the study area, thereby constraining the percolation of contaminants to the water saturated layer.

The estimated values of overburden longitudinal conductance of the aquifer in the study area ranged from 0.0878 Ohm-1 – 0.9343 Ohm-1. The interpreted results of overburden layer show 6% good (where the conductance is greater than 0.7mhos), 61% moderate (where the conductance ranges between 0.2 to 0.69 mhos), 22% weak (area with conductance values ranging from 0.1 to 0.19) and 11% poor (where conductance value is less than 0.1 mhos) aquifer protective capacity (Table 3).

The longitudinal unit conductance map (Figure 5), derived from equation 1 for all the VES locations, was used for the overburden protective capacity rating of the study area. The highly impervious clayey overburden, which is characterized by relatively high longitudinal conductance, offers protection to the underlying aquifer (Abiola *et al.*, 2009). The aquifer in the study area is therefore not very prone to contamination from wastes from the hostel. However, the weakly and poorly protected part of the area of study could be liable to contamination from near-surface wastes.

This result is in agreement with the interpreted or the inferred lithology across the study area for the soil type. From the interpreted geoelectric parameters, the inferred lithology for the layer directly overlying the aquifer is sandy clay for the most parts of the study area. This lithologic unit is highly impervious thereby offering protection to the underlying aquifer. Usually, clays act as suitable protective cover when they are found as thick layers above aquifer. Although there are weak and porous parts of the study area in terms of its protective capacity, however, this could be as a result of the thinness of the sandy clay unit. The weak or porous portion offer little or no protection to the underlying aquifer as contaminating fluids can migrate relatively easy through this lithologic unit to pollute the aquifer.

Table 2. Geoelectric Parameter and Dar Zarrouk parameter of the study area

S. no. Capacity	Protecting layers	Protecting layers Resistivity (Ohm-m)	Layer Thickness (m)	Longitudinal Cond. (mhos)	Protective Rating
VES 1	1,2,3,4	175, 29, 320, 650	1, 3, 9	0.1372	Weak
VES 2	1,2,3,4	242, 93, 369, 304	1, 4, 15	0.0878	Poor
VES 3	1,2,3,4	304, 71, 171, 144	1, 4, 15	0.1473	Weak
VES 4	1,2,3,4	533, 40, 151, 544	1, 6, 12	0.2314	Moderate
VES 5	1,2,3,4	224, 35, 187, 572	2, 6, 9	0.2284	Moderate
VES 6	1,2,3,4	60, 625, 33, 2566	1, 3, 9	0.2942	Moderate
VES 7	1,2,3,4	193, 28, 163, 646	1, 5, 10	0.2451	Moderate
VES 8	1,2,3,4	211, 14, 325, 1116	1, 4, 7	0.3119	Moderate
VES 9	1,2,3,4	637, 80, 287, 631	1, 4, 27	0.1457	Weak
VES 10	1,2,3,4	557, 1110, 292, 285	2, 5, 25	0.0937	Weak
VES 11	1,2,3,4	300, 42, 109, 2240	1, 2, 16	0.1977	Moderate
VES 12	1,2,3,4	155, 52, 460, 562	1, 5, 10	0.1244	Weak
VES 13	1,2,3,4	82, 13, 147, 865	2, 8, 7	0.6874	Moderate
VES 14	1,2,3,4	139, 14, 202, 5533	2, 4, 3	0.3149	Moderate
VES 15	1,2,3,4	108, 304, 11, 1277	1, 1, 4	0.3762	Moderate
VES 16	1,2,3,4	254, 269, 55, 913	1, 1, 13	0.2440	Moderate
VES 17	1,2,3,4	78, 105, 31, 738	1, 2, 7	0.2576	Moderate
VES 18	1,2,3,4	78, 24, 17, 673	1, 8, 10	0.9343	Good

Table 3. Summary of Longitudinal conductance (mho) and aquifer protective capacity rating in the study area.

ST (mho)	**APC Rating**	**Percentage (%)**	**VES Points**
>10	Excellent	-	
5–10	Very good	-	
0.8–4.9	Good	6	18
0.2–0.79	Moderate	61	4, 5, 6, 7, 8, 11, 13, 14, 15, 16, 17
0.1–0.19	Weak	22	1, 3, 9, 12
<0.1	Poor	11	2, 10

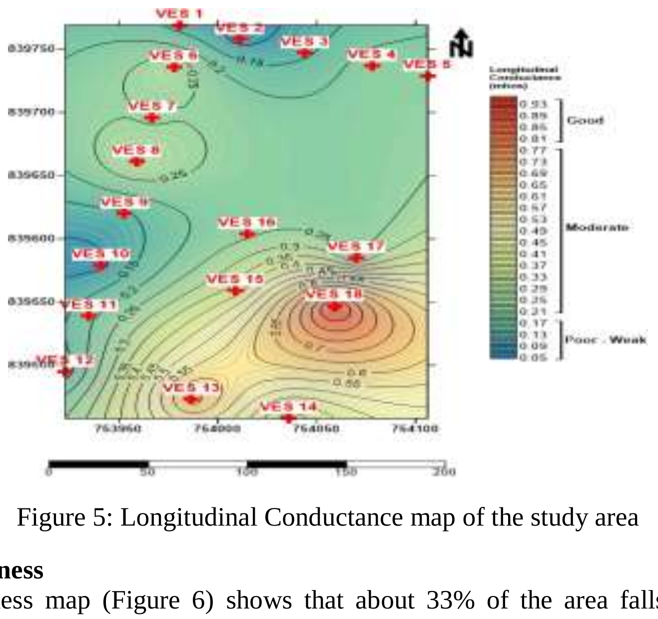

Figure 5: Longitudinal Conductance map of the study area

4.4 Overburden Thickness

The Overburden thickness map (Figure 6) shows that about 33% of the area falls within the poor/weak overburden protective capacity, while about 67% constitutes the moderate/good protective capacity rating. This work has revealed that overburden materials around the north-eastern, western and southern portions of the study area have moderate protective capacity and are moderately thick (between 5 to 10 m thick). The northern and central part of the region exhibit weak to poor overburden protective capacity and thin overburden thickness (less than 5m thick). Generally, the study area has moderately thick overburden greater than 5m which cover greater percentage of the study area.

The weak and poor aquifer protection zones coincide with zones of shallow or thin overburden and relatively high electrical resistivity. These areas are vulnerable to easy and quick migration of near-surface/surface contamination sources. This result is also in agreement with the interpreted or the inferred lithology across the study area for the overburden. From the interpreted geoelectric parameters, the topsoil layer and sandy clay layer are generally less than 10m thick.

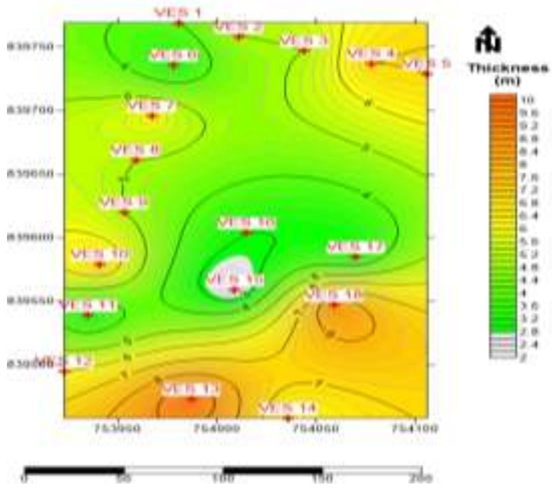

Figure 6: Overburden thickness map of the study area

5.0 CONCLUSION AND RECOMMENDATION

In this work, the electrical resistivity sounding method using the Schlumberger array configuration was used to explore the study area. Groundwater protective capacity evaluation of the rock units around Abuja hostel within the Federal Polytechnic Ado Ekiti was undertaken using 18 Schlumberger vertical electrical soundings (VES). The results provide data on the formation parameters revealing four geoelectric layers (top soil, sandy clay, partially weathered/fractured layer and fresh basement). The curve types identified are majorly HA and KH types.

The area has been classified into area of moderate, weak and poor aquifer protective capacity characterized by low values of longitudinal conductance ranges between 0.0878 and 0.9343 Ohm-1. This corresponds to aquifer protective rating between poor and moderate capacity which shows that the area studied has poor to moderate aquifer protective capacity. The highest value of the longitudinal conductance was observed at VES 18 indicating a good aquifer protective capacity making the area adequately protected from contamination. Eleven (11) locations, representing 61% of the surveyed locations have aquifer capacity rated moderate while six (6) locations representing 33% have weak to poor protective capacity rating.

The studied area also revealed a moderately thick to shallowly thick overburden layers with sandy clay unit directly above the aquifers in the study area. The Overburden thickness map shows that about 33% of the area (areas with thickness < 5) falls within the weak/poor overburden protective capacity, while about 67% (areas with thickness > 5) constitutes the moderate/good protective capacity rating.

Areas with good to moderate aquifer protective capacity coincide with zones of appreciable overburden thickness with clayey columns moderately thick enough to protect the aquifer in the area from the surface polluting fluid. The area with shallow overburden also coincided with weak protective capacity thereby exposing the groundwater in the area to pollution. Therefore vulnerable zones include the northwestern and central region. It is therefore evident that groundwater in most part of the area especially around the hostel is moderately protected from pollution that may arise from effluent, open defecation and indiscriminate waste disposal in the study area.

This study has provided reliable information for an elaborate groundwater protection within Federal Polytechnic Ado Ekiti which can serve as good reference materials for future research work in the areas of geophysical approaches to hydrogeology.

For effective groundwater protection and health of students in the study area, it is recommended that school management should endeavor to provide adequate waste disposal and sanitation system in order to prevent indiscriminate waste disposal and open defecation.

It is suggested that the integration of different geophysical method should always be adopted for more detailed investigation. Hence, for more information on the subsurface lithology and resistivity, other geophysical methods like 2-D resistivity and VLF-EM methods can be employed.
Also, a physicochemical study of water sample from the existing borehole supplying the hostel with water can be integrated with the results from this study in order to corroborate this work.

REFERENCES

Abiola O, Enikanselu P A and Oladapo M I (2009). Groundwater potential and aquifer protective capacity of overburden units in Ado-Ekiti, southwestern Nigeria; *Int. J. Phys. Sci.* 4(3) 120–132.

Adeniji A E, Omonona O V, Obiora D N and Chukudebelu J. U. (2014). Evaluation of soil corrosivity and aquifer protective capacity using geo-electrical investigation in Bwari basement area; *Abuja. J. Earth Syst. Sci.* 123(3) 491–502.

Ako, B.D; Ajayi, T.R; Arubayi, J.B; Enu, E.I (2005). The Groundwater and its Occurrence in the Coastal Plains Sands and Alluvial Deposits of Parts of Lagos State. *Nigeria Water Res.*, 16: 7– 17

Alabi, A. A., Ganiyu S. A., Idowu O. A. Ogabi A. F., Popoola O. I. (2021). Investigation of groundwater potential using integrated geophysical methods in Moloko-Asipa, Ogun State, Nigeria. *Applied Water Science* (2021) 11:70. https://doi.org/10.1007/s13201-021-01388-3

Atakpo, E.A, Ayolabi, E.A (2009). Evaluation of Aquifer Vulnerability and the Protective Capacity in Some Oil Producing Communities of Western Niger Delta. *Environmentalist*, 29: 310–317

Dahlin T. (2001). The development of DC resistivity imaging techniques. *Computers & Geosciences.* 27(9):1019-1029

George N J, Nathaniel E U and Etuk S E (2014). Assessment of economical accessible groundwater reserve and itsprotective capacity in eastern Obolo local government area of Akwa Ibom State, Nigeria, using electrical resistivity method; *Int. J. Geophys.* 7(3) 693–700.

Henriet, J.P. (1976). Direct applications of the Dar Zarrouk parameters in groundwater survey. Geophys. Prospect. 24, 344–353.

Ibuot J C, Akpabio G T and George, N. J. (2013). A survey of the repository of groundwater potential and distribution using geoelectrical resistivity method in Itu local government area (L.G.A), Akwa Ibom State, southern Nigeria; *Cent. Eur. J. Geosci.* 5(4) 538–547.

Kayode F.O, Olawale B.O. (2021). Geophysical evaluation of subsurface protective capacity and groundwater prospect in a typical sedimentary zone, eastern Dahomey Basin using electrical resistivity technique. Malaysian Journal of Geosciences (MJG) 5(2) (2021) 85-92

Keswick B H, Wang D and Gerba, C. P. (1982). The use of micro-organisms as groundwater tracers – A review; *Groundwater* 20(2) 142–149.

Lashkaripour, G.R. (2003). An Investigation of Groundwater Condition by Geoelectrical Resistivity Method in Korin Aquifer, Southeast Iran. *Journal of Spatial Hydrology*, 3, 1-5.

Oladapo M.I, Akintorinwa O.J (2007). Hydrogeophysical Study of Ogbese Southwestern, Nigeria. Global J. Pure and Applied Sci. 13(1): 55-61.

Oladapo M I, Mohammed M Z, Adeoye O O and Adetola, O. O. (2004). Geoelectric investigation of the Ondo State Housing Corperation Estate; Ijapo, Akure, southwestern Nigeria; *J. Mining Geol.* 40(1) 41–48.

Olajide A., Bayode S., Fagbemigun T., Oyebamiji A., Amosun J., Owasanoye A. (2020). Evaluation of Aquifer Protective Capacity and Groundwater Potential in Part of Iju, Akure-North, Ondo State, Nigeria. *J. Nig. Soc. Phys. Sci.* 2 (2020) 197–204

Olanrewaju, V.O. (1987). Charnockite-granite Association in Southwest Nigeria. Rapakivi granite type and charnokitic plutonism in Nigeria. *Journal of African Earth Science*, T (1): 67 – 7

Olateju O. B, Moroof O. O, Ganiyu O. M, Temitope A. L, Stephen O. A, Julius O. F. (2018). Assessment of groundwater prospect and aquifer protective capacity using resistivity method in Olabisi Onabanjo University campus, Ago-Iwoye, Southwestern Nigeria. *NRIAG Journal of Astronomy and Geophysics* 7 (2018) 347–360.

Olorunfemi MO, Ojo JS and Akintunde OM (1999). Hydrogeophysical evaluation of the groundwater potential of Akure metropolis, southwestern Nigeria. *International Research Journal of Geology and Mining* 35(2) 207-228.

Omoyoloye N A, Oladapo M I and Adeoye, O. O. (2008). Engineering geophysical study of Adagbakuja Newtown development, southwestern Nigeria; *J. Earth Sci.* 2(2) 55–63.

Onyenweife, G. I., Nwozor, K.K., Nwike, I.S., Onuba, L.N., Egbunike, M.E., and Anakor, S.N. (2020). Application of Electrical Resistivity Method in Estimating Aquifer Protective Capacity of Awka and its Environs, Anambra State, Nigeria. *Int. J. Innovative Environ. Studies Res. 8(4):1-17, 2020*

Paper 13 *Accelerating Access to Sustainable Urban and Rural Water Sanitation and Hygiene in Nigeria*

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ABSTRACT: Despite efforts to improve water, sanitation, and hygiene (WASH) services, a significant proportion of the population still lacks access to these necessities in Nigeria. This paper explored the challenges, opportunities and strategies for accelerating access to sustainable urban and rural water sanitation and hygiene in Nigeria. The methodology adopted included a literature review, case studies and information gathered from experts. Challenges facing the acceleration of WASH in the water sector were itemized. Opportunities for accelerating access to WASH were equally highlighted. Strategies for accelerating access to WASH were also listed. It was concluded that accelerating access to sustainable urban and rural water sanitation and hygiene in Nigeria requires a comprehensive and integrated approach. Many promising avenues exist to strengthen WASH and the water sector generally through research, publications and industrial contributions. Proper coordination, involvement of water experts and collective efforts of the government, individuals and private sectors will yield tremendous benefits. Although infrastructure development appeared to be a key development required, social aspects and rural-urban sensitization and funding require special attention. Appropriate cultural attitudes, organizational structures, new approaches, project management aspects, sustainable development goals, and legal frameworks within and across the water sector will dramatically accelerate the development of new approaches to access sustainable urban and rural water sanitation and hygiene in Nigeria. Smart Innovation, implementation strategies and sustainable development Initiatives for expanding and accelerating WASH were recommended.

Keywords: legal frameworks**,** implementation strategies, accelerating access**,** rural water sanitation, smart innovation

1.0 INTRODUCTION

Access to clean water, proper sanitation, and good hygiene practices are essential for the health, well-being, and socio-economic development of individuals and communities. In Nigeria, despite efforts to improve water, sanitation, and hygiene (WASH) services, a significant proportion of the population still lacks access to these necessities. As a socially conscious individual, you likely share the dream of a world where everyone has access to clean water and basic sanitation. In 2015, the United Nations adopted the 17 Sustainable Development Goals (SDGs) to address global challenges and achieve a better and more sustainable future for all by 2030. Life depends on having access to safe, sufficient water. The World Health Organization (WHO) estimates that 3.6 billion people lack access to "safely managed sanitation services" and that 2 billion people lack access to "safely managed drinking water" globally. The difficulties in providing access to water and sanitation in Nigeria as well as the differences across developed nations are reflected in these statistics. Only 23% of Nigerians have access to even the most basic water supply services. 87% of the population, or 179 million people, do not have access to services that provide clean drinking water. Additionally, just 10% of the population has access to services for hygiene, sanitation, and water. Even though access to safe drinking water and basic sanitation is one of humanity's greatest gifts, this issue affects billions of people worldwide. Figure 1 presents information on children's vulnerability to water bornediseases.

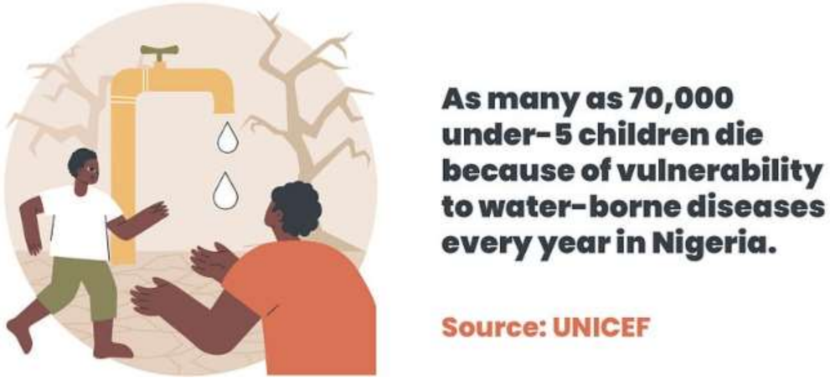

Figure 1: Children's vulnerability to waterborne diseases
Source: WHO and UNICEF (2006)

Sanitation is the provision of facilities and services for the safe management and disposal of human urine and faeces. Hygiene encompasses the conditions and practices that help maintain health and prevent the spread of disease including handwashing, menstrual hygiene management and food hygiene. Access implies facilities close to home that can be easily reached and used when needed. In light of the global COVID-19 Pandemic crisis, which has also had an impact on Nigeria, the Government of Nigeria has acknowledged the significance of WASH. Beyond the current crisis, having access to water supply, sanitation, and hygiene (WASH) is a key factor in determining outcomes related to human capital, such as early childhood survival, health, and educational attainment, all of which have an impact on labour productivity and efficiency. Inadequate WASH is linked to about 73 per cent of Nigeria's overall burden of enteric illnesses. In 2016, 119,900 of the 253,800 deaths in Nigeria that could be attributed to WASH were caused by diarrheal illnesses. There is convincing evidence that having access to a clean water supply and better hygienic conditions reduces the frequency of diarrhoea in young children. A significant portion of the burden of chronic malnutrition is attributable to the unsanitary environment in which children are raised, which is frequently brought on by high rates of open defecation in densely populated places. By allowing kids to spend less time collecting water to go to school, lowering the occurrence of illnesses that could keep them home from school, and fostering a secure and healthy learning environment while they are there, access to WASH can have an impact on the number of years they spend in school. Investing in water, sanitation and hygiene is critical both to preventing and recovering from pandemics and local outbreaks.

The implementation of WASH services by all three levels of government is hampered by ambiguity surrounding sanitation and wide variations in institutional and legal frameworks between states. At the federal level, the Federal Ministry of Water Resources (FMWR) is in charge of formulating policies, exercising oversight, and providing investment support for the management and development of water resources (surface water and groundwater), as well as for water delivery, hygienic practices, irrigation, and drainage. Both the FMWR and the Federal Ministry of Environment (FMEnv) claim accountability for sanitation. While the FMEnv is in charge of providing wastewater and faecal sludge management and overseeing the coordination of environmental sanitation in Nigeria, since state and municipal governments have significantly different institutional and legal frameworks, they are responsible for providing all WASH services. State waste agencies (SWAs) are increasingly taking over the duty of providing sanitation services as part of the reform agenda.

2.0 LITERATURE REVIEW

Water, sanitation, and hygiene practices are major area of interest for environmental public health in terms of disease prevention and control (Orimoloye et al., 2015). The effects of lack of access to WASH (water, sanitation, and hygiene) on health and well-being have recently drawn a lot of attention. According to WHO and UNICEF (2015), there are 663 million people without access to better water sources, and 2.4 billion people, or more than 35% of the world's population, lack access to improved sanitation facilities (Prüss-Üstün et al., 2008). Inadequate sanitation is estimated to cause 280,000 diarrheal deaths annually and is a major factor in several neglected tropical diseases (Liu et al., 2012; Umahi et al., 2020).

Hygiene practices are closely linked to health, and access to water is substantially correlated with both. Access to clean water is an objective of the 2030 Agenda for Sustainable Development because of these factors. Health, nutrition, education, and gender equality are just a few of the Sustainable Development Goals that can advance with the help of safe water (Folayan et al., 2020; WHO, 2017). Most Neglected Tropical Diseases (NTDs) can be prevented and managed with the help of safe water, sanitation, and hygiene (WASH). One of the five main public health methods for preventing, controlling, and eventually eradicating disease is the provision of safe water, appropriate sanitation, and hygiene (WASH). To varied degrees, WASH is essential for the management and prevention of all diseases.

The potential to link work on WASH and diseases has largely been untapped, even though that it is recognized that action on WASH is necessary for the elimination of the majority of diseases. WASH components of global and national programs have received little attention (Boisson et al., 2016). To stop the threat of diseases becoming more common in Nigerian towns due to a lack of potable water and poor hygiene habits there, WASH practices and related issues are crucial. Sanitation, cleanliness, and access to clean water are essential for human health and welfare. Safe WASH is important for livelihoods, school attendance, and dignity in addition to being a requirement for good health. It also helps build strong communities with wholesome surroundings.

According to WHO and UNICEF (2006), drinking water is defined as water used by people for drinking, cooking, food preparation, personal hygiene, or other comparable functions. When a household uses water from a protected community source like a well, spring, or borehole, or when they collect rainwater, these sources are regarded as providing a "basic" drinking water service. Rapid and effective WASH interventions are critical for saving the lives of children across a range of crises and complex humanitarian situations due to disease outbreaks and public health emergencies, conflicts, acute and chronic malnutrition, forced migration, and natural disasters (UNICEF, 2016).

3.0 METHODOLOGY

The methodology used included expert information gathering, case studies, and literature reviews. This review assessed the status of water, sanitation and hygiene services in Nigeria and provided solutions for the acceleration of WASH activities. There were several of obstacles to the expansion of WASH in the water industry. Opportunities to quicken access to WASH were also emphasized. There were also suggestions for expediting access to WASH. Table 1 presents variables, data sources and values for 'convenience' time savings and Table 2 presents the total population to serve from 2015 to 2030 to reach universal access to basic services (million).

Table 1: Variables, data sources and values for 'convenience' time savings

Variable	Data source	Access time	
		Urban areas	Rural areas
Water supply (baseline = distant water source)			
Unimproved source	Expert opinion, and evidence review[1]	40 minutes roundtrip	60 minutes roundtrip
Improved source		20 minutes roundtrip	20 minutes roundtrip
Household piped water		Less than 5 minutes roundtrip	Less than 5 minutes roundtrip
Sanitation (baseline = open defecation)			
Open defecation	Expert opinion, studies from Southeast Asia[2]	15 minutes travel time roundtrip	20 minutes travel time roundtrip
Shared sanitation		5 minutes travel and waiting time roundtrip	5 minutes travel and waiting time roundtrip

Table 2: Total population to serve from 2015 to 2030 to reach universal access to basic services (million)

MDG Region	Drinking-water			Sanitation		
	Urban	Rural	Total	Urban	Rural	Total
Latin America and the Caribbean	114	19	133	127	35	161
Sub-Saharan Africa	417	521	939	431	586	1,017
Northern Africa	34	15	49	35	14	49
Western Asia	44	19	63	41	17	58
Caucasus and Central Asia	11	12	23	9	5	14
South Asia	345	239	584	389	765	1,155
South-East Asia	189	65	254	136	95	230
Eastern Asia	240	0	240	277	3	280
Oceania	0	0	1	0	1	1
Developed countries	2	0	2	3	2	5
World	**1,396**	**892**	**2,287**	**1,448**	**1,523**	**2,971**

WASH is the collective term for Water, Sanitation and Hygiene. WASH aims to provide education, awareness, and funding to supply clean drinking water and sanitation education to schools and children in underdeveloped regions. Figure 2 presented map indicating access to water in Nigeria. Table 3 presented benefits of drinking water supply, sanitation and hand washing.

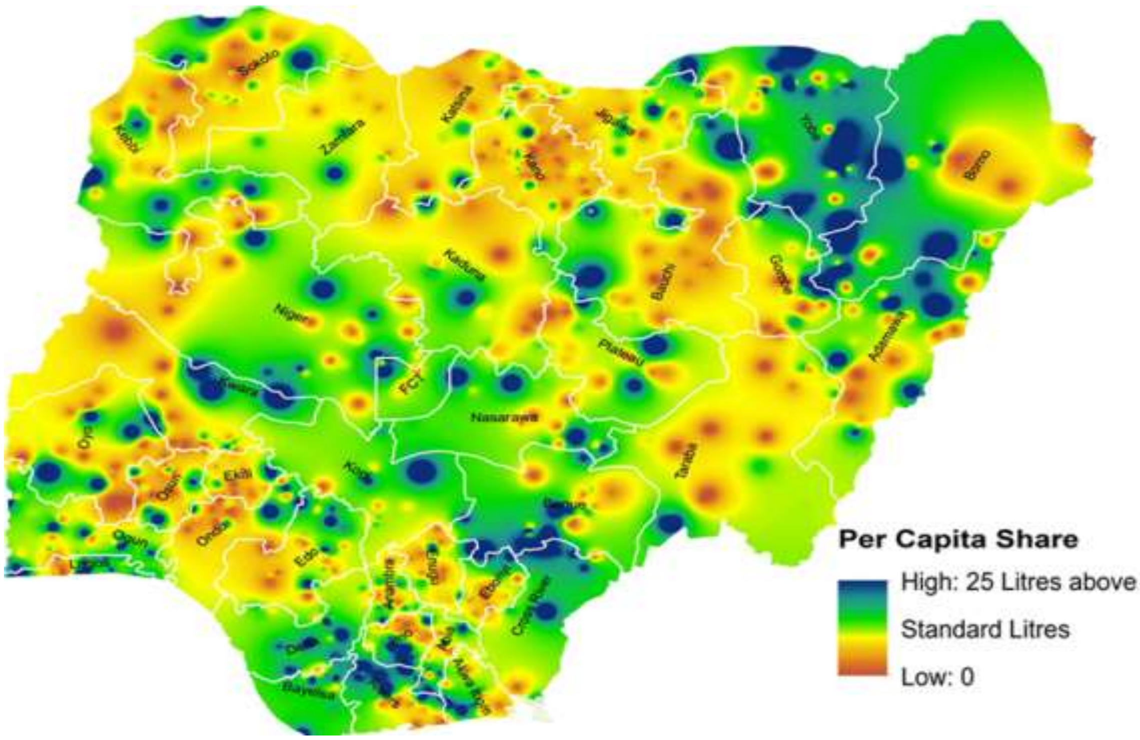

Figure 2: Map indicating access to water in Nigeria

Table 3: Benefits of drinking water supply, sanitation and hand washing

Benefit	Water	Sanitation
	Included benefits	
Health	• Averted cases of diarrhoeal disease • Averted cases of malnutrition-related diseases	
		• Averted cases of helminths
Health economic	• Costs related to diseases such as health care, lost productivity and premature mortality	
Time value	• Travel and waiting time averted when water supply and sanitation access is improved	
	Excluded benefits	
Other health	• Dehydration from lack of access to water	• Dehydration from not drinking due to poor latrine access (especially women) • Less flood-related health impacts
Reuse of nutrients		• Use of human faeces or sludge as soil conditioner and fertilizer in agriculture
Energy		• Use of human (and animal) waste as input to biogas digester leading to fuel cost savings and income opportunities
Education	• Improved educational levels due to higher school enrolment, attendance and completion rates • Impact of averted childhood malnutrition on education	
Water treatment		• Less household time spent treating drinking water, including boiling
Water security		• Safe reuse of treated wastewater in agriculture
Environment		• Improved quality of water supply available from surface and groundwater, and related savings
Leisure and quality of life / intangibles	• Leisure and non-use values of water resources • Reduced effort of associated with water hauling and gender impacts	• Safety, privacy, dignity, comfort, status, prestige, aesthetics, gender impacts
Reduced access fees		• Reduced payment of for toilets with entry fee
Property	• Rise in value of property	
Income	• Increased incomes due to more tourist income and business opportunities	

The figures and data sources for the time savings attributable to easier physical access and shorter lines for water sources and sanitizing facilities at home or in the community are shown in Table 6. For water delivery, it is expected that each home will require two roundtrips to satisfy their needs (minimum 20 litres per person per day). Roundtrip times in urban areas are reduced from 40 to 20 minutes and in rural areas from 60 to 20 minutes when households have access to basic upgraded water supplies. Because there are more water points and they are closer together, there is less time spent in line. Only one defecation trip per day is assumed for sanitation in the baseline.

The breakdown of the many advantages of providing metropolitan areas with universal access to a basic water supply is shown in Figure 1. Nearly 70% of the benefits globally come from the economic value of access time saved, with the remaining 20% coming from health care, health-related productivity and avoided mortality. Both rural and urban areas were found to have similar proportions. There are some variations between regions, such as a higher percentage of mortality decrease being accounted for in sub-Saharan Africa. Health benefits make up over 50% of all benefits in both South Asia and sub-Saharan Africa (Hutton and Whittington, 2015).

3.1 Challenges in Nigeria's WASH Sector

Major challenges being faced in the sector include inadequate funding, loose sector coordination, insufficient skilled manpower, lack of engagement of the private sector and limited monitoring and evaluation system and database coverage. A minimum of three times the existing WASH investment would be needed to address this need, according to the National WASH Action Plan, and the total investment needed to reach the country's SDG 6.1 and 6.2 targets by 2030 is expected to be US$122 billion. Although budgetary allocations are the primary source of funding for the industry, development partners also make important contributions through grants and direct project implementation.

The lack of national policy was named as a major barrier to sanitation achievement by Mara et al. (2010). They pointed out that governments in general and health ministries, in particular, cannot fulfill their crucial roles as promoters and enforcers of sanitation without suitable policies. According to them, policies are required to turn national institutions into the industry's leaders in sanitation, enhance home behaviour and community involvement, encourage demand generation, and make it possible for health systems to embrace sanitation and hygiene. Other challenges include:

i. **Limited infrastructures**: Insufficient infrastructures, including water treatment plants, distribution networks, and sanitation facilities, pose a significant challenge in providing clean water and sanitation services to urban and rural areas alike.
ii. **Population growth and urbanization:** Rapid population growth and urbanization exacerbate the strain on existing water and sanitation infrastructure, leading to inadequate access and increased health risks.
iii. **Funding constraints**: Insufficient funding, both from the government and international donors, hinders the development of new WASH projects and the maintenance of existing infrastructure.
iv. **Poor governance and institutional capacity**: Weak governance, corruption, and limited institutional capacity undermine the effective implementation of WASH policies and programs.

Recently, Nearly 3 out of 4 people in Africa lacked safely managed sanitation. 26 countries in Africa had estimates for safely managed sanitation services as indicated in figure 3.

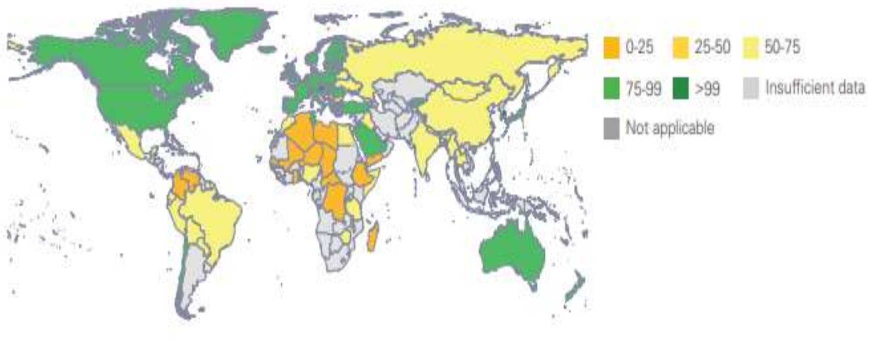

Figure 3: Proportion of population using safely managed sanitation services in percentage

In essence, self-supply refers to how these homes meet their water and hygienic needs. This refers to households developing or enhancing water resources, in whole or in part, at their own expense. This tactic has helped to increase coverage in locations where it would be impractical or expensive for the government to develop a local supply. Self-supply can also support presently provided services by improving water quality, quantity reliability, and availability. Despite its potential to expand service, self-supply is typically not expressly acknowledged as a paradigm of service delivery in sector policy and institutions. Initiatives in the water supply sector that stimulate household investment include rainwater collection, shallow well construction and renovation, and home water treatment. Figure 4 presented information on the collection of water for Drinking, sanitation and hygiene and Figure 5 presented regional, urban and rural sanitation ladders (%), 2015-2020.

Figure 4: Collection of water for Drinking, sanitation and hygiene

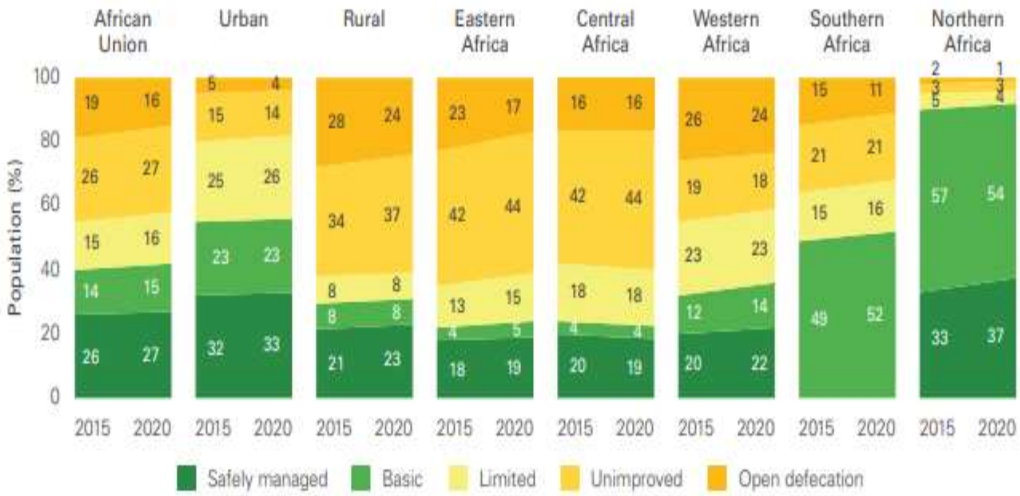

Figure 5: Regional, urban and rural sanitation ladders (%), 2015-2020

Human health is impacted by water, including sources, forms of treatment, sanitation, and hygiene standards. It is essential to avoid, manage, and defend against water-related illness epidemics.

3.2 Opportunities for Accelerating Access to WASH

There are several opportunities for accelerating access to WASH. This includes improved health, better food production, improved viability of industry, a cleaner environment and better maintenance of appliances and sanitary appliances. Opportunities for accelerating access to WASH can be achieved through:

i. Policy and regulatory framework: Strengthening the policy and regulatory framework is crucial for creating an enabling environment that encourages investment, innovation, and collaboration in the WASH sector. The Nigerian government should prioritize the development and implementation of comprehensive WASH policies and enforce existing regulations effectively.

ii. Public-private partnerships: Collaborations between the government, private sector, and civil society organizations can leverage resources, expertise, and innovation to accelerate the provision of WASH services. Public-private partnerships can facilitate the construction of infrastructure, promote sustainable financing models, and enhance service delivery.

iii. Technology and innovation: Embracing technological advancements and innovative solutions can significantly improve access to WASH services. For example, mobile technology can be used for real-time monitoring of water quality and the functionality of water points, allowing for prompt maintenance and repairs.

iv. Community engagement and behaviour change: Promoting community ownership, participation, and behaviour change is essential for the sustainable adoption of improved WASH practices. Empowering communities through education, awareness campaigns, and training programs can lead to better sanitation and hygiene practices, reducing waterborne diseases.

v. Reduced health costs. Fewer opportunity costs are associated because of improved WASH – that's extra time they have to dedicate to other more productive activities at home. They can earn money and do other things. Studies have shown that living in areas with clean drinking water is associated with reduced rates of mortality, as well as a lowered risk of developing cardiovascular disease. Drinking contaminated water may also lead to an increased risk of cancer and liver disease.

4.0 STRATEGIES FOR ACCELERATING ACCESS TO WASH

The strategies for accelerating access to WASH include the following:

i. Infrastructure development: Prioritize investment in the construction, maintenance, and expansion of water treatment plants, distribution networks, and sanitation facilities in both urban and rural areas. This includes the provision of piped water supply, improved sanitation facilities, and safe disposal of human waste.

ii. Capacity building and training: Enhance the technical skills and knowledge of professionals working in the WASH sector through training programs, workshops, and knowledge-sharing platforms. This will strengthen the capacity of government agencies, water utilities, and community-based organizations to plan, implement, and manage WASH projects effectively.

iii. Financing mechanisms: Develop sustainable financing mechanisms that involve a combination of government funding, private sector investments, and innovative financing models such as microfinance and community-based contributions. This will ensure the availability of adequate resources for WASH infrastructure development and service provision.

iv. Monitoring and evaluation: Establish robust monitoring and evaluation systems to assess the progress, impact, and effectiveness of WASH interventions. Regular data collection, analysis, and reporting will enable evidence-based decision-making, identify gaps, and inform the allocation of resources.

v. There is a need to give priority to WASH as a top national priority with the highest level government leadership. Establishment of clear institutional arrangements for Water, sanitation and hygiene practices. Increase in WASH finances and sector efficiency and make gender equality and social inclusion central to WASH.

vi. A distinct advantage for WASH can be seen in the development of digital technologies and the availability of new data sources for monitoring, particularly those from satellite remote sensing.

vii. Effective accountability: Accountability refers to sets of mechanisms that make institutions in the public and private sector answerable for their actions and ensure that sanctions can be applied against poor performance, illegal acts and/or abuses of power. Users as citizens can claim their rights to services from the policy-maker and the policy-maker can influence the behavior of the service provider using policy and regulatory instruments. In addition, users can draw on the "short route" of accountability that links them directly with the service provider, using their consumer voice and power to demand better service. Accountability thus enhances the quality of relationships between the different stakeholders to better respond to rights holders' needs

In addition to improving sanitation for everyone, a top priority should be given to cleaning and maintaining current systems. Human health and well-being are impacted by the lack of universal access to clean water, sanitation, and hygiene (WASH). Since everyone should have access to clean water and sanitation, this fundamental human right necessitates participation from all stakeholders, including local communities and the highest levels of government.

5.0 CONCLUSION

Accelerating access to sustainable urban and rural water sanitation and hygiene in Nigeria requires a comprehensive and integrated approach. By addressing the challenges, leveraging opportunities, and implementing effective strategies, Nigeria can make significant progress in improving WASH services. The collective efforts of the government, clean water and sanitation are vital for maintaining good health, improving economic productivity, and achieving gender equality, all of which contribute to sustainable development. Many promising avenues exist to strengthen WASH and the water sector generally through research, publications and industrial contributions. Drinking water supply and sanitation both generate high economic returns to society. The federal government and states must create institutional and financial underpinnings for sustainable water, sanitation, and hygiene services to spur change and move Nigeria closer to its goal of ensuring universal access to these services by 2030. Improving access to water, sanitation and hygiene (WASH) is at the core of the Global 2030 Agenda for Sustainable Development, but achieving this goal depends on the extent to which policy decisions reflect local science and circumstances. Appropriate cultural attitudes, organizational structures, new approaches, project management aspects, sustainable development goals, and legal frameworks within and across the water sector will dramatically accelerate the development of new approaches to access sustainable urban and rural water sanitation and hygiene in Nigeria.

6.0 RECOMMENDATIONS

The following recommendations were made:

i. Effective coordination is necessary within the WASH sector and other relevant sectors for the National Action Plan to succeed.

ii. Expansion of World Health Organization (WHO) advocacy, leadership and activities at all levels of the organization on improving WASH in healthcare facilities can also be done.

iii. To safeguard their drinking water, all householders should be sensitized and mobilized to, at least, boil their drinking water before use.

iv. For the National Action Plan to be successful, effective coordination is required within the WASH sector and other pertinent sectors. Coordination is essential for effective financing and enhanced sector performance because the WASH sector in Nigeria involves several state and non-state entities. Therefore, for a long-lasting impact, the federal and state governments must place a high priority on cooperation and communication with areas including governance, public health, and education.

v. Although infrastructure development appeared to be a key development required, social aspects and rural-urban sensitization and funding require special attention.

vi. Government at federal and state levels must priorities coordination and dialogue to integrate with sectors like public health, education, urban and rural development, environment, and governance for sustained impact.

vii. Current water policy in both Nigeria and individual states should be revised to include self-supply as a relevant alternative in meeting the water and sanitation needs of the people especially in areas of water scarcity.

viii. A lot of difference can be made by raising awareness, advocating for change, supporting nonprofits and initiatives, and adopting sustainable water practices at home and in the workplace.

ix. Smart Innovation, implementation strategies and sustainable development initiatives for expanding and accelerating WASH will yield great benefits.

REFERENCES

Boisson, S., Engels, D., Gordon, B. A., Medlicott, K. O., Neira, M. P., Montresor, A., ... & Velleman, Y. (2016). Water, sanitation and hygiene for accelerating and sustaining progress on neglected tropical diseases: a new Global Strategy 2015–20. *International health*, *8*(suppl_1), i19-i21.

Folayan, M. O., Obiyan, M. O., & Olaleye, A. O. (2020). Association between water, sanitation, general hygiene and oral hygiene practices of street-involved young people in Southwest Nigeria. *BMC Oral Health*, *20*, 1-11.

Hutton, G., & Whittington, D. (2015). *Benefits and costs of the water sanitation and hygiene targets for the post-2015 development agenda*. Copenhagen Consensus Center..

Liu, L., Johnson, H. L., Cousens, S., Perin, J., Scott, S., Lawn, J. E.,... & Mathers, C. (2012). Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000. The Lancet, 379 (9832), 2151-2161.

Mara, D, Lane, J, Scott B and Trouba, D (2010) Sanitation and Health, PLoS Med 7 (11): e1000363.doi:10.1371/journal.pmed.1000363

Orimoloye, E. O., Amadi, C. O. A., Amadi, A. N., Azuamah, Y. C., Nwoke, E. A., Zacchaeus, U., Dozie, I. N. S. (2015). Assessment of water sanitation and hygiene practices in Ibadan, Nigeria. International Journal of Research, 2 (2), 94-100.

Prüss-Üstün, A., Bos, R., Gore, F., Bartram, J. (2008). Safer water, better health: Costs, benefits and sustainability of interventions to protect and promote health. World Health Organization, Geneva.

Umahi, E. N., Obiano, E. C., & Joel, R. U. (2020). A Preview of Water, Sanitation and Hygiene Practices in Kofai Community of Taraba State, Nigeria. *Cent. Afr. J. Public Health*, *6*, 213.

UNICEF (2016) Strategy for Water, Sanitation and Hygiene, 2016- 2030, Programme Division, New York, https://www.unicef.org/wash/files/ UNICEF_Strategy_for_WASH_ 2016-2030.pdf

WHO and UNICEF (2006). Meeting the MDG Drinking Water and Sanitation Target. The Urban and Rural Challenge of the Decade, WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. WHO, Geneva and UNICEF, New York.

WHO & UNICEF. (2015). Progress on sanitation and drinking water: 2015 update and MDG assessment. World Health Organization.

World Health Organisation. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. Geneva: Licence: CC BY-NC-SA 3.0 IGO; 2017.

Paper 14

Determination of Microbial Contaminant (Bacteria) on Vegetables Irrigated with Municipal Wastewater in Kawo Irrigation Farm

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ABSTRACT: Famer preferred untreated wastewater because of the presence of its enriched nutrient and inexpensive system for wastewater disposal which contains dangerous micro-organisms that can cause illness or disease, and are mostly associated with animal and human faecal matter, irrigation water polluted with this micro-organism has often been associated with outbreaks of food-borne illness. The location selected for this study is the Kawo Kaduna Abattoir Irrigation Farm. A total of eight (8) samples comprising Spinach, Lettuce, and control samples were collected and analysed within 24hrs for the following Bacteria, Coliform (*E coli*) using Maconkey agar (MA), *Bacillus spp* using plate count agar (PCA), *Vibrio spp* using thiosulfate citrate bile sucrose agar (TCBS), *Salmonella spp* using salmonella-shigella ager (SS), *Staphylococcus spp* using bird parker agar (BPA). The standard plate count method (SPC) as described by WHO/FAO (2004) was employed for the analysis. These studies revealed that vegetables grown within the study area are highly contaminated especially with *salmonella spp* which could be a threat to consumer's health. It is recommended that farmers should practice the use of stabilization ponds (aerobic, facultative, and maturation), and also Irrigation methods such as surface or drip Irrigation as such method reduces direct contact with the edible part of the vegetable.

Keywords: Municipal, Wastewater, Vegetable, Irrigation, Bacteria

1.0 INTRODUCTION

Agriculture in many areas of developing countries to some extent depends on wastewater as source of irrigation water (Khaled and Muhammad, 2016). In less developed countries, the quality of the wastewater and the conditions under which wastewater is used varies, the water is in the form of diluted raw sewage (Huibers *et al.*, 2004). In most part of Nigeria, farmers prefer untreated wastewater even when freshwater is available because they earn higher profits. This shows that wastewater can be a more reliable source both in terms of availability and volume than rain or freshwater supply for irrigation systems. However, many households in poorer areas lack access to fertilizers and have a limited supply of fresh water, wastewater reuse at the individual level can provide a combined solution to these problems by supplying the water and nutrients needed for household food production, this strategy is already practice by millions of farmers worldwide and it is estimated that 10% of the world's population consumes foods irrigated with Wastewater (WHO 2006).

The microbial population of untreated water is very diverse, and dangerous organisms can be present. Microorganisms that can cause illness or disease are usually associated with human or animal fecal matter present in wastewater and surface water sources. Irrigation water contaminated with pathogens has often been blamed for outbreaks of food borne illness.

The health hazards associated with direct and indirect wastewater use are of two kinds: the rural health and safety problem for those working on the land or living on or near the land where the water is being used, and the risk that contaminated products from the wastewater use area may subsequently infect humans or animals through consumption or handling of the foodstuff or secondary human contamination by consuming foodstuffs from animals that used the area (WHO, 2000). The pathogens are transmitted to the public through consumption of irrigated produce, especially crops eaten raw (Blumenthal *et al*., 2000). Several studies throughout the world have demonstrated a very close relation between the consumption of fruits and vegetables irrigated with raw wastewater and many food borne diseases like gastroenteritis, cholera, chemical toxicity etc (Sou *et al*., 2011). A research carried out by (Igomu, 2011) reported that in the last quarter of 2009, more than 260 people died of cholera in northern part of Nigeria. Epidemiological data from Public Health Department of Kano State Ministry of Health revealed that the frequency and distribution of cholera epidemics in the State during the period of studies from 1995 to 2001, records 2,630 between 1995 to 1996, 847 in 1997, 2,347 in 1999, 173 in 2000 and 163 in 2001 (Usman *et al*., 2005).

The study is aimed at assessing the health risk associated with the use of untreated wastewater (municipal and abattoir) for irrigating vegetables in kawo irrigation farm of Kaduna state, where high level of typhoid fever, diarrhea and cholera outbreak as always been the case in Kawo general hospital, with average monthly cases of 85 and 93 for children less than five years, 142 and 239 for people greater than five year records diarrhea and typhoid fever respectively, which is considered very high compared to other health centers. (Kawo General Hospital, 2018)

Table 1.0 below shows four categories of microbiological quality assigned based on standard plate counts, levels of indicator organisms and the number or presence of pathogens. These are satisfactory, marginal, unsatisfactory and potentially hazardous.

Table 1.0 *Guideline levels for determining the microbiological quality of ready-to-eat foods*

Test	Microbial Quality CFU/g			
	Satisfactory	Marginal	Unsatisfactory	PotentiallyHazardous
Indicators				
Enterobacteriaceae	$<10^2$	10^2-10^4	$\geq10^4$	
Escherichia coli	<3	3-100	≥100	
Pathogens				
Coagulase +ve staphylococci	*$<10^2$*	10^2-10^3	10^3-10^4	$\geq10^4$
Bacillus cereus and other pathogenic Bacillus spp	*$<10^2$*	10^2-10^3	10^3-10^4	$\geq10^4$
Vibrio parahaemolyticus	*<3*	*<3-10^2*	10^2-10^4	$\geq10^4$
Salmonella spp	*Not detected in 25g*			*Detected*

SOURE: ICMSF International Commission on Microbiological Specifications for Foods (2001)

Satisfactory *- Results indicate good microbiological quality. No action required.*

Marginal *- Results are border line in that they are within limits of acceptable microbiological quality but may indicate possible hygiene problems in the preparation of the food.*

Unsatisfactory *-Results are outside of acceptable microbiological limits and are indicative of poor hygiene or food handling practices.*

Potentially Hazardous *-The levels in this range may cause food borne illness and immediate remedial action should be initiated.*

2.0 MATERIALS AND METHOD

2.1 Study Area

The study site selected for this study is the Kawo Abattoir irrigation farm site (Figure 2.1) which lies between latitude 10^0 34' 40.8'' E and longitude 07^0 26'39.1'' N of Kaduna North local Government Area Kaduna State Nigeria. Kaduna North lies completely in Western Africa, well within the northern limit of the movement of the *intertropical* convergence zone (ITCZ). It is characterized by two distinct seasonal regimes, oscillating between cool to hot dry and humid to wet season. The climate is tropical in Kaduna. When compared with winter, the summers have much more rainfall. The climate here is classified as Aw by the Köppen-Geiger system *(Aw = Tropical wet and dry or savanna climate; with the driest month having precipitation less than 60 mm (2.4 in) and less than 4% of the total annual precipitation)*. The average annual temperature in Kaduna is 25.2 °C. About 1211 mm of precipitation falls annually. The driest month is January. There is 0 mm of precipitation in January. In August, the precipitation reaches its peak, with an average of 284 mm. (Figure 1) shows the map of the study area.

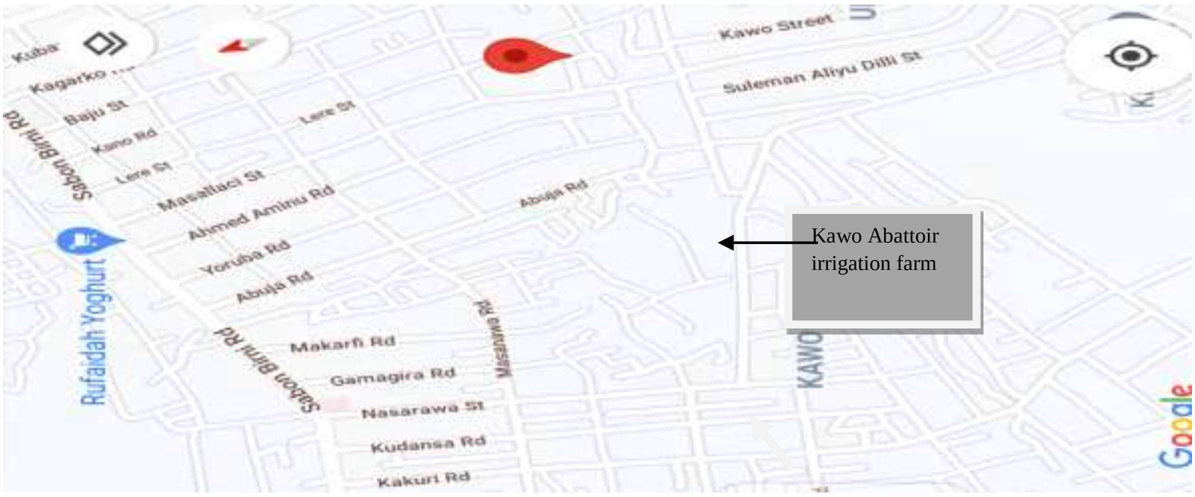

Figure 1. Map of kawo Kaduna showing irrigation farm Area. (Google Earth, 2021)

2.2 Sampling

2.2.1 Sample collection for vegetables.

Vegetable (spinach and lettuce) samples were collected under normal conditions, from three selected site of the irrigation farm, put in paper bags and then transported immediately to the laboratory where they were analyzed within 24hrs. The same method was also applied to a control group of vegetables (spinach and lettuce) grown using open well water under identical conditions as shown in plate 1.0

Plate 1.0 Vegetables samples (lettuce, spinach and control)

2.3 For the Bacteria analysis, the following Bacteria's were enumerated

i. Coliform (*E coli*) using Maconkey ager (MA)
ii. *Bacillus spp* using plate count ager (PCA)
iii. *Vibrio spp* using thiosulfate citrate bile sucrose ager (TCBS)
iv. *Salmonella spp* using salmonella-shigella ager (SS)
v. *Staphylococcus spp* using bird parker ager (BPA)

2.4 Experimental procedure and evaluation of bacteria on the vegetable

The mesophilic aerobic bacteria in the product were enumerated using the standard plate count method (SPC) as described by WHO/FAO (2004). 10g of each vegetable sample were weighed and blended using RM 206 model blender containing 100mL of sterile saline solution for 2 min under sterile conditions, the blender was carefully disinfected to prevent any cross contamination, and this was well mixed making $1:10^4$ dilution of the sample. 1ml of each homogenate mixture of the sample was aseptically transferred into a sterile tube containing 9ml of sterile ringer's solution to obtain $1:10^{-2}$ dilutions. Using separate sterile pipette decimal dilution of $1:10^{-3}$, $1:10^{-4}$, $1:10^{-5}$ and $1:10^{-6}$ were prepared by aseptically transferring 1ml of previous dilution to 9mls of diluent in different test tubes. 1ml of each dilution was transferred to separately marked glass made petri-dishes (15x100mm) in duplicate. 15ml of plate count ager (M77) cooled to 45^0C and then added to each plate and gently rocked clockwise and anti-clockwise to mix well. The plates were allowed to set and solidified and then incubated at 30^0C for 18-28 hours in a BTI-26 model incubator. The colonies on the plate were counted and the colony-forming units per milliliter (CFU/mL) were calculated with the following formula:

Count (CFU/mL) = (number of colonies counted X dilution factor)/volume plated (in mL)

Enumeration of all other bacteria as stated above employed the same method as describe for the mesophilic aerobic bacteria except for the use of different culture media i.e instead of plate count ager we use salmonella-shigella Ager (SS) for enumeration of salmonella e.t.c.

3.0 RESULTS AND DISCUSSION

3.1 Results

A total of 8 samples comprising of Spinach and Lettuce was collected and analyzed for Bacteria, Table 2 shows the result for bacteria found in the samples and the results are further discussed below using chart.

Table 2 Result for Cultivation, Enumeration and Isolation of Bacteria

S/N	Code	SAMPLE NAME	*Bacillus spp* CFU/g/ml	*E Coil* CFU/g/ml	*Salmonella spp* CFU/g/ml	*Vibrio spp* CFU/g/m	*Staphylococcus spp* CFU/g/ml
1.	SP 01	SPINACH FARM A	$2.0x10^5$	Nil	$2.5x10^4$	$1.4x10^2$	$3.0x10^2$
2.	SP 02	SPINACH FARM B	$1.6x10^4$	Nil	$1.6x10^3$	$1.2x10^2$	$3.5x10^2$
3.	SP 03	SPINACH FARM C	$1.1x10^4$	$<1.0x10^2$	$1.3x10^3$	$1.6x10^2$	$5.6x10^2$
4.	SP 04	SPINACH CONTROL	$1.2x10^3$	Nil	Nil	Nil	$4 .0 x10^2$
5.	LT 01	LETTUCE FARM A	$1.3x10^4$	Nil	$1.5x10^3$	$<1.0x10^2$	$1.8x10^2$
6.	LT 02	LETTUCE FARM B	$1.2x10^4$	Nil	$5.0x10^2$	$5.0x10^2$	$1.2x10^3$
7.	LT 03	LETTUCE FARM C	$1.0x10^4$	$<1.0x10^2$	$3.5x10^2$	$1.8x10^2$	$8.0x10^2$
8.	LT 04	LETTUCE CONTROL	$1.1x10^3$	Nil	Nil	Nil	$3.0x10^2$

i. Bacillus Spp

As shown in figure 2 below, *Bacillus* appeared in the entire sample with the spinach from Farm A, having the highest count and lettuce control having the lowest count, this could be because *Bacillus* is a common environmental organism. The ICMSF guideline levels for determining the microbiological quality of ready-to-eat foods, for *Bacillus* is 10^3 (log CFU 3) above which is considered unsatisfactory and Potentially Hazardous.

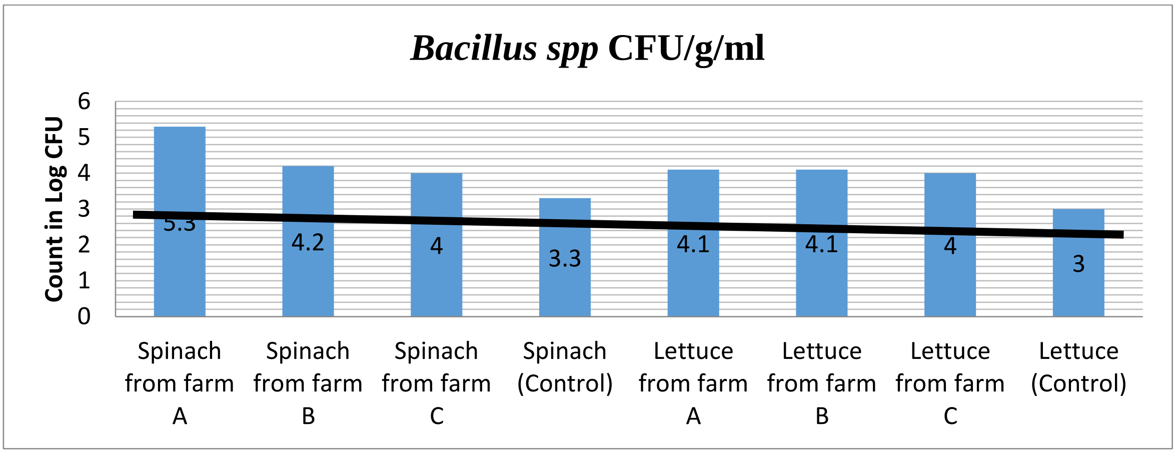

Figure 2 Sample against count in log CFU for *Bacillus Spp*

ii. **Coliform *(E coli)***

As shown in figure 3 below, Coliform *(E coli)* appeared to be less in the entire sample with spinach and lettuce from Farm C having 2 count in log CFU respectively which is within the ICMSF Guideline levels for determining the microbiological quality of ready-to-eat foods for *E Coli* is 100 (log CFU 2) above which is considered unsatisfactory Potentially Hazardous.

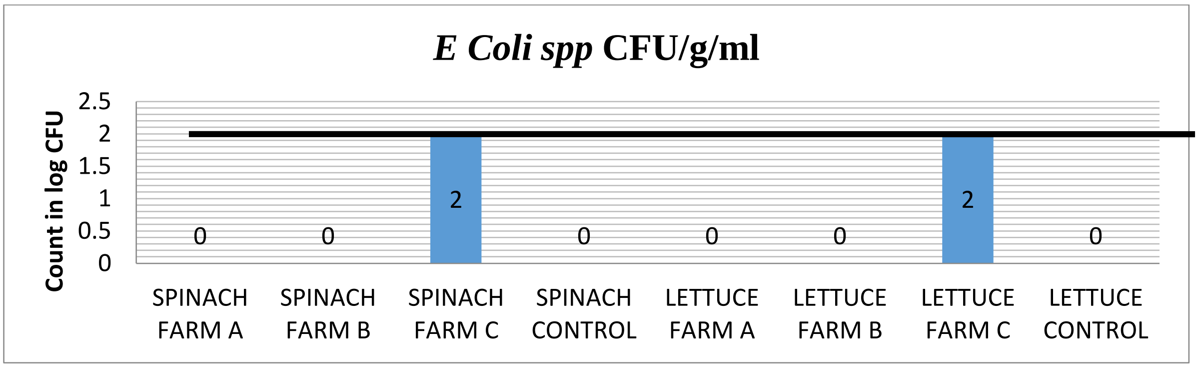

Figure 3 Sample against count in log CFU for *E Coli Spp*

iii. Salmonella SPP

As shown in figure 4 below, *Salmonella spp* appeared to be present in the entire sample with exception in spinach from Farm A and lettuce control having zero count in CFU, which is far above the recommended limit of ICMSF Guideline levels for determining the microbiological quality of ready-to-eat foods for which should not be detected in sample as such the salmonella spp of the vegetable is highly contaminated and Potentially Hazardous for consumers

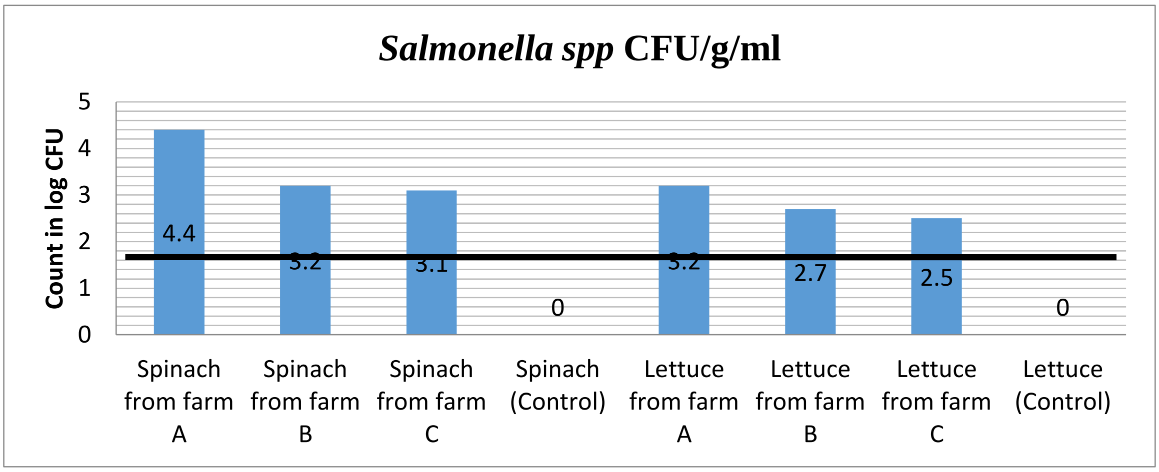

Figure 4 Sample against count in log CFU for *Salmonella Spp*

iv. Vibro SPP

As shown in figure 5 below, *Vibro spp* appeared to be present in the entire sample with exception in the spinach control which is far above the recommended limit of ICMSF Guideline levels for determining the microbiological quality of ready-to-eat foods having a marginal line of 10^2 (log CFU 2) for *Vibrio parahaemolyticus* above which is considered unsatisfactory.

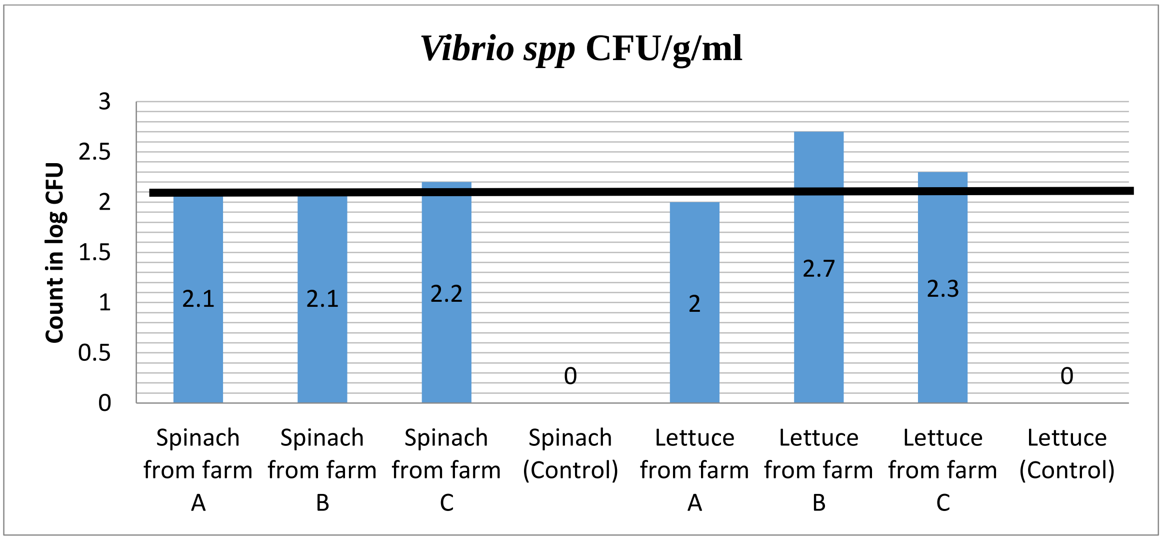

Figure 5 Sample against count in log CFU for *Vibro Spp*

i. Staphylococcus SPP

As shown in figure 6 below, *Staphylococcus spp* appear to be present in all samples, the ICMSF Guideline levels for determining the microbiological quality of ready-to-eat foods for mold as 10^3 (log CFU 3) above which is considered unsatisfactory.

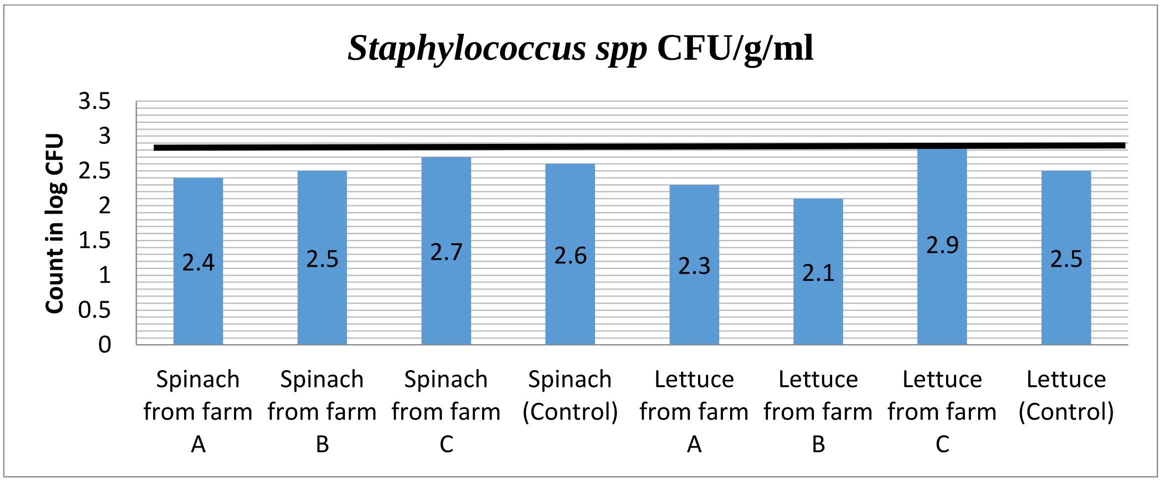

Figure 6 Sample against count in log CFU for *Yeast Spp*

4.0 CONCLUSION

The research carried out in kawo abattoir irrigation farm aimed to assess pollutant (Bacteria) on vegetable irrigated with municipal wastewater, These studies also revealed that vegetable grown within the study area are highly contaminated most especially with *salmonella spp* which could be of treat to consumers health and could be the reason behind high record of typhoid fever with people around the area. It is recommended that farmers should practice the use of stabilization pond (aerobic, facultative and maturation) which is one of the cheapest and easiest way of disinfecting wastewater before use for irrigation, Adoption of safer irrigation methods such as drip or surface irrigation to minimize contact of crops with contaminants present in irrigation water especially crops that are eaten raw, famers should also practice the use of personal protective equipment due to their long term contact with the wastewater.

REFERENCES

Blumenthal UJ, Peasey A, Ruiz-Palacios G & Mara DD. (2000). Guidelines for wastewater reuse in agriculture and aquaculture: recommended revisions based on new research evidence. WELL study, Task No: 68 Part 1.

Huibers, F.P., O. Moscoso, A.Duran and J.B.V. Lier. (2004). The use of waste water in cochabamba, Bolivia: a degrading environment.

Igomu, T. (2011). Cholera epidemics: Far from being over. NBF. News. *www. Nigerian best forum.com/blog/? P=60321.* Accessed 23 August 2011.

International Commission on Microbiological Specifications for food ICMSF, (2001). Microorganisms in foods, Sampling for Microbiological Analysis: Principles and specific Applications.

Kawo General Hospital., (2018). Health facility monthly summary form

Khaled S. B, Muhammad A. (2016). Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia, *Saudi Journal of Biological science, 23,S32-S44* http://dx.doi.org/10.1016/j.sjbs.2015.09.023

Sou, M., Yacouba, H. and Mermoud, A. (2011). Fertilising value and health risks assessment related to wastewater reuse in irrigation, case study in a Soudano-Sahelian city. Ouagadougou.

Usman, A., Sarkinfada, F., Mufunda, J., Nyarando, P., Mansur, K. and Daiyabu, T.M. (2005). Recurrent cholera epidemics in Kano-Northern Nigeria. Central African Journal of Medicine March-April 51(3-4): 34-38.

Wescott D. W., (1997). Quality control of wastewater for irrigated crop production. (Water Reports – 10). Food and Agriculture Organization of the United Nations, Rome.

WHO (1989) Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture. Report of a WHO Scientific group, Technical Report Series No. 778 World Health Organization, Geneva.

WHO, (2000). Global Water Supply and Sanitation Assessment 2000 Report. World Health Organization (WHO) United Nations Children Fund (UNICEF), Geneva and New York.

WHO, (2006). Guidelines for the safe use of wastewater, excreta and grey water: Wastewater use in agriculture (Volume 2).Report of a WHO Scientific Group. WHO Technical Report Series 778. World Health Organization, Geneva, Switzerland, pp74-219.

Paper 15

Assessment of WASH Sustainability Issues Associated with the Home-Grown School Feeding Programme in Plateau State

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ABSTRACT: WASH sustainability issues associated with the Home-grown school feeding program (HGSFP) in Plateau state was investigated in this study. The study investigated the impact of the programme on school enrolment, the current status of WASH coverage in the schools and the required gaps to be filled. A cross-sectional study was carried out across 170 schools selected using the Stratified random sampling technique and proportionately distributed amongst the 17 LGAs of the state. Computer assisted personnel Interview (CAPI) method of survey was adopted using a predesigned questionnaire and checklist. The study revealed that the programme has led to increase in pupils' enrolment across the LGAs. It also revealed that the WASH facilities, even without the programme are grossly inadequate. The increased enrolment occasioned by the programme has further exacerbated the WASH predicaments in the public primary schools. The study therefore, recommended that a concerted effort be made by relevant stakeholders to solve the problem of WASH in public primary schools in Plateau State.

Keywords: WASH, Home-grown school feeding programme, Sustainability, Plateau

1.0 INTRODUCTION

Access to safe water is essential for maintaining good hygiene and preventing waterborne diseases such as diarrhoea (Cairncross et al., 2010). Ensuring access to clean Water, Sanitation, and Hygiene (WASH) services within educational institutions stands as a universally acknowledged imperative (Jordanova et al., 2015). This pivotal intervention not only upholds students' fundamental right to health and a pristine environment but also serves as a catalyst for elevated academic success and enhanced gender equality. According to UNICEF (2016), only about half of its programme countries are able to report on WASH facilities in schools. This dearth of reliable data on the functionality of WASH facilities in schools is worrisome, as such data is required for good programme design and management.

The National Home-Grown School Feeding Programme (NHGSFP) was re-launched in Nigeria in 2016, with Plateau as one of the beneficiary States primarily to improve the health of school children and aid in the realization of Universal Basic Education (UBE) goals (Agu et al., 2023). while evidences about that the programme has been instrumental to the increase in school enrolment, there is a need to evaluate the sustainability of the programme from the lens of Water, Sanitation and Hygiene infrastructure and services available in the schools. The implication of the NHGSFP on WASH infrastructure therefore need to be investigated as the gains of the programme can be eroded by the neglect of the WASH components.

It is therefore crucial to evaluate the water, sanitation and hygiene infrastructure and its sustainability within the context of the NHGSFP in Plateau State especially with the increasing students' population occasioned by the NHGSFP (Ejemot-Nwadiaro et al., 2015). This study therefore investigated the WASH sustainability issues associated with NHGSFP in Plateau State, Nigeria.

2.0 MATERIALS AND METHODS

2.1 The Study Area

The study was carried out in all the 17 Local Government Areas (LGAs) of Plateau state (Figure. 1). The state lies between latitudes 8.55° and 10.64° and longitudes 8.36° and 10.40° in the North Central geopolitical Zone of Nigeria. The state is divided into three senatorial zones: North, Central, and South with distinct characteristics in terms of geography, demographics, and socio-economic activities. Plateau State is the twelfth largest state in Nigeria, covering an area of 30,913 square kilometres with a projected population of approximately 4,717,305 persons as at 2022 (NPC, 2020). The Northern Zone is characterized by a mix of highlands and savannah grasslands include the Jos metropolis which is known for its cool climate and fertile soil, the Central Zone comprises a mix of hills, valleys, and plains and is traversed by rivers and streams, making it suitable for agricultural activities while the Southern Zone is characterized by undulating terrain, forests, and river valleys with a more tropical climate compared to the other zones.

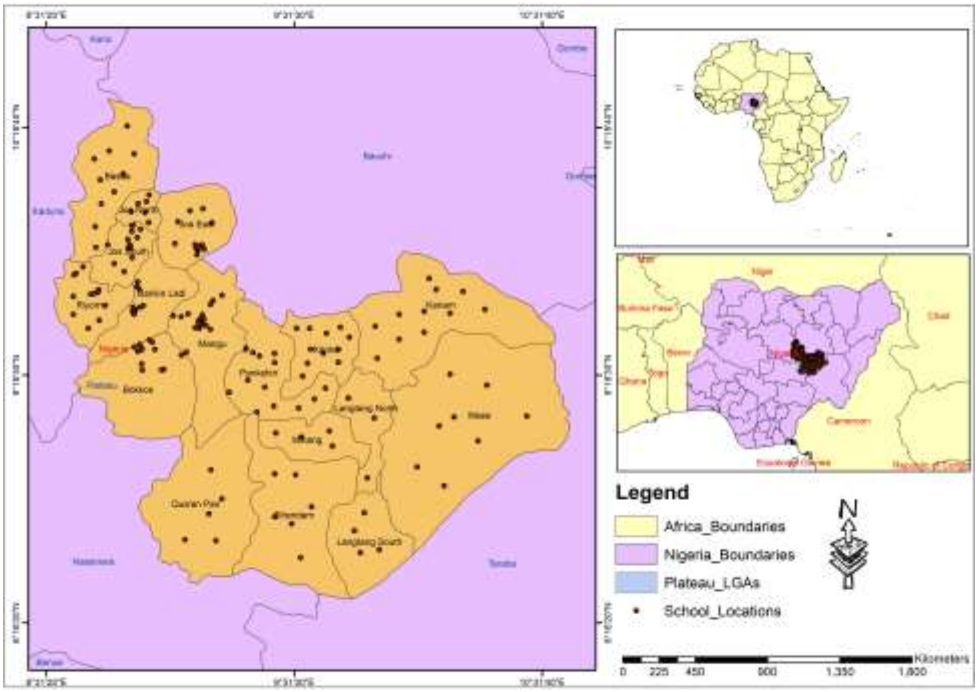

Figure 2: Map of Study Area

2.2 Study approach and Sample Size Estimation

A cross-sectional study was carried out among key informants from public schools participating in the NHGSFP across the 17 LGAs of Plateau State using quantitative method of data collection. The sample size was estimated using the equation of Krejcie and Morgan (1970) as expressed by Eq. (1).

$$n = \frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)} \qquad (1)$$

Where:

n	=	Sample Size
X^2	=	the table value of chi-square for 1 degree of freedom At the desired confidence level.
N	=	the population size.
P	=	the population proportion.
d	=	the degree of accuracy expressed as a proportion.

With a total population of 2,347 schools participating in the NHGSFP, a sample size of 170 was estimated at 95% confidence level which was proportionally distributed amongst the 17 LGAs as shown in Table 1.

Table 1: Distribution of Sample Size amongst the 17 LGAs

LGA	Number of Schools
Barkin Ladi	11
Bassa	11
Bokkos	14
Jos East	5
Jos North	4
Jos South	7
Kanam	12
Kanke	10
Langtang North	12
Langtang South	4
Mangu	17
Mikang	9
Pankshin	12
Qua'an pan	9
Riyom	8
Shendam	13
Wase	12
Total	170

2.3 Data collection

The collection of data for the study was done using semi-structured interviewer administered questionnaires and predesined checklist. The computer aided personal interviewing method of administration was employed. The questionnairs and checklists were pretested in the city of Jos before proceeding to the field for actual data collection.

The data obtained were analysed using simple descriptive statistics are the results presented using tables and charts. The specifications of the Universal Basic Education's Minimum standard for basic eductaion (2010) were used to determine the required gaps to be filled in the sampled schools.The standard specified 40 toilet compartments to two (2) pupils shared equally between boys and girls

3.0 RESULTS AND DISCUSSION

The demographic characteristics of respondents, age of school as well as the age of NHGSFP in schools are presented in Table 2. The respondents who provided key information on the schools and the WASH facilities available were Head Teachers (45.9%), Assistant Head Teachers (35.3%) and other key staff of the schools such as Dean of studies etc. constituting 18.8%. Similarly, only 0.6% of the schools were less than 5 years since their establishment while majority (97.6%) were more than 10 years old which makes well suited for the study. More so, 94.7% of the schools have participated in the NHGSFP for about 2 to 5 years. These demographics were required to determine the suitability of the schools to provide useful information as it relate to the NHGSFP and WASH sustainability issues.

The population of teachers as well as those of pupils before the commencement of the NHGSFP, during the NHGSFP before and after the COVID-19 Lockdown are presented in Tables 3 and 4. The population of both staff and pupils are essential for the establishment of gaps in sanitation facilities within the schools. Out of the total 3,182 teachers in the 170 schools visited, 33.28% were male while 66.72% were female.

Table 2: Demographic Characteristics of the Schools and Respondents

Description	Frequency	Percentage
Respondents		
Head Teacher	78	45.9
Assistant Head Teacher	60	35.3
Others	32	18.8
Total	170	100
Age of School (Years)		
Less Than 5	1	0.6
5 to 10	3	1.8
Greater than 10	166	97.6
Total	170	100
Age of HGSFP in School (Year)		
2 to 5	161	94.7
Less than 2	9	5.3
Total	170	100

Table 3: Population of Teachers in the Sampled Schools

LGA	Number of Teachers				
	Male	**%**	**Female**	**%**	**Total**
Barkin Ladi	32	25.81	92	74.19	124
Bassa	55	24.23	172	75.77	227
Bokkos	46	29.49	110	70.51	156
Jos East	24	23.76	77	76.24	101
Jos North	25	25.00	75	75.00	100
Jos South	29	19.73	118	80.27	147
Kanam	137	50.74	133	49.26	270
Kanke	153	55.64	122	44.36	275
Langtang North	64	28.07	164	71.93	228
Langtang South	28	34.57	53	65.43	81
Mangu	76	21.35	280	78.65	356
Mikang	50	42.74	67	57.26	117
Pankshin	102	34.69	192	65.31	294
Qua'an pan	66	33.17	133	66.83	199
Riyom	50	45.87	59	54.13	109
Shendam	43	24.43	133	75.57	176
Wase	79	35.59	143	64.41	222
Total	1,059	33.28	2,123	66.72	3,182

Table 4: Enrolment of Pupils before and during the NHGSFP including effect of the COVID-19 Lockdown

LGA	Number of Pupils (Before NHGSFP)				Number of Pupils during NHGSFP (Before COVID-19 Lockdown)				Number of Pupils during NHGSFP (After COVID-19 Lockdown)			
	Male	%	Female	%	Male	%	Female	%	Male	%	Female	%
Barkin Ladi	1054	49.93	1057	50.07	1296	47.54	1430	52.46	943	49.63	957	50.37
Bassa	1625	51.51	1530	48.49	2015	49.58	2049	50.42	1342	53.40	1171	46.60
Bokkos	1439	48.19	1547	51.81	1571	49.61	1596	50.39	1556	48.67	1641	51.33
Jos East	487	49.90	489	50.10	636	47.86	693	52.14	456	53.08	403	46.92
Jos North	564	52.27	515	47.73	626	48.53	664	51.47	492	50.31	486	49.69
Jos South	1454	47.83	1586	52.17	1964	47.37	2182	52.63	1846	47.13	2071	52.87
Kanam	1268	48.92	1324	51.08	994	50.74	965	49.26	1271	48.94	1326	51.06
Kanke	1171	49.22	1208	50.78	1134	50.40	1116	49.60	1243	49.07	1290	50.93
Langtang North	1748	47.26	1951	52.74	1876	48.46	1995	51.54	1803	47.98	1955	52.02
Langtang South	709	49.68	718	50.32	746	49.24	769	50.76	695	49.75	702	50.25
Mangu	2126	46.98	2399	53.02	2690	48.06	2907	51.94	2635	48.75	2770	51.25
Mikang	1142	47.44	1265	52.56	1209	48.36	1291	51.64	1255	46.64	1436	53.36
Pankshin	1145	43.74	1473	56.26	1166	47.75	1276	52.25	1176	44.08	1492	55.92
Qua'an pan	1690	48.68	1782	51.32	1742	48.82	1826	51.18	1627	47.37	1808	52.63
Riyom	1349	50.28	1334	49.72	1851	51.49	1744	48.51	1685	51.22	1605	48.78
Shendam	1675	49.19	1730	50.81	1858	49.41	1902	50.59	1739	50.61	1697	49.39
Wase	1807	45.40	2173	54.60	1979	46.02	2321	53.98	1836	45.65	2186	54.35
Total	22,453	48.25	24,081	51.75	25,353	48.68	26,726	51.32	23,600	48.56	24,996	51.44

In the context of educational initiatives, the National Home-Grown School Feeding Programme (NHGSFP) serves as a significant paradigm aimed at enhancing both nutritional sustenance and educational progress among the younger population. This analysis delves into gender-based enrollment statistics emerging from the NHGSFP, unveiling nuanced patterns across various Local Government Areas (LGAs) within Plateau State.The provided tabulated data, meticulously composed to reflect post-NHGSFP enrollment figures for males and females, offers a comprehensive insight into the educational landscape. A detailed examination of the figures reveals notable trends and variances, shedding light on a range of considerations from social dynamics to resource allocation. Upon closer examination, a consistent pattern emerges, where certain LGAs, such as Jos North and Langtang South, exhibit slight disparities in gender enrollment percentages. Jos North demonstrates a marginally higher male percentage (52.27%), while Langtang South showcases a slight inclination towards female enrollment (50.32%). These variations suggest intricate local dynamics that warrant deeper investigation into the socio-cultural factors shaping enrollment trends. Furthermore, when aggregating the data, Plateau State's overall male enrollment constitutes 49.93% (22,453 students) of the total NHGSFP participants, while the female enrollment accounts for 50.07% (24,081 students). This nearly balanced representation underscores the program's inclusivity, transcending gender divisions to foster comprehensive educational advancement. Interestingly, specific LGAs such as Mangu and Langtang North manifest notable gender enrollment disparities, with a higher male percentage (53.02% and 52.74% respectively). In contrast, regions like Wase and Jos South highlight a greater female enrollment (54.60% and 52.17% respectively). These divergent gender participation rates may be attributed to multifaceted factors including cultural norms, household dynamics, and social priorities.

The intersection of engineering principles with educational initiatives is most exemplified by programs like the National Home-Grown School Feeding Programme (NHGSFP). These initiatives, exemplifying the marriage of technology and societal welfare, bridge educational advancement with sustainable nourishment, echoing the core tenets of socio-technical systems. This analytical exposition meticulously probes into the pre-COVID-19 gender-based enrollment data, offering an illuminating panorama across various Local Government Areas (LGAs) in Plateau State, prior to the global pandemic's disruptive influence. The meticulously structured dataset offered herein encapsulates the gender-specific enrollment matrix during the NHGSFP. This matrix is an essential barometer reflecting both gender dynamics and the broader implications for socio-educational equilibrium. Scrutinizing these figures in detail, as necessitated by engineering inquiry, unfolds insights that traverse the spectrum from localized cultural norms to macroscopic systemic effects. Under closer scrutiny, a discernible pattern emerges whereby certain LGAs, including Jos North and Langtang South, exhibit a modest gender enrollment discrepancy. In Jos North, the male enrollment constitutes 48.53%, while Langtang South demonstrates a slightly elevated female enrollment at 50.76%. These variations, albeit subtle, beckon for a deeper exploration into contextual factors that might underscore these enrollment dynamics. Zooming out, the composite male enrollment for Plateau State totals 25,353 students, embodying 48.62% of the NHGSFP participants. Concurrently, the female enrollment encompasses 26,726 students, composing 51.38%. This nuanced equilibrium attests to the program's foundational premise of fostering gender-balanced educational progress. Intriguingly, certain LGAs, such as Mangu and Riyom, spotlight considerable gender-based enrollment divergences. In Mangu, the enrollment tilt is toward females at 51.94%, while Riyom slightly sways toward males at 51.49%. These distinctive participation trends are interwoven with local socio-cultural dynamics that transcend mere numeric representation. To encapsulate, this meticulous exploration of gender-based enrollment patterns unveils the proactive resonance of NHGSFP in harmonizing nutritional nourishment with educational pursuits. As engineering ethos inherently embraces interdisciplinary realms, it is apropos to regard such initiatives as a perfect marriage of societal well-being and engineering acumen. The study of gender-enrollment dynamics not only champions educational progression but also accentuates the symbiotic connection between socio-economic elevation and engineering advancements.

Within the tapestry of dataset lies a dual-layered story, encapsulating post-COVID-19 gender-specific enrollment matrices during NHGSFP, this data is an entreaty to be viewed through the analytical lens of engineering inquiry. When we traverse the terrain of time and delve into the previous dataset, nuanced trends surface, painting distinct pictures of locales like Jos North and Langtang South. In the prior dataset, these regions presented subtle gender enrollment disparities. In Jos North, 50.31% enrollment was male, in contrast to Langtang South's 50.25% female enrollment. Remarkably, the post-COVID-19 analysis mirrors this pattern closely: Jos North holds at 50.31% male enrollment, and Langtang South at 50.25% female enrollment. This persistence hints at the enduring influence of socio-cultural underpinnings in these areas. Zooming out for a panoramic view, a composite comparison of gender-enrollment dynamics within NHGSFP pre- and post-COVID-19 projects equilibrium. Pre-COVID-19, male enrollment stands at 48.62%, tapering marginally post-COVID-19 to 48.40%. Likewise, female enrollment pre-COVID-19 comprises 51.38%, inching slightly upwards post-COVID-19 to 51.60%. This sustained equilibrium underscores NHGSFP's resilient commitment to upholding gender-inclusive education amidst external disruptions. Further discernment within select LGAs, like Mangu and Riyom, unveils persistent variations. Post-COVID-19, Mangu sustains a higher female enrollment at 51.25%, while Riyom continues to tip towards male enrollment at 51.22%. This consistency underscores the abiding influence of local socio-cultural nuances on educational dynamics.

While the sutained increase in enrolment inspite of the COVID-19 lockdown is commendable, the avialble toilets and urinals for both staff and pupils (Table 5) is grossly insufficient at an average of less than 1 toilet compartment per school for teachers for instance. The value is worse in the case of toilet compartment for pupils.

Figure 2 presents the availbility of handwashing facilities in the schools

Table 5: Number of Toilets and Urinals for both Staff and Pupils

LGA	Number of Toilets Compartments				Number of Urinals Stance			
	Male Teachers	Female Teachers	Male Pupils	Female Pupils	Male Teachers	Female Teachers	Male Pupils	Female Pupils
Barkin Ladi	8	8	10	10	0	0	0	0
Bassa	20	20	2	2	0	0	0	0
Bokkos	6	6	0	0	0	0	0	0
Jos East	2	2	19	20	0	0	0	0
Jos North	2	2	9	9	0	0	0	0
Jos South	11	9	9	9	2	2	0	0
Kanam	17	17	6	4	0	0	0	0
Kanke	11	11	0	0	0	0	0	0
Langtang North	11	12	7	6	6	2	1	1
Langtang South	2	2	7	7	0	0	0	0
Mangu	22	22	0	0	11	11	3	1
Mikang	5	3	0	0	2	2	0	0
Pankshin	11	11	6	6	0	0	0	0
Qua'an pan	9	8	7	7	0	0	0	0
Riyom	12	7	9	8	1	1	2	2
Shendam	10	12	19	18	6	7	11	11
Wase	9	9	12	10	0	0	0	0
Total	168	161	122	116	28	25	17	15

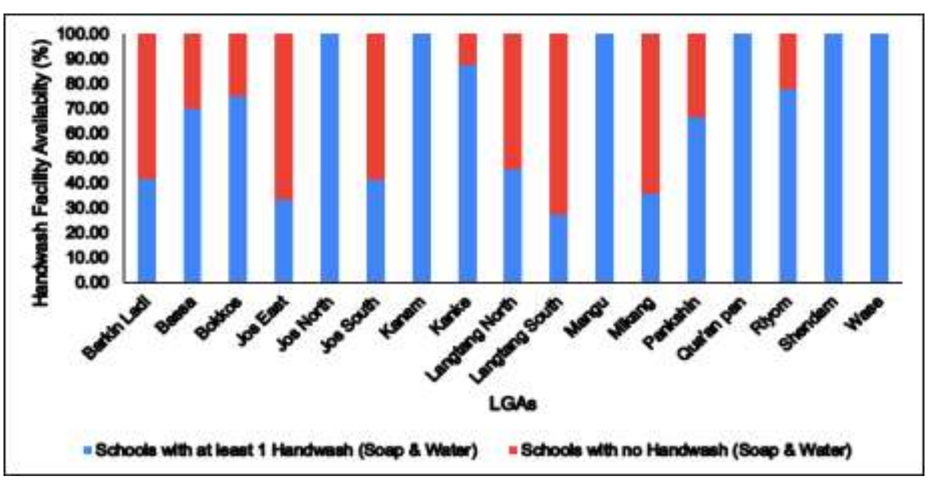

Figure 3: Availability of Hand washing facilities equiped with soap and Water in Schools

The avialbility of hand washing facilities equiped with both water and soap (basic service) as presented in Figure 2 shows tha while Jos South, Kanam, Mangu, Quan'pan, Shendam and Wase LGAs have 100 % basic hygiene service coverage in terms of hand washing facilities, the remaining LGAs required upgrade in the hygiene service coverage.

Furthermore, solid waste (garabge) management system across the schools is very poor as schools across 12 LGAs do not have a single waste bin for waste collection and disposal.

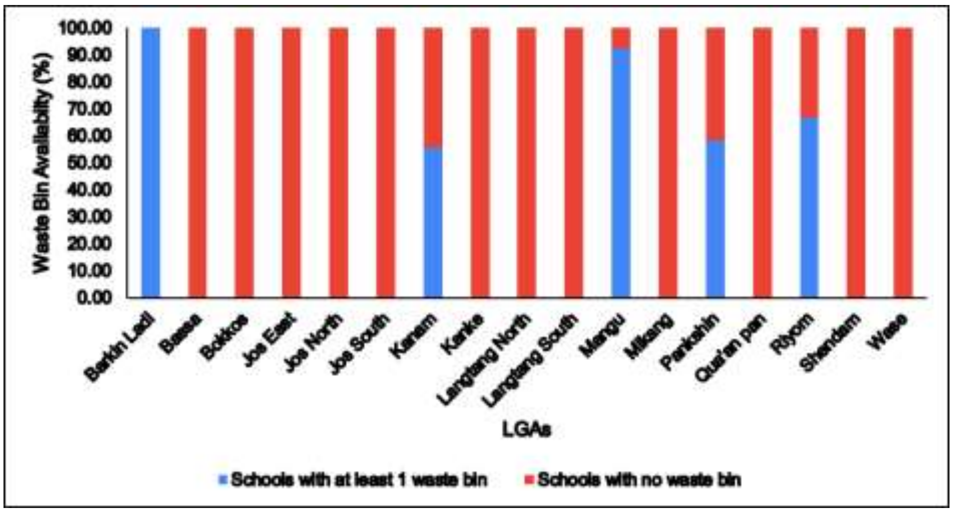

Figure 4: Availability of Waste bin for Solid Waste Disposal

The water supply coverage in the schools (Figure 4) is fair though with a high number of facilities needing repairs.

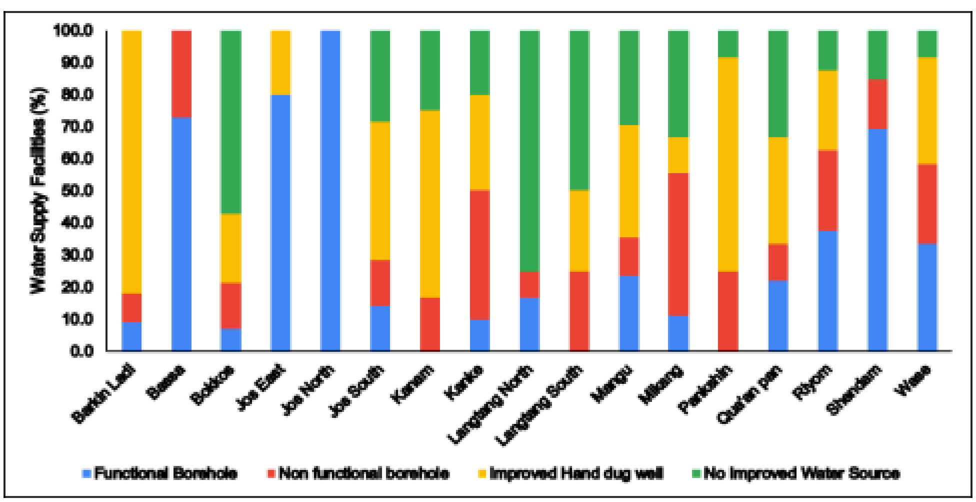

Figure 5: Percentage distribution of Technology Options for Water Supply in Schools

However, schools in Bokkos, Langtang North and Langtang South LGAs require urgent intervention in terms of provision of improved water supply facilities for the schools.

The estimated number of toilet compartments for both staff and pupils across the 17 LGAs are presented in Table 6 while the number of required number of new hand washing facilities, waste bins, new hand pump borehole and boreholes needing rehabilitation are presented in Table 7.

Table 6: Sanitation Facilities Gaps for both Staff and Pupils

LGA	Number of Toilets				Number of Urinals			
	Male Teachers	Female Teachers	Male Pupils	Female Pupils	Male Teachers	Female Teachers	Male Pupils	Female Pupils
Barkin Ladi	3	3	55	62	11	11	65	72
Bassa	0	0	99	100	11	11	101	102
Bokkos	8	8	79	80	14	14	79	80
Jos East	3	3	13	16	5	5	32	35
Jos North	2	2	22	24	4	4	31	33
Jos South	0	0	89	100	5	5	96	109
Kanam	0	0	44	42	12	12	50	48
Kanke	0	0	57	56	10	10	57	56
Langtang North	1	0	87	93	6	10	88	99
Langtang South	2	2	30	31	4	4	37	38
Mangu	0	0	135	145	6	6	124	144
Mikang	4	6	60	65	7	7	58	65
Pankshin	1	1	52	58	12	12	58	64
Qua'an pan	0	1	80	84	9	9	87	91
Riyom	0	1	84	78	7	7	92	85
Shendam	3	1	74	76	7	6	87	84
Wase	3	3	87	104	12	12	99	116
Total	30	31	1,146	1,214	142	145	1,240	1,321

Table 7: Required Handwash, waste bin and water supply facilities in the schools

LGA	Required New Facilities			Borehole for Rehabilitation
	Hand Washing	Waste Bin	Hand Pump Borehole	
Barkin Ladi	7	0	1	0
Bassa	3	10	3	0
Bokkos	3	12	2	8
Jos East	8	12	0	0
Jos North	0	4	0	0
Jos South	10	17	1	2
Kanam	0	4	2	3
Kanke	1	8	4	2
Langtang North	6	11	1	9
Langtang South	8	11	1	2
Mangu	0	1	2	5
Mikang	9	14	4	3
Pankshin	4	5	3	1
Qua'an pan	0	5	1	3
Riyom	2	3	2	1
Shendam	0	4	2	2
Wase	0	7	3	1
Total	61	128	32	42

The findings of this study share similar pattern with the previous find of Alfa and Effanga (2021) in a similar study carried out in Kaduna State. This buttresses the fact that educational policy makers need to pay more attention to

WASH components of policies such the NHGSFP since health is wealth. This will ensure the overall sustainability of such programme.

4.0 CONCLUSION

The study concludes that there is a surge in pupils' enrolment in schools participating in the NHGSFP which has added pressure to the already insufficient WASH facilities within the schools. There is therefore need for additional WASH facilities within the schools based on the identified gaps.

The 170 schools surveyed will require a total of 30 new toilet compartments for male teachers, 31 for female teachers, 1,146 for male pupils, 1,214 for female pupils, 142 new urinals for male teachers, 145 for female teachers, 1,240 for male pupils and 1,321 for female pupils. In addition, a total of 61 schools require new hand washig facilities, 128 schools require new waste bins to be provided, 32 existing boreholes need rehabilitation while 42 schools require new boreholes.

A comprehensive assessment of WASH facilities within all schools participating in the NHGSFP in Plateau State (on a case-by case basis) is strongly recommended to ascertain the WASH needs Policy makers should always consider the WASH implications and sustainability issues in implementing policies such as the NHGSFP for holistic gains.

REFERENCES

Agu, C. I., Ossai, E. N., Ogah, O. E., Agu, I. C., Akamike, I., Ugwu, G. O., ... & Azuogu, B. N. (2023). An appraisal of the implementation of the national school feeding programme and its effect on enrolment and attendance in public primary schools in Southeast, Nigeria: perception of heads of schools. *BMC nutrition*, *9*(1), 37.

Alfa M. I. & Effanga F. E. (2021). WASH Sustainability Issues associated with the Home-Grown School Feeding Programme in Developing Economies: A case Study of Kaduna State, Nigeria. *Proceedings of the 42nd WEDC International Conference* (Online), 13 – 15 September 2021.

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I. C., & Schmidt, W. P. (2010). Water, sanitation and hygiene for the prevention of diarrhoea. *International journal of epidemiology*, *39*(suppl_1), i193-i205.

Ejemot-Nwadiaro, R. I., Ehiri, J. E., Arikpo, D., Meremikwu, M. M., & Critchley, J. A. (2021). Hand-washing promotion for preventing diarrhoea. *Cochrane database of systematic reviews*, (1).

Jordanova, T., Cronk, R., Obando, W., Medina, O. Z., Kinoshita, R., & Bartram, J. (2015). Water, sanitation, and hygiene in schools in low socio-economic regions in Nicaragua: A cross-sectional survey. *International journal of environmental research and public health*, *12*(6), 6197-6217.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and psychological measurement*, *30*(3), 607-610.

National Population Commission Nigeria (2020). *Nigeria Population Projection and Demographic Indicators-State and National*. Abuja, Nigeria. Author

United Nations International Children Emergency Fund (2016). *Strategy for water, sanitation and hygiene 2016-2030*. New York. Author

Universal Basic Education Commission (2010). *Minimum Standard for Basic Education in Nigeria.* Abuja. Author

Paper 16

Community Participation in Rural Water Supply and Sanitation in Nigeria: A Review on Successes and Barriers

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ABSTRACT: Access to safe water, sanitation and hygiene (WASH) is considered as a basic human right by the UN sustainable development goals. In Nigeria, over 65 million people do not have access to basic water sanitation and hygiene. In present era WASH sustainability is largely dominated by efforts towards promoting citizens' participation in community WASH development. This paper reviews the aspects of Community participation in Rural Water supply and Sanitation in Nigeria, the paper reports on the major successes recorded in community participation and some of the barriers to effective engagement of communities in rural WASH programmes. Improved water supply, capacity building and unity amongst community are found to be the major achievement in terms of community participation in rural WASH implementation and operation across Nigeria. However, it was found that low partnership between service providers and communities, lack of technical support, proper monitoring, lack of commitment by communities, gender imbalance and women involvement, financial constraints and entrust in leadership are spotted to be the barriers to effective community participation in rural WASH activities. The study conclude that community participation strategy is an efficient approach to WASH sustainability in Nigeria and call on the relevant authorities to bridge the gaps identified as barriers to enhance effective community participation in Rural WASH.

Keywords: safe water; sustainable; community; participation; gender

1.0 INTRODUCTION

Access to safe water is considered as a basic human right by the UN sustainable development goals. Water is essential and plays a vital role not only for the survival of human being, but also for all forms of human activities. Thus, it is imperative to maintain, preserve and defend the access to clean water for the existence of mankind (Jack, 2009). However, globally 2.1 billion people do not have access to safely managed drinking water services (World Health Organization, 2017), in Nigeria, over 65 million people do not have access to basic water sanitation and hygiene (WaterAid, 2021), of which majority are in rural areas in developing countries (Chumbula and Massawe, 2018; Sridhar et al; 2020), leading to the deaths of thousands of people particularly children. In Nigeria more 70% of deaths are related to clean water accessibility. On the other hand, hygiene facilities such as excreta disposal (toilets) have also been inadequate for usage at community households and public places such as schools, markets, and even hospitals (Eremutha *et al.,* 2016; Hothur *et al.,* 2019, WaterAid, 2021), as result 48 million people practice open defection and over 170 million lack access to hygiene services (WaterAid, 2021). Moreover, toilet facilities available were poorly maintained and mostly shared among numerous people with no consideration of gender segregation and women integrity Adeleye *et al.,* 2014, USAID, 2019; Kurui *et al.*, 2019).

Despite heavy financial investments in rural water, sanitation and hygiene infrastructures in Nigeria over las decades by various organization including Non-governmental Organizations, and private entities, the state of sustainable Water, sanitation and hygiene (WASH) in Nigeria still remains a nightmare. Many of the WASH facilities are either found always in a state dysfunctional or abandoned prematurely. Hence, there is lack of integrity in the sense of service delivery and upkeep of services basically due to sustainability and management issues. However, the World Bank (2004) asserts that the present era is largely dominated by efforts towards promoting citizens' participation in community rural sanitation and water development, which would require a fundamental shift in attitudes and techniques, thereby encouraging planning with the communities at the grass-root. This policy places an obligation on benefiting communities to actively participate in the development activities of WASH services by empowering them to mobilize their own creative potentials, manage resources, take decisions and control activities in the WASH sector

(Bailur, 2007); If the people participate passively in projects, they become inactive and will depend on external inputs. In order to avoid this situation, local decision-making in project planning and implementation is important. In other words, a project that the local people themselves plan and implement is given priority as local materials and human resources are utilized effectively by the local people's initiative and responsibility. This in addition brings benefits to projects by reducing conflicts and increasing cooperation between the organisers and the community either culturally or politically (UGBAH, et al. 2017).

However, in Nigeria, various approaches such as VLOM (Village level operations and maintenance), WCA (Water Consumer Association) and WASH COM (Water Sanitation and Hygiene Communities), CLTS (Community led total sanitation) has been developed in recent times to achieve continuous operations and sustainability of water and sanitation projects, these approaches recognize the involvement of community to participate in the processes of design, planning, construction and management WASH facilities, as a strategy for effective and sustainable water and sanitation service delivery in Nigerian, the approach further allows communities to assume responsibility and develop sense of ownership to the WASH projects sited in their respective location, as such WASH projects will be guarded jealously, consequently ensuring better maintenance and sustainability, this method was found to be effective and yielding positive results in many areas in Nigeria and most developing countries (Rural Water Supply Network, 2010). Nevertheless, it has been estimated that nearly 30% of the water projects in Nigeria fails within the first year of operation (World Bank. 2017), which has often resulted to dead and spread of waterborne diseases from the use of unsafe sources of ponds and river. At present not more than 31% of the population in Nigeria currently have access to clean drinking water (World Bank. 2017). And currently, Nigeria is among top countries globally with high level of open defacation with over 20% of the population being involve in it (Ngwu, 2017, UNICEF, 2017), of which poor sanitation facilities is one of the culprits. This observation instigated this review towards identifying the various success, failures and challenges relating to communities' involvement and participation in the provision and management of water facilities in Nigeria, and recommending means of ensuring better management and delivery of clean water to communities.

2.0 SUCCESSES

Improvement in Water supply and sustainability: The participation of communities in rural water supply is essential towards continuous operation and maintenance of water projects, in the last decades this approach has been recommended and widely in use across Nigeria (Ishaku and Majid, 2010), it has shown tremendous success towards the improvement and sustainability of water projects in Nigeria. Studies by Ufuoku, 2011 in Delta State; Adesida and Okunlola, 2015 in Ondo State; Jelili et al. 2020 in Kwara State and Chima and Itabita, 2018 in Abia State, revealed that there was a significant relationship between community participation and sustainability of water projects in the study areas. In that Communities Rural households' participation contributed to the project in many ways such as financial contribution to pay counterpart funds, replacement of damaged project parts, provision of labour, provision of security at project site, thus protecting the properties, fencing of projects, in addition to attending regular meetings to review project performance and problems (Obeta and Nwankwo, 2015; Adesida and Okunlola, 2015).

Community participation leads to empowerment/capacity building: Community participation includes people's involvement in decision making process and implementing programmes, their sharing in benefits of development programmes and their involvement in efforts to evaluate such programmes. Hence, participation as an end in itself focus on participation as a process in which people are directly involved in shaping, deciding and taking part in the development process from the bottom-up perspective. Participation become a process of achieving greater individual fulfilment, personal development, self-awareness and some immediate satisfaction. In participation, as an end, people directly involved in process, they will get power and control over decisions that effect on their lives. Thus, participation as an end leads to empowerment. However, Participation by manipulating or passive participation cannot empower community, but both interactive participation and participation by self-mobilization can be highly empowered. Further, institutional support in operation & maintenance enhances capacity building of community-based organizations (CBOs) (Aashiq, 2020).

It creates unity amongst rural communities: Community participation techniques requires involvement of communities in the various processes of execution of water and sanitation projects. However, in that it was observed to increase unity amongs communites resulting from conduction of regularly meetings and division of tasks as shown in the studies by Ufuoku, 2011 in Delta state, Nigeria. Tasks division on the other hand also leads to good attitudes of discipline and dedication amongst people. Also a research by Obeta and Nwanko, 2015 observed that lack of community participation has resulted to sociocultural problems and management issues has resulted to water supply and sanitation problems in Northwestern Nigeria.

3.0 CHALLENGES/OBSTACLES TO EFFECTIVE PARTICIPATION

Low partnership between the government and people as grassroot: Community-government partnership is a worthwhile management approach that acquaint with the strength and weaknesses inherent in other management methods, and is able to use these effectively and circumspectly. A balanced Community-Government partnership was suggested for water problems in Anambra state and Enugu State by Dominic and Ezeabasili, 2014 and Obeta, 2016, as the most appropriate management approach that will ameliorate rural water problems. It could stimulate the relationship between government and rural people as partners in progress (Laah et al. 2014).

Lack of technical support: The local community members who are supposed to participate in and monitor water supply and sanitation projects lack the capacity to do so. First, they lack contract information as well as the required technical knowledge and skills to operate and maintain WASH facilities or participate in their monitoring and evaluation. Worse still, there no training undertaken to equip them for the roles they are expected to play (Obeta, 2016).

Lack of commitment to participate amongst community members: It is quite regrettable that some people are more concerned about their personal welfare than the provision of infrastructural facilities that can benefit the entire communities. A study by Ukah et al. 2020 in Imo State, Nigeria, where level of community participation in rural infrastructural development including WASH related were assessed, it was revealed that only 10% of the sampled population participated in community development services, this is quite discouraging, whereas collective bargaining and execution of projects would assist the community to achieve greater heights. Similarly, a study in Kwara State communities by Jelili et al. 2020, also concluded that extent of community participation was low in most project components. However, lack of trust and credibility of political leaders and corruption has resulted to communities developing less interest in the organizers and political leaders and whatever they come up with, because they have experienced so many failed WASH projects and betrayals, leading to less attention and participation to community projects (Ugbah et al., 2017).

Financial constraints/lack of fund: Indeed this is one of the major challenges facing rural water supply and sanitation facilities, poverty are often times the main reason for failures in WASH services sustainability across most developing countries in the World (Ugbah et al. 2017; Aashiq, et al. 2020, Sridhar et al. 2020; Anthonj *et al.,* 2020) where communities may be willing to participate in terms of financial contribution for operation, maintenance or water tariff payment, but lack fund will result to water projects being abandoned, ultimately affecting health of public. This can be related to studies by Toyobo and Tanimowo, 2011 in Oyo; Miner *et al.,* 2016 in Jos, Obeta, 2016 in Enugu State, Sridhar *et al.,* 2020 in Kaduna and Mustapha et al. 2022 in Sokoto, where community members identified lack of fund a great barrier to WASH access and affordability among people, in that many community members were reluctant to contributes for the betterment and sustainability of WASH projects in the regions. Moreover, A study by Laah et al., 2014, in Plateau State, Nigeria, where community participation in rural infrastructural development including WASH services in Riyom area was assessed shows that about 30% of the population studied expressed their heart-felt opinion that there was little or no encouragement from the government even when it was entrenched in the national development plan that government would give technical and financial assistance to communities that embark upon projects. All resulting due to poverty.

Low involvement of the communities during planning and implementation: Rural development, project beneficiaries are still being deprived of participating in the identification, planning, implementation, monitoring, and evaluation of projects that are meant to improve their welfare. Findings show that most of the rural water projects were sited while the rural people were not consulted, this has created a lot of problem as water projects were sited based on political patronage and party affiliation, without involvement of communities to decide the preferred location of the borehole. Some experienced of the rural communities have project abandonment because of wrong location (Toyobo et al;

2011). This top-down approach may not go down well with the people, some may even openly display their anger by vandalizing the project after commissioning. A finding by Toyobo et al; 2011 at ogboro village in saki east local government area of Oyo state, Nigeria where a pump break down due to negligence in maintenance and repairs, resulting from non-involvement of rural community members in planning and implementation of water schemes. Similarly, water projects were note planned and designed based on need base rather base on politics some study finding reveal duplication of same number of projects in communities. These communities enjoy similar water project provided by State Government, Federal Government, International Agencies, Cooperate bodies and community efforts. It turn out to be that some communities are favoured with three to four water stations while others have at all. Thus communities that needed more were neglected (Toyobo et al; 2011). Therefore communities may not be willing to maintain and take good care of water project not demanded. Therefore involvement of communities at the early stage of the projects will help to improve decisions such as about the introduction of technology that is affordable and accessible, both in economic terms and in terms of the acquisition of technical maintenance skills (Nwankwoala, 2011; Ofuoku, 2011).

Low women participation: As reported by Obeta, 2016. Women are key stakeholders and play an integral part in community development, despite the fact that women make up a significant number of the Nigeria population. The lack of desired skills and engineering knowledge among most community members undermines their ability to such as contribute to repairs and preventive maintenance. Worse still, women members are confined to gender stereotype activities and are not consulted on matters concerning rural water supply and sanitation projects, even though they bear great burden of water fetching and sanitation use (washing children, cleaning, etc) in community. However, women are excellent in some skills in community participation, such as Treasury and financial management, they are known to play vital roles as mothers, producers, managers, community developers/organizers etc. moreover women constitutes large, yet their participation in decision making processes and issues regarding WASH is very low. However a survey in Ajegunle Community in Ifelodun LGA, Kwara state, Nigeria, revelated that women were involved and participate actively involved in community WASH projects in terms of contribution of final contribution and manual labour, but were neglected through the decision making processes of implementation of the project (Olubukola, 2012).

In efficient monitoring by water service providers: This is also another hurdling factor which has interfered with effective community participation, there should be a routine monitoring to observe the communities level of participation in the water management and correct where necessary through sensitization and education on the importance of communities involvement, and reviewing the participation processes. A study by Obeta and Nwankwo, 2015 hinted that total neglect by the government and other service providers after handing over was a great concern which led to slow in community participation in rural water projects maintenance. Similarly Laah et al. (2014) studied on community participation in Plateau State, Nigeria also clearly shows that governments at all levels and development partners have not really succeeded in mobilizing and creating desired awareness on how community participation should be addressed and achieved. Understanding the fact that participatory models have neither imposed any task upon governments nor other development agency but effective community participation is unlikely to occur without serious attention from the government.

Nature of the Leadership: This is attributed to the problem of poor and inefficient leadership on the part of community leaders. This is particularly true to situation where the leaders are corrupt and out to enrich themselves at the expense of the masses (Ugbah et al., 2017). After inadequate capacity at the community level, corruption was second most frequently reported factor limiting CP in rural water supply and sanitation in Nigeria.

4.0 CONCLUSION AND RECOMMENDATION

i. The executing agency should give administrative and technical training to the CBOs to address disputes or other technical problem and to maintain a functional and enduring water supply scheme
ii. It is obvious that governments at all levels and development agencies have not really succeeded in mobilizing and creating desired awareness on how community participation should be addressed and achieved. Effective community participation is unlikely to occur without serious attention from the government.
iii. There is need to mobilize and create awareness through mass media, seminars and workshops about the relevance of community participation in rural development. Citizens and most especially the beneficiaries of

any development project or programme should be encouraged and educated through intensive public enlightenment on the importance of community participation in infrastructural development

iv. Moreover, government should create enabling environment where the people at the grass-root will participate actively in decision-making process that affect their condition of living and by so doing, it could stimulate the relationship between government and rural people as partners in progress.

v. Proper channels towards implementing necessary community participation strategies should be strictly adhered to in order to deal with the prevailing challenges.

REFERENCES

Aashiq, U., Khalid, A., Alam, M. and Hassan, S S. (2020). Community-Based Management Strategies in Sustainability of Rural Water Supply Schemes. Review of Applied Management and Social Sciences (RAMSS) 3(1), 271-278.

Adesida, I. E. and Okunlola, J. O. (2015). Effects of Community Participation on the Sustainability of Rural Infrastructure in Ondo State, Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology* 7(1), 1-9

Akpomunie, O. B. (2010), "Self-help as a strategy for rural development in Nigeria: A bottom-up approach. *Journal of alternative perspectives in the social science*, 2(1), 88-111.

Anthonji, C., Setty, K.E., Ezbakhe, F., Manga, M., Hoeser (2020). A systemic review of water, sanitation and hygiene among Roma communities in Europe: Situation analysis, cultural context, and obstacles to improvement. *International Journal of Hygiene and Environmental Health*, 226, 113506.

Bailur, S. (2007). "Community participation in rural information system projects. The complexities of community participation in ICT for development projects: Case of "Our Voices. *London School of Economics*. Available online: http://www.ifipwg94org.br/fullpapers/R0010-1.pdf. [July 2009].

Blackman, R. (2003) In Ghazala, M. and Vijayendra, R. (2004), (eds) "Community-base and–driven development: The World Bank Research Observer, 19,(1). The International Bank for Reconstruction and Development.

Cheetham, N. (2002). Community participation: What is it? *Transitions*, 14(3), 4.

Chima, G.N. and Itabita, J.O. (2018). Community Participation as Strategy to Ensure Sustainability of Rural Water Supply Projects. *FUPRE Journal of Scientific and Industrial Research*, 2 (1), 109-118.

Chumbula, J. J., & Massawe, F. A. (2018).The role of local institutions in the creation of an enabling environment for water project sustainability in Iringa District, Tanzania. *Environmental & Socio-economic Studies*, 6(4), 1-10.

Cleaver, F. and A. Toner. (2006). The Evolution of Community water Governance in Uchira, Tanzania: The Implications for Equality of Access, sustainability and Effectiveness. *Natural resources Forum* 30, 207-218.

Dominic C. M. U, Ezeabasili A.C. C. (2014). Community-Government Partnership and Sustainability of Rural Water Programmes in Anambra State, Nigeria Okoro, B.U. *Journal of Environment and Earth Science* 4(13), 1-12.

Eremutha, F. A., Taiwo, H.B., Sridhar. M. K.C.and Olufemi, O. A. (2016). Evaluation of sanitary condition in Kuje market in Abuja, Nigeria with diverse cultural practices and provision of a dry ecological toilet system. *Sociology and Anthropology*, 4(1), 1011-1-19.

Health Developing Countries, Natasha Potgieter and Afsatou Ndama Traore Hoffman, Intech Open, DOI: 10.5772/intechopen.80392. Available from: https://www.intechnopen.com/books/the-relavance-of-hygiene-to-health-in-developing-countries/household-water-handling-in-the-arid-and-semi-arid-lands-in-kenya

Hothur, R. Arepalli, S. and DoddojuVeera, A B. (2019). A KAP study on water, sanitation and hygiene among residents of Parla Village, Kurnool district, AndraPradesh. *International Journal of Community Medicine and Public Health*, 6(5), 2081-2085.

Ishaku H. T. and Majid M. R. (2010). Community Participation: Alternative Approach to Water Supply In Nigerian Rural Communities. *International Conference on Built Environment in Developing Countries*, 2010 (ICBEDC 2010), 1 – 2 Dec 2010, USM, Pulau Pinang.

Jack, M. (2009). Water ethics and business. Water Ethics (pp. 241-269). Taylor & Francis. http://dx.doi.org/10.1201/9780203875438-c15

Jelili, Y. O. Oyeniyi A, A, Folorunsho A I. (2020). Community Participation and Sustainability of the Community and Social Development Projects in Kwara State, Nigeria. *Journal of Agricultural Extension*, 24(1), 138-147.

Laah, E. D., Adefila, J. O., Yusuf, R. O. (2014). Community Participation in Sustainable Rural Infrastructural Development in Riyom Area, Plateau State of Nigeria. *Journal of Economics and Sustainable Development*, 5(4), 49-57.

Mckeown, T., Record, R.G. and Turner, R.D. (1975). An interpretation of the decline of Mortality in England and Wales during the twentieth century. *A Journal of Demography*, 29(3), 391–422.

Miner, C. A.; Dakhin A. P.; Zoakah, A. I.; Afolaranmi, T. O.; Envuladu, E. A. (2015). Household drinking water; Knowledge and practice of purification in a community of Lamingo, Plateau State, Nigeria. *E3 J. Environ. Res. Management*, 3, 0230-0236.

Nwankwoala, H.O. (2011). Localizing the strategy for achieving rural water supply and sanitation in Nigeria. African *Journal of Environmental Science and Technology*, 5(13), 1170-1176.

Obeta, M. C. (2016). Community Participation in the Rural Water Supply Sector of Enugu State, Nigeria." *American Journal of Water Resources*, 4 (3), 58-67. doi: 10.12691/ajwr-4-3-2.

Obeta, M. C. and Nwankwo C. F. (2015). Factors responsible for Rural Residential Water Supply Shortage in Southeastern Nigeria Journal of Environmental Geography, *Journal of Environmental Geography*, 8(3–4), 21–32. DOI: 10.1515/jengeo-2015-0009.

Ofuoku A. U. (2011). Effect of community participation on sustainability of rural water projects in Delta Central agricultural zone of Delta State, Nigeria. *Journal of Agricultural Extension and Rural Development*, 3(7), 130-136.

Olubukola, F. O. (2012). Participation of Women In The CSDP Water Project Facilitated By The Kwara State Community and Social Development Agency (KWSCDP): A Study of Bada Ajegunle Community in Ifelodun Local Government Area of Kwara State, Nigeria. Research Project Submitted to: University of Applied Sciences Van Hall Larenstein, Part of Wageningen University, Netherlands In Partial Fulfilment of the Requirements for the Master Degree in Management of Development Specialization in Gender and Rural Development.

Rural Water Supply Network. (2010). Sustainable Rural Water Supplies. Rural Water Supply Network, St. Gallen.7pp.

Sridhar, M. K. C., Okareh, O. T., and Mustapha, M. (2020). Assessment of Knowledge, Attitudes, and Practices on Water, Sanitation, and Hygiene in Some Selected LGAs in Kaduna State, Northwestern Nigeria. *Journal of Environmental and Public Health*, 2020, 1 – 14. https://doi.org/10.1155/2020/6532512

Toyobo, A. E. and Tanimowo, N. B. (2011). Evaluation of Rural Water Supply Scheme in Selected Communities in Oke-Ogun Area, Oyo State, Nigeria. *Global J. Sci. Frontier Res*, 2011, 1 – 11.

Ugbah, R., Meldrum, A. and Ehiwario, K. (2017). Water access and Community Engagement: Creating the Right Environment for Maximizing the Benefits of Community Engagement Processes and Increasing Water Participation in Nigeria. *Water Resources Management*, IX, 129 - 139. http//doi:10.2495/WRM170131

Ukah, F. O., Akor, E. S. and Ngozi, J. O. (2020). Community Partcipation and Rural Development in Imo State. *International Journal of Management, Social Sciences, Peace and Conflict Studies (IJMSSPCS)*, 3(3), 127 – 139.

WaterAid. (2021). WASH National outcome Routine Mapping (WASH NORM). World Toilet Day, 19th - 21November, Abuja, Nigeria

World Bank (2004), World development report: Making services work for poor people. Washington DC: World Bank.

World Bank. (2017). A Wake-Up Call: Nigeria Water Supply, Sanitation, and Hygiene Poverty Diagnostic. WASH Poverty Diagnostic. World Bank, Washington, DC.

World Health Organization. (2017). Safely Managed Drinking Water – Thematic Report on Drinking Water. Geneva, Switzerland.

Paper 17 *Residential Water use and Hygiene Promotion: Implication for Public Health in Mowe/Redemption Camp axis of Ogun State, Southwest Nigeria*

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ABSTRACT: Hygiene promotion is a planned approach of enabling people to act and change their behaviour in order to avert incidences of water, sanitation and hygiene (WASH) related diseases. This is enhanced by the provision of sanitation facilities and availability of potable water. This study investigates residential water use and its effect on sanitation practices in Mowe/Redemption Camp axis of Ogun State, Nigeria, using structured questionnaire and interviews. Two hundred (200) questionnaires were distributed between November 2020 and March 2021. Statistical analysis was performed using Microsoft Excel, while hypothesis were tested using Chi-square (X^2). The result obtained showed that 80% of households have water within their premises. Available water sources include private boreholes, private wells, in-house connection, and public standpipes. Basic hygiene practices include regular flushing of toilets, bathing, and hand washing with soap after using the toilet. There are concerns about water source protection among the respondent and risks associated with water points, and reported cases of typhoid, cholera, and diarrhea. While sanitation facilities are readily available in houses, there are concerns about water borne disease which is directly correlated to water availability at $R=.884$, $P<.05$.

Keywords: Sanitation facilities, hygiene promotion, WASH, Water borne disease, water availability.

1.0 INTRODUCTION

Humans have the right to 'sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses' (UNHCR, 2015). A minimum quantity of water should be available for drinking, food preparation, basic hygiene, bathing and sanitation to ensure sustainable, healthy urban living (Oyerinde & Jacobs 2021). The most basic water requirement is stipulated by the World Health Organization (WHO) and varies between 20 and 50 litres per capita per day (l/c/d). The basic water requirement determined by the WHO is limited to access at an offsite tap and does not include consideration of homes with piped water. Public water supply in Nigeria is managed by the state water agency. However, most households in Nigeria do not have access to piped connections. Generally, the level of service is unsatisfactory, coupled with high intermittency and unreliable supply (Kumpel & Nelson 2016; Loubser et al. 2021).

The percentage of access to pipe connections is about 10% and may vary significantly across cities. According to the World Health Organization (WHO/UNICEF, 2015), access to improved water supply has made substantial progress in recent years, with 91% (2015 statistics) of the global population now using an improved drinking water source compared to 76% in 1990. Although, 771 million people still lacked access to basic level of service (WHO/UNICEF, 2021) including basic sanitation. Almost half of these individuals live in sub-Saharan Africa, where rapid population growth has posed a serious challenge to the progress of accessing improved water sources (WHO/UNICEF, 2017). A large portion of the world's population lives in the urban centres of developing countries where public water delivery systems are restricted and unreliable. A large proportion of the people lack access to potable water while a larger proportion does not have access to safe water (WHO/UNICEF, 2017).

Providing sanitation to people requires attention to the entire system, not just focusing on technical aspects such as the toilet, fecal sludge management or the wastewater treatment plant (Tilley et al., 2014). The Sustainable Sanitation Alliance (SuSanA) includes five features (or criteria) in its definition of "sustainable sanitation". It needs to be economically and socially acceptable, technically and institutionally appropriate and protect the environment and natural resources (Susan, 2008). Maintaining and sustaining sanitation has challenges that are technological, institutional and social in nature. Sanitation infrastructure has to be adapted to several specific contexts including consumers' expectations and local resources available. A lack of clean water, decent toilets and hand washing facilities in homes makes people vulnerable to potentially fatal diseases. It contributes to the spread of infections and make it very difficult for people to protect themselves and others from the spread of diseases.

2.0 MATERIALS AND METHODS

2.1 Study Area

Mowe is located in Obafemi-Owode Local Government Area in Ogun State, along the Lagos-Ibadan express way. Mowe originated as a market, serving the villages surrounding it. It began to develop as a result of the development of major places of worship like the Redemption Camp and Deeper Life International Christian Centre. Redemption Camp is the international headquarters of the Redeemed Christian Church of God, and has over 5,000 houses, roads, police station, hospital, supermarkets, banks, a fun fair, a post office, schools, printing press, Redeemed Bible College and a power plant (turbine power station). Mowe like most major towns in Ogun State do not have public water supply. While the Redemption Camp has a central water system for the residents, households within the Mowe community depends on self-help provision of water through private boreholes and wells.

2.2 Methodology

In the absence of any existing water consumption data and the inability of the researchers to carry out field studies using smart meter, water consumption data was acquired through administration of survey questionnaire. Data obtained included socioeconomic characteristics of the residents, household water availability and consumption, sanitation and hygiene practices of each residential household and the relationship between water consumption and sanitation practices in residential household. Systematic sampling was used to select respondents in each of the 25 residential zones, every 5^{th} house was selected and sampled. Out of the 225 survey questionnaire that was returned, only 200 were found useful for analysis. Descriptive statistic techniques was employed in analysing data collected using frequency table, percentages, averages, standard deviation, while Chi-square (X^2) method was used to test the hypothesis formulated for this research.

3.0 RESULTS AND DISCUSSION

3.1 Household Demographic Characteristics

A total of 200 survey questionnaire were analysed. The demographic characteristic of survey responses was classified based on: Respondents age range, gender, employment status, income group, house type, level of education, and household size. The distribution of household characteristics are shown in Table 1. Household size is averagely 4 person at 44%, house type are majorly bungalow and self-contained at 76%, low and middle income households are predominant in the study sample at 92%.

Table 1: Household /demographic characteristics

Age range	**Percentage of respondent**
Below 40yrs	46%
Above 40yrs	54%
Gender	**Percentage of respondent**
Male	63%
Female	37%
Employment status	**Percentage of respondent**
Paid employment	63%
Self employed	37%
Income group (₦)	**Percentage of respondent**
Low (10,000 - 50,000)	27%
Middle (50,000 - 200,000)	65%
High (200,000 - 500,000)	8%
Type of houses	**Percentage of respondent**
Bungalow	28%
Duplex	7%
Storey Building	9%
Self-Contained	48%
Multi rooms	8%
Level of education	**Percentage of respondent**
Primary and Non-formal	30%
Secondary	15%
Post-secondary	55%
Household size	**Percentage of respondent**
1	4%
2	7%
3	15%
4	44%
5	20%
6	10%

3.2 Availability of Water and Water Use Habit

The absence of municipal water sources was quite vivid in the respondent data collected from the survey. All water sources are from self-help project mainly from wells and boreholes at 61%, while the remaining 39% (pipe connection and standpipes are from central water system obtained from boreholes. The data is similar to those obtained from Abeokuta at 69% for wells and boreholes, 89% for south-west Nigeria (Oyerinde & Jacobs, 2022). The study locations boast of ease of access to domestic water supply. About 80% of respondent affirm ease of access, while 83% affirm sufficiency of supply. About 78% of respondent have water supplied at least once in 2 days and 99% once in 3 days. The available water are not fit for drinking as it is common in many place where households depend on packaged water either in form of sachet, bottled or refill water for drinking purposes. The sachet water is readily available and most affordable consumed by 49% of respondent, refill bottle is consumed by 36% and finally bottled water at 15%. While there is abundant freshwater from wells and boreholes, these water may not meet specific requirements required for drinking purpose. As such all households within the study sample depends on alternative water sources for drinking.

Table 2: Availability of water, water use and personal hygiene

Water source	**Percentage of respondent**
Private borehole	49%
Private well	12%
Pipe Connection	24%
Standpipes/Tap	15%
Ease of accessibility to water source	**Percentage of respondent**
Yes	80%
No	20%
Frequency of water supply	**Percentage of respondent**
More than once a day	23%
Once a day	23%
Once in two days	32%
Once in three days	21%
Once a week	1%
Sufficiency of water supply	**Percentage of respondent**
Yes	83%
No	17%
Drinking water sources	**Percentage of respondent**
Bottled	15%
Sachet	49%
Refill	36%

3.3 Sanitation Facilities and Personal Hygiene

Availability of toilet and sanitary facilities are prevalent in the study area. All houses have toilet facilities in form of water closet and VIP latrine. Availability of toilet facilities is the basic requirement for an effective personal hygiene, however, sanitation will be impossible in the absence of sufficient water. All houses have at least one toilet facility. Other aspect of personal hygiene include regular hand washing especially after defecating and after eating. A sizeable 30% of the respondent do wash their hands twice daily. Effective hand washing required an individual to wash their hands with soap and water. Though, all households claimed to wash their hands daily, the data collected was silent on the use of soaps. Frequency of flushing peaked at thrice (51%), while most households have between 1- 3 bathrooms. Most households in the study area (51%) used bucket /bowls for bathing, while bathing was carried out once (88%) or twice (12%).

Table 3: Sanitation and personal hygiene

Type of toilet	Percentage of respondent (%)
Water closet	87
VIP latrine	13
No of toilets	**Percentage of respondent (%)**
1	24
2	24
3	12
4	20
5	20
Frequency of flushing	**Percentage of respondent (%)**
2	32
3	51
4	14
Number of bathroom	**Percentage of respondent (%)**
1	36
2	23
3	23
4	18
Frequency of hand washing	**Percentage of respondent (%)**
Twice a day	30
After defecation before Eating	23
After Eating before Bed.	47
Method of bathing	**Percentage of respondent (%)**
Bucket/Bowl	51
Shower	32
Bathtub	2
Jacuzzi	15
Frequency of bathing daily	**Percentage of respondent (%)**
Twice a day	12
Once a day	88

3.4 Health Risk Associated with Water Source

There are reported cases of water related diseases in study area. There are 29% reported cases of Typhoid, 10% reported cases of Diarrhea and 16% reported cases of Cholera. These may not be unconnected to the health risk associated to the water sources especially those without protective measure against sure risks. The challenge of water source protection and groundwater pollution from septic tanks, open drainage, improper solid waste disposal could positively increase the risk associated with water related diseases. Though drinking water quality was not covered in this research, the quality of water consumed for drinking could as well be the scapegoat.

Table 4: Health risk associated with water source

Health risk at water sources/point	Percentage of respondent (%)
Yes	26
No	74
Protective measures against sure risk	**Percentage of respondent (%)**
Yes	27
No	73
Incidence of reported case of typhoid	**Percentage of respondent (%)**
Yes	29
No	71
Incidence of reported case of diarrhea	**Percentage of respondent (%)**
Yes	10
No	90
Incidence of reported case of cholera	**Percentage of respondent (%)**
Yes	16
No	84

3.5 Effect of water and sanitation facilities provision on the health risk and water borne disease.

The effect of water and sanitation facilities provision on the health risk and the relationship with water borne diseases were tested using two hypotheses.

Hypothesis 1

H_0: There is no significant effect of water and sanitation facilities provision on the health risk of the people of Obafemiowode Local Government Area

H_1: There is a significant effect of water and sanitation facilities provision on the health risk of the people of Obafemiowode Local Government Area

This was tested using a non-parametric chi-square test and is presented in Table 5

Table 5: Effect of water and toilet facilities on the health risk of the residents

Response	Observed N	Expected N	Residual	Df	Chi-square	Sig
Cholera	32	7.2	-1.2			
Diarrhea	20	7.2	-1.2			
Typhoid	58	7.2	2.8	4	9.56	<.05
Total	110					

Table 5 shows that 32 of the respondents indicated that cholera was one of the effects of lack of water and toilet facilities which posed a serious health risk on the residents of Mowe in Obafemi Owode Local government area of Ogun state, 20 indicated diarrhea, while 58 of the respondent indicated Typhoid. The chi-square test shows a significant effect of water and toilet facilities on health risk of the residents in Obafemi Owode Local Government area of Ogun state (χ^2 = 9.56, df=4, p<.05).

Hypothesis 2

H_0: There is no significant relationship between water availability and water borne disease in the study area

H_1: There is significant relationship between water availability and water borne disease in the study area

Table 6a: The relationship between water availability and water borne disease in the study area (Descriptive statistics)

	Mean	Std. Deviation	N
Water availability	10.04	3.152	99
Water borne disease	6.03	2.606	99

Table 6b: The relationship between water availability and water borne disease in the study area (Correlation)

		Water availability	Water borne disease
Water availability	Pearson Correlation	1	.884**
	Sig. (2-tailed)		.000
	N	99	210
Water borne disease	Pearson Correlation	.884**	1
	Sig. (2-tailed)	.000	
	N	99	99

**. Correlation is significant at the 0.01 level (2-tailed).

The Table 6b shows the Pearson Moment Correlation Coefficient between the availability and water borne diseases with R=.884 which implies that there is a very strong positive relationship between water availability and water borne disease in the study area. The p-value of .000 at 5% level of significance shows that there is a strong evidence against H_0 (i.e. H_0 is not accepted) this indicate that there is a significance relationship between the water availability and water borne disease in the study area. The comparison between the two mean value; water availability has highest mean value 10.04 against the Water borne disease in the study area with 6.03 mean value.

4.0 CONCLUSION

In conclusion, the goal 6 of the sustainable development goal (SDGs) of the United Nations is to ensure universal and equitable access to safe and affordable drinking water, access to adequate and equitable sanitation and hygiene for all (United Nations, 2016). The availability of water in required quantity and quality is a requirement for a healthy living, however, when the available water does not have the required quality, it poses serious health risk and challenges. The failure of state water agencies to provide water in desired quantity and quality has made many households to result to self-help leading to proliferation of water boreholes and wells. However, there is a gap in the continuous monitoring of water quality to ensure constant compliance with relevant quality standards. Many household water sources are exposed to one form of contamination or the other from septic tanks, open drainage, improper solid waste disposal, industrial effluent discharge and sea water intrusion. Moreover, the quality of processed and package water need constant monitoring to ensure adequate compliance to water quality. Many of the reported cases of infections in the hospital are directly or indirectly related to water. The impacts on health and wellbeing of a lack of water, sanitation and hygiene in communities, public places, schools and healthcare facilities, especially in Nigeria homes are devastating. This highlights more than ever before the need for the Nigerian government, at all levels, to take urgent action to implement key recommendations and commitments for the provision of inclusive and sustainable water, sanitation and hygiene services.

REFERENCES

Kumpel, E. & Nelson, K.L. 2016. Intermittent water supply: Prevalence, practice and microbial water quality. *Environ. Sci. Technol*. 2016, 50, 542–553.

Loubser, C. Chimbanga, B.M. & Jacobs, H. 2021. Intermittent water supply: A South African perspective. Water SA 47(1) /Jan 2021; doi.org.10.17159/wsa/2021/v47.i3.xxxx

Oyerinde, A.O., & Jacobs, H.E., (2022). The Complex Nature of Household Water Supply: An Evidence-Based Assessment of Urban Water Access in Southwest Nigeria. *Journal of Water, Sanitation and Hygiene for Development*, 12(3), 237 doi: 10.2166/washdev.2022.176.

WHO/UNICEF 2015. *Progress on sanitation and drinking water: 2015 update and MDG Assessment,* World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), Geneva, Switzerland. ISBN 9789241509145.

WHO/UNICEF 2017. *Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines,* World Health Organization (WHO) and the United Nations Children's Fund (UNICEF).

WHO/UNICEF JMP 2021. *Progress on household drinking water, sanitation and hygiene* 2000-2020: Five years into the SDGs. Accessed from data.unicef.org on 2nd January, 2023.

UNHCR (2015) Council resolution 15/9, *Human rights and access to safe drinking water and sanitation*, available from http://www.right2water.eu/sites/water/files/UNHRC%20Resolution%2015-9.pdf (accessed on 6 February, 2021).

SuSanA (2008). Towards more sustainable sanitation solutions - SuSanA Vision Document. Sustainable Sanitation Alliance (SuSanA)

Tilley, E., Ulrich, L., Lüthi, C., Reymond, Ph. and Zurbrügg, C. (2014).Compendium of Sanitation Systems and Technologies.2nd Revised Edition. Swiss Federal Institute of Aquatic Science and Technology (Eawag), Duebendorf, Switzerland.

United Nations (2016)"The Sustainable Development Goals Report". New York. Print.

Paper 18

Characterization of Wastewater Generated from Hand Wash for Efficient Design of Onsite Treatment Systems

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ABSTRACT: Covid-19 rejuvenated the habit of hand washing, which is crucial in the prevention of many diseases and also results in wastewater generation. This paper investigates the characteristics of wastewater generated from hand washing, which is important in the design of efficient onsite wastewater treatment systems. The research was conducted over a period of three weeks, during which wastewater samples were collected from two different hand wash sites within Ahmadu Bello University, Zaria. Physicochemical and microbial analysis were carried out for parameters such as pH, biological oxygen demand (BOD), chemical oxygen demand (COD), sulphate, phosphate, electrical conductivity, and total coliforms. Results showed that BOD levels ranged from 45 to 180 mg/L, COD levels ranged from 200 to 320 mg/L. Sulphate levels ranged from 503.5 to 640 mg/L, phosphate levels ranged from 0.35 to 1.2mg/L, while electrical conductivity levels ranged from 395 to 1152 µS/cm. Furthermore, total coliforms in the samples ranged from 170 to 332 CFU/100mL, with an average of 320 CFU/100mL. Based on the results, it can be concluded that hand wash wastewater is characterized by low levels of BOD and COD, and contains high levels of coliforms. A BOD/COD ratio of 0.21 indicates low biodegradability which suggests that biological treatment alone may not be sufficient. The study provides valuable information that can be used in the design of efficient onsite treatment systems for hand wash wastewater.

Keywords: handwash, wastewater, Biological Oxygen Demand, Chemical Oxygen Demand

1.0 INTRODUCTION

COVID-19 rejuvenated the habit of hand washing, which is crucial in the prevention of many diseases and also results in wastewater generation. Wastewater generated from handwash is a type of greywater that contains soap, dirt, and other contaminants. The characterization of this wastewater is important for the efficient design of treatment systems. The treatment system should be designed to remove the contaminants present in the wastewater effectively. (Sijimol and Joseph, 2021). The design of an on-site treatment system should be based on the characteristics of the wastewater generated from handwash. This will ensure that the treatment system is efficient and effective in removing the contaminants present in the wastewater (Oteng-Peprah et al., 2018).

Handwashing is a practice that is as old as man's existence and has continued to gain more prominence overtime to this present moment where a lot of attention is being given to it for obvious reasons, one of which was due to the outbreak of coronavirus disease called COVID-19.

The United Nations has reported that nearly 850,000 people die every year from lack of access to clean water, sanitation, and hygiene (WHO and UNICEF, 2017). Water used in handwashing translates all into waste, unlike consumptive uses where it is a certain percentage of the water that results in waste. As indicated by the United Nations (UN), a 40% setback in new water assets by 2030 combined with a nonstop expansion in the total populace is shifting the world towards a worldwide water emergency. In acknowledgment of the expanding challenge of water shortage, the UN General Assembly dispatched the Water Action Decade, 2018-2028 in 2018 to prepare activities that will help change how we oversee and manage water. With all hands on deck to conserve the finite resource called fresh water, treatment of wastewater generated from handwashing has become necessary. This is pertinent not just because it will provide alternative reuse purposes but that if eventually, it were to be discharged into the environment it would not create problems for it just as asserted by Eva et al., 2019. However, before there can be treatment, prior information about the general characteristics of the waste is important to enable the efficient and economic design of such treatment systems and also help policymakers in decision-making making, hence The need of this study is to characterize wastewater generated from handwashing in a typical African country like Nigeria where both soap and soapless detergents of phosphate constituents and other environmentally unfriendly constituents are still in use.

Handwash is the act of washing one's hands with soap and water, usually to prevent the spread of germs and diseases U.S. Geological Survey. (2019). Wastewater on the other hand is any water that has been used or contaminated by human activities, such as domestic, industrial, agricultural, or storm water runoff, RMA Environmental. (2014). Furthermore, BOD is a measure of the amount of oxygen consumed by microorganisms in decomposing organic matter in water under aerobic conditions. BOD indicates the level of organic pollution and the potential impact on aquatic life U.S. Environmental Protection Agency. (2003). While Chemical Oxygen Demand (COD) is a measure of the amount of oxygen required to oxidize both organic and inorganic matter in water by using a chemical agent, such as potassium dichromate. COD indicates the total amount of organic and inorganic pollutants and the potential oxygen demand in water, U.S. Environmental Protection Agency. (2003).

Household activities account for the pollution and hydraulic loads which are highly pertinent in the design of appropriate treatment systems according to Ridderstolpe, 2004 and Berger, 2012. For instance, phosphate levels in greywater depend on whether a country has banned the use of phosphorous-containing detergents. Concentration levels range from 4 to 14 mg/l where non-phosphorous detergents are still being used and also from 6 to 23 mg/l where detergents still contain phosphorous (Eriksson et al, 2002). These values could even be expected to be smaller when only handwashing greywater is considered. According to Eriksson et al. (2002), total nitrogen levels in greywater range from 0.6 to 74 mg/l, which will not likely be expected to even feature if only handwashing wastewater is considered, as the main source of nitrogen in greywater is usually from urine. Organic matter concentration levels are usually expressed as biological oxygen demand, (BOD) and chemical oxygen demand, (COD). COD in greywater range from 13 to 8000 mg/l. The high values are simply based on the fact that the main source of COD in grey water is due to chemicals such as dishwashing or laundry detergents (Eriksson et al., 2002). The main objective of this study is to determine the physical, chemical, and biological characteristics of handwashing wastewater generated from two main sources: commercial and institutional.

2.0 MATERIALS AND METHODS

The materials used included 120 ml sterile containers and 5 liters plastic containers for collection of samples, digital pH and electrical conductivity meters, measuring cylinders, burette, pipettes, conical flasks, beakers, COD machines, reagent bottles, autoclave, incubator, etc. reagents/chemicals used included the following; Mercuric sulfate, sulphuric acid, potassium dichromate, phenolphthalein indicator, ferrous ammonium sulfate, manganous sulfate solution, sodium thiosulphate solution, starch indicator, alkali-iodide azide solution, ferroin indicator, concentrated sulphuric acid with silver sulfate.

2.1 Methods

2.1.1 Sample Collection: Samples were collected from a handwashing stand at the Department of Water Resources and Environmental Engineering, Ahmadu Bello University Zaria, Nigeria, and from a restaurant on the same campus of the university using sterilized 5litres container and 120ml sterile plastic bottles and transferred quickly to the laboratory for analysis. Analysis was done for both physical, chemical, and biological characteristics with a total of seven parameters considered which are; BOD, COD, Sulphate, Phosphate, Electrical conductivity, pH, and total coliform.

2.1.2 Sulfate

The amount of sulfate was determined using the spectrophotometer method according to Kim, & Lee, (2011). The procedure is as follows:

i. 100ml of sample was measured using a measuring cylinder and poured into a beaker
ii. The beaker containing the sample was placed on a magnetic stirrer and a bar magnet was gently dropped in the beaker.
iii. 5ml of conditioning reagent was then measured using a pipette and transferred into the beaker containing the sample.
iv. The stirrer was then switched on to mix the solution.
v. While the solution was undergoing mixing, 1 spoonful of Barium chloride (BaCl) was added and continued to stir for 1 minute.

vi. A blank was prepared with 100ml of distilled water following the same procedure but without Barium Chloride (BaCl).
vii. A wavelength of 420nm was set on the spectrophotometer and standardized by adjusting the transmittance and absorbance to zero respectively.
viii. A cuvette was rinsed with distilled water and then with the prepared blank. It was filled with the blank and placed in the spectrophotometer.
ix. Another cuvette was rinsed with distilled water and then with the prepared sample and placed in the spectrophotometer.
x. The transmittance reading was taken and compared with the standard curve to determine the concentration. The amount of Sulphate was then determined using the following formula;

$$Mg/l\ SO_4 = \frac{mgSO_4 \times 1000}{ml\ of\ sample\ taken} \quad \ldots\ldots (1)$$

2.1.3 Phosphate: The amount of phosphate was determined using the molybdenum blue method, Kowalska, & Kowalski, (2022), U.S. Environmental Protection Agency (1978). The following procedures were used accordingly;
i. The sample was properly mixed by shaking it vigorously
ii. 100ml of the sample was then measured and poured into the conical flask.
iii. 4 ml of ammonium molybdate was added to the measured sample.
iv. 10 drops of stannous chloride were then added to the sample solution and allowed to stand for 10 minutes for color development.
v. A blank was prepared following the same procedure but using distilled water.
vi. A wavelength of 690nm was set on the spectrophotometer and standardized by adjusting the transmittance and absorbance to zero respectively.
vii. A cuvette was properly rinsed with distilled water and then with the prepared blank. It was then filled with the blank and placed in the spectrophotometer.
viii. Another cuvette was rinsed with distilled water and then with the prepared sample and placed in the spectrophotometer.
ix. The absorbance reading was taken and compared with the standard curve to determine the concentration. The amount of Phosphate was then determined using the formula below;

$$Mg/l\ PO_4 = \frac{mgPO_4 \times 1000}{ml\ of\ sample} \quad \ldots\ldots (2)$$

2.1.4 BOD DETERMINATION

To measure the BOD5 of wastewater, the modified Winkler-azide method for BOD determination was used as follows according to Sahoo, & Satpati (2010)
i. The sample was kept and allowed to reach room temperature and afterward mixed properly.
ii. The sample was measured into two 300ml BOD bottles.
iii. One of the bottles was gently stopped without adding any chemicals and incubated for 5 days at 20˚C.
iv. To the other bottle, 1ml of Manganous sulfate ($MnSO_4$) solution was added followed by 1ml of Alkali-iodide azide solution.
v. The bottle was stopped gently to exclude air bubbles and then mixed by inverting the bottle a few times.
vi. The bottle was allowed to stand for a few minutes to allow the precipitates formed to settle sufficiently to leave a clear supernatant above the Manganese hydroxide floc.
vii. 1 ml of concentrated sulphuric acid was then added.
viii. The bottle was re-stoppered and mixed by inverting several times until completely mixed.
ix. 200ml of the prepared sample was then taken and titrated with 0.0021M sodium thiosulphate ($Na_2S_2O_3$) to a pale straw color.
x. A few drops of the starch solution were added and titration was allowed to continue to the first disappearance of the blue color.
xi. The reading was taken and recorded as the initial Dissolved Oxygen, DO_i.
xii. After the 5 days of incubation of the other bottle, the sample was removed and the same procedure was applied the reading was then taken and recorded as final Dissolved Oxygen, DO_f.
xiii. The BOD was calculated as follows;

$$BOD_5 = Initial\ DO - Final\ DO \quad \ldots\ldots (3)$$

2.1.5 Determination of Dichromate Value

The dichromate reflux method is a common method for the analysis of chemical oxygen demand in water. The dichromate value is a measurement of the oxygen required to oxidize soluble and particulate organic matter in water. The following procedure was adopted for use in this research according to ASTM International. (2020).

i. 0.4g of Mercuric sulfate was weighed using the weighing balance and poured into a refluxing flask.
ii. The sample was then vigorously shaken and 20ml was measured and poured into the flask.
iii. 10mls of standard potassium dichromate and 3 glass beads were also added to the flask and gently mixed.
iv. 30 ml of concentrated sulphuric acid containing silver sulfate was measured and added to the solution in the fluxing flask.
v. The solution was gently mixed and mounted on the refluxing condenser and refluxed for 1-hour duration.
vi. The refluxed solution was then allowed to cool to room temperature.
vii. The solution was made up to 100ml by adding 40ml of distilled water.
viii. 3 drops of ferroin were added as an indicator.
ix. The solution was then titrated with standard ferrous ammonium sulfate (titrant) to a reddish brown end-point.
x. A blank was prepared using the same procedure with 20ml of distilled water and titrated accordingly and the concentration was determined using the following equation.

$$mg/l\ Dichromate\ Value = \frac{(a-b)c\times 8000}{ml\ of\ Sample} \quad (4)$$

Where, a= titration of blank
b= titration of sample
c= normality of ferrous sulphate (0.25N)

2.1.6 pH: The pH was determined using a standardized digital pH meter. It is a dimensionless quantity.

2.1.7 Electrical Conductivity, EC: The electrical conductivity was determined using a standardized calibrated digital instrument. It is measured in µmhos/cm

Total Coliform:
Following is the procedure that was used for determining the total coliform using the plate count method according to Lee (2021);

i. A series of dilutions of the sample was prepared using sterile water.
ii. Plates with EMB agar for coliforms were labeled with the dilution factor and the sample name.
iii. 1 mL of each dilution was transferred to the corresponding plate using a sterile pipette. The sample was evenly spread over the surface of the agar using a glass rod.
iv. The plates were incubated upside down at 35°C for 24 hours for colonies to appear.

The number of coliform colonies on each plate was counted and multiplied by the dilution factor to obtain the total coliform count per milliliter of the sample.

3.0 RESULTS AND DISCUSSION

Handwashing wastewater samples were obtained from commercial and institutional sources for three weeks and characterized for physical, chemical, and biological characteristics. Parameters considered were biological oxygen demand (BOD), chemical oxygen demand (COD), phosphate (PO_4^{3-}), sulfate (SO_4^{2-}), electrical conductivity (EC), and Total coliform count as shown in table 1 and Table 2.

Table 1: Characterisation of commercial handwash wastewater

PARAMETER	AVERAGE WEEKLY CONCENTRATIONS (mg/l)			AVERAGE CONCENTRATIONS (mg/l)	STANDARD[a] (Effluent)	NSDWQ[b] (2015)
BOD	180	45	170	131.67	30	N/A
COD	320	200	260	260.00	80	N/A
SULPHATE	503.5	640	520	554.5	500	100
PHOSPHATE	1.2	0.35	0.4	0.65	5	N/A
EC $\mu S/cm$	395	1152	973	840.00	N/A	1000
Ph	7.86	7.97	7.64	7.82	6-9	6.5-8.5
Total Coliform$\times 10^5$ cfu/100ml	332	170	458	320.00	600MPN/100ml	10cfu/100ml

[a] Federal Ministry of Environment. (2011)
[b] Standards Organisation of Nigeria. (2015)

Table 2: Characterisation of institutional handwash wastewater

PARAMETER	AVERAGE WEEKLY CONCENTRATIONS (mg/l)			AVERAGE CONCENTRATIONS (mg/l)	STANDARD[a] (Effluent)	**NSDWQ[b] (2015)**
BOD	80	75	92	82.33	30	N/A
COD	450	390	400	413.33	80	N/A
SULPHATE	446	450	420	438.67	500	100
PHOSPHATE	3.4	4.3	2.3	3.33	5	N/A
EC $\mu S/cm$	425	474	525	474.67	N/A	1000
Ph	7.76	7.82	7.73	7.77	6-9	6.5-8.5
Total Coliform$\times 10^5$	256	220	310	262.00	600MPN/100ml	10cfu/100ml

[a] Federal Ministry of Environment. (2011)
[b] Standards Organisation of Nigeria. (2015)

The BOD of the commercial source obtained from the restaurant showed higher value averagely of 131.67mg/l than its counterpart of 82.33mg/l in the institutional source. This could be as a result of the presence of food particles that have been washed into it by the customers thereby increasing the organic matter content. The values for BOD, COD, sulfate, phosphate, EC, pH, and total coliform count are similar to those reported by Olupot et al. (2021). On the other hand, the COD value 260mg/l recorded for commercial is similar to that obtained by Zhang et al. (2021) who obtained 250mg/l for handwash wastewater characterization. This could be a result of the substantial use of liquid soap by students in handwashing which consists of high level of inorganic substances. Phosphate which is of higher significance to the environment due to being a major cause of eutrophication in water bodies, has lower values of the average of 0.65 mg/l and 3.33 mg/l respectively for commercial and institutional sources which are within the required standard of European Union (1-2mg/l) according to Council Directive, 1991, and Italy (2mg/l) according to Chaillou et al, (2009) except for the institutional that was slightly higher. These lower values can rise over time as long as there is continuous untreated discharge of the wastewater into an unhealthy environment. Phosphate showed very low values in both cases as compared to the range of values 6-23 mg/l stated by Eriksson et al, (2002) for places where phosphorus-containing detergents are still being used. This value for phosphate is similar to that reported by Nwankwo et al. (2020) who had 0.5mg/l. However, the lower values here could be because only handwashing wastewater is considered neglecting laundry which should account for higher phosphate values due to the higher use of detergents in washing clothing. The total coliform count on assessment showed 320.00×10^5CFU/100ml in the commercial source while that from the Institutional showed 262.00×10^5CFU/100ml of sample which shows its unsafe for discharge directly into the environment without treatment.

The ratio of BOD to COD for the commercial handwash wastewater is 0.51 while that for the institution is 0.20. The commercial handwash wastewater showed a higher biodegradability than that of the institutional wastewater. This could be as result of the food particles washed into it from the restaurant. According to García et al, (2021), the value of 0.51 for commercial handwash wastewater falls within the zone of partial biodegradability while the 0.20 of the institutional handwash wastewater is non-biodegradable, i.e. contains inorganic matter.

A BOD/COD ratio of 0.51 indicates that the wastewater is partially biodegradable and may need both physical and biological treatment processes (Olupot et al, 2021). One possible option for an on-site treatment system for wastewater from a handwash facility is a roughing filter-slow sand filter system, which can reduce the turbidity, COD, and BOD of the wastewater by using gravel and sand media and natural microorganisms (Olupot et al, 2021). The effluent from the slow sand filter can then be disinfected by chlorination or UV radiation before reuse or discharge. Another possible option is a membrane bioreactor system, which can achieve high removal of COD, BOD, and pathogens by using a membrane filtration process along with biological treatment, (WaterAid 2020). The effluent from the membrane bioreactor can also be disinfected by chlorination or UV radiation before reuse or discharge (WaterAid 2020).

4.0 CONCLUSION

From the study, it can be seen that

i. COD recorded higher values of 260 mg/l on average in commercial sources and 486 mg/l on average in institutional sources as compared to the international standards of 125 mg/l for the EU and 100 mg/l for Italy and Jordan according to Dalahmeh et al, 2020. This means that the wastewater needs treatment before final discharge or reuse purpose.
ii. Electrical conductivity showed a normal range of values as compared to the standard of Jordan according to Dalahmeh et al, 2020. Similarly, pH also fell within the normal range of 6-9.5 for both irrigation, urban, and reclaimed domestic reuse according to the standards of Italy and Jordan.
iii. A roughing filter-slow sand filter system, which can reduce the turbidity, COD, and BOD of the wastewater by using gravel and sand media and natural microorganisms will be enough to treat the wastewater having a BOD/COD ratio of 0.51 which is that of the commercial.
iv. The moving bed biofilm reactor (MBBR), which uses plastic carriers with attached biofilm to treat the organic load, Zarei, & Azimi, (2017), can be used in treating the wastewater having a BOD/COD ratio of 0.2. This system has been shown to have acceptable efficiency and meet the related standards for treating handwashing facility wastewater. However, the optimal design and operation of the MBBR may depend on other factors such as flow rate, temperature, pH, etc.

REFERENCES

ASTM International. (2020). *Standard test method for pH of saturated soil extracts* (ASTM D1252-06(2020)). https://doi.org/10.1520/D1252-06R20

Berger, C (2012): Examensarbete/Thesis no: 2012:14 ISSN 1654-9392 Uppsala, Sweden.

Chaillou, K., Gérente, C., Andrès, Y., Wolbert, D. 2009. Bathroom greywater characterization and potential treatments for reuse. Water Air Soil Pollution. 215, 31-42.

Council Directive (EC) 1991/271/EEC of 21 May 1991 concerning urban wastewater treatment. (1991). Official Journal of the European Communities, L135, 40 52.Retrievedfromhttp://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1991:135:0040:0052:EN:PDF

Dalahmeh, S. S., Al-Saidi, M., & Al-Salaymeh, A. (2020). An Analytical Review of Different Approaches to Wastewater Discharge Standards: A Case Study of Jordan. *Environmental Management*, 66(6), 1038-1051. https://doi.org/10.1007/s00267-020-01344-y

Eriksson, E., Auffarth, K., Henze, M., Ledin, A. (2002).Characteristics of grey wastewater. Urban Water, 4 (1), 85-104.

Federal Ministry of Environment. (2011). *National Environmental (Effluent Limitation) Regulations*. https://leap.unep.org/countries/ng/national-legislation/national-environmental-effluent-limitation-regulations

García, A. A., Pérez, J. A., & García, M. A. (2021). Relationship, importance, and development of analytical techniques: COD, BOD 5, and TOC. *SN Applied Sciences*, *3*(11), 1-19. https://doi.org/10.1007/s42452-023-05318-7 https://www.un.org/sustainabledevelopment/water-and-sanitation/

Kim, J., & Lee, S. (2011). *Development and Validation of a Spectrophotometric Method to Measure Sulfate in Mine Water. Mine Water and the Environment*, *30*(2), 131–137. https://doi.org/10.1007/s10230-011-0140-x

Kowalska, A., & Kowalski, A. (2022). *Determination of phosphorus compounds in plant tissues: from extraction to quantification. Plant Methods, 18(1), 1–15*. https://doi.org/10.1186/s13007-022-00854-6

Lee, J. (2021, August 9). Lab Procedures- Viable Plate Count. Biology LibreTexts. https://bio.libretexts.org/Courses/North_Carolina_State_University/MB352_General_Microbiology_Laboratory_2021_%28Lee%29/05%3A_Enumeration_of_Bacteria/5.03%3A_Lab_Procedures-_Viable_Plate_count

Nwankwo, C., Nnaji, C. C., & Onukwuli, O. D. (2020). Characterization and recovery of phosphorus from wastewater streams using different technologies. *Reviews in Environmental Science and Bio/Technology*, 19(4), 1047-1072. https://doi.org/10.1007/s11157-020-09533-1

Olupot, P. W., Kiggundu, N., Kansiime, F., & Niwagaba, C. B. (2021). Development and appraisal of handwash-wastewater treatment system for rural schools in Uganda. *Journal of Water, Sanitation and Hygiene for Development*, 11(3), 487-497. https://doi.org/10.2166/washdev.2021.062

Oteng-Peprah, M., Acheampong, M. A., & deVries, N. K. (2018). *Greywater Characteristics, Treatment Systems, Reuse Strategies and User Perception—a Review. Water, Air, & Soil Pollution*, 229(7), 255.

Reynaert, E., Greenwood, E. E., Ndwandwe, B., Riechmann, M. E., Sindall, R. C., Udert, K. M., & Morgenroth, E. (2020). Practical implementation of true on-site water recycling systems for hand washing and toilet flushing. Water Research X, 100051. https://doi.org/10.1016/j.wroa.2020.100051

Ridderstolpe, P., (2004). Introduction to greywater management. EcoSanRes Publication Series. Stockholm Environment Institute, Stockholm.

RMA Environmental. (2014). Chemical oxygen demand (COD) vs biological oxygen demand (BOD). https://www.rmagreen.com/rma-blog/what-is-chemical-oxygen-demand-cod-what-is-biological-oxygen-demand-bod

Sahoo, R. K., & Satpati, A. K. (2010*). Modification of Winkler's method for determination of dissolved oxygen concentration in micro samples. Analytical Methods,* 2(10), 1526–1530. https://doi.org/10.1039/c0ay00110d

Sijimol, M. R., & Joseph, S. (2021). Constructed wetland systems for greywater treatment and reuse: a review. International Journal of Energy and Water Resources, 5(2), 357-369.

Standards Organisation of Nigeria. (2015). *Nigerian Standard for Drinking Water Quality (NIS 554:2015)*. https://africacheck.org/sites/default/files/Nigerian-Standard-for-Drinking-Water-Quality-NIS-554-2015.pdf

U.S. Environmental Protection Agency. (1978*). Method 365.3: Phosphorous, all forms (colorimetric, ascorbic acid, two reagents). https://www.epa.gov/sites/production/files/2015-08/documents/method_365-3_1978.pdf*

U.S. Environmental Protection Agency. (2003). Dissolved oxygen and biochemical oxygen demand. https://archive.epa.gov/water/archive/web/html/vms52.html

U.S. Geological Survey. (2019). Biochemical oxygen demand (BOD) and water. https://www.usgs.gov/special topics/water-science-school/science/biochemical-oxygen-demand-bod-and-water

WHO and UNICEF. (2017). *Progress on drinking water, sanitation, and hygiene: 2017 update and SDG baselines*. (924151289X). World Health Organization and UNICEF

WHO. (2017). *Guidelines for Drinking-water Quality: Fourth edition incorporating first addendum* (4th Ed.). Geneva, Switzerland: World Health Organization.

Zarei, M., & Azimi, A. A. (2017). *Modelling of moving bed biofilm reactor (MBBR) efficiency on handwashing detergent wastewater treatment.* International Journal of Environmental Science and Technology, 14(7), 1609–1618. https://doi.org/10.1007/s13762-017-1255-9

Zhang, Y., Li, Y., Wang, J., & Zhang, J. (2021). Wastewater COD characterization: RBCOD and SBCOD characterization analysis methods. *Scientific Reports*, 11(1), 1-13. https://doi.org/10.1038/s41598-020-80097-0

Paper 19

Preliminary Studies on the Characterization of Residential Water End-Use in Abeokuta, South-Western Nigeria

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ABSTRACT: Residential water end use studies are relatively few when compared to other areas of water supply because of the paucity of data especially for households that depends on water from non-tap sources which are predominant in most developing countries. As the available fresh water is globally on the decrease, there is the need to understand water end-use to implement appropriate demand management and water reduction programs. This study characterized residential end-use in Abeokuta, Southwest Nigeria. A data collection program was executed using a structured questionnaire for 659 households to determine household and water use characteristics, and the factors that influenced end uses. Statistical analysis was performed using Microsoft Excel and SPSS software. The result showed that 8.80% of the households used piped water supply, 43.25% used well water, 26.56% used boreholes, 6.53% used water tanker, 6.07% used water fetcher and the remaining 8.80% used other unspecified sources. The average household size is 4.2 while 4 is the modal value. Average water consumption increased with household size from 115 l/hh/d to 587l/hh/d, while per capita water demand reduced from 115l/c/d to 64l/c/d. A breakdown of household water end use characterization shows drinking at 2.48%, cooking at 6.43%, laundry at 7.13%, bathing at 48.73%, car washing at 1.56%, toilet flushing at 31.77%, floor washing at 1.84%, and gardening at 0.04%. In conclusion, to achieve a significant water reduction, it is recommended that bathing and toilet flushing facilities can be properly retrofitted to achieve demand management assessment.

Keywords: End-use, demand management, non-tap sources, characterization, water reduction programs

1.0 INTRODUCTION

The goal 6 of the sustainable development goal (SDGs) of the United Nations is to provide clean water and sanitation, to ensure availability and sustainable management of water and sanitation for all. With targets to achieve *universal and equitable access to safe and affordable drinking water, access to adequate and equitable sanitation and hygiene for all* (United Nations, 2016). Sustainable urban water supply management requires, ideally, accurate evidence based estimations on per capita consumption and a good understanding of the factors influencing the consumption (Hussein *et al*. 2016). The determinants of household water consumption include access to water, household size, trip number, monthly income, payment for water, educational qualification, trip time and house type (Oyerinde & Jacobs, 2021). These determinants or variables differ considerably as we change geographical locations and also the extent or impact of each determinants also varies across different socio-economic groups.

End use studies are highly important in planning water supply programs and developing water demand management models. There is the need to have a clear understanding of household water use. A common characteristic of water demand in urban areas worldwide is its inexorable rise over many years, and projections of continuing growth over coming decades. Water consumption varies widely across locations and it is increasing everywhere as global population rises. The demand for water is the amount of water required for a given purpose. Sometimes supply cannot meet local demand, which creates conflict. The chief influencing factors are population growth and migration, together with changes in lifestyle, demographic structure and the possible effects of climate change. Meeting this increasing demand from existing resources is self-evidently impossible as such the emphasis should be shifted towards managing water demand by best utilising the water that is already available.

The failure of state-owned water agencies in Nigeria to provide municipal water to households have made groundwater a better option (Macheve *et al.* 2015).This in turn has led to total dependence on groundwater in form of boreholes and hand-dug wells. Groundwater is the world's largest source of freshwater, and many regions rely heavily on it for irrigation and drinking water. Many regions around the world are experiencing rapid depletion of their groundwater resources which is a crucial source of freshwater and which can take centuries or even millennia to recharge (Thomas & Famiglietti, 2019). However, groundwater depletion is a growing problem in many parts of the world, including Indian subcontinent, North Africa, the Middle East, China, US, Mexico and Nigeria. Satellite data from NASA shows that many major aquifers are being depleted at an alarming rate (Speiser, 2015).

Residential water end-use studies are relatively few in developing countries especially in sub-Saharan Africa. End-use studies include water, energy, and electricity use, however, in the last few decades, efforts have been focused on energy and electricity use. Water end-use studies help us to understand where and how water is being used, the micro-components of water use (quantitative and qualitative), and factors influencing per capita consumption. As a result, the need for the end-use data is increasing in recent years to aid in policymaking, and to have tailor-made solutions for targeted households. Residential water use is primarily divided into two categories, i.e. indoor and outdoor usage of water. Activities like cooking, dishwashing, laundry, bathing, toilet flushing come under the indoor use category while activities like irrigation, swimming pool filling, car washing comes under the outdoor use category.

This paper examines water consumption for 659 different types of households, and explores the influence of various household characteristics on the consumption patterns currently prevailing in urban areas of Abeokuta, Nigeria. The collected water consumption data has been used to develop statistical models demonstrating the influence of household characteristics on the total per capita daily water consumption. This preliminary paper is an initial part of whole study.

Table 1: Results from completed domestic end use studies

Previous studies										
End use category	USA (1999) Mayer & DeOreo		Perth (2003) Loh & Coghlan		Melbourne (2005) Roberts		Auckland (2007) Heinrich		Duhok (2016) Hussien et al.	
	l/c/d	percent	l/c/d	percent	l/c/d	percent	L/c/d	Percent	L/c/d	Percent
Clothes washer	56.8	8.7%	42.0	13%	40.4	19%	39.9	24%	34.4	12.7%
Shower	43.9	6.8%	51.0	15%	49.1	22%	44.9	27%	36.8	13.6%
Tap	41.3	6.3%	24.0	7%	27.0	12%	22.7	14%	87.3	32.2%
Dishwasher	3.8	0.6%	NA	NA	2.7	1%	2.1	1%	36.8	13.6%
Bathtub	4.4	0.7%	NA	NA	3.2	2%	5.5	3%	0.5	0.2%
Toilet	70	10.8%	33.0	10%	30.4	13%	31.3	19%	26.2	9.6%
Irrigation	381.6	58.7%	180[a]	54%	57.4[a]	25%	13.9	8%	NA	NA
Swimming pool	NA	NA	NA	NA	NA	NA	NA	NA	0.1	0.0%
Car washing	NA	NA	NA	NA	NA	NA	NA	NA	1.2	0.4%
House washing	NA	NA	NA	NA	NA	NA	NA	NA	13.9	5.1%
Cooking & drinking	NA	NA	NA	NA	NA	NA	NA	NA	15.7	5.8%
Gardening	NA	NA	NA	NA	NA	NA	NA	NA	19.0	7.0%
Leaks	36.0	5.5%	5.0	1%	15.9	6%	7.0	4%	NA	NA
Other	12.5	1.9%	NA	NA	0.0	0%	0.8	0%	NA	NA
Total Consumption	650.3	100%	335.0	335.0	226.2	100%	168.1	100%	271.4	100%

a Note: Irrigation volume per person calculated from provided volumes per household and end use break downs.
Sources: Extracted from Willis, Rachelle M., et al., (2011), Hussein et al., (2016)

2.0 MATERIALS AND METHODS

2.1 Study Area and Water Supply Description

The study area, Abeokuta metropolis is the state headquarters of Ogun state in southwestern Nigeria. It is situated about 70km north of Lagos and together with its environs has an area coverage of about 212km^2. It can be described by Latitudes 7° 10' N to 7° 15' N and Longitudes 3° 17'E to 3° 26' E., geographically located within the basement complex, The area is located in a hummocky terrain with a well pronounced undulating topography with prominent hills characterized by steep slope varying in altitude between 30 m and 180 m above sea level (Bello *et al*. 2009). Geologically, the study area falls within the Precambrian Basement rocks of southwestern Nigeria. Gneiss was found across the Northeastern part to the Southwestern part. Granites covers mostly the Northern part of the city, and also occurs as pockets within the Southeastern part. Hydrogeologically, groundwater occurrence in the northern parts of the city is limited to the fractured and in-situ weathered portions of the rocks which are usually exploited through wells and boreholes. Movement of water is currently influenced by topography and the metropolis is majorly drained by the River Ogun, River Oyan and many small streams (Akinse & Gbadebo, 2016).

2.2 Data Collection

Studies in the developed world employed the use of high resolution water meters, data Loggers and trace wizards® software to disaggregate flow data. However, installation of water meters and data loggers are highly expensive. In addition, survey questionnaires are also used to collect household data. In this study, only survey questionnaire and interviews were employed for data collection, because most households do not have access to municipal water source. A survey was conducted using questionnaire(s) on residential end use of water in Abeokuta, Ogun state. Socio-demographic characteristic of respondents such as the age of the household head, education level, living standard of the family, average monthly income of the household and family size and domestic water use behavior at the household level such as the source of water supply and source of water were investigated. Furthermore, questions regarding each water end use (e.g., bathing, hand washing, toilet flushing, dish washing, cleaning, cooking and watering the garden) were also included. The data collection involves the random sampling technique. A simple random sampling technique was followed to select households so that each household has an equal probability of being included in the sample. Eight hundred houses are randomly selected to represent the study area.

3.0 RESULTS AND DISCUSSION

3.1 Household Demographic Characteristics

Of the 800 surveys sent, a total of 659 usable responses were received, representing an effective response rate of 82%. The demographic characteristic of survey responses was classified based on: Respondents age, employment status, income group, household type, level of education, household size and type of water source.

Table 2. Survey participant demographics

Survey Age Range	**Percentage of Respondent**
20-29	16.54%
30-39	11.38%
40-49	38.69%
50-59	24.28%
60 and older	9.11%
Survey Employment Status	**Percentage of Respondent**
Government work	18.06%
Private company	4.40%
Self employed	32.32%
Others (employee, traders, casual workers, etc)	45.22%
Survey Income Group (₦)	**Percentage of Respondent**
Low (10,000 - 50,000)	38.54%
Middle (50,000 - 200,000)	52.05%
High (200,000 - 500,000)	9.41%
Survey Type of Houses	**Percentage of Respondent**
Bungalow	18.36%
Duplex	6.98%
Storey Building	19.12%
Self-Contained	12.44%
Multi rooms	26.25%
Others (mud houses, etc)	9.41%
Survey Level of Education	**Percentage of Respondent**
Primary	7.13%
Secondary	22.76%
Diploma	33.84
Degree	15.78
Post graduate	12.75
Non formal education	7.74
Survey Household Size	**Percentage of Respondent**
1	11.99%
2	8.50%
3	25.04%
4	24.30%
5	16.69%
6	20.18%
7	8.19%
Survey Water Source	**Percentage of Respondent**
Pipe	8.8%
Well	43.25%
Borehole	26.56%
Tanker	6.53%
water-fetcher	6.07%
Others (rain, river, bottle water, etc)	8.80%

3.2 Water Use Habits and End-Use of Water

Average water consumption increased with household size from 115 l/hh/d to 587l/hh/d, while per capita water demand reduced from 115l/c/d to 64l/c/d. A breakdown of household water end use characterization shows drinking at 2.48%, cooking at 6.43%, laundry at 7.13%, bathing at 48.73, car washing at 1.56%, toilet flushing at 31.77%, floor washing at 1.84%, and gardening at 0.04%.

Table 3: Household size versus domestic water consumption

Household size	Average (l/hh/d)	Average (l/c/d)
1	115	115
2	196	98
3	270	90
4	348	87
5	430	86
6	438	73
7	587	64

Daily water consumption: Average household daily water consumption increases from 115l/hh/d to 587 l/c/d, while per capita water consumption reduces as the number of person per household increases. A range of 115-64l/c/d was obtained from the analysis.

Drinking: The analysis of drinking water shows that the average amount of water used for drinking is 2.13 litres per capita day and that most households (53%) used 2 - 3 litres of water daily for drinking. In addition, 28% use 1.2 – 1.9 litres, 11% used 3 – 3.9 litres and 10% used 4 -5 litres.

Bathing: The analysis of water used for bathing shows that the average amount of water used for bathing per household is 257.1 litres and the highest numbers of households use 200 litres of water daily for bathing which was used by 7.5% of the total household surveyed. Significantly, 6.5% use 480 litres, 5.5% use 180 litres and another 5.5% use 300 litres. More data on the amount of water used daily for bathing by different household. Average per capita water consumed for bathing (shower and bath) is 42.4 l/c/d.

Cooking: The analysis of water used for cooking shows that the average amount of water used per household is 33.93 litres and the highest numbers of households use 20 litres of water for cooking daily which was used by 28.5% of the total household surveyed. Significantly, 26% use 40 litres, 14.5% use 60 litres and 13% use 30 litres. Average daily per capita water consumed for cooking is 6 l/c/d.

Laundry: The analysis of water used for laundry shows that the average amount of water used is 37.31 litres and most household use 40 litres of water for laundry daily. The first quartile of the water used for laundry ranges from 10-20 litres, the middle quartile ranges from 24-45 litres and the last quartile ranges from 50-100 litres. Average daily per capita water consumed for laundry is 6.2 l/c/d.

Floor washing: The analysis of water used for washing floor shows that the average amount of water used for washing floor is 9.71 litres and most household use 10 litres of water for washing floor daily. The first 25% of the respondent do not carry out floor washing, the middle quartile ranges from 10-15 litres and the last quartile ranges from 20-30 litres. Average daily per capita water consumed for floor or house washing is 1.6 l/c/d.

Toilet flushing: The analysis of water used for flushing toilet shows that the average amount of water used for flushing the toilet is 167.62 litres and most household use 300 litres of water daily for flushing the toilet. The first 25% of water used for toilet flushing ranges from 15-90 litres, the middle 50% ranges from 96-240 litres and the last 25% ranges from 250-360 litres. Average daily per capita water consumed for toilet flushing is 27.6 l/c/d.

Gardening: The analysis of water used for gardening shows that the average amount of water used for gardening is 0.035 litres which is rather insignificant. Only 1.5% of the total household surveyed admitted carrying out garden irrigation.

Car washing: The analysis of water used for washing car shows that the average amount of water used for car washing is 8.25 litres. 70.5% of the household surveyed claimed not to wash their cars at home and the 29.5 uses between 10-60 litres of water daily translating into an average of 1.36 litres per capita per day (l/c/d)

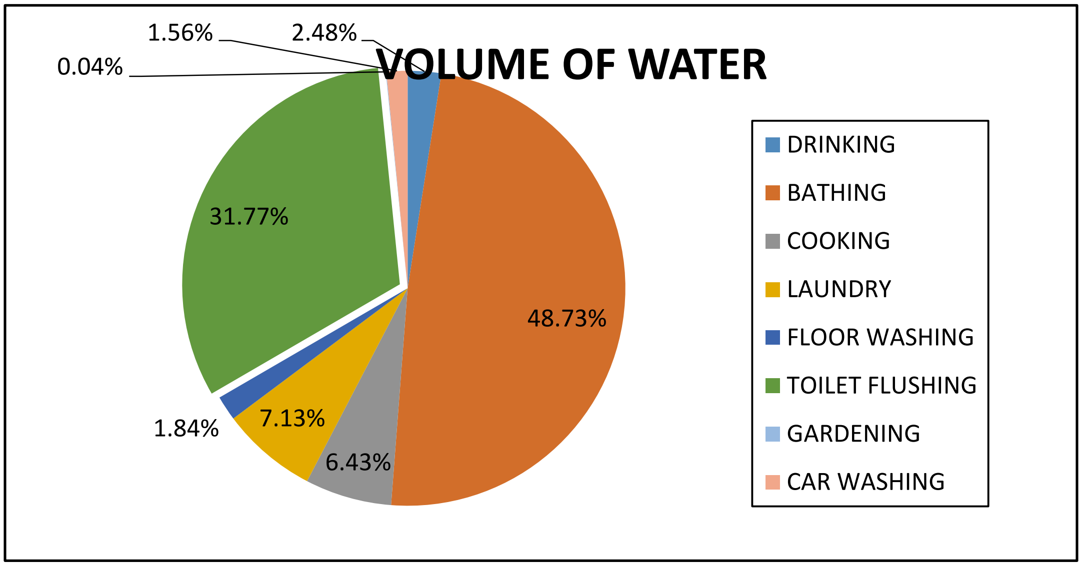

Figure 1: End-use of water in Abeokuta

Household Water Consumption: Global Comparison

Our daily water consumption when compared to other clime USA (650.3), Perth (335.0), Melbourne (226.2), Auckland (168.1), Duhok (271.4), and Abeokuta (94.5) is considerable low.

Table 4: Comparison of two developing countries (Duhok vs Abeokuta)

End-use category	Duhok (2016) Hussien et al.		Abeokuta (2023) Oyerinde et al.	
	L/c/d	Percent	L/c/d	Percent
Clothes washer/Laundry	34.4	12.7%	6.74	7.13%
Shower	36.8	13.6%	NA	NA
Tap	87.3	32.2%	NA	NA
Dishwasher	36.8	13.6%	NA	NA
Bathtub/ Bathing	0.5	0.2%	46.05	48.73%
Toilet	26.2	9.6%	30.02	31.77%
Irrigation	NA	NA	NA	NA
Swimming pool	0.1	0.0%	NA	NA
Car washing	1.2	0.4%	1.47	1.56%
House washing/Floor washing	13.9	5.1%	1.74	1.84%
Cooking and drinking	15.7	5.8%	8.01	8.48%
Gardening	19.0	7.0%	0.038	0.04%
Leaks	NA	NA	NA	NA
Other	NA	NA	0.43	0.45%
Total Consumption	271.4	100%	94.5	100%

The end-use of water in Abeokuta metropolis does not favourably compete with the rest of the world as average daily per capita demand is the lowest as shown in Table 1 and Table 4. This might not be unconnected to lack of access to municipal water sources as over 90% of the respondents depend on non-tap sources for their daily domestic consumption. The Nigeria national average water demand for cities stands at 120l/c/d, as such the resulting daily per capita of 94.5l/c/d is considerably lower. The implication of lower water consumption is thr danger of sanitation and hygiene issues especially the water washed diseases.

Many factors are responsible for lower water consumption including lifestyle, type of house, in-house facilities, income group, and access to water source. Majority of household surveyed falls within the low-middle income group, which significantly influenced the volume of water consumed and consumption pattern.

4.0 CONCLUSION

Sustainable access to water required access for all without jeopardizing the need of the future. It is worth nothing that over 70% of water consumed in Abeokuta is obtained from groundwater source. Most of the world's aquifer are gradually depleted at a faster rate than they are replenished, and except concerted effort is put in place to increase access to municipal water supply, there may be no water for the next generation. There are existing report of groundwater lowering in many countries and this is a signal to the depletion of our aquifers.

REFERENCES

Akinse, A.G, & Gbadebo, A.M. (2016). Geologic Mapping of Abeokuta Metropolis, Southwestern Nigeria. *International Journal of Scientific & Engineering Research,* 7(8), August-2016, ISSN 2229-5518.

Bello, J., Eruola, A., Ufoegbune, G., & Awomeso, J. (2009) "An Assessment of Water Supply Potential for Crop Production: Comparative Study of River Basins under the Jurisdiction of Two River Basin Development Authorities Located in Different Ecological Zones of Nigeria". *Journal of Meteorology and Climate Science,* 7(8), 49-57.

Hussein, Wa'el A. Memon, Fayyaz A. & Savic, Dragan A. (2016). Assessing and modelling the influence of household characteristics on per capita water consumption. *Water Resour. Manage.* 30, 2931-2955, DOI 10.1007/s 11269-016-1314-x

Macheve, B. Danilenko, A. Abdullah, R. Bove, A. & Moffitt, L.J. (2015). *State water agencies in Nigeria: A performance assessment*. Washington, DC: World Bank Group Available at https://openknowledge.worldbank.org/handle/10986/22581.

Matthew Speiser (2015), Business Insider https://www.businessinsider.com/nasa-data-shows-the-world-is-running-out-of-water-2015-6?r=US&IR=T, accessed 23rd September 2023.

Oyerinde, A. O. & Jacobs, H. E. (2021). Determinant of household water demand: a cross-sectional study in South West Nigeria. *Journal of Water Sanitation and Hygiene for Development.* doi:10.2166/washdev.2021.175.

Thomas, B.F., Famiglietti, J.S. Identifying Climate-Induced Groundwater Depletion in GRACE Observations. *Sci Rep* 9, 4124 (2019). https://doi.org/10.1038/s41598-019-40155-y.

Willis, Rachelle M., Stewart, Rodney A., Panuwatwanich, Kriengsak, Williams, Philip R., Hollingsworth, Anna L. (2011), Quantifying the influence of environmental and water conservation attitudes on household end use water consumption. Journal of Environmental Management, 92 (2011) 1996-2009, Elsevier Publisher.

Paper 20 Assessment of Menstrual Hygiene Management in some Secondary Schools within Kaduna South LGA

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ABSTRACT: Menstrual hygiene management (MHM) plays a crucial role in the overall health, well-being, and educational attainment of adolescent girls. In many low-resource settings, girls face numerous challenges related to menstruation, such as inadequate access to menstrual hygiene products, limited sanitation facilities, and societal stigmatization. This study presents a comprehensive assessment of the existing menstrual hygiene management in some Secondary schools within Kaduna South LGA. The aim of this study is to analyze the current state of MHM practices in secondary schools, identify gaps and challenges, and propose recommendations for effective interventions. A mixed-methods approach was employed, combining quantitative surveys and qualitative interviews. Key aspects of the assessment included the availability and accessibility of menstrual hygiene products, adequacy of sanitation facilities, provision of accurate information and education, and the impact of MHM on girls' educational outcomes. Data was analyzed using appropriate statistical methods. The findings indicated that numerous challenges persist in ensuring effective MHM in secondary schools. Insufficient availability and affordability of menstrual hygiene products, inadequate sanitation infrastructure, and social stigma surrounding menstruation were common barriers. Moreover, limited knowledge and misconceptions about menstruation among school girls contributed to ineffective management practices. To address these challenges, several interventions and recommendations were identified. In conclusion, this comprehensive study underscores the urgent need for improved menstrual hygiene management in secondary schools. By addressing the identified gaps and implementing evidence-based interventions, policymakers, educators, and stakeholders can contribute to enhancing the overall well-being and educational opportunities for adolescent girls. Further research and monitoring are required to evaluate the long-term impact of such interventions and promote sustainable MHM practices in educational settings.

Keywords: menstrual hygiene management, menstruation, sanitation facilities, secondary schools and adolescent girls

1.0 INTRODUCTION

Menstrual hygiene management (MHM) or menstrual health and hygiene (MHH) refers to access to menstrual hygiene products to absorb or collect the flow of blood during menstruation, privacy to change the materials, and access to facilities to dispose of used menstrual management materials (UNICEF, 2019). It can also include the "broader systematic factors that link menstruation with health, wellbeing, gender equality, education, equity, empowerment, and rights" (UNICEF, 2019). Menstrual hygiene management can be predominantly challenging for girls and women in developing countries, where access to clean water and toilet facilities are lacking. According to a sustainability study undertaken by UNICEF in 2012, 35% of WASH facilities in schools were not functional.

Menstruation can be a barrier to education for many girls, as lack of effective sanitary products restricts girls' involvement in educational and social activities. Girls and women frequently lack the water, toilets, and disposal mechanisms to manage their menstruation at school, at home, at work, and in other public institutions such as healthcare facilities or government buildings. In some cases, it can be barrier to school attendance, causing girls to miss out on their education (World Vision International, 2016). Inadequate water supply and sanitation facilities deter schoolgirls if they cannot wash or change in privacy (WATERAID, 2009). Poor menstrual hygiene can lead to urinary or reproductive tract infections and affect the well-being of students.

Knowledge about menstruation and menstrual hygiene is critical to the dignity and well-being of girls and women in general (UNICEF, 2008). Accurate knowledge and hygienic practices during menstruation has impact on multiple areas across the sustainable development goals including health, education, gender equality, and water and sanitation.

Menstruation has been surrounded by misperceptions and taboos in society causing reluctance to talk about it (WHO, 2022; Thakre et al., 2011; WASH United, 2017).

Because of the significance of Menstrual Hygiene, May 28 is celebrated globally as the Menstrual Hygiene Day (MHD) to highlight the importance of good menstrual hygiene management (MHM) at a global level (Amme, 2015). MHD was initiated with the aim to break the taboos and end the stigma surrounding menstruation, raise awareness about the challenges regarding access to menstruation products, education about menstruation and period friendly sanitation facilities. Menstrual hygiene day is meant to serve as a platform to bring together individuals, organizations, social businesses and the media to create a united and strong voice for women and girls. It was designed to break the silence about menstrual hygiene management (Bosco, 2014).

Many adolescent girls and women of menstruating age live in poor socio-economic environments. 663 million people lack basic access to safe water, and 2.4 billion people lack adequate access to basic sanitary conditions (Bosco, 2014; Cheizom and Choden, 2014).

With the adoption of the Sustainable Development Goals (SDGs) in 2015, MHM as part of the broader topic of WASH in Schools (WinS) plays a role for the achievement of several of the declared goals. MHM is implicitly addressed in SDGs 4 and 6, as well as being an essential element for the attainment of several other goals, including SDG3 (health and well-being) and SDG5 (gender equality). Furthermore, MHM can contribute to the achievement of two out of the three goals of the Global Partnership for Education strategy, specifically Goal 1 on improved and more equitable learning outcomes, and Goal 2 on increased equity, gender equality, and inclusion. Experts agree that the education sector has a lead role to play in promoting non-discriminatory gender roles as well as inter-sectoral collaboration with the health sector (reproductive health) and the water sector, to make access to MHM a universal service available for all girls (Garba et al., 2018).

Despite its significance, there is a lack of comprehensive research on the assessment of MHM in girls' schools and other secondary schools with mixed gender settings particularly in the northern part of the country. This research aims to address this gap by conducting a thorough assessment of MHM practices in some secondary schools within Kaduna South LGA, identifying challenges and gaps, and proposing evidence-based interventions for improvement.

1.1 Case Study Areas and Location

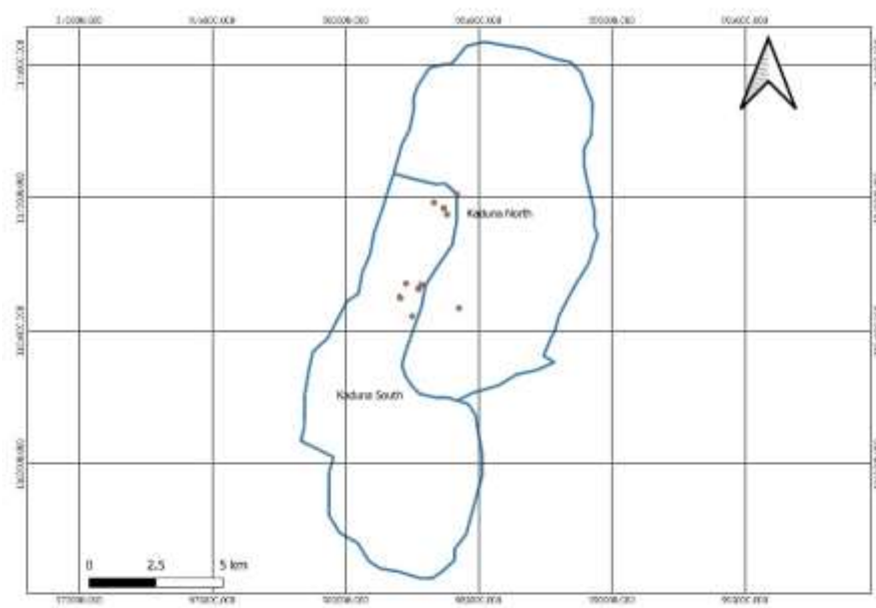


Figure 1: Map showing the location of the case study area

This study was conducted amongst eleven (11) Secondary Schools in different locations as presented in the table 1.1. The school types cut across Government and Private owned. For the Gender Settings, nine out of the eleven schools are mixed gender (with both male and female students), while only two schools have single gender (with female students only).

Table 1.0 School Assessed and their locations

S/N	School Name	Type	Gender Setting	Location	Coordinate
1	Haseeb Achiever’s Academy	Private	Mixed (M & F)	Sabon Garin / Tudun Wada	N10^{0}30’48” E7^{0}24’20”
2	Government Girls Secondary School Tudun Nupawa	Government	Female only	Tudun Nupawa	N10^{0}30’57” E7^{0}25’18”
3	Government Secondary School Kurmin Mashi	Government	Female only	Kurmin Mashi	N10^{0}33’6” E7^{0}24’49”
4	Yombe Schools	Private	Mixed (M & F)	Kurmin Mashi	N10^{0}33’16” E7^{0}25’17”
5	T&T Schools	Private	Mixed (M & F)	Kurmin Mashi	N10^{0}32’51” E7^{0}25’5”
6	Prime Rose Academy	Private	Mixed (M & F)	Kurmin Mashi	N10^{0}32’59” E7^{0}25’1”
7	MBS Science Academy	Private	Mixed (M & F)	Kurmin Mashi	N10^{0}31’11” E7^{0}24’5”
8	Al-Athariyya Home School	Private	Mixed (M & F)	Sabon Gari / Tudun Wada	N10^{0}31’10” E7^{0}24’6”
9	Arewa Model School	Private	Mixed (M & F)	Unguwan Sunusi	N10^{0}31’28” E7^{0}24’13”
10	Cleverland Academy	Private	Mixed (M & F)	Kurmin Mashi	N10^{0}31’21” E7^{0}24’28”
11	Government Secondary School Maimuna Gwarzo	Government	Female only	Tudun Wada	N10^{0}31’26” E7^{0}24’32”

2.0 RESEARCH METHODOLOGY

2.1 Study Design & Settings:
A mixed-methods approach was employed, combining quantitative surveys and qualitative interviews. For the Gender Setting, nine out of the eleven schools are mixed gender (with both male and female students), while only two schools have single gender (with female students only). The selected locations were was chosen purposively. Questionnaires were administered in each school visited and assessment of WASH facilities carried out, pictures were taken of the existing facilities. Facilities assessed include water supply sources, toilets, washrooms / changing rooms. The data collection was carried out for 5 days in the first week of August, 2023.

2.2 Sample Selection and strategy:
Secondary Schools in some areas of Kaduna South LGA were purposively selected. A representative sample of students, teachers, and school administrators were included among those responded to the questionnaires.

2.3 Data Collection:

a. **Quantitative**: Structured survey questionnaires were administered to collect information on menstrual hygiene practices, access to water and sanitation facilities and products, and educational outcomes. Data was analyzed using appropriate statistical methods.
b. **Qualitative**: In-depth interviews and focus group discussions were also conducted to gather insights into perceptions, attitudes, and experiences related to MHM. A series of observations were made and photographs taken to analyze the existing infrastructures and facilities, both in the public and in the private Schools. A literature review was also conducted, focusing on the perceptions linked to menstruation and their impact on the living conditions of school girls in the region. Thematic analysis was used to analyze qualitative data.

2.4 Ethical Considerations:

Informed consent was obtained from participants, ensuring confidentiality and privacy. Anonymity was maintained in responding to the questionnaires. Ethical guidelines was followed throughout the research process.

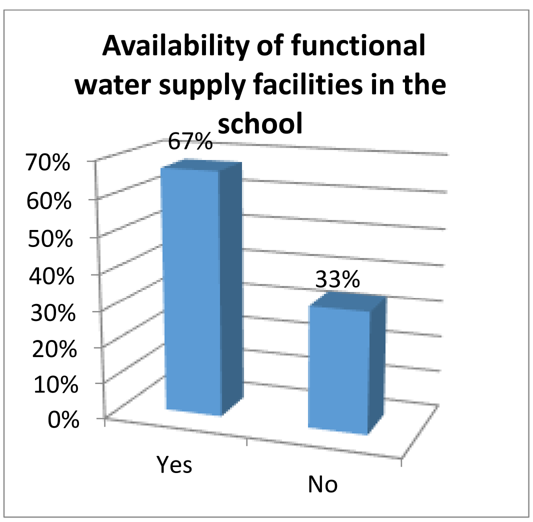
2.5 Data Analysis:

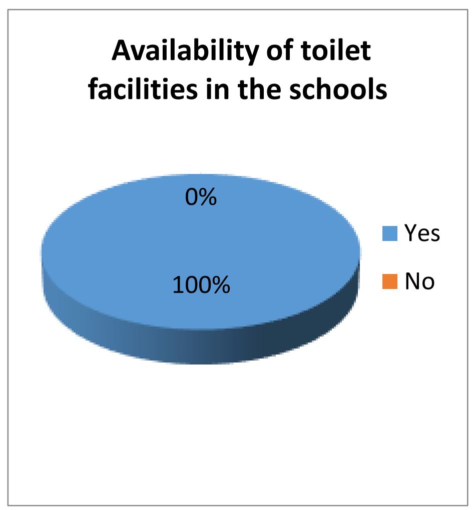
All quantitative data were coded and typed into a word file. The quantitative data was initially entered in Microsoft Excel and later analyzed using the SPSS Statistics. Various quantitative as well as qualitative analyses of the questionnaires have been performed, aimed at gaining through knowledge and understanding of the data. Descriptive statistics of frequencies, percentages, mean and standard deviation were used to describe the study population with relevant variables.

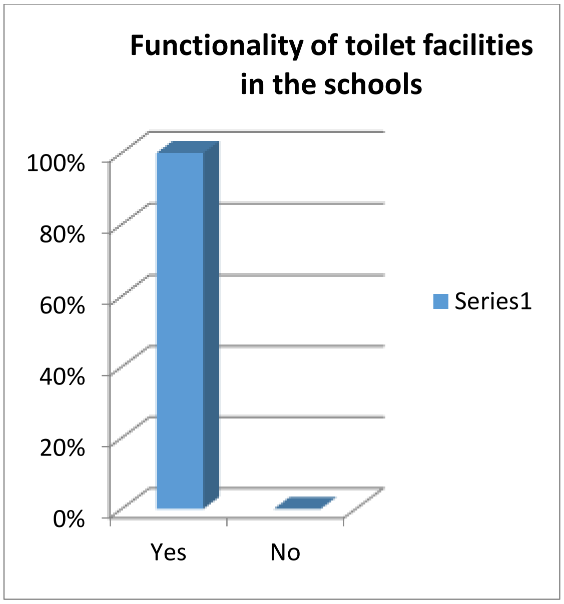
Quantitative and qualitative data were analyzed separately and integrated to provide a comprehensive understanding of MHM in the targeted schools.

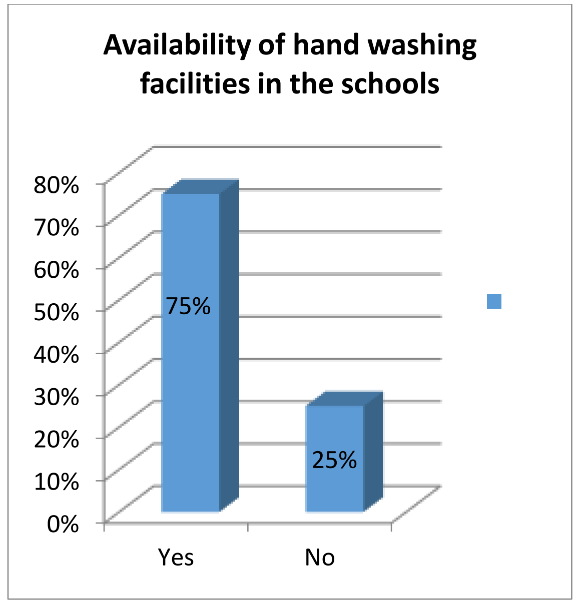
3.0 RESULTS

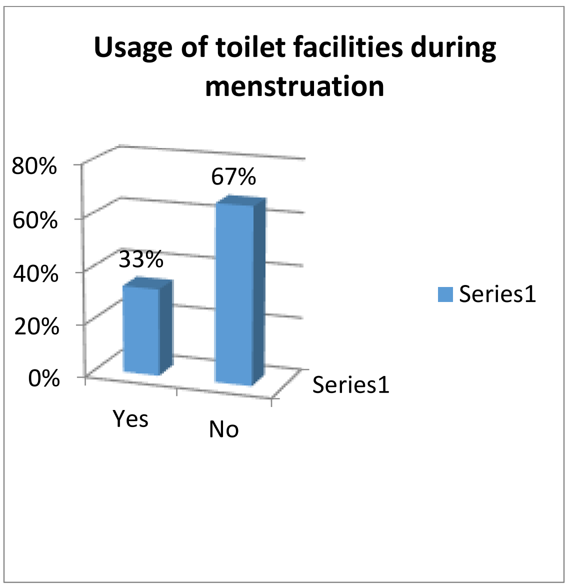
From the survey conducted, it was revealed that majority (67%) of the schools assessed have availability of functional water supply facilities in their schools. Also, it was revealed that all (100%) of the schools have functional toilet facilities. Hand washing facilities are available in majority (75%) of the schools. Responses from the survey revealed that the majority (67%) of students do not make use of the toilet facilities in the schools during their monthly menstrual periods. The reason being that majority (90%) of them are not comfortable using the available toilet facilities. It was revealed that majority (67%) of the schools have included of Menstrual Hygiene Education in the School's Curriculum, while only few (10%) of the schools have extracurricular activities in menstrual Hygiene promotion. Majority (76%) of the respondents attend school during their period and they do not miss classes. This revealed that majorly (67%) menstruation period does not affect their academic performance.

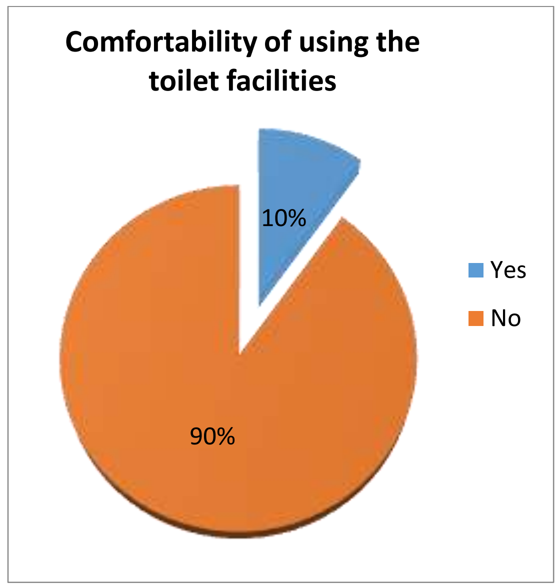


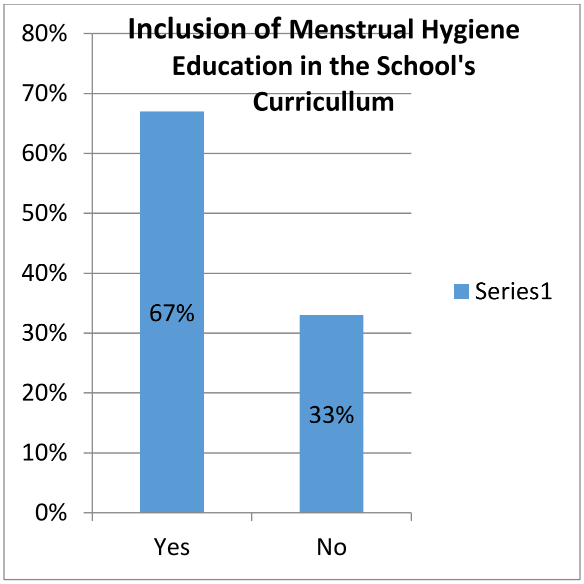


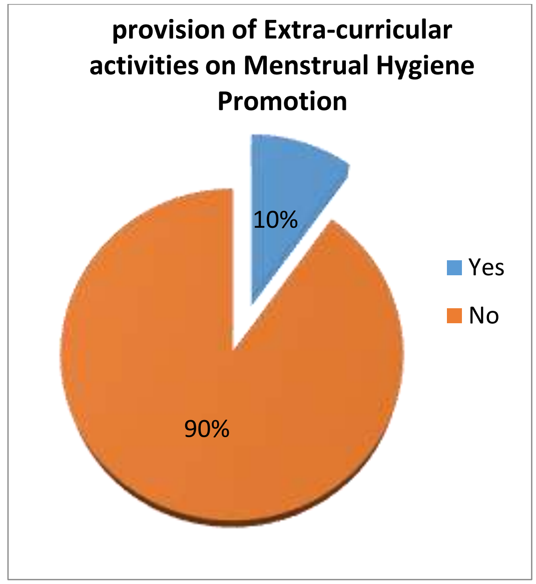

Functionality of toilet facilities in the schools
100%
80%
60%
40%
20%
0%
Yes
No
Series1


Availability of hand washing facilities in the schools
80%
70%
60%
50%
40%
30%
20%
10%
0%
75%
25%
Yes
No


Usage of toilet facilities during menstruation
80%
60%
40%
20%
0%
33%
67%
Yes
No
Series1
Series1


Comfortability of using the toilet facilities
10%
90%
Yes
No



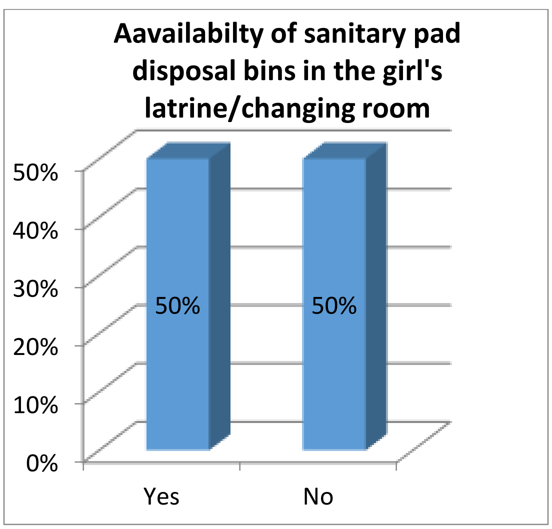


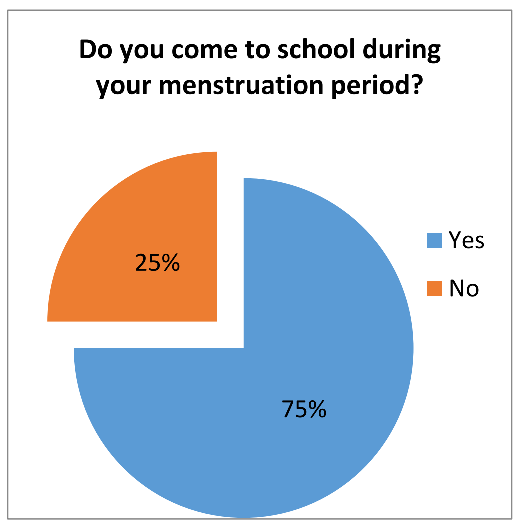
9. During menstruation, is there a separate room/place in the school for changing disposable pad/cloth?		
	Yes	No
	0%	100%

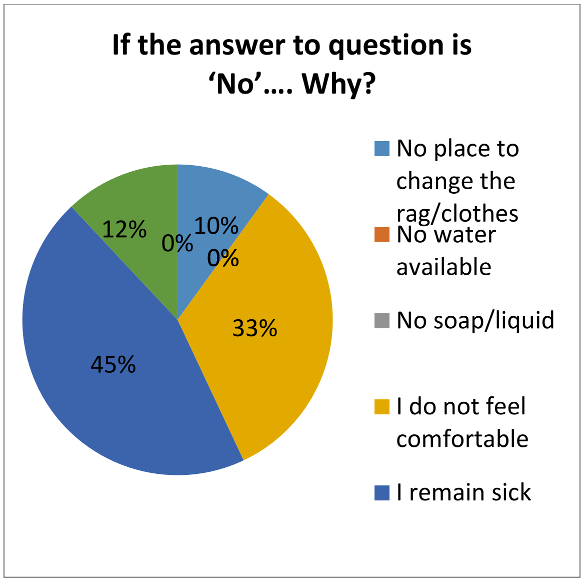
10. Is the changing room/place safe to use?	
Yes	No
0%	0%

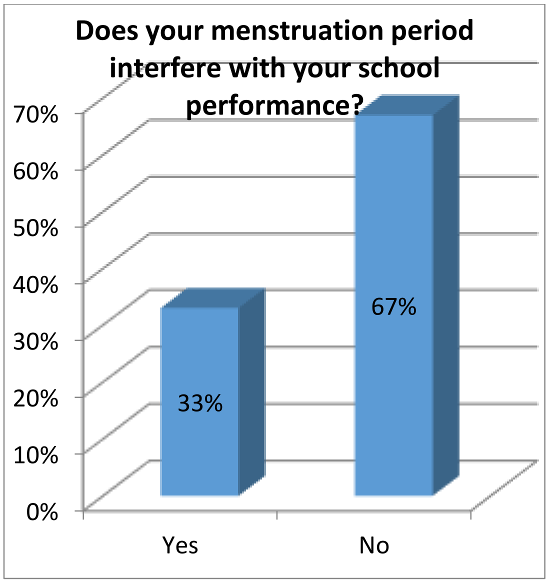
11. Is there privacy in using the hanging room/place?	
Yes	No
0%	0%

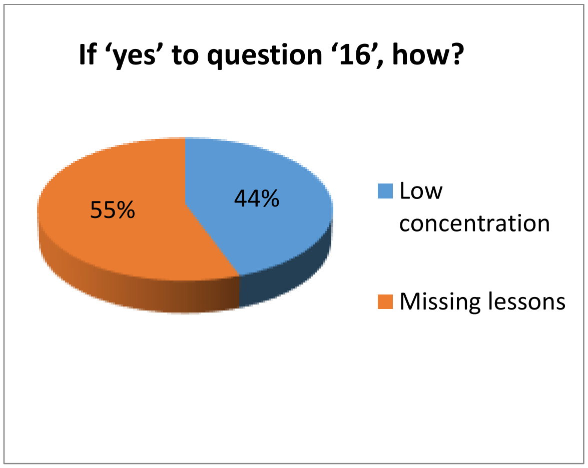
12. Is the changing room/place clean?	
Yes	No
0%	0%

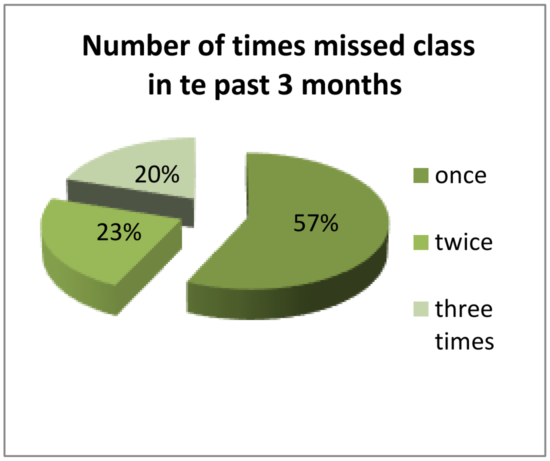












4.0 DISCUSSIONS

From the interaction and discussions with the schools, it was observed that most of the students are aware of menstrual hygiene but have little awareness on menstrual hygiene management, hence the need for more awareness on MHM. For those already aware, most of them learnt their menstrual hygiene management from Home Economics, Basic Sciences, Health Education, while some of the students learnt from the lectures given during Gender Base Assembly or Guidance & Counselling or Religious body lectures or a group called the Adolescent Girls Initiative for Learning and Empowerment (AGILE). AGILE is a World Bank assisted project of the Federal Ministry of Education, geared at improving secondary education opportunities for adolescent girls aged between 10 and 20.

While the private schools were more up and doing in the sense that they provide polybags for proper disposal of used sanitary pads, dustbins into changing rooms/toilets, and as far as even providing pads for the girls with pain reliever pills when necessary; the public schools on the other hand are a huge step behind in the sense that some of them don't have proper and adequate water supply systems, the toilets are not properly maintained and are inadequate, no disposal bins for used pads in the toilets/changing rooms except the general waste dump. Also, the students either bring nylon bags from home or buy from the school shop and some students even have no idea how to dispose the pads in school because they hardly change in school, and even if the need arose, they are asked to go to a nearby student's house close to the school to do so. There are no provisions for sanitary pads, not aware of Education, Health and care (EHC) or extra curriculum activity except for the AGILE

5.0 CONCLUSION

This detailed assessment of MHM practices in the schools, highlighted weaknesses, and gaps. The study brings evidence that MHM activities are lesser prioritized in the schools assessed. It also identified the kind of challenges faced by girls in managing menstruation and their impact on educational outcomes. It also gives an understanding into the knowledge, attitudes, and perceptions of students, teachers, and school administrators regarding MHM.

6.0 RECOMMENDATIONS

By addressing the identified challenges, policymakers, educators, and stakeholders can contribute to creating supportive environments that promote the health, well-being, and educational opportunities for adolescent girls. The following recommendations were put forward by the researchers.

1. Sensitization of schools on the importance of menstrual hygiene management so that all schools will be aware and can be carried along.
2. Encouraging the inclusion and making compulsory of home economics, basic science for all students in school curriculums so that all schools will be on the same page, and even boys will be taking the class so that they can have an idea how to handle their spouses and daughters in the future.
3. Advocate the provision of adequate and functional WASH facilities such as water supply systems, toilets, hand washing stations, changing rooms, waste disposal systems etc. so as to promote proper hygiene and sanitation during menstruation.
4. Sensitization on the importance of having EHC in schools, emphasizing the importance and encouraging the schools with EHC to share their experiences, and commending them.
5. Creating a WASH team to check the schools to ensure that menstrual hygiene management are being practiced.

REFERENCES

Amme, G. (2015). "Uganda Celebrates Menstrual Hygiene Day" (http://ugandaradionetwork.com/a/story.php?s=74142). Uganda Radio Network. Retrieved 2023-08-28.

Bosco, I. (2014). "E. Equatoria Marks Global Menstrual Hygiene Day" (http://search.ebscohost.com/login.aspx?direct=true&db=nfh&AN=2W62674349549&site= ehost-live). Sudan Tribune. Retrieved 29 June 2015 – via Newspaper Source.

Cheizom, P. and Choden, T. (2014). Role of Rural Women in Sanitation and Hygiene: A Gender Study from Bhutan. Bhutan. Bhutan: Ministry of Health and SNV (2014).

Garba, I. Rabiu, A. and Abubakar, I. S. (2018). Menstrual hygiene among adolescent school girls in Kano. *Tropical Journal of Obstetrics and Gynaecology*, 35(2), 153–157.

Thakre, S. B., Thakre, S. S., Reddy, M., Rathi, N., Pathak, K. and Ughade, S. (2011) Menstrual hygiene: Knowledge and practice among adolescent school girls of Saoner, Nagpur District. *J Clin Diagnostic Res.*, 5, 1027–33. Available online at: https://www.ircwash.org/sites/default/files/Thakre-2011-Menstrual.pdf.

UNICEF (2019). Guidance on Menstrual Health and Hygiene, UNICEF, New York, USA.

UNICEF. (2008). Sharing Simple Facts: Useful Information about Menstrual Health and Hygiene. New Delhi, India: UNICEF India; 2008.

WASH United (2017). InfographicMHM and SDGs. Available online: http://menstrualhygieneday.org/wp-content/uploads/2016/05/MHD_infographic_MHM-SDGs.pdf

WATERAID (2009). Is Menstrual Hygiene and Management an Issue for Adolescent School Girls? A Comparative Study of FourSchools in Different Settings of Nepal, Nepal, WaterAid.

World Vision International (2016). Menstrual Hygiene Management. Available online: https://www.wvcentral.org/community/wash/Pages/Menstrual-Hygiene-Management.aspx

WHO. (2022). 27 May 2022 | News release | https://www.who.int/europe

Paper 21

Assessment of Water, Sanitation, and Hygiene (WASH) Practices in some Higher Institutions within Kaduna, in the post Covid-19 Era

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ABSTRACT: The COVID-19 pandemic has emphasized the critical importance of effective Water, Sanitation, and Hygiene (WASH) practices in preventing the spread of infectious diseases. This study presents a comprehensive assessment conducted to evaluate the status and impact of WASH practices after the COVID-19 pandemic. This study aimed to understand the changes in WASH practices, identify challenges faced, and explore opportunities for improvement. It employed a mixed-methods approach, combining quantitative surveys, qualitative interviews, and observational studies to gather comprehensive data from diverse populations and settings in some institutions within Kaduna. The institutions assessed include, College of Forestry Mechanization Afaka, Nigerian Defense Academy (NDA), National Water Resources Institute (NWRI), College of Agriculture and Animal Sciences and Airforce Institute of Technology (AFIT). Key findings revealed both positive and negative impacts on WASH practices in the post-COVID-19 period. Improved hand hygiene practices were observed from some individuals, including increased frequency and duration of hand washing, and the widespread use of hand sanitizers at some institutions. These positive changes were attributed to heightened awareness of personal hygiene and public health education initiatives during the pandemic. However, challenges were identified in certain areas. Access to clean water and sanitation facilities remained inadequate, exacerbating the risk of infectious diseases. Behavioral changes were also observed to be variable, with some individuals reverting to previous habits especially the periods after the pandemic restrictions were lifted. The assessment also highlighted opportunities for enhancing WASH practices in the post-COVID-19 era. Strengthening public-private partnerships and community engagement initiatives were identified as essential strategies to promote behavior change and sustain improved WASH practices over time. In conclusion, the assessment of WASH practices after the COVID-19 pandemic highlighted the need and importance of continued investment in infrastructure, education, awareness and behavior change interventions. Sustaining positive changes in hand hygiene practices while addressing existing challenges and disparities is crucial for long-term public health outcomes. By leveraging opportunities for innovation and collaboration, stakeholders can foster resilient WASH systems that are better prepared to handle future health crises.

Keywords: COVID-19, WASH practices, hand hygiene, water and sanitation, public health

1.0 INTRODUCTION

The global COVID-19 pandemic that emerged in late 2019 has posed an unprecedented challenge to public health systems worldwide, bringing to the forefront the critical importance of Water, Sanitation, and Hygiene (WASH) practices. As the pandemic unfolded, societies have to cope with the tough realities of the highly contagious virus that could be mitigated somehow, through diligent attention to WASH practices. Handwashing, clean water access, and sanitation became not only individual responsibilities but global imperatives to curtail further spread of the virus. Handwashing with soap (HWWS) has actually been suggested by the World Health Organization as the most effective and low-cost strategy to prevent coronavirus 2 (SARS CoV-2) transmission (WHO, 2020).

Hand hygiene is defined as the behavior of cleaning the hands with soap and water and by hand-rubbing using hand sanitizer without water (Assefa et al., 2021). Hand washing is an inexpensive and effective way to prevent infection and control disease (Team, 2020). According to studies, hand hygiene was established as one of the essential measures to curtail the transmission of the disease (Team, 2020; Odusanya et al., 2020). A recent study reported that hand hygiene together with other protective measures such as wearing mask and avoiding the crowd also known as social distancing have also contributed to the decrease in other respiratory infections during COVID-19 pandemic (WHO, 2020; Chiu et al., 2022). Research is clear that proper hand hygiene is the key to reducing the occurrence of Coronavirus in many different types of communities, including healthcare settings, daycare centers, and grade schools (Aiello et al., 2008; Peters et al., 2020). Poor hand hygiene was significantly linked to a higher incidence of the Covid-19 virus (Peter et al., 2016).

In 2010 the United Nations General Assembly explicitly recognized water and sanitation as human rights that are "essential for the full enjoyment of life and all human rights". Addressing the sanitation and hygiene infrastructure deficit and improving the quality of public services has been an important component of SDG 6: Ensure Availability and Sustainable Management of Water and Sanitation for all (McMicheal and Robinson, 2016). Other Water, Sanitation and Hygiene (WASH) related studies have shown that this social norm is an important factor that can trigger and sustain behaviour change (McMicheal and Robinson, 2016; Olukanni, 2013) and thus this factor should also be incorporated into post-pandemic WASH planning.

Global access to water, sanitation, and hygiene (WASH) services plays a vital role in protecting the health and wellbeing of individuals and society (Olukanni and Okorie, 2015; Paolo et al., 2001). As it is clearly defined, Water is one of the precious natural resources and an integral part of our lives. It is the most immediate and critical limiting factor for the well-being of humans and the environment (Mara et al., 2010). Sanitation refers to the hygienic means of protecting human contact from the dangers of waste to promote good health. Sanitation includes the provision of facilities and services for the safe disposal of waste. Hygiene refers to good practices that prevent disease and lead to good health, especially in terms of cleanliness, proper disposal of wastewater, and supply of clean drinking water (Aiello et al., 2008; Olukanni et al., 2020). A meta-analysis of 30 hand hygiene studies found that improvements in hand washing decreased the prevalence of gastrointestinal diseases by 31% and upper respiratory tract infections by 21% (Aiello et al., 2008). It also mentions that in sub-Saharan Africa, where sanitation and hygiene habits are poor, washing hands with soap might cut the incidence of infectious diseases by 52%, and hand washing promotion has been projected to save many lives (Gastaldi et al., 2021; Seid et al., 2022).

In the wake of the pandemic, it has become crucial to evaluate and improve WASH practices to prevent the spread of the diseases and ensure public health. Evidence from previous studies (Walker et al., 2014; Obeta et al., 2021) has shown hand hygiene to be an important measure in the prevention of COVID-19 transmission, but there is a deficiency of data on the practice of hand hygiene in higher institutions of learning that serves as the seat of intellectuals, who are expected to comply with hygiene practices (Adesina et al., 2023). A study conducted in a South-western state of Nigeria, revealed that respondents had good knowledge of hand hygiene, but less practice (Wada and Oloruntoba, 2021). A study conducted in Sri Lanka on knowledge, attitude and practice of hand hygiene showed that majority were seen to have poor hand hygiene practices (Kudavidnange et al., 2015). The findings from a study conducted in a higher institution in South-west Nigeria revealed that knowledge of hand hygiene as a preventive strategy for COVID-19 does not translate to practice (Oyeyemi et al., 2020; Adesina et al., 2023). These findings are correspond with some finding from other studies that observed the most typical obstacles to hand hygiene, including: lack of soaps, antiseptics, detergents, and alcohol sanitizers, lack of running water, and negligence (Nuwagaba et al., 2021; Al-Naggar and Al-Jashamy, 2013). Furthermore, the benefits of hand hygiene happen to prevent many infectious diseases including gastrointestinal illnesses, trachoma and soil helminth infection, as well as respiratory infection (Aiello et al., 2008; Bartram and Cairncross, 2012; Pruss et al., 2002).

As we now find ourselves in the post-COVID-19 era, the lessons learned from the pandemic must serve as a catalyst for comprehensive reassessment and advancement of WASH practices. Therefore, assessing WASH practices in the post-COVID-19 era in some selected higher institutions in Kaduna in North-West Nigeria, has become crucial to evaluate and improve these practices in order to prevent the spread of the virus and ensure public health. However, intentional campaign in higher institutions as a tool is necessary to improve hand hygiene promotion or programming aiming for sustained behaviour change for better prevention and management in case of any possible disease outbreaks in the future. Overall, a thorough assessment of water, sanitation, and hygiene practices post COVID-19 requires collecting data, conducting surveys, engaging with communities, and collaborating with relevant stakeholders to identify areas that need improvement and develop targeted interventions. This research paper before you seeks to address this imperative by trying to understand the changes in WASH practices, identify challenges faced, and explore opportunities for improvement.

1.1 Case Study Areas and Locations

Table 1 Case Study Areas (Higher Institutions) Description and Location

S/N	Institution	Affiliations (MDA)	Location	Coordinate
1	Federal College of Forestry Mechanization	Forestry Research Institute of Nigeria (FRIN)	Afaka, Igabi LGA, Kaduna	N10^{0}36.480'E0 7^{0}26.326'
2	Nigerian Defense Academy (NDA)	Nigerian Army	Afaka, Igabi LGA, Kaduna	N10^{0}35.349'E0 7^{0}21.971'
3	National Water Resources Institute (NWRI)	Federal Ministry of water Resources	Mando Road, Kaduna North LGA, Kaduna	N10.58454^{0}E0 7.420343^0
4	College of Agriculture and Animal Sciences	Ahmadu Bello University (ABU), Division of Agricultural Colleges	Mando Road, Kaduna North LGA, Kaduna	N10.58617^{0}E0 7.423981^0
5	Air Force Institute of Technology (AFIT)	Nigerian Air Force Base, Kaduna	NAF Base, Kawo, Kaduna	N10.608085^0 E07.438793^0

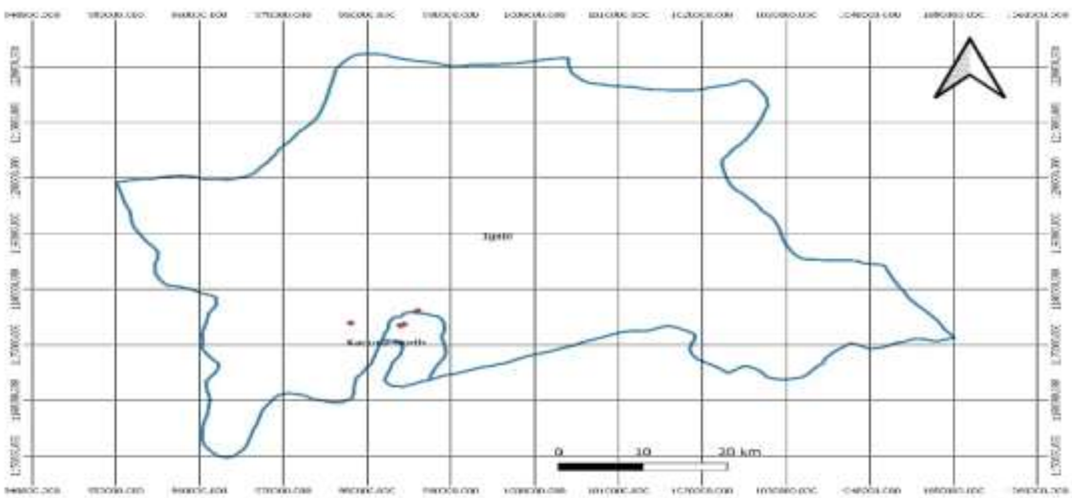


Figure 1: Map showing the location of the case study areas

The institutions assessed include, Federal College of Forestry Mechanization Afaka, Nigerian Defense Academy (NDA), National Water Resources Institute (NWRI), College of Agriculture and Animal Sciences and Air Force Institute of Technology (AFIT) all located in Kaduna State in Nigeria. The institutions types / settings are all Federal Government higher institutions of learning, providing higher education and awarding advanced Certificates in National Diploma (ND), Higher National Diploma (HND), Postgraduate Diploma (PGD), Bachelors (BSc.) and Masters (MSc.) Degrees in Kaduna State, Nigeria. All the institutions are located at the same axes not far away from each other see Table 1 and Figure 1.

2.0 RESEARCH METHODOLOGY

2.1 Study Design & Settings:
The researchers employed a mixed-methods approach, integrating quantitative and qualitative data collection methods to obtain a comprehensive understanding of WASH practices. The approach involves quantitative surveys, qualitative interviews, and observational studies to gather comprehensive data from diverse populations of staff and students randomly selected in those higher institutions. The selected locations were was chosen purposively. Questionnaires

were administered in each institution visited and assessment of WASH facilities carried out, pictures were taken of the existing facilities. Facilities assessed include water supply sources, water storages, Handwashing points/stations, etc. The data collection was carried out for 4 days in the month of August, 2023.

2.2 Data Collection:

i. Quantitative surveys: Structured questionnaires were administered to a representative sample of staff and students of the institutions to gather information on WASH behaviors, attitudes and experiences, including hand hygiene practices, water source accessibility, sanitation facilities, and waste management.

ii. Qualitative interviews: In-depth interviews and focus group discussions were conducted with key stakeholders, including student community members, staff and other workers from the institutions to explore perceptions, challenges, and opportunities related to WASH practices.

iii. Direct observations: Observational studies were conducted to assess hand hygiene compliance, sanitation infrastructure conditions, and water sources at selected locations. A series of observations were made and photographs taken to analyze the existing condition of WASH infrastructures and facilities,

2.3 Ethical Considerations:
Ethical approval was obtained from the relevant authorities of the institutions prior to the start of the study and before data collection. Informed consent was obtained from all participants, as participants were informed of the nature of the study and the data was anonymized and stored securely to ensure confidentiality.

2.4 Data Analysis:

All quantitative data were coded and typed into a word file. The quantitative data was initially entered in Microsoft Excel and later analyzed using the SPSS Statistics. Various quantitative as well as qualitative analyses of the questionnaires have been performed, aimed at gaining through knowledge and understanding of the data. Descriptive statistics of frequencies, percentages, mean and standard deviation were used to describe the study population with relevant variables. Quantitative data was analyzed using statistical techniques such as descriptive statistics to examine patterns and associations between variables. Qualitative data was thematically analyzed to identify the barriers and opportunities related to WASH practice

3.0 RESULTS

From the survey conducted, it was revealed that majority (86%) of the higher institutions assessed do have functional water supply facilities. In more than half (55%) of the institutions, there are handwashing points/stations available and majority (59%) of them are not functional as 61% of them do not have Liquid Soap and Sanitizers available. It was obvious from the researchers observations there has been a decline in the availability of the handwashing points currently after the COVID period as compared to the time of COVID. During the COVID, every faculty, department and units of those institutions have a handwashing point and every building have hand sanitizers available. But presently, as the years gone by, most of those handwashing facilities are nowhere to be found in most of the buildings of the institutions (Plates 1,2,3,4 and 5).

With regards to hygiene practices especially handwashing, more than half (55%) of the respondents still practice handwashing hygiene but not as frequently, compared to the time of COVID, where majority (93%) of the population did. This revealed a drastic decline in the observation of hand hygiene practices and behaviours in the various institutions. To find out the reason for the decline, majority (63%) of the respondents admitted to not facing any challenge limiting them from observing hand washing Hygiene practices. From interactions and discussions of the researchers' interviews with the respondents, few of them feel that since they perform ablution when observing their prayers, they don't see any need to wash their hands again. This is an issue of attitude and individual behaviours towards the WASH practices. But majority (89%) feel that there is need for individuals to adopt the habit, and continue the practice of hand washing Hygiene in an ideal situation. (Figure 2, 3, and 4).

Besides the handwashing hygiene practices, the COVID-19 protocols are not observed any longer, as revealed by majority (74%) of the respondents and there is no continuous awareness on COVID or hand washing hygiene promotion in their various institutions, as expressed by majority (74%) of the participants in the survey. But higher percentage (93%) do think that the campaigns and awareness on hand washing hygiene promotion should continue to minimize the widespread of future diseases (Figures 5 and 6).

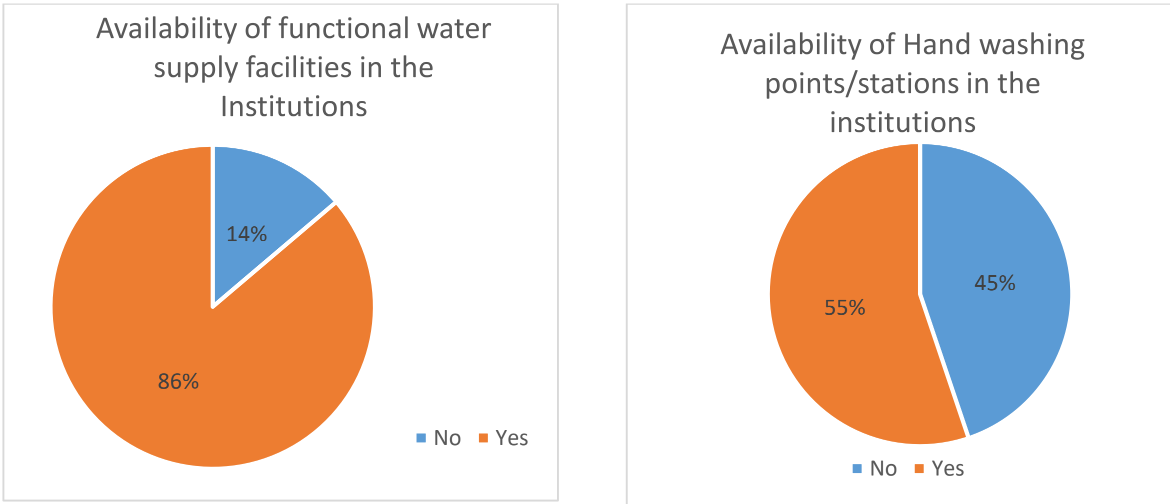


Figure 2: Showing Summary of availability of water supply and Handwashing Points/stations

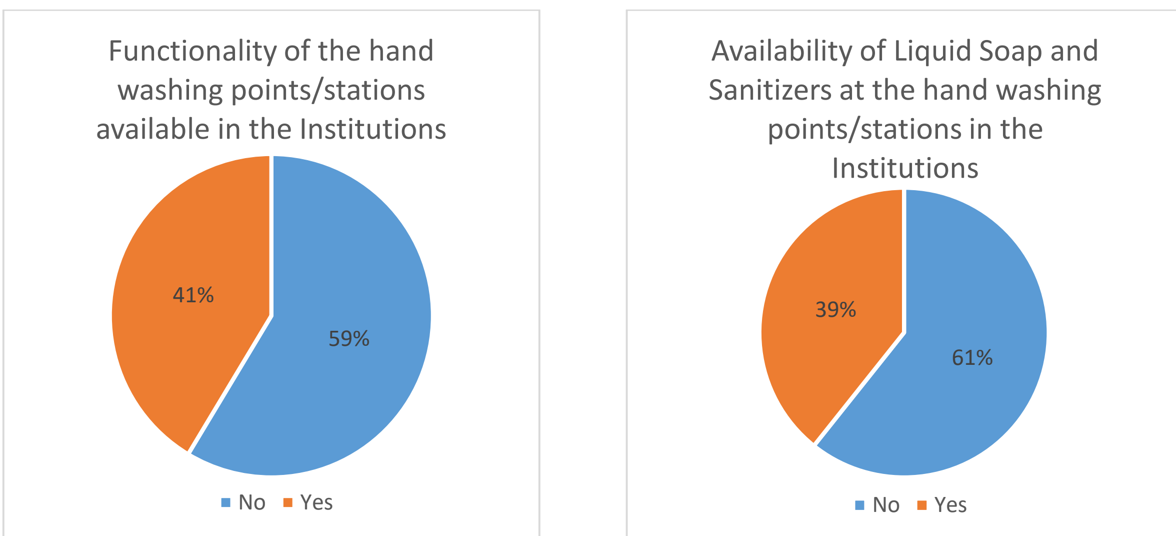


Figure 3: Showing Summary of functionality of Handwashing Points/stations and availability of Liquid Soap and Sanitizers

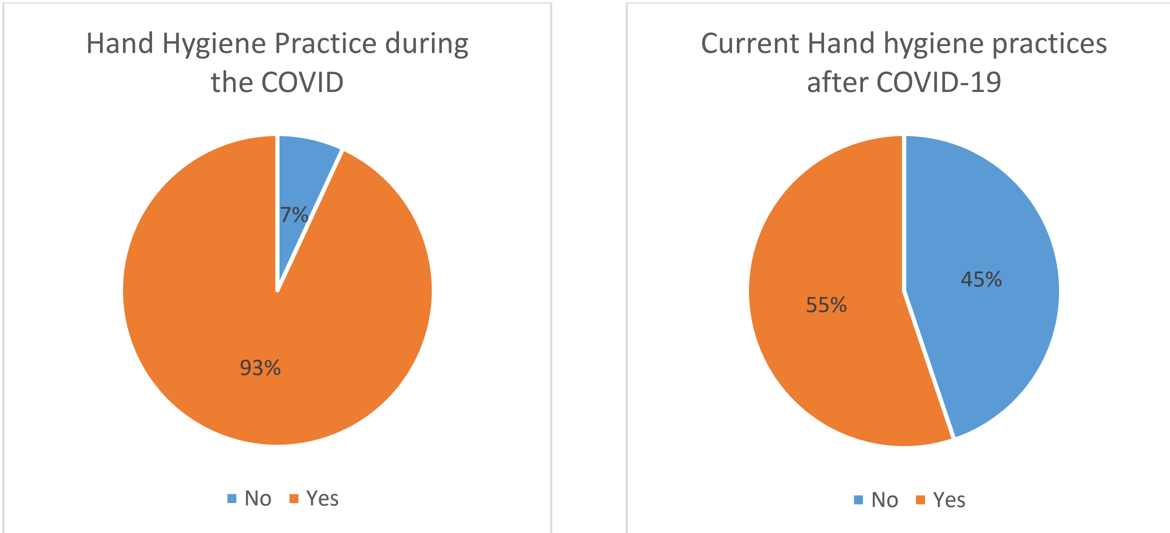


Figure 4: Showing Summary of Hand Hygiene Practices and behaviours during and after Covid-19

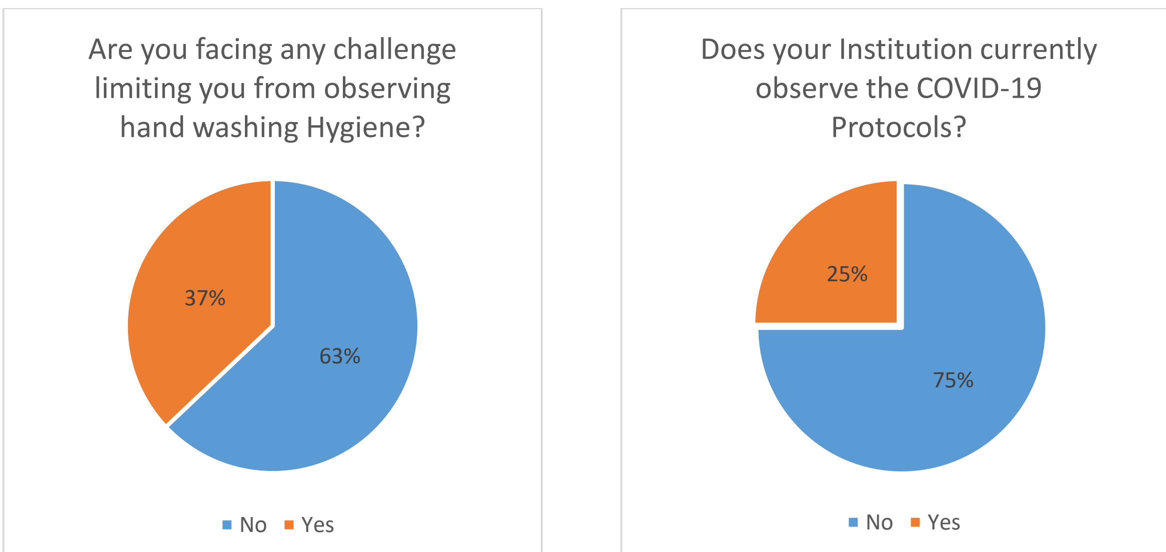
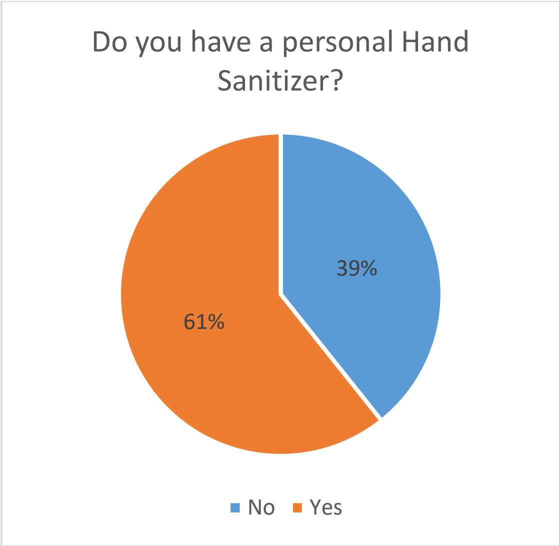


Figure 5: Showing Summary of Hand Hygiene Practices and behaviours during and after focusing on personal and institutional limitations post Covid-19



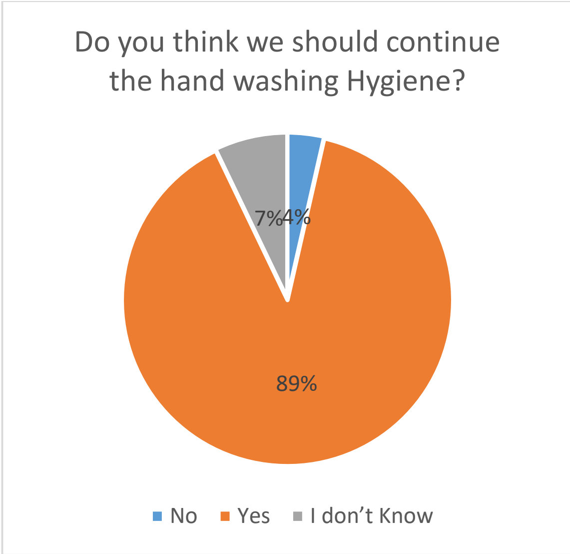
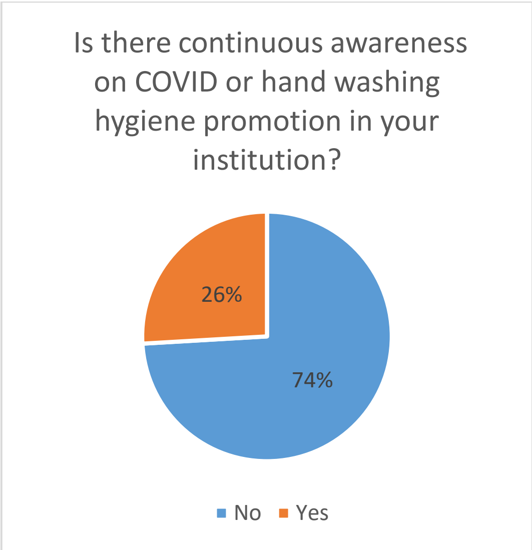


Figure 6: Showing Summary of Hand Hygiene Practices and behaviours post Covid-19



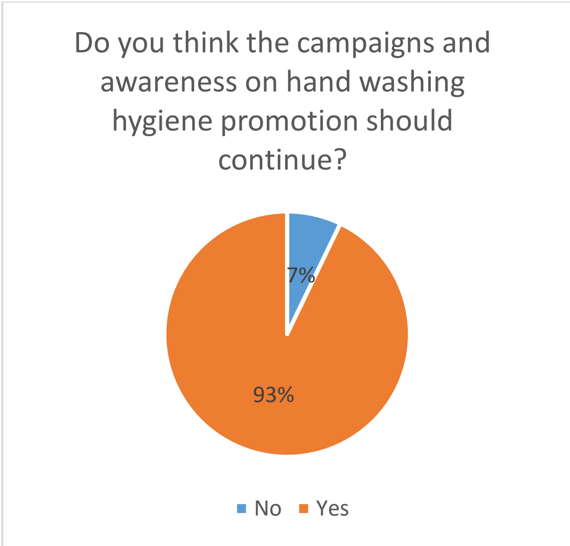


Figure 7: Showing Summary of Hand Hygiene with soap HHWS Practices promotion and campaigns post Covid-19

Plate 1: Showing some buildings at the Federal College of Forestry Mechanization Afaka with no Handwashing Point(s)/station(s)

Plate 2: Showing the entrance gate and some faculty buildings at the Nigerian Defense Academy (NDA) with no Handwashing Point (s)/station(s)

Plate 3: Showing the entrance gate of the National Water Resources Institute, Kaduna with a functional Handwashing Point(s)/station(s) but no Soap or sanitizer available

Plate 4: Showing the entrance gate of the College of Agriculture and Animal Sciences, Kaduna with a Handwashing Point(s)/station(s)

Plate 5: Showing some buildings at the Air-Force Institute of Technology, Kaduna with no Handwashing Points/stations

4.0 CONCLUSION

This detailed assessment study revealed the overall conclusion that WASH practices especially Hand Washing with Soap HWWS is declining in the post COVID era as compared to the situation during and immediately after the COVID. Also, the study highlighted issues that have to do with attitude behavior change on the negative side, towards hand hygiene practices.

In conclusion, the research study highlight on the current status and effectiveness of WASH practices especially Hand Washing with Soap HWWS after the COVID-19 pandemic. By identifying both positive changes and persistent challenges, it provides valuable insights for policymakers, organizations, and communities to develop targeted interventions and strategies for sustainable improvements in WASH practices.

5.0 RECOMMENDATIONS

1. By addressing the identified challenges, like provision of hand washing facilities with soap at strategic positions should be treated a matter of urgency in the respective institutions.
2. Policymakers, educators, and all relevant stakeholders can further contribute to creating supportive environments that promote WASH practices especially Hand washing with soap (HWWS) in our higher institutions of learning so as to help increase hand hygiene.
3. Continuous awareness and campaigns for hand hygiene promotion as well as WASH practices in general to prevent the further spread of diseases in the event of future pandemic.
4. Strengthening public-private partnerships and community engagement initiatives are essential strategies to promote behavior change and sustain improved WASH practices over time.

REFERENCES

Adesina, K.A., Afolalu, O.O., Oyekale, R.A., Afere, D.M. Hand Hygiene: major panacea for prevention of the spread of Covid-19 in a Nigerian south-western university. *Res. J. Health Sci., 11(2), June 2023*

Aiello, A. E., Coulborn, R. M., Perez, V. and Larson, E. L. (2008). Effect of hand hygiene on infectious disease risk in the community setting: a meta-analysis. *Am J Public Health*, 98(8), 1372-81.

Assefa, D., Melaku, T., Bayisa, B. and Alemu, S. (2021). Knowledge, attitude and self-reported performance and challenges of hand hygiene using alcohol-based hand sanitizers among healthcare workers during covid-19 pandemic at a tertiary hospital: A cross-sectional study. Infection and Drug Resistance. 2021, 303-313.

Al-Naggar, R. A. and Al-Jashamy, K. (2013). Perceptions and barriers of hands hygiene practice among medical science students in a medical school in Malaysia. *IIUM Medical Journal Malaysia*, 12(2), 1 – 11.

Bartram, J. and Cairncross, S. (2010). Hygiene, sanitation, and water: forgotten foundations of health. *PLoS Med.*

Chiu, N. C., Chi, H., Tai, Y. L., Peng, C. C., Tseng, C. Y. and Chen, C. C. (2022). Impact of wearing masks, hand hygiene, and social distancing on influenza, enterovirus, and all-cause pneumonia during the coronavirus pandemic: retrospective national epidemiological surveillance study. *J Med Internet Res*. 22:e21257. doi: 10.2196/21257

Gastaldi, A., Donà, D., Barbieri, E. and Giaquinto, C. (2021). *Hand Hygiene and COVID-19 prevention Adesina et al.* Bont LJ, Baraldi E. COVID-19 Lesson for Respiratory Syncytial Virus (RSV): Hygiene Works. Children, 8(12), 1144.

Kudavidnange, B. P, Gunasekara, T. and Hapuarachchi, S. (2015). Knowledge, attitudes and practices on hand hygiene among ICU staff in Anuradhapura Teaching hospital.

Mara, D., Lane, J., Scott, B. and Trouba, D. (2010). Sanitation and health. PLoS Medicine 7(11) Available at: http://www.pubmedcentral.nih.gov

McMichael, C. and Robinson, P. (2016). Drivers of sustained hygiene behaviour change: a case study from Mid-Western Nepal. *Soc Sci Med.*163, 28– 36. doi: 10.1016/j.socscimed.2016.06.051

Nuwagaba, J., Rutayisire, M., Balizzakiwa, T., Kisengula, I., Nagaddya, E. J. and Dave, D. A. (2021). The Era of Coronavirus: Knowledge, Attitude, Practices, and Barriers to Hand Hygiene among Makerere University Students and Katanga Community Residents. *Risk Management and Healthcare Policy*, 021;14:3349. 7:e1000367. doi: 10.1371/journal.pmed.1000367

Obeta, U., Matthew, G., Ejinaka, O., Oreh, A., Etukudoh, N. and Sabulu, J. (2021). Determining the Comparison of Knowledge, Attitude and Practice of Hand Hygiene among Medical Laboratory Technician and Nursing Students in Jos, Nigeria. *Emerging Trends in Disease and Health Research*, 1, 13-31.

Odusanya, O. O., Odugbemi, B. A., Odugbemi, T. O. and Ajisegiri, W. S. (2020). COVID-19: A review of the effectiveness of non-pharmacological interventions. *Nigerian Postgraduate Medical Journal*, 27(4), 261.

Olukanni, D.O. (2013). Assessment of WASH Program in Public Secondary Schools in South-Western Nigeria. *ARPN Journal of Engineering and Applied Sciences*, 8(3), 1 – 13.

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

Olukanni, D. O., Pius-Imue, B. F. and Joseph, O.S. (2020). Public Perception of Solid Waste Management Practices in Nigeria: Ogun State Experience Recycling 5(8)

Oyeyemi, O., Oladoyin, V., Okunlola, O., Mosobalaje, A., Oyeyemim, I. and Adebimpe, W. (2020). COVID-19 pandemic: Nigerians' knowledge, perception and adherence to preventive measures.

Paolo, F. R., Richard, C. R., Goldstein, R. and Smith, W. (2001). Global Water Quality, Supply, and Demand: Implications for Megacities International Seminar on Nuclear War and Planetary Emergencies 25th Session.

Peters, A., Vetter, P., Guitart, C., Lotfinejad, N. and Pittet, D. (2020). Understanding the emerging coronavirus: what it means to health security and infection prevention. *J Hosp Infect*, 104, 440-448.

Prater, K. J., Fortuna, C. A., McGill, J. L., Brandeberry, M. S., Stone, A. R. and Lu, X. (2016). Poor hand hygiene by college students linked to more occurrences of infectious diseases, medical visits, and absence from classes. *American journal of infection control*, 44(1), 66-70.

Prüss, A., Kay, D., Fewtrell, L. and Bartram, J. (2002). Estimating the burden of disease from water, sanitation, and hygiene at a global level. *Environ Health Perspect*, 110, 537–42. doi: 10.1289/ehp.110-1240845WHO

Seid, M., Yohanes, T., Goshu, Y., Jemal, K. and Siraj, M. (2022). The effect of compliance to Hand hygiene during COVID-19 on intestinal parasitic infection and intensity of soil-transmitted helminthes, among patients attending general hospital, southern Ethiopia: Observational study. *PLoS One*, 17(6), e0270378.

Team, E. (2020). The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19)—China, 2020. China CDC weekly, 2(8), 113.

UNICEF. (2016). Strategy for Water, Sanitation and Hygiene 2016–2030

Wada, O. Z. and Oloruntoba, E. O. (2021). Safe reopening of schools during COVID-19: An evaluation of handwash facilities and students' hand hygiene knowledge and practices. *European Journal of Environment and Public Health*, 2021;5(2):em0072.

Walker, J. L., Sistrunk, W. W., Higginbotham, M. A., Burks, K., Halford, L. and Goddard, L. (2014). Hospital hand hygiene compliance improves with increased monitoring and immediate feedback. *American journal of infection control*, 42(10), 1074-8.

WHO, World Health Organization. (2020) Rapid assessment of service delivery for NCDs during COVID-19 pandemic. Geneva: World Health Organization. 2020.

WHO. (2020). Water, Sanitation, Hygiene and Waste Management for the COVID 19 Virus: Interim Guidance. Geneva: World Health Organisation.

Paper 22

Revitalizing Nigeria's Safely Managed Water Supply System for Economic Growth

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ABSTRACT: The 2021 Water Supply and Sanitation Routine Mapping revealed that 87% of Nigerians cannot access Safely Managed Water Supply. This figure represents about 179 million Nigerians living in urban centers nationwide. This scenario is particularly worrisome especially when the target year of achieving SDG 6 is just seven years away from now. This paper aims to elucidate the problems of urban WASH in Nigeria and provide workable strategies for closing the identified gaps. The paper identified the problems of urban WASH in Nigeria, including but not limited to lack of autonomy due to centralization, lack of proper incentivization of the staff, diversion of investment in the sector, the unfavorable political climate in the governance of State Water Agencies (SWAs), lack of operational funds, the introduction of the so-called "Single Treasury Accounting", absence of succession planning, etc. Appropriate strategies for overcoming these challenges must be agreed upon among stakeholders to develop a workable action plan. The connection between water, sanitation, and health cannot be overemphasized; the Nigerian Governors Forum (NGF) greatly makes our Safely Managed Water Supply Systems work. The paper recommends short, medium, and long-term solutions to the lingering problems.

Keywords: Water Supply; Sustainability; Efficiency; Access; SDG

1.0 INTRODUCTION

Water, Sanitation, and Hygiene (WASH) are essential elements for human development and economic progress. Access to clean water, sanitation facilities, and good hygiene practices are vital for public health, education, and economic productivity. Despite being Africa's largest economy, Nigeria still faces significant challenges in its WASH sector. A lack of access to clean water and adequate sanitation services poses serious health risks, hampers educational attainment, and diminishes overall economic potential. This article examines the current state of Nigeria's WASH sector, identifies key challenges, and proposes strategies for revitalizing the sector to drive sustainable economic growth. The analysis draws on a comprehensive review of existing literature, official reports, and case studies from other countries that have successfully tackled similar challenges.

1.1 Access to Clean Water

Access to safe drinking water in Nigeria's WASH sector is a significant challenge. Approximately 66.3 million Nigerians lack access to safe drinking water (Ighalo and Adeniyi, 2020), spreading waterborne diseases such as cholera and typhoid. The National Water Supply and Sanitation Policy of 2000 aimed to achieve universal access to safe drinking water by 2020, but this target has not been fully realized due to a range of issues including population growth, urbanization, and underinvestment in water infrastructure. The implementation of water regulations and proper water management has not received adequate attention from the government (Nwinyi et al. (2020). Rapid urbanization strains existing water infrastructure, exacerbating the problem. While urban areas generally have better access, rural communities suffer from inadequate infrastructure and limited availability of potable water sources.

Households are investing in alternative water sources due to irregular and inadequate piped water supply. Therefore, commercially available water, particularly bottled and packaged water, is currently the best source of drinking water for the Nigerian population (Adeoti et al. 2021). The quality of surface water in the country is generally poor, and groundwater pollution is prevalent due to domestic soakaway, waste dumpsite leachate, oil and gas exploration, sewage, and hydrogeological interactions (Wada et al, (2021). Rainwater in Nigeria has a low pH but is relatively clean (Balogun et al. (2019). In a specific community, water sources mainly come from vendors, boreholes, wells, and rainwater, with various water treatment methods being used (Arowosegbe et al. 2021). Nigeria has made insufficient progress in delivering clean water to its entire population, underscoring the urgency of increased efforts towards achieving Sustainable Development Goal 6.

1.2 Sanitation and Hygiene

Sanitation remains a pressing issue in Nigeria, with open defecation rates among the highest in the world. Inadequate sanitation facilities contribute to the spread of diseases, particularly in densely populated urban slums and rural areas. Poor hygiene practices further exacerbate health challenges. The Nigerian government's efforts to promote improved sanitation practices include the launch of the "Clean Nigeria: Use the Toilet" campaign, with the ambitious goal of ending open defecation by 2025. The current state of Nigeria's WASH sector, specifically sanitation and hygiene, shows a mix of progress and challenges generally, water supply receives more attention than sanitation, and rural areas are favoured over urban areas regarding sanitation interventions (Enovwo et al. 2021). Although within rural areas, there are wider disparities between access to WASH facilities compared to urban areas (Ojima et al, 2021). In traditional birth homes/centers, poor WASH conditions and infection prevention and control practices were found, highlighting the need for improvements in these areas (Obiora, 2020). Handwashing facilities are limited, and open defecation is still practiced by a significant portion of the population (Umahi et al. 2020). There is a need for better access to safe water sources, improved sanitation facilities, and enhanced hygiene practices in Nigeria's WASH sector.

1.3 Economic Implications

The current state of the WASH sector in Nigeria has significant economic implications. Poor or absent WASH infrastructure, weak regulation and enforcement, and socio-economic factors contribute to inequality in WASH services (Akpabio and Udofia 2017). Additionally, the lack of safe water and poor hygiene behavior in Nigerian communities has far-reaching economic consequences. Waterborne diseases substantially burden the healthcare system, diverting resources that could otherwise be allocated to development initiatives (Oloruntoba et al. (2014). Increased healthcare expenditures and reduced workforce productivity due to illness directly impact economic growth. Moreover, inadequate sanitation facilities in schools contribute to absenteeism and reduced educational attainment, limiting human capital development. The inequality in access opens up space for differentiated practices and standards that align with specific interests, further exacerbating the economic impact. Furthermore, the competition for freshwater resources for domestic and agricultural use challenges the country's economy (Garuba et al 2016). The unsustainable management of water resources and the low development and supply status of water contribute to vulnerability, depletion, and degradation, affecting economic growth and development (Alade, 2019). The degradation of water quality in Nigeria's water bodies not only poses risks to public health but also hinders economic growth. In Nigeria's Niger Delta Region, and indeed across the country, the availability of good-quality water is a significant concern due to environmental pollution and degradation. This problem is further exacerbated by the fact that valuable man-hours and resources are spent travelling long distances to fetch water of doubtful quality (Ezugwu et al., 2021). To address these economic implications, institutional reforms, policy review, and integrated approaches for sustainable management of WASH are necessary (Nwankoala 2014).

2.0 CHALLENGES IN NIGERIA'S WASH SECTOR

Despite the potential for sustainable economic growth through the revitalization of Nigeria's water, sanitation, and hygiene sector, several challenges need to be addressed.

2.1 Institutional and Policy Challenges

Nigeria should strengthen its water governance framework by establishing clear policies, regulations, and accountability mechanisms (Ngene et al., 2021). Institutional fragmentation and overlapping responsibilities among government agencies have hindered effective WASH governance and policy implementation. There is a lack of accurate and up-to-date data on water resources, population growth, and water demand, which hampers effective planning and decision-making in the WASH sector. The existing institutions responsible for managing water resources and implementing water projects in Nigeria often lack the necessary capacity, expertise, and resources to respond effectively to the challenges in the water sector.

Nigeria must also address the issue of inaccurate data and poorly estimated population and costing of water facilities. Accurate and reliable data is crucial in designing and implementing effective water projects. Without accurate data, water schemes may be either over-designed or under-designed, resulting in inefficiencies and waste of resources (Jimoh and Jacob-Oricha, 2022). Therefore, it is essential for Nigeria to invest in accurate data collection and analysis to ensure that water projects are properly planned and implemented.

2.2 Infrastructure Deficit

The limited investment in water and sanitation infrastructure has resulted in inadequate facilities and limited coverage, particularly in rural areas. Nigeria faces a significant deficit in water infrastructure, with many communities lacking access to clean and safe water sources.

2.3 Funding Constraints

Limited budget allocations for WASH services, coupled with insufficient revenue collection mechanisms, have constrained the sector's growth. The funding allocated to the WASH sector in Nigeria is often insufficient to meet the growing needs and demands of the population.

2.4 Behavioral and Cultural Factors

Deeply ingrained cultural practices, lack of awareness about hygiene, and resistance to change pose challenges to adopting improved WASH practices. Many communities in Nigeria have limited knowledge on proper sanitation and hygiene practices, leading to the spread of diseases and health complications that could have been prevented with proper education and awareness.

3.0 STRATEGIES FOR REVITALIZING NIGERIA'S WASH SECTOR FOR ECONOMIC GROWTH

3.1 Policy Reforms

Implement comprehensive and coordinated policies that clarify institutional responsibilities and streamline governance mechanisms for WASH. Strengthening the capacity of institutions responsible for water management, such as the Federal Ministry of Water Resources and State Water Boards or Corporations, is crucial for effectively implementing and monitoring policies and programs in the water sector. This can be achieved through capacity-building initiatives and establishing regulatory frameworks to oversee water governance and management practices.

3.2 Infrastructure Development

It is vital for Nigeria to prioritize investment in water infrastructure, including the construction and maintenance of water treatment plants, distribution networks, and storage facilities (Ezugwu et al., 2021). This will help improve the efficiency and reliability of water supply, ensuring that adequate and safe water is available to meet the population's growing demands. Investing in water supply and sanitation infrastructure prioritizing underserved areas to ensure equitable access.

3.3 Ensuring Sustainable Financing

Adequate and sustainable financing is crucial for the revitalization of Nigeria's WASH sector (Jimoh and Jacob-Oricha, 2022). This includes identifying and implementing innovative financing mechanisms, such as public-private partnerships and user fees, to ensure the availability of funds for infrastructure development, capacity-building programs, and maintenance of water and sanitation facilities. Engaging the private sector to invest in WASH infrastructure, leverage expertise, and enhance service delivery efficiency is important. All this will not be possible without policy changes; all the water utilities in Nigeria are government-owned, and unbundling or privatization of these utilities and liberalization of the operating environment will encourage investors into the sector. This will not be complete without appropriate regulatory frameworks.

3.4 Water Tariffs

Water tariffs can be a powerful management tool to achieve various objectives in the water and sanitation system (Ezugwu et al., n.d). However, it is important to consider the affordability aspect, especially for low-income groups. To achieve a functional and sustainable system, willingness to pay should be promoted through effective service delivery. People will naturally pay for an efficient and effective service; even though varied water tariffs should be available for low, medium, and high-income areas. The rich should be made to subsidize the poor, not the government subsidizing everyone. Water has attained the status of an economic good above a social good because of the need to run the system sustainably. Water utilities should be run profitably, though, occasional government grants may be needed for starters, and loss of revenue should be prevented at all costs. A functional system will reduce unaccounted water to the barest minimum.

3.5 Capacity Development and Behavioural Change Campaigns

Promoting hygiene education and behavior change is key to community health. Investment in education, research, and training programs for water management, engineering, and environmental sciences is crucial (Jimoh, 2022). By investing in research and development, Nigeria can identify and implement innovative water management approaches tailored to its unique challenges and needs (Ngene et al., 2021; Jimoh, 2022). By raising awareness and providing education, individuals can contribute to reducing water wastage, and adopting responsible water use behaviors and hygiene practices (Moglia et al., 2018), which in turn will reduce the spread of diseases and improve overall health outcomes.

3.6 Community Engagement

Involving all stakeholders, including government agencies, local communities, NGOs, and private sector entities, in decision-making processes is essential for the successful revitalization of Nigeria's WASH sector. This can be done through the establishment of multi-stakeholder platforms, where different actors can collaborate and contribute their expertise and resources towards achieving common goals (Jimoh and Jacob-Oricha, 2022). Local communities should be involved in the planning, implementing, and monitoring WASH projects to ensure sustainability and ownership. Local communities should be involved in the planning, implementing, and monitoring of water and sanitation programs to ensure that they meet the unique needs and preferences of the people they serve, and to achieve sustainability.

3.7 Harnessing Technology and Innovation

Adopting new technologies and innovative approaches can greatly enhance the efficiency and effectiveness of water and sanitation services. By utilizing remote sensing technologies, data analytics, and real-time monitoring systems, Nigeria can promptly improve decision-making processes, detect and address water leaks or system malfunctions, and optimize the allocation and distribution of water resources (Ngene et al., 2021). For instance, the use of mobile-based platforms for monitoring water quality and managing water systems can provide real-time data and improve decision-making processes. Additionally, the empowerment of experienced professionals in water resources and the utilization of the latest technology are crucial for developing water supply infrastructure (Ezugwu et al., n.d).

4.0 POTENTIAL OF THE WASH SECTOR IN BOOSTING ECONOMIC GROWTH

Revitalizing Nigeria's water, sanitation, and hygiene sector has the potential to contribute to sustainable economic growth in several ways. First, improved access to clean and safe water sources will enhance productivity and well-being among the population. Access to clean water is crucial for maintaining a healthy and productive labour force. Workers who have access to safe drinking water are less likely to fall ill, resulting in reduced absenteeism and increased productivity. Additionally, providing access to improved sanitation facilities will reduce the spread of diseases, leading to improved public health and reduced healthcare expenditures. Furthermore, investing in the WASH sector can create employment opportunities and stimulate economic activity.

The construction and maintenance of water infrastructure, such as pipelines, treatment plants, and sanitation facilities, will create jobs and stimulate economic growth in the construction sector. This, in turn, will have a ripple effect on other sectors of the economy as increased economic activity leads to increased consumer spending and business investments. By prioritizing the revitalization of Nigeria's water, sanitation, and hygiene sector, the government can create an enabling environment for sustainable economic growth.

Improved management of water supply schemes plays a vital role in various sectors, such as agriculture, manufacturing, and tourism. In the agricultural sector, reliable and clean water supply is essential for irrigation, livestock watering, and crop cultivation. Improved water supply can also spur economic growth and productivity in the manufacturing sector. Industries that rely on water for production, such as food processing and textiles, will benefit from a reliable and safe water supply, leading to increased production levels and improved product quality. In addition, a well-functioning water supply system can attract investment and stimulate economic activity in the tourism sector. Tourism is a significant contributor to Nigeria's economy, and tourists expect to have access to clean and safe water during their travels. Revitalizing Nigeria's water supply system will enhance the country's ability to meet these expectations, attracting more tourists and boosting revenue in the tourism industry.

Furthermore, focusing on the WASH sector aligns with the United Nations Sustainable Development Goals, particularly SDG 6 which aims to ensure availability and sustainable management of water and sanitation for all. By achieving SDG 6, Nigeria can contribute to the global efforts of providing clean water and sanitation for all, while also reaping the economic benefits of a revitalized WASH sector.

5.0 LESSONS FROM SUCCESSFUL CASES

Experiences from countries like India, Bangladesh, and Ethiopia demonstrate that a combination of policy commitment, innovative financing mechanisms, and strong community engagement can substantially improve WASH services and economic development (Nelson et al.2012).

One notable example is Singapore, which has transformed itself from a water-scarce country to a global leader in water management. Through innovative approaches such as wastewater recycling, desalination, and water conservation measures, Singapore has been able to ensure a sustainable and reliable water supply system for its population (Ng and Zheng, 2022). Another success story is the city of Melbourne, Australia, which implemented a long-term water management plan in response to a severe drought. Through measures such as water restrictions, investment in water-saving technologies, and improved infrastructure, Melbourne was able to successfully increase its water resilience and secure its water supply for future generations.

Uganda presents a very successful case of how institutional reforms and effective cost management and recovery can help Nigeria and other African Countries improve the WASH sector. The robust system developed became a template for upward growth with the ever-increasing number of connections.

6.0 CONCLUSION

Revitalizing Nigeria's WASH sector is crucial for achieving sustainable economic growth, improving public health, and enhancing overall human development. By addressing institutional, infrastructural, and behavioural challenges, and adopting successful strategies from other countries, Nigeria can unlock the full potential of its WASH sector to drive economic progress and improve the quality of life for its citizens.

The current state of Nigeria's WASH sector reflects a critical need for comprehensive and coordinated efforts to improve access to clean water, sanitation, and hygiene practices. Addressing these challenges is a matter of public health and a catalyst for sustainable economic growth. In collaboration with stakeholders, the Nigerian government must prioritize investments in water and sanitation infrastructure, implement effective policies, and promote behaviour change to bring about lasting improvements in the WASH sector. By doing so, Nigeria can pave the way for its citizens' healthier, more prosperous future.

REFERENCES

Adebisi, David, Alade. (2019). Water Resources and Sub-Saharan African Economy: Anthropogenic Climate Change, Wastewater, and Sustainable Development in Nigeria. Canadian Social Science, doi: 10.3968/11293

Emmanuel, M., Akpabio, Eti-ido, S., Udofia. (2017). Unsafe water, sanitation and hygiene in Nigeria's public spaces: the political economy angle. International Journal of Water Resources Development, doi: 10.1080/07900627.2016.1189814

A, O, Arowosegbe, D.A., Ojo, O, B, Shittu, Opeoluwa, Iwaloye, Uwem, F, Ekpo. (2021). Water, sanitation, and hygiene (WASH) facilities and infection control/prevention practices in traditional birth homes in Southwest Nigeria. BMC Health Services Research, doi: 10.1186/S12913-021-06911-5

Enovwo, Odjegba, Abayomi, O., Bankole, Barakat, O., Layi-Adigun., Victoria, O., Dada. (2021). Water, sanitation, and hygiene in healthcare centres: appraisal in a pandemic. Journal of Water Sanitation and Hygiene for Development, doi: 10.2166/WASHDEV.2021.075

Stanley, A., Garuba, Ezebunwa, E., Nwokocha, Ediri, Iruaga, Simeon, S., Nyiakaa. (2016). Socioeconomic Context of Water, Sanitation and Hygiene Practices in Delta, Edo and Ekiti States, Nigeria. doi: 10.36108/NJSA/6102/14(0110)

O., Adeoti, F., F., Akinola, S., A., Ogundare, B., S., Awe. (2021). Freshwater requirement to attain open-defecation-free status in Nigeria by 2025. Journal of Water Sanitation and Hygiene for Development, doi: 10.2166/WASHDEV.2020.135

Joshua, O., Ighalo, Adewale, George, Adeniyi. (2020). A comprehensive review of water quality monitoring and assessment in Nigeria.. Chemosphere, doi: 10.1016/J.CHEMOSPHERE.2020.127569

H., O., Nwankwoala. (2014). Problems and Options of Integrated Water Resources Management in Nigeria: Administrative Constraints and Policy Strategies. International Letters of Natural Sciences, doi: 10.18052/WWW.SCIPRESS.COM/ILNS.14.12

Obinna, C., Nwinyi., Osariyekemwen, O., Uyi., Emmanuel, Jolaoluwa, Awosanya., Ifeoluwa, T., Oyeyemi., Anthony, M., Ugbenyen., Aliyu, Muhammad., Okunola, A., Alabi., Obinna, Ikechukwu, Ekwunife., Charles, O., Adetunji., Iyekhoetin, Matthew, Omoruyi. (2020). Review of Drinking Water Quality in Nigeria: Towards Attaining the Sustainable Development Goal Six. doi: 10.2478/AST-2020-0014

Obiora, B., Ezeudu. (2020). Urban sanitation in Nigeria: the past, current and future status of access, policies and institutions. Reviews on environmental health, doi: 10.1515/REVEH-2019-0025

Ademiluyi, Odugbesan. (2008). Sustainability and impact of community water supply and sanitation programmes in Nigeria: An overview. African Journal of Agricultural Research, doi: 10.5897/AJAR.9000668

Ojima, Z., Wada, David, B., Olawade, Omotayo, Asogbon, Fiyinfoluwa, Taiwo, Makinde, Ismaeel, Adebayo. (2021). Evaluation of Household Water, Sanitation, and Hygiene Management in a Nigerian Rural Community. International Journal of Tropical Disease & Health, doi: 10.9734/IJTDH/2021/V42I530455

Olajumoke, Rukayat, Balogun, Балогун, Оладжумоке, Рукайат, Margarita, Redina, Редина, Маргарита, Михайловна. (2019). Water supply regulation in Nigeria: problems, challenges, solutions and benefits. doi: 10.22363/2313-2310-2019-27-1-65-81

Oloruntoba, E. O., Folarin, T. B., & Ayede, A. I. (2014). Hygiene and sanitation risk factors of diarrhoeal disease among under-five children in Ibadan, Nigeria. African health sciences, 14(4), 1001–1011. https://doi.org/10.4314/ahs.v14i4.32

Esther, Nnennaya, Umahi, Emmanuel, Chukwuma, Obiano, Rimande, Ubandoma, Joel. (2020). A Preview of Water, Sanitation and Hygiene Practices in Kofai Community of Taraba State, Nigeria. doi: 10.11648/J.CAJPH.20200604.15

Ezugwu, Charles et al. (2021). Community Water Demand and Sustainable Water Supply Planning in Nigeria: A Review. https://doi.org/10.17576/jkukm-2021-33 (3)-13

Ngene, U., Ben et al. (2021). Assessment of water resources development and exploitation in Nigeria: A review of integrated water resources management approach. https://doi.org/10.1016/j.heliyon.2021.e05955

Moglia, M., Cook, S. D., & Tapsuwan, S. (2018, October 25). Promoting Water Conservation: Where to from here? https://scite.ai/reports/10.3390/w10111510

Jimoh, M. O., & Jacob-Oricha, S. O. (2022). Sustainable Management of Humanitarian Water Supply, Sanitation, and Hygiene (WASH) Interventions. In *Modern Challenges and Approaches to Humanitarian Engineering* (pp. 41-57). Hershey, PA, USA: IGI Global. DOI: 10.4018/978-1-7998-9190-1.ch003.

Jimoh, M. O. (2022). Spotlighting the disparity of funding, personnel and policy in Africa's water research. Hydrolink 2022-1 Africa. Editor: Angelos N. Findikakis; Moez Louati; David Ferras; Feleke Arega. Published by the International Association for Hydro-environment Engineering and research. ISBN: 1388-3445. pp 15- 17.

Ng, P.J.H. & Zheng, S. (2022). Water Security in the Face of Climate Change: Singapore's Way. In: Biswas, A.K., Tortajada, C. (eds) Water Security Under Climate Change. Water Resources Development and Management. Springer, Singapore. https://doi.org/10.1007/978-981-16-5493-0_2

Nelson, S., Drabarek, D., Jenkins, A., Negin, J., & Abimbola, S. (2021). How community participation in water and sanitation interventions impacts human health, WASH infrastructure and service longevity in low-income and middle-income countries: a realist review. *BMJ open*, *11*(12), e053320. https://doi.org/10.1136/bmjopen-2021-053320