Water and Wastewater Treatment in Nigeria: Advancements, Challenges, Climate Change and Socioeconomic Impacts

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Abstract. The research addresses the prevalent issue of inadequate water and wastewater treatment in Nigeria. Over the years, advanced countries have developed substantial and robust systems for the treatment of water and wastewater, which ensures the preservation and sustenance of societal health and mitigates against the negative impacts that untreated and unregulated wastewater could cause to the environment, including water pollution, transmission of illnesses, destruction of ecosystems etc. The study examines the historical and most recent water treatment methods, including boiling and more advanced techniques such as Membrane Filtration, Ultraviolet Disinfection and Reverse Osmosis. Also, an overview of the potential threats to water treatment, including poor power supply, poor infrastructure, poor waste management system, poverty, policy issues, and corruption, was conducted. With the advent of technology, treatment methods such as biological and chemical treatments have been instituted. For example, biological treatment entails using bacteria to destroy contaminants in water, leveraging the natural ability of microorganisms to survive in unseemly harsh conditions. The paper explores the economic analysis of waste management strategies in Nigeria, stating the costs, benefits and challenges faced.

While implementing these strategies can be costly due to a lack of infrastructural and institutional capacity, it benefits societal health protection and promotes environmental sustainability in the long run. Stakeholder engagement includes supporting water and wastewater treatment technology implementation and setting up local committees. That can help educate and ensure proper disposal of waste and wastewater by homeowners, industries and local businesses, which is discussed as an essential factor in providing adequate water reforms. The research examines important organisations in Nigeria responsible for conducting research, developing policies, enforcing environmental laws, and developing national guidelines and standards. These organisations include the Federal Ministry of Water Resources, the National Water Resources Institute, River Basin Development Authorities, the Federal Environmental Protection Agency, the Federal Ministry of Environment and the National Environmental Rules and Regulations Enforcement

Agency. We examined the relationship between climate change, water and wastewater treatment, discussing the effects of climate change on water resources, including irregular rainfall patterns, decreasing ice sheets, increasing sea levels, floods and droughts. The efforts of the Nigerian government to combat climate change, such as the introduction of the national climate change policy and the enactment of the Climate Change Act 2021, were highlighted. The study also highlights the need for comprehensive strategies and cooperation to achieve long-term climate goals and promote climate-resilient economic development. We looked into the socioeconomic impact of effluent discharge and socioeconomic factors related to climate change in Nigeria. It reveals how wastewater affects agricultural activities such as fishing and farming and negatively impacts aquatic life, farmers and consumers. Discussions revolved around societal rights and obligations stated in the Nigerian Constitution regarding the government's responsibility to provide access to healthcare, shelter, food, employment, and education. Recommendations were made, emphasising the need for properly designed and operated water treatment systems, prioritising water management, the importance of considering local conditions and the use of appropriate technology in ensuring the success of projects. Financial support from international organisations is essential. However, local commitment is likewise crucial for long-term sustainability.

Keywords: water treatment; wastewater treatment; water pollution; water resource management; effluent discharge; waste management.

INTRODUCTION

Throughout history, water use for several purposes has played a crucial role in human civilisation. Over time, humans deeply understood the importance of clean and accessible water and the risks associated with contaminated water. Early civilisations used filtration techniques like sand, charcoal, and boiling as their water treatment. The advancements around water treatment occurred in the 19th and 20th centuries when pioneers like Louis Pasteur and Robert Koch contributed to developing the germ theory, which established a link between microbial contaminants and waterborne diseases [1]. Such discoveries have been known to be part of the foundation for implementing more effective water treatment processes. In recent years, the treatment technologies and methods have only advanced further.

However, even with these advancements, some parts of the world, mainly developing nations, still lack efficient water and wastewater treatment processes. Nigeria's water and wastewater treatment infrastructure experiences considerable challenges due to several variables, including population growth, poverty, corruption, urbanisation, industry and climate change. Nigeria's Federal Ministry of Water Resources (FMWR) and UNICEF stated in the WASHNORM 2021 report that only about 11% of the entire population could access essential drinking water and sanitation (WASH) services [2]. Also, only 14% access safely managed drinking water supply services [2]. Water being a crucial basic necessity means that its uses should be made more sustainable to reduce waste, and wastewater should be treated appropriately and disposed of, but this is hardly the case in the country. Wastewater in Nigeria comes from various sources such as households, markets, hospitals, agriculture and industry and is mainly discharged into the environment without treatment. A study reported that over 80% of most industrial wastewater (tagged hazardous) does not receive therapy in Nigeria.

Untreated water and wastewater entering the environment leads to degradation, transmission of illnesses, pollution of water sources and destruction of ecosystems (mainly aquatic habitats). Therefore, adequate water and wastewater treatment is vital for preserving and sustaining human life, health, and environmental and socioeconomic development.

Climate change impacts, such as fluctuating weather, rainfall patterns, and temperature increase, impact Nigeria's water and wastewater treatment systems. Climate change in Nigeria has increased the severity and frequency of floods, and rainfall intensity is projected to increase [2]

steadily. This may negatively impact wastewater treatment plants and further discharge untreated wastewater into the environment.

RESULTS AND DISCUSSION

1. Water Treatment in Nigeria

1.1. Overview of Water Treatment Methods and Technologies Used in Nigeria. Treating water entails improving its aesthetic qualities and making it useful for different purposes like drinking [3]. As far back as early 4000 BC, the Greeks and Sanskrits recommended water purification methods to improve its taste and odour [4]. Some treatment methods include filtering, exposure to sunlight, and boiling. In Nigeria today, treatment methods combine old methods like boiling and new techniques like Ultraviolet (UV) disinfection, membrane filtration, and reverse osmosis.

Obtaining biologically safe water is crucial to preventing exacerbating waterborne disease outbreaks, a growing challenge for tropical countries like Nigeria [5]. Millions of people across developing countries like Nigeria rely on polluted water for drinking and other uses due to a lack of water treatment, which has enormous health and environmental impacts [6].

Although efforts are poor, developing countries like Nigeria employ large-scale Central Source Treatment Systems (CSS) and small-scale point-of-use (POU) treatment systems due to inadequacies and challenges facing water treatment. The CSS involves water treatment at a central location and distribution from the source to other areas. This is usually done using tankers when no piping system is in place and risks contamination or recontamination during transportation. POU system, as the name suggests, involves treatment on a smaller scale where the water is directly being used. Both CSS and POU, when sustainably implemented, can help meet water demands. In Nigeria, many communities still rely heavily on untreated surface water supplies, which has been reported to lead to increased waterborne disease cases [5]. The importance and benefits of treating water, especially in developing nations like Nigeria, with a surging population, cannot be overemphasised. Figure 1 shows basic water treatment steps in developed countries, and widespread adoption is needed in Nigeria.

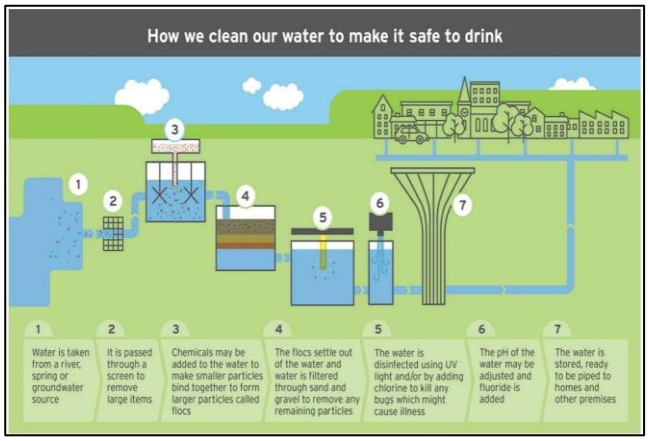

Figure 1 – Drinking water treatment [7]

1.2. Current Status and Challenges Facing Water Treatment in Nigeria. The research found that some challenges facing modern conventional water treatment technologies in Nigeria are lack of maintenance, poor power supply, security, and policy issues [3]. Climate change, floods, and water scarcity in some areas also pose serious threats [5]. Climate change worsens as it causes fluctuating weather and rainfall patterns, affecting water supply and quality. There is a huge financial gap in Nigeria's water and sanitation sectors [8], and these challenges must be addressed if the country is to achieve its water and sanitation targets. Authors [9] stated that the water-supply infrastructure, which handles treatment, pumping, storage and distribution of safe drinking water, faces challenges of quality and damage from catastrophes like floods and other crises which lead to contamination and disease infestation. It was also found that the water sector faces a lack of public awareness and capacity building. Nigeria's poor waste management system poses a significant threat to water contamination, which can defeat the purpose of water treatment. An article stated the relationship between waste management and water quality, stating that sustainable waste management helps improve drinking water quality and availability [4, 10].

There have been efforts to enhance water treatment technologies and infrastructure in Nigeria, but these meagre efforts continue to meet considerable challenges during the treatment, supply, and monitoring/regulation phases. Authors [11] reported that ecosystems could be severely affected in Nigeria due to ineffective treatment systems. The research also noted that wastewater national discharge requirements are not met by the treatment plants, leading to further environmental degradation. The water sec-

tor in Nigeria can not optimally function if all the other sectors are poorly managed. Access to clean water and technologies can only work with electricity, good transport and policy infrastructure. This has led to many researchers calling for adopting more integrated systems vertically and horizontally across sectors.

2. Wastewater Treatment in Nigeria

2.1. Overview and Current Status of Wastewater Treatment Methods and Technologies Used in Nigeria. Clean and improved water access remains unsustainable in Nigeria, as Reported by UNDP in 2015 and WASHNORM in 2018. Wastewater discharged from households, pharmaceuticals and other industries remains a critical issue [12], leading to environmental degradation, health impacts and economic risks. The social, economic, health and ecological effects of untreated and unregulated wastewater prove very costly, as seen in countries like India, where an epidemic outbreak linked to wastewater caused an estimated $200 million loss [13]. A hepatitis outbreak in Shanghai, China, also related to unsustainable wastewater systems, had colossal health and economic costs [14]. Finland's two episodes (2016 and 2018), linked to Wastewater intrusion into the distribution system, proved costly [15]. A 2010 waterborne disease outbreak in Lagos [16] had severe negative impacts.

In several other countries like Kuwait, Australia, Israel, Germany, the United Kingdom and the United States of America, wastewater treatment & reuse is an integral part of the water demand management (WDM) schemes [17]. Evaluating and implementing such plans sustainably across Nigeria will help reduce pollution, degradation, and health and economic losses. Research reported that Kano (Nigeria's 3rd largest city) had poor treatment and storage facilities for wastewater, and their wastewater was mostly being discharged into the environment.

According to [18], Nigeria's wastewater treatment focuses on removing biological oxygen demand (BOD). It often gives minimal consideration for removing phosphorus and nitrogen, which are also in high concentrations [18]. When these nutrient-packed wastewater effluents are released into the environment, they often lead to eutrophication.

Twenty-six wastewater plants in Nigeria's urban cities were listed in a research paper, and 22 reported having functional and four non-functional systems. These non-functional sewerage plants are in Ifurga, Port Harcourt, Rivers State, Makurdi central, University College Hospital (UCH), Ibadan and Kano central. The type of treatment and geographical distribution were also listed [19].

The treatment methods listed are:

1. Biological treatment. In this treatment, microorganisms can feed on complex materials to reduce the BOD level and turn them into simpler forms for further treatment.

2. Mechanical Treatment. Here, biological, physical and chemical procedures are engaged to achieve the desired treatment outcomes. A series of tanks, pumps, blowers & grinders are used, and equally regulatory and control steps are taken. Methods such as activated-sludge, trickling filters, and oxidation ponds are used.

Table 1 shows the states, current status, and treatment method, while Figure 2 shows the geographical spread of the sewerage plants.

Table 1 – Wastewater treatment and collection plants in Nigerian Urban cities [19]

State	Location	Treatment Method	Status
FCT, Abuja	Wupa central Plant	Mechanical	Functional
Markurdi	Markurdi Central	Mechanical	Not Functional
Kaduna	Nigerian Brewery, Kaduna	Mechanical	Functional
Kano	Kano Central	Mechanical	Not Functional
Enugu	Abakpanike Estate	Biological	Functional
Edo	Nigerian Brewery, Benin	Mechanical	Functional
Delta	NNPC, Warri, Shell Petroleum Main Office Staff Quarters Warri	Mechanical Mechanical	Functional Functional
Rivers	Ifruga Estate, Rivers Etope Estate, Rivers Chevron Office, Rivers Shell Petroleum office,	Mechanical Biological Mechanical Mechanical	Not functional Functional Functional Functional

State	Location	Treatment Method	Status
Lagos	Abesan Oke Afa Alausa Olusosun Nigerian Brewery, Lagos University of Lagos	Biological Biological Mechanical Biological Mechanical Biological	Functional Functional Functional Functional Functional Functional
Ekiti	ABUAD	Mechanical and Biological	Functional
Oyo	UCH University of Ibadan IITA Ibadan Nigerian Brewery, Ibadan	Mechanical Biological Mechanical Mechanical	Not functional Functional Functional Functional
Osun	OAU, Ile-Ife Nigerian Brewery, Ilesha	Biological Mechanical	Functional Functional
Ogun	Agbara Industrial Estate	Mechanical	Functional

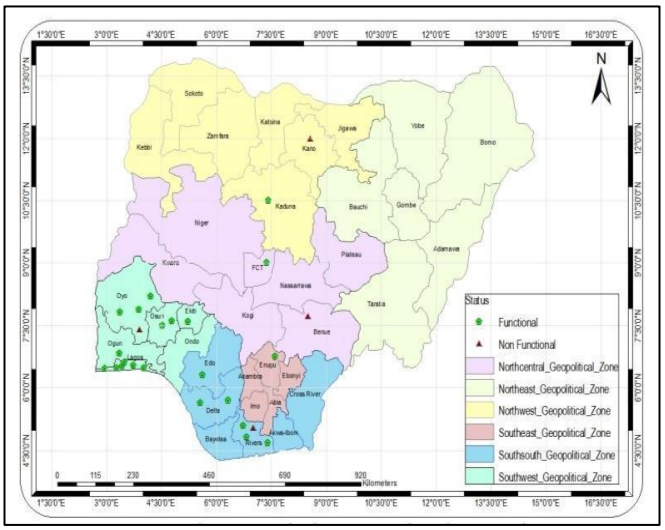

Figure 2 – The Geographical Spread of the 26 wastewater Collection and treatment plants [19]

In Nigeria, the effectiveness of the different Wastewater Treatment technologies varies depending on the treatment method used and the facility's treatment capabilities. Despite the efforts and options available today, untreated wastewater discharged into the environment poses significant challenges, leading to several health and environmental issues [20].

2.2. Challenges Facing Wastewater Treatment in Nigeria. Some challenges that impact the effectiveness and efficiency of Wastewater Treatment in Nigeria include:

1. No unstable electricity can hinder or slow down wastewater collection, treatment and safe storage [21].

2. Poor waste management can lead to contaminants getting into water bodies [22].

3. Climate change causes changing weather patterns, hurricanes, floods, or tornadoes [22].

4. Negligence, poor monitoring and evaluation of water and wastewater treatment systems.

5. Population growth, industrialisation and urbanisation have exacerbated unsafe and untreated Wastewater discharge issues. A Lagos State Environmental Protection Agency (LASEPA) report stated that a galvanising and a metal company released their oil and sludge untreated into water bodies [23]. Industrialisation, which has seen a rise in businesses and industries, has also increased pollution and unsafe acts relating to wastewater handling.

6. Poor infrastructure lacks or abandoned (stagnant) central sewerage systems like in Abuja and Lagos [24].

7. Policy issues. There is no review of current laws and lack of regulation compliance.

8. Poverty. The National Bureau of Statistics highlighted in the 2022 Multidimensional Poverty index survey that over 63% of Nigerians (over 133 million people) are multidimensional poor. This has significantly impacted safe water and wastewater treatment and use, exacerbating existing issues and hindering equitable and sustainable water services provision.

9. Corruption has had a detrimental impact on all sectors, including the water sector, undermining all efforts towards achieving efficient water and wastewater treatment services and providing sustainable and clean water to the entire population:

- corruption leads to misallocation and diversion of funds and resources, resulting in poor investments in infrastructure, poor maintenance and poor service delivery;

- lack of accountability, as corruption, creates a positive feedback loop, which leads to more difficulties in mitigating these challenges;

- corruption creates inequality, as roles are often to individuals not out of competence but out of

connections to the elite, leading to weaker anti-corruption measures and poor and unsustainable water systems.

10. Lack of adequate finance. This causes weak investments in the sector, little or no operation and maintenance structures, and poor technological advancements and makes affordability for the users a big challenge, leading to environmental injustices and inequities [21].

3. Technological advancements in water and wastewater treatment

3.1. Recent Technological Advancements in Water and Wastewater Treatment. In Nigeria, the technologies used in wastewater treatment consist mainly of primary treatments like screening, filtration, centrifugation, sedimentation, coagulation, and flotation. These old water and wastewater treatment methods needed improvement because of the recent increase in strict water quality standards. There is a need for modern technologies because they not only reduce energy consumption but are also eco-friendly, more reliable, cleaner, and increase sustainability [25]. Countries that have implemented these approaches have witnessed a continued improvement in the efficiency by which energy, nutrients, and other chemicals are recovered from treatment plants, helping create a sustainable market and becoming a revenue generation source for wastewater processing facilities. The recent advancements in water and wastewater treatment point toward advanced biological therapies; some of these newer technologies are discussed further in this work, and depending on the sewage characteristics and contaminants it contains, it might require only one of these treatments or combined.

3.1.1. *Biological treatments*. The Biological approach uses indigenous bacteria to destroy contaminants, including nitrate and perchlorate. Studies show 85-90% of contaminant removal using biological therapies. Generally, the process involves a bioreactor containing the bacteria in a media bed. As contaminated water flows through the bed, the contaminants react with the bacteria and an electron donor and nutrients. It produces biomass and other non-toxic by-products. In this way, the biological treatment chemically "reduces" the contaminant in the water. This method does not require chemicals or a lot of energy; instead, it exploits the natural ability of microorganisms to survive in unseemingly harsh conditions to treat contaminants, some of which are listed below.

A. Reverse Osmosis (RO) / Nanofiltration (NF)

As the name implies, reverse osmosis is the reverse of the osmosis process [26]. It involves an external force that causes the water to flow through a semi-permeable membrane from a higher to lower solute concentration. Only low-weighted substances flow through the membrane, retaining the high-weighted meanings, including many undesirable contaminants. At the same time, nanofiltration is a technology that separates different fluids or ions using membranes. Due to this combined process's ability to function at low pressures, it is employed in conditions where vital, moderate inorganic and organic removal are sought, and more salts can be absorbed. The treated water is known as permeate, and the portion that does not pass through the membrane (about 15-30%) is known as concentrate.

RO and NF are valid for the removal of a wide range of contaminants, including many inorganics, dissolved solids, radionuclides, synthetic organic chemicals, salts from brackish water or seawater, removal of hardness, colour, odour-causing compounds, and some disinfection by-product precursors.

B. Aeration processes

Aeration is the process of adding air in its dissolved form into wastewater to allow biodegradation of the organic materials by transferring contaminants from water to stand in the presence of aerobic bacteria. Adding oxygen stimulates the activity of the bacteria, and the resulting 'purified' water trickles out through pipes for further treatment.

This approach can be used to reduce up to 90-99% of biodegradable organics in the water, including phosphates, nitrates, volatile organic compounds, dissolved and suspended organics, Hydrogen sulfide, Carbon dioxide, chemical oxygen demand (COD), biological oxygen demand (BOD), and other pollutants. Oxidation ponds, aeration lagoons (e.g., PTA), and activated sludge are the principal techniques used to carry out the aerobic process. The equation gives a simple depiction of aerobic degradation.

Organic-matter + O_2+ Bacteria → CO_2 + H_2O + Bacteria + Byproducts.

Packed tower aeration (PTA) is mechanically designed to use towers filled with a packing media to increase the area of water exposed to non-contaminated air. Water falls from the top of the building through the packing media while a blower forces air upwards through the tower. In this technique, volatile contaminants with concentrations below 1 μg/L pass from the water into the air. The more volatile the contaminant, the more easily PTA will remove it. It generates no liquid or solid waste residuals for disposal.

In the activated sludge process, the sewage is pumped into an aeration tank mixed with air and bacteria-laden sludge. This sludge-sewage mixture is allowed for several hours, during which the bacteria break down the organic matter into harmless by-products. The activated sludge, consisting of billions of bacteria and other tiny organisms, can be reused for new sewage. The partially treated effluent then flows to another sedimentation tank to remove excess bacteria.

For aeration to be adequate, there must be a sufficient and evenly distributed air supply. Bacteria cannot break down the incoming organic matter in a reasonable time, resulting in septic conditions that can become toxic.

C. Anaerobic processes

Anaerobic treatment involves the degradation of organic pollutants by microorganisms in the absence of air. When no free dissolved oxygen is in the wastewater, facultative anaerobes break down complex organic substances, producing carbon, biogas, and sulfur-based organic molecules through biochemical events. Examples of anaerobic treatment systems are up-flow anaerobic sludge bed (UASB) reactors, anaerobic filter reactors, and anaerobic Lagoons. The equation represents the anaerobic process.

Organic-matter + Bacteria → CO2 + CH_4 + Bacteria + Byproducts

This approach minimises the number of bacteria in wastewater. Anaerobic technologies are generally used as pre-treatment in streams rich in high organic material (BOD, COD, or TSS) before the aerobic process. It is a more environmentally benign process than aerobic wastewater treatment as it generates by-products that can be used as fertilisers. It does not require a big reactor capacity or oxygen, reducing the power needed to deliver oxygen in the aerobic approach.

3.1.2. Chemical Treatments. These are efficient chemical methods to remove organic contamination that cannot degrade using biological processes in water and wastewater.

A. Oxidation / Reduction

Redox reactions, as it is generally called, involve different advanced phases of reduction and oxidation reactions that aim at effectively removing chlorinated hydrocarbons and pesticides from wastewater. Ozone helps oxidise iron and manganese in healthy water. As such, oxidation removes problematic biodegradable chemicals. Photochemical purification occurs when UV light reacts with ozone to create hydroxyl radicals. Reduction processes are needed to convert heavy metal ions into easily dissolved sulfides. These Advanced Oxidation Processes (AOP) destroy antibiotics, hormones, cytostatic drugs, and other anthropogenic trace chemicals which can not biodegrade.

B. Electrodialysis

This method involves the use of two electrodes that have Ion-selective semi-permeable membranes (anion or cation exchangers) arranged in parallel or series, which allows water-soluble ions (anions and cations) to flow out of the system once an electric current flows through them. This process is also called demineralisation. Voltage is supplied to two electrodes in a continuous or batch process. Factors such as pH, temperature, nature of contaminants, membrane selectivities, flow rate, and volume affect the removal of dissolved solids. It is mainly applied in the treatment of salty water. TDS concentrations up to 200 mg can be reduced by 90%.

For all levels of wastewater treatment, disinfection is an essential last step. Ultraviolet radiation is a better alternative for dechlorination than chlorine because chlorine residuals in the effluent may adversely affect aquatic life. Still, UV will disinfect without leaving any residual in the effluent.

Drawbacks: Chemical methods are challenged by increased chemical usage, difficulty in disposing of sludge as it cannot be reused as fertiliser due to its chemical content, scarcity of experienced labour, and increased energy needs.

3.2. Case studies. Using advanced treatment technologies with traditional methods will lead to more efficient wastewater treatment and increased reuse and recycling of treated water.

Some case studies that justify this claim are highlighted below.

Case 1 – Amherstburg consolidation of three sewage treatment plants into one. Amherstburg, a town in Ontario, Canada, with a population of 21,936, created a system that combined three sewage service areas into one. This was because one service area was approaching approved treatment capacity limits while the other was far behind in meeting the current requirements for effluent quality. In this way, space was conserved, resources, expansion in service capacity, and the goals of the Detroit River Remedial Action Plan were met. The upgrade produced many environmental, social, and economic benefits because it transitioned from traditional primary treatment to an advanced biological (activated sludge, UV disinfection) treatment process.

Some upgrades to the Amherstburg PCP included [27] headworks and screening, installing primary clarification and aeration systems, installation of secondary treatment technologies, including bioreactor tanks with fine bubble diffusion and secondary clarifiers, improvements to the dewatering system, installation of UV disinfection system and setting up a unique two-stage bio trickling odour control system that significantly minimised the odour coming from the plant.

Some environmental benefits include decreased energy use and greenhouse gas (GHG) emissions, improved wastewater quality, decreased water consumption, reduced hazardous residuals, minimised environmental impact, and protected biodiversity and ecosystem. Some social benefits include protection and improvement of public health, increased opportunities for recreational activities, and increased access to shared space. Economic benefits include reduced operating and maintenance costs, deferred or avoided capital expenses, increased district land values, the increased potential to attract new businesses, increased ability to attract new residents, and support for local business development.

Case 2 – Wastewater Treatment and Reuse – Elattaouia, Morocco. Like Nigeria today, many rural areas of Morocco significantly lacked Wastewater treatment in the past. About 70 million cubic meters of untreated wastewater irrigated an area of more than 7000 hectares yearly. In 2003, An innovative wastewater treatment technology was established based on the pilot-scale research carried out at the Institute Agronomies et Vétérinaire Hassan II to treat the town's wastewater [28]. The wastewater system consists of two stages. Stage 1 provides primary and secondary treatment, which consists of two up-flow anaerobic reactors arranged in series, followed by a settling chamber and sludge drying beds. Stage 2 offers tertiary treatment, consisting of a high-rate algae pond and two maturation basins in series. Stage 1 was completed in 2006, while Stage 2 was completed in 2011. The system could remove 85% of the chemical oxygen demand (COD) and 80% of total suspended solids (TSS).

The essence of this system was to improve on the limitations of the existing form of water treatment used back then, which was the lagoon systems. The upgrade not only led to an effective wastewater treatment but also helped reduce the area occupied by the basins, simplification of sludge management, recover of biogas and elimination of odours, reuse of treated wastewater for agricultural production and demonstrate the technology's capacity at full scale.

3.3. Economic analysis. An economic analysis of the costs and benefits associated with implementing sustainable wastewater management strategies in Nigeria can provide valuable insights into such an initiative's potential financial gains and challenges. The prices of implementing sustainable wastewater management strategies can be substantial, including capital investment and operational and maintenance costs. However, the benefits of these strategies can also be significant and far-reaching. Some of the primary benefits of sustainable wastewater management strategies are protecting public health, promoting environmental sustainability by reducing pollution, conserving natural resources and generating revenue from the recovery of resources from wastewater, such as energy, nutrients, and water. Implementing sustainable wastewater management strategies in Nigeria also faces significant challenges. The lack of infrastructure and institutional capacity can increase the costs of implementing these strategies, which may require substantial infrastructure and human resources investments. The availability of funding and political will can also be a significant challenge in Nigeria.

The three types of actions needed for wastewater management are wastewater collection, wastewater treatment, recovery of resources from wastewater, and safe reuse. In wastewater management, cost functions are a suitable tool to help analyse costs. They provide a mathematical

framework for analysing the relationship between the inputs used in wastewater management and the outputs generated. They can be used to determine the cost of various wastewater management activities and identify cost-saving measures. As reported by [&&], there are three principal methodologies for developing cost functions related to "wastewater economics." These are the engineering-based, statistical-based, and econometric-based methodologies. The engineering-based procedure involves analysing wastewater treatment's physical and chemical processes and associated costs. The statistical-based method analyses historical data on wastewater management costs to develop cost functions. The econometric-based methodology uses economic models to estimate the costs of various wastewater management activities. Previous studies show that the statistical method is the most common approach for developing cost functions in wastewater management.

A couple of existing studies have developed cost functions for wastewater systems. An estimate of wastewater treatment costs based on an engineering approach to provide insight into the relationship between wastewater treatment costs and the volume of wastewater treated in Spain. The authors developed a method for estimating the cost functions of wastewater treatment based on Spanish data. They identified variables such as the volume (V in m3/year) of wastewater treated, plant age, and removal efficiency of pollutants, and estimated costs (C in €/year) for removing suspended solids, organic components, nitrogen, and phosphorus. The estimated cost functions for seven different treatment levels are presented below.

Examples of cost functions of different wastewater treatment systems

TECHNOLOGY	COST FUNCTIONS	R^2
Extended aeration without nutrient removal	$C = 169.4844V^{0.4540}\, e^{(0.0009A+0.6086SS)}$	0.61
Activated sludge without nutrient removal	$C = 2.1165V^{0.7128}\, e^{(0.0174A+0.1512SS+0.0372BOD)}$	0.68
Activated sludge with nutrient removal	$C = 2.518V^{0.7153}\, e^{(0.007A+1.455SCOD+0.15BN+0.243P)}$	0.73
Bacterial beds	$C = 17.3671V^{0.5771}\, e^{(0.1006A+0.6932COD)}$	0.99
Peat beds	$C = 1,510.84V^{0.2596}\, e^{(0.0171SS)}$	0.52
Biodisk*	$C = 28.9522V^{0.4493}\, e^{(2.3771SS)}$	0.81
Tertiary treatment	$C = 3.7732V^{0.7223}\, e^{(0.6721COD+0.0195BN+0.7603P)}$	0.90

Figure 3

The cost functions presented in the table depict the relationship between the cost of annual operation, volume treated, percentage of pollutants extracted, and plant age for each technology. Using these cost functions helps determine the most suitable technologies based on the importance of wastewater to be treated and the set objectives for removing contaminants.

In conclusion, an economic analysis of the costs and benefits of implementing sustainable wastewater management strategies in Nigeria highlights the initiative's potential financial gains and challenges. However, the prices of implementing these strategies can be substantial, and overcoming the challenges associated with implementing them requires significant investments in infrastructure, institutional capacity, and political will.

3.4. Public health impacts. Advanced wastewater purification processes involve biological and chemical treatments sensitive to the environment. They can go as far as resulting in climate change, changing populations, health challenges and ageing infrastructure [29]. Feces and urine from humans and animals may carry many disease-causing organisms known to cause various environmental and health problems.

Humans risk exposure to various diseases from wastewater in multiple ways. Pathogens in wastewater may be transmitted through direct contact with sewage, poor living and eating hygiene, or indirect contact with human, animal, or insect carriers. Diseases contracted by drinking contaminated water or eating contaminated food are often called waterborne and foodborne diseases. Harmful chemicals and heavy metals found in wastewater, such as cadmium, copper, lead, nickel, and zinc, are needed in trace amounts by our bodies but can be harmful in larger doses and lead to acute poisoning. Other potentially toxic substances can enter wastewater from various sources, such as local businesses, industries, or stormwater runoff. These substances include pesticides and chemicals like chlorinated hydrocarbons, phenol, PCBs (polychlorinated biphenyls), and benzene. In communities where wastewater treatment is inadequate, some health complications are due to reduced drinking and bathing water quality, Increased burden of disease due to unsafe food (contaminated fish, vegetables, and other farm produce), Increased risk of diseases when working or playing in the wastewater-irrigated area and Increased financial burden on health care, consuming food made with contaminated water, eating food improperly handled carriers or con-

taminated by irrigation with polluted water or fertilised with untreated sludge.

Preventing potentially harmful substances from polluting water is always the best strategy for protecting the health and the environment and preserving valuable water resources for community use and recreation. The effectiveness of water treatment can be limited when water is heavily contaminated with waste. So, to ensure safe drinking water, communities need clean water and effective wastewater treatment. In addition, communities need to make sure that untreated wastes are not disposed of improperly on land or water where people can come in direct contact with it or where it can attract disease-carrying insects or animals.

3.5. Stakeholder engagement. Stakeholder engagement helps legitimise final decisions. Their role is vital, primarily because of the accountability that comes with publicly funded projects toward society in general. They seek to share ongoing reforms, projects, lessons, and good practices in support of better governance in the water sector. Their roles involve the following:

1. Advise governments to implement effective water reforms through policy dialogue across decision-makers at different levels.

2. Provide technical platforms to discuss water management and treatment improvements through peer-to-peer exchanges, [30] public participation in data collection, and situation analysis.

3. Provide an open consultation mechanism to raise the profile of governance issues in the developmental agenda [30].

4. Support the implementation of the technologies designed for water and wastewater treatments and participate in selecting the appropriate treatment system.

5. Contribute to the design of water usage and governance principles and engage decision-makers at all levels, within and outside the water sector, to commit to action.

6. Stakeholders should set up local committees that can help through programs to educate and ensure local businesses, homeowners, and industries properly pretreat and dispose of the waste, wastewater, and household chemicals they generate. Furthermore, ensure that communities mobilise people to set up special dates and locations for collecting these substances.

One of the drawbacks of stakeholder engagement is the possibility of having conflicting interests in resource allocation and costs, which can delay final decision-making. Therefore, the project management team should engage with stakeholders to balance the project's and stakeholders' values concurrently. This creates a balance between economic, environmental, and social goals. Despite these acknowledged drawbacks and challenges, stakeholder engagement is increasingly encouraged in water resource management.

4. Policy and Regulatory Framework for Water and Waste Water Treatment in Nigeria

The Organization for Economic Cooperation and Development (OECD) streamlined practices and principal frameworks that provide conditions for effective, efficient, and inclusive water policy, therefore, the OECD Principles on Water Governance. The Regional Development Policy Committee of the OECD endorsed the principles in 2015 as a framework for understanding public policy responses: a plan to promote sound water governance as a means to a goal. It has been noted that water crises are frequently primarily "governance" problems, particularly given the fragmented nature of the water industry and its bleak prognosis, which "requires doing better with less" [31]. Based on these findings, the governance framework project was created to motivate all relevant parties to engage in conversation to formulate solutions and implement them [32]. The implementations show improved access to potable water, improved sanitation services, and increased water security. The program was expected to enhance the governance process from policy conception to implementation, according to [33]. Although this goal may encourage integrated water resource development and management, the effects of deteriorating water security on food, energy, and the environment have not been fully considered [34]. Because of this, a water governance gap needs to be filled by creative framework directives.

Nigeria's government owns natural resources, and relevant agencies regulate their exploitation [35]. However, the resources were deregulated to improve access to the water supply as a human right, a claim that tends to meet the water needs of the growing population. Deregulation ought to have included a water policy to guarantee that sound water management regulatory

frameworks are successfully implemented and enforced for the benefit of the public, but this seems to be a challenge, especially given that water managers, which include experts, are no longer consulted before water development. As a result, artisanal workers who provide services at a lower cost than experts have taken over the most private aspects of the development of water infrastructure, including some government contracts, leading to indiscriminate water exploitation, even to the point of drilling boreholes without taking into account ecological risks, especially some tendencies of over-abstraction. Then, stakeholders looked to become detached from water supply planning, which appeared to jeopardise water security and sanitation services, particularly the lack of interest in examining areas vulnerable to natural and land-use-related threats. As a result, general people are more susceptible to severe health disorders linked to environmental activities, primarily BBS, lung, liver, and blood cancers. These health problems are a symptom of inadequate water governance. Similar to [36, 37] instances, they attributed the situation to a dual-purpose mindset brought on by a conflict of interest in the governance structure.

Other Nigerian cities have no central sewage systems, except for a few neighbourhoods in Abuja and a few locations in Lagos. Therefore, individual residents or businesses manage wastewater through a decentralised wastewater management system. As a result, one of the most apparent types of pollution in the nation is water pollution. Waterways can absorb hazardous compounds significantly, but local pollution has already exceeded this capacity. As a result, it is clear that contaminants in various aquatic habitats are excessive, and an effective environmental management and monitoring program is urgently needed [38]. The law in Nigeria mandates that businesses, regulated private or public facilities, such as hotels and hospitals, treat their wastewater to a predetermined quality before releasing it into the environment. However, wastewater treatment before release or reuse by these facilities is typically improperly done or nonexistent. Because most industries in Nigeria lack adequate effluent treatment facilities, they discharge their effluents into water bodies without sufficient treatment, frequently into the nearby water bodies [39, 40].

The result is that without effective implementation or enforcement, the standards have devolved into theoretical regulatory instruments. Although the restrictions are still considered insufficient enforcement, they exist in writing. Even though these instructions have been published in gazettes and the Nigerian environmental agency also regularly inspects regulated sites, compliance has often been deficient. The literature claims that ecological laws in Nigeria are either not enforced at all, are poorly implemented, or are frequently enforced to collect money. A recent assessment also noted that political and other factors contributed to the failure of attempts made by various administrations to reduce the incidence and effects of water contamination through the formation of laws and, in many cases, decrees [41]. The lack of effectiveness of the institutions established to protect the environment has frequently been attributed to political interference, a lack of coordination among the relevant agencies, and a lack of institutions or laboratories for environmental quality monitoring, among other factors.

According to [38], the regulatory framework for handling wastewater-related environmental issues does not appear to have produced the intended outcomes for which it was first developed, necessitating the adoption of concrete reform measures. Poor policymaking in Nigeria exacerbates problems with cleanliness, water, security, safety, and well-being and encourages potential issues, including hunger, disease, poor governance, and conflict risks [42]. By failing to address the shortcomings faced by women and children, Nigeria's regulatory frameworks have been unable to contribute to achieving a fair admission to protected and clean drinking water for everyone [43]. Suppose an integrated approach is taken by monitoring all sectors and sources from which wastes, wastewater and contaminants emerge to manage and treat their wastes and effluents and adopt sustainability thinking in their design processes. In that case, there will be a significant improvement. Bans and incentives could act as regulatory tools used to improve the processes.

4.1. Implementation Challenges and Potential Solutions. As a result, dealing with the water presents several challenges for relevant authorities [42]. One of the current challenges in water management is how to allocate water effectively among competing uses, particularly in [hydropower] energy production and flow [44], which constitutes a complex interaction and can occasionally hurt the ecosystem [45], especially in places like Nigeria where climate change is caus-

ing some rivers to become ephemeral [46]. To ensure a sustainable water supply, different relevant decision-making agencies control management policies [46]. As a result, the management of water resources is characterised by the engagement of several stakeholders with conflicting goals and interests [1]. Even though Integrated Water Resource Management (IWRM) was developed by the Global Water Partnership (GWP) to balance the conflicting interests, the implementation has not been successful [37]. This may be because water governance lacks creativity.

Unsuitable regulations, a lack of infrastructure investment, ineffective wastewater treatment technologies, improper sludge management, and a lack of monitoring and awareness of pollution levels are a few of the difficulties that must be overcome during wastewater management. According to [38], Nigeria's issue with inappropriate wastewater management is closely related to the institutional structure that the Nigerian government has built up for environmental monitoring and control. Public policy responses can close the gap between the design and implementation of water policies. Still, they will only be effective if the guidelines are coherent, have sufficient information and well-designed regulatory frameworks, and the stakeholders are appropriately involved, have integrity, and have the necessary skills. These requirements primarily focus on implementing the OECD [Principle 11] on water governance, intending to promote water governance frameworks that aid in managing trade-offs across generations, from rural to urban areas. As a result, the multi-stakeholder (bottom-up) dialogue method is developed.

Innovative framework directives are required to close this water and wastewater treatment gap. When the appropriate authorities, levels of government, responsible stakeholders, and local communities work together, the directions can be provided with multi-stakeholder engagement for general acceptability "even as voluntary roles." Indicators of effective water governance that will be adopted and put into practice [Principle 8] can be found in the universal acceptance of this [novelty] course. Such indicators are designed as a self-evaluation framework for the government and the stakeholders to carry out the dialogue on the water governance system, track timely progress, and map out the necessary actions to close the identified gaps [47]: implementation strategy developed in the OECD [principle 1] based on clear roles and responsibilities across all levels of government.

Although identifying the duties and responsibilities for each level of water governance is crucial, the focus of the current study was on shared roles and responsibilities, which is a suggestion to strengthen the bottom-up and multi-stakeholder process. However, because the concepts of water governance are theoretical, they are not applicable at the bottom level or local scale, where communities and municipalities predominate [33]. It appears from this review that the bottom corridor's local municipalities won't be able to work out the bottom-up dialogue process if they are unfamiliar with the terms used in the framework of the principles. The OECD Principles on Water Governance have not been well known at the grassroots and appear to be hanging at that level. Therefore, it is in the best interest of the relevant [governance] authorities to further increase public exposure to OECD principles by interpreting data from River Basins through publications (at regional conferences) of local practical examples.

A helpful approach for more economical watershed management can be created by identifying severely polluted areas [48]. The country must adhere to the OECD Principles on Water Governance to strengthen the Nigerian water governance system and provide new input indicators that track actions that help produce positive results, such as budgeting/planning for risk assessment and regulatory and preventive predictive measures. These practices promote ecological health, which measures the overall impact of sound water management.

Governments must endorse the 12 Principles of Water Governance to develop and implement effective, efficient, and inclusive water policies to stop this governance failure [31]. The first tangible breakthrough that can considerably aid in creating better water policies is a tool [32].

The government's commitment to preventing pollution through effective decentralised wastewater management must be shown through appropriate policies that support affordable and accessible wastewater treatment systems and enable increased participation of the regulated community in environmental protection activities and programs. There has to be more coordination between and among the relevant regulators at these three tiers of government since ecological governance in Nigeria is

carried out at the federal, state, and local levels of government. The current policies must be reviewed and updated to more clearly define the roles and responsibilities of the prominent participants in environmental protection. Additionally, rewarding compliance and encouraging facilities to manage wastewater properly are likely to encourage them, and sustainable decentralised wastewater management by the regulated community requires an appropriate regulatory framework. The regulatory framework is intended to give a general overview of environmental laws and regulations to safeguard public health and the environment from potential risks associated with wastewater disposal. However, it appears that neither the regulators nor those who are regulated have been fulfilling the requirements outlined in the To safeguard public health and the environment from potential risks associated with wastewater disposal, the regulatory framework is intended to give a general overview of environmental laws and regulations. However, it appears that neither the regulators nor those who are regulated have been fulfilling the requirements outlined in the To safeguard public health and the environment from potential risks associated with wastewater disposal, the regulatory framework is intended to give a general overview of environmental laws and regulations. However, it appears that neither the regulators nor those regulated have fulfilled the requirements outlined in the rules. By taking into account the current economic and technological conditions, as well as with proper regard for the peculiarities of the receiving local context, it is necessary to critically assess the existing standards and make them more practical and practicable. Setting up and effectively enforcing fair norms and regulations can significantly improve the sustainability of current wastewater treatment techniques in regulated plants. A better understanding of regulated facilities' difficulties and treating compliance issues on an industry-by-industry basis rather than combining all industries can result in a significant change since the traditional "command and control" policy/instrument of enforcing compliance has not produced results. Even though effluent limitation rules are created for whole industries, the discharge limits might be included in licenses given to industrial facilities based on their unique circumstances. Additionally, proper sanctions should be administered to defaulters without regard for their motives or favours within the bounds of the law.

It is necessary to regularly train and strengthen the capability of regulatory authorities who ensure that wastewater management standards are followed. They must be capable of advising the regulated community on wastewater management in a solid technical manner. It is possible to increase compliance with wastewater management rules and their enforcement by paying adequate attention to training staff members of environmental regulatory bodies and educating the regulated community on effective wastewater management. Along with regular staff training, providing the agencies with the tools they need to perform their regulatory duties will give the staff more confidence and show regulated facilities that the agency is serious about preventing the harmful effects of untreated wastewater discharge on the environment. Additionally, the regulated facilities must be adequately educated on the dangers of indiscriminately releasing untreated wastewater into the atmosphere and on effective management techniques that use the area's most advanced, environmentally friendly, and financially viable technology.

The various levels of government must commit financial resources to all aspects of environmental legislation, and they should not be viewed primarily as a means of earning income. These funds are essential for carrying out ecological regulations, personnel training, purchasing the tools required for environmental monitoring, and other monitoring-related logistics. The sectors' difficulties also seem to have a solid financial component. In particular, small and medium-sized businesses (SMEs) should be given credit facilities to help them comply with wastewater management regulations. Additionally, local finance agencies established to support the industry may be able to help mobilise the funds required to design and execute effective wastewater treatment systems through soft loans and subsidies from relevant financial institutions.

The information gathered from the semi-formal interviews and stakeholder questionnaires [38] allowed for the derivation of a few reasonable recommendations from this study, which are listed as follows:

1. Regarding the financial ramifications, the Nigerian government should ensure proper program and policy implementation by providing critical

agencies involved in environmental management with sufficient money. These agencies should have well-developed institutional frameworks to properly direct the regulated facilities and better enforce rules and standards. This development should be ongoing. Furthermore, credit facilities should be made available to the participating organisations, as the difficulties the industries encounter also seem to be somewhat financial.

2. While lowering the current guideline limits for industrial wastewater discharge in Nigeria may not be simple, establishments may be encouraged to make minor adjustments to comply with the regulations on an industry-by-industry basis. This is because making significant, frequently pricey investments will make it much harder for polluters to increase compliance over time.

3. Based on the best treatment technology that is commercially feasible, effluent standards are the framework by which responsible authorities safeguard the environment and public health from the harmful effects of wastewater. The national discharge standards should be routinely evaluated and updated to reflect the country's current conditions. It is essential to conduct thorough monitoring studies and data gathering on water quality, water use and reuse patterns, and the dilution and assimilation potential of receiving water bodies. The definition of effluent limit values ought to be based on this.

4. Pilot-scale demonstration studies should be conducted using free-of-charge natural treatment methods, such as wetlands, to remove fertilisers and other pollutants. Such systems will reduce the need for synthetic fertilisers and improve the environment for nearby animal species [49].

5. many developing nations have recently used the multi-level contact oxidation method (MLCOP) to treat high-strength wastewater. Due to its numerous benefits, including cheap operating costs, compact footprints, minimal sludge creation, and high treatment efficiency, such novel treatment methods ought to be investigated by Nigerian enterprises as well [50].

6. Because this is a fundamental problem for failing wastewater technology and policies in developing economies, the transfer of advanced or novel wastewater treatment systems from developed countries should be done cautiously [51]. "The sunk nature of highly specialised infrastructures and the ensuing susceptibility of utilities to political and institutional factors make deploying modern wastewater treatment technology challenging. Additionally, it necessitates the participation of numerous actors (utilities, suppliers, contractors) and is influenced by multiple stakeholders (communities, business users, citizens' organisations) who typically have divergent goals [38]. Governments must collaborate with the significant WASH stakeholders to enhance local water governance. It is necessary to strengthen data management frameworks and the local and national authorities' ability to administer and control sanitation systems. Introduce best practice solutions for water preservation in areas where the water supply is insufficient to rank water efficiency as highly important across activities [43].

4.2. Review critical laws and regulations governing water and wastewater treatment in Nigeria, including those related to climate and socioeconomic factors. The Nigerian government has established environmental preservation and conservation institutions over the years. The Federal Ministry of Water Resources (FMWR) was established in 1977 after the National Water Resources Institute (NWRI) and River Basin Development Authorities (RBDA) were founded in 1976 [52]. The NWRI oversees research and workforce training, while the FMWR oversees policy formation and advice. Conversely, the RBDAs provide towns with water for domestic, industrial, and agricultural uses. Similarly, with Decree 58 of December 1988, the government formed the Federal Environmental Protection Agency (FEPA) in 1988 [53]. Specifically in water quality, effluent discharge, and air and atmospheric quality, FEPA's principal objective was to develop national environmental guidelines, standards, and criteria. 1999, this organisation became the Federal Ministry of Environment (FMENV). Even after the FMENV was founded, there was still a gap in the country's ability to enforce environmental laws, rules, and regulations effectively. The federal government established the National Environmental Rules and Regulations Enforcement Agency (NESREA) to fix this issue.

The most recent and significant development in introducing environmental regulating institutions in Nigeria was the creation of NESREA in 2007. The organisation is in charge of the preservation of biodiversity, the development of environmental technologies, and the sustainable use of Nigeria's natural resources in general. The Act

that established the agency gives it the authority to enforce all environmental laws, regulations, standards, and laws in Nigeria, as well as the provisions of international environmental agreements, protocols, conventions, and treaties to which Nigeria is a signatory [54].

The old "command and control" approach to industrial pollution control is still utilised by NESREA, specifying the precise "end-of-pipe" treatment methods that industrial sites must apply. It uses regulations that advocate that no wastewater be discharged from any facility without treatment and exact effluent discharge requirements that must be adhered to by the regulated facilities based on the best technology available. According to the requirements, facilities must install pollution control equipment, make suitable provisions for effluent treatment, and be in charge of all generated wastewater until final discharge. Penalties for non-compliance might include paying fines, imprisoning the individuals at fault, paying any external costs, and closing the facilities. Even though the Nigerian economy is not strong enough for most facilities to meet the country's high wastewater treatment demand, the stipulated effluent standards appear to have been created to correspond to a high level of wastewater treatment technology compared to other developing and developed nations [38].

The Federal Ministry of Environment, state commissioners, and the National Council on Water Resources (NCWR) are all represented on this top water resources policy-making body, which the FMWR governs. Although not all states have a stand-alone ministry of water resources (such as the Rivers State), State Ministries of Water Resources are responsible for policy, regulation, and monitoring passed down to control the local governments. Therefore, while essential water supply-related institutions and procedures are in place across the nation, there is a lot of variance in the management and provision of water between jurisdictions [55].

Authors [56] assert that the Harmful Waste [Special Criminal Provisions] Act [Cap H1 LFN 2004] Law forbids the transport, dumping, and disposal of hazardous waste in territorial waters. There are environmental protection organisations in each of the 36 states. The Lagos State Environmental Protection Agency (LASEPA) law, for instance, allows officers to detain violators who pour raw, untreated human waste into any public drain, gorge, or pour any oil, grease, or spent oil, including manufacturing trade waste, into any public drain or watercourse.

The National Environmental (Surface and Ground Water Quality Control) Regulations, 2011, enacted according to section 34 of the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act 2007, govern the quality control and required standards of surface waters and groundwater. They also define water pollution violations, impose punishments for such offences, and provide for enforcement. The laws are designed to safeguard water resources for use in agriculture, clean water supply, and aquatic life, among other services. The National Environment Protection (Pollution Abatement in Industries and Facilities Generating Wastes) Regulations state that a permit is necessary:

a) To store, handle, and transport dangerous toxic waste.

b) When effluents with constituents are discharged into public drains, rivers, lakes, the ocean, or as an underground injection.

c) When the oil is dumped into public sewers, rivers, lakes, or oceans or injected underground.

d) For an industry, a facility, or process line with a new point source of pollution. The agency must receive an application for a discharge permit from such a business or facility.

A violation is responsible for restoring or remedying the polluted environment and paying a fine, compensation, or damages to individuals harmed. Failure to follow environmental regulations can also result in a first-time sentence of up to two years in prison. Terminating the lease, license, and/or permit is the harshest penalty for repeat offenders. National Guidelines and Standards for Water Quality in Nigeria, Nigerian Industrial Standards for Potable Water and Natural Mineral Water, State Water Supply Edicts/Laws, Local Government Water and Sanitation Bylaws, National Water Supply and Sanitation Policy, Federal Ministry of Water Resources, National Water Resources Institute Act, River Basin Development Authorities Act, and Navigable Waterways (Declaration) Act are some other regulatory frameworks for water that make provisions against water pollution [56].

5. Climate Change, Water and wastewater treatment

Climate change and water are intricately intertwined. The complicated effects of climate change on the water are well known. Most climate change products are water-related, including irregular rainfall patterns, decreasing ice sheets, increasing sea levels, floods, and droughts [57]. The United Nations Framework Convention on Climate Change (UNFCCC) received Nigeria's first national report in 2003. Since then, the country has made some progress in managing climate change, even though it does not have a strategy for renewable energy. The government acknowledges climate change threatens its economic well-being and continued progress under its current national development plan. The federal government introduced a national climate change policy in 2015 to direct the execution of climate change measures. According to [56], the policy will provide comprehensive national goals, objectives, and strategies for reducing the effects of climate change.

Nigeria's Climate Change Act of 2021, according to [58], provides a framework for the country to achieve low greenhouse gas emissions (GHG) through inclusive green growth, sustainable economic development, and the implementation of Nigeria's commitment to net zero emissions, which was made public at COP26 in 2021. The National Council on Climate Change is established, and its job will be to carry out the nation's climate action plan. President Muhammadu Buhari signed the legislation on November 18, 2021. This suggests that Nigeria has entered the club of countries that have passed emission-target legislation intending to eradicate carbon emissions. This is perfect for a nation that relies heavily on oil and is considered to be among the world's most climate change-vulnerable nations. Its primary goal is to offer a comprehensive legal framework for achieving Nigeria's long-term climate goals, including a net-zero carbon emission target, national climate resilience, adequate climate finance, and mainstreaming climate change actions into national development priorities. According to the law, efforts to promote inclusive, green, and sustainable economic development for Nigeria are placed within a larger context, including efforts to address climate change [59]. Thus, the law aims to promote the nation's climate-resilient social and economic development while facilitating the intensive and complex cross-ministerial coordination of climate change action and the involvement of businesses and the civil society needed to achieve long-term climate objectives.

Additionally, it aims to create a systematic approach for the nation to identify the primary climate risks and vulnerabilities it faces and how to improve its current capacity for adaptation to climate change. Nigeria is attempting to prevent the dangers of climate change with the recent progress of passing the Climate Change Act. However, individuals can contribute to this campaign by refraining from actions that abuse the environment, particularly the illegal logging of trees, which ultimately leads to climate change [59]. The stakeholders have all contributed to Nigeria's fight against climate change in different ways. For instance, the Niger Delta Climate Conference and regional Pre-COP25 meeting in October 2019 marked a significant step forward in mobilising stakeholders committed to fighting climate change. This was put on by the Federal University of Petroleum Resources, Effurun, and the African Centre for Climate Actions and Rural Development (ACCARD). The attendees agreed that a wide range of stakeholders needed to be involved in developing shared solutions and mobilising funding and other support for climate management, particularly in the Niger Delta. Additionally, the nation used its first sovereign green bond to finance a few environmental initiatives related to climate change management [60].

5.1 Climate change impact of untreated wastewater on the environment. The most immediate effect of sewage on the environment is its contribution toward the contamination and destruction of natural habitats and the wildlife that live in those habitats by exposing them to harmful chemicals that would otherwise not be present over the natural course. This leads to a high rate of fish mortality, eutrophication, threats to corals, swamp ecosystems, sea grass beds and loss of biological diversity, a significant threat to natural tourist centres. Also, due to the elevated numbers of pathogenic microorganisms (such as viruses, algal bloom and bacteria) present in untreated wastewater, even human health is threatened when exposed to it.

Recent studies reveal that untreated wastewater (particularly ponds) emits a significant amount of greenhouse gases (GHGs), such as methane (CH_4), carbon dioxide (CO2), and a comparatively low amount of nitrous oxide (N_2O) into the atmosphere. According to [61], the high nutrients in untreated wastewater provide an ideal envi-

ronment for methane (CH_4) production and emission. This emission rate differs according to climatic regions. It is influenced by several biotic and abiotic factors, such as temperature, nutrients and pH (C, N, and P), dissolved oxygen, sediments, and water depth. These parameters are analysed in the table below.

Table 2 – Impact of different factors on greenhouse flux from water bodies

Factors	Correlation with CH_4 Flux	Correlation with CO_2 Flux	Correlation with N_2O Flux
Water temperature	Increased exponentially up to a specific limit	Positive	Positive
	No correlation	No correlation	-
	-	Negative	Negative
Nitrate concentration	No impact	Positive	Positive
	Negative	-	-
Dissolved organic matter (DOM)	Positive	Positive	Positive correlation
Water pH	-	Positive	Positive
	Non-significant correlation	-	Non-clear correlation
	-	Negative	Negative
Dissolved oxygen (DO)	-	-	Positive
	No correlation	-	-
	Negative	Negative	Negative
Surface area of the pond	Negative	-	Positive
Total nitrogen (TN)	-	Positive	Positive
Total phosphorus (TP)	Positive	Positive	Positive
Sulphate	Negative	-	-
Eutrophication	Enhanced CH4 flux	Positive	-
	-	Negative	Negative

The table above shows that Dissolved Organic matter (DOM) positively correlates with CH4 production and emission from wastewater. Similarly, authors [62] investigated the CH_4, N_2O, and CO_2 emissions from 15 untreated Virginia, USA, water ponds. Dissolving organic matter positively correlates with CH4 (methane) emissions. Other research shows that CH_4 emissions contribute 94% of the total greenhouse gasses GHG, and the mean CH4 flux was 15.1 mg m^{-2} h^{-1}. Organic carbon contributes roughly 6% and 20% to total carbon emissions from ponds and reservoirs [63, 64].

Methane's presence in the atmosphere is small compared to CO_2, but it is the most abundant reactive hydrocarbon [65]. Its globally averaged atmospheric surface abundance in 2010 was 1780 ppbv, corresponding to a total atmospheric burden of about 4850 tg methane. The resource [30] reports that methane has more than 80 times the warming power of carbon dioxide over the first 20 years after it reaches the atmosphere, making at least 25% of today's global warming.

5.2. Socioeconomic impact of effluent discharge. Farmers lament that effluent discharge impaired water use in farming areas by hindering them from performing fishing activities. It negatively affects the productivity of other farming activities such as crop planting, livestock keeping, and irrigation, which could be impeded. Consequently, it creates a severe negative impact on the aquatic and wildlife, the farmers and finally on the consumers [66].

5.3. Socioeconomic Factors of Climate Change. As a member of society, man is endowed with certain inherent rights, inalienable, indivisible, and inviolable. In a social contract with the state, the civil authority must uphold his rights as a citizen. In exchange, the citizen fulfils his civil obligations, which include paying taxes and defending the state when necessary [61].

The Nigerian Constitution's Chapter II mentions ECOSOC rights as Fundamental Objectives and Directive Principles intended to guide and influence state policy on governance-related matters. To put it another way, the government should ensure that everyone has access to adequate health and medical care, direct its policies toward ensuring that people have a suitable and proper shelter so they can exercise their right to live in peace and dignity, provide timely and adequate food, a reasonable minimum living wage, and provide pensions for the elderly. Additionally, [31, s. 16-2-d] includes provisions for welfare for the disabled and unemployment and sickness payments. Since the Nigerian governments are not required to abide by these principles, their relevance primarily stems from the voluntary nature of their commitment. It just acts as a guide for government actions and choices in these areas. For instance, this chapter's provisions on the right to employment provide that everyone shall, without any form of discrimination, have the op-

portunity to acquire both a sufficient means of subsistence and enough chance to find an acceptable job [31, s. 17-3-a]. In addition, it states that reasonable accommodations must be made for social, religious, and cultural activities and that working conditions must be fair and humane [31, s. 17-3-c]. It guarantees equal compensation for effort without sex or other discrimination [31, s. 17-3-e]. They are following [31, s. 17-3-b]. It also created provisions for the sanctity of human beings and mandated that human dignity be upheld and improved. As has been noted numerous times, these provisions are not enforceable in a court of law due to their non-justiciable nature. Therefore, it is unsurprising that many Nigerian administrations have made lip service to supplying job prospects, including a conducive atmosphere for collective bargaining. These issues are crucial to workers' ability to function.

Regarding the right to education, the Constitution states in its Fundamental Objectives and Directive Principles of State Policy that the government should direct its policy toward ensuring equal and adequate educational opportunities at all levels [31, s. 18-1], promote science and technology [31, s. 18-2], and work to eradicate illiteracy. Government should, as and when practicable, provide free compulsory and universal education, free secondary education, free higher education, and other forms of free education. These clauses are reduced to words on paper by [31, s. 6-6-c] of the Constitution's limiting restrictions. Poor funding for federal and state tertiary institutions, ongoing and never-ending strikes by academic and non-teaching staff at state and national universities, and the growth of for-profit tertiary institutions are all guaranteed to compromise standards. Unless this area is given serious consideration, the realisation of a free and democratic society, a just and egalitarian society, a united, strong, and self-reliant nation, a great and dynamic economy, and a land full of bright opportunities for all citizens will only remain a pipe dream [61, 67].

CONCLUSIONS

When water treatment systems are improperly designed, Installed, or operated, they tend to perform correctly, which can lead to groundwater and surface water contamination. These failures are often preceded by apparent signs, which are often overlooked and lead to system breakdown after a while, which can only be remedied by total system replacement. Wastewater management is usually not a priority in developing countries due to political interference, lack of appropriate institutions, and legislation enforcement. Like the Nigerian Government, they tend to focus more on other pressing needs like fighting insecurity or curbing unemployment and neglect the importance of having clean and sustainable water treatment facilities. Financial support from international organisations and developed countries is essential, but local conditions must be considered to ensure the success of projects. Inappropriate technology and failure to consider local conditions lead to project failure.

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