



## URBAN WATER MANAGEMENT FOR PUBLIC HEALTH IN NIGERIA: EFFECTIVE GOVERNANCE AND SUSTAINABILITY PERSPECTIVES

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### **Abstract**

Urban water management cannot be achieved in both developed and developing nations without adequate attention to effective governance, innovative solutions, implementation strategies, and sustainable development goals. This study aims to evaluate urban water management in Nigeria, emphasizing sustainability and effective governance. This study employs a desk-based, thematic literature review and qualitative method approach to provide comprehensive water resources management for sustainable development, public health, and economic growth. The issues facing Nigeria's water sector were found to have creative solutions. Significant findings revealed that overlapping mandates and governance issues among state agencies, federal ministries, and River Basin Development Authorities have affected Integrated Water Resources Management (IWRM). Rapid urbanization, population growth, and industrialization are just a few of the complex issues plaguing Nigeria's water sector, undermining its contribution to sustainable development and public health. The contribution of smart water management systems, green infrastructure, and artificial intelligence to enhancing the resilience and sustainability of urban water systems cannot be overstated. The study concluded that effective water management and enforcement of water quality standards are essential for improving livelihoods, public health, and environmental sustainability. To do this, though, water policy must be linked to economic policy. Innovative engineering solutions like decentralized rainwater harvesting, managed aquifer recharge, IoT-enabled monitoring, infrastructure rehabilitation, and artificial intelligence can also be deployed. Increased efforts should be directed toward practical political will, comprehensive institutional and policy reforms, including modernizing water laws and appropriate governance in the water sector. Without a doubt, this will enhance interagency collaboration, generate long-term funding sources, and offer targeted, innovative engineering solutions.

**Keywords:** *Innovative Engineering Solutions, Integrated Water Resources Management, Effective Governance, Environmental Sustainability, Urban Water Management*

## Introduction

Human survival, economic growth, and the maintenance of a sustainable environment all depend on water on Earth. A strategic approach must be put into place to effectively safeguard ecosystems in our environment, urban water management, and human health. Urban areas require more water supply due to expanding populations, industrial developments, and agricultural needs (Olajuyigbe, 2020). Particularly in developing countries like Nigeria, rapid globalization initiatives, poor infrastructure, and environmental change have resulted in severe water problems and poor resource management. One of the main places where urban water management faces difficulties at the local level is Anambra State, which selected Idemili South Local Government Area as its primary case study due to population growth, industrial activity, and agricultural needs. For urban water systems to be sustainable, it is essential to strike a balance between present water consumption demands and future conservation requirements. Sustainable water management includes wastewater treatment, pollution control, efficient distribution, and the implementation of eco-friendly methods. It is estimated that 2.1 billion, an equivalent of some three in 10 people, worldwide lack access to safe and readily water at home, whilst 6 in 10 people amounting to some 4.5 billion, lack safely managed sanitation. This situation is far more challenging in Sub-Saharan Africa (SSA), where it is estimated that 319 million people almost half of the region's population is without access to improved reliable drinking water sources (UNICEF, 2022; Uwazie, 2022; Adiele, 2023; WHO, 2022; NESREA, 2019; Suileiman *et al.*, 2019; Kalu and Origbakpor, 2023). Inadequate water supply and the usage of tainted water from streams and boreholes plague many Nigerian cities. Lack of community awareness and insufficient implementation of regulations result in other problems that have a detrimental effect on people's health and the environment by seriously disrupting the economy

### Concept of Urban Water Sustainability

Urban water sustainability defines the comprehensive control of water supplies within cities to maintain both present and future access for all people without harming nature and providing long-term water availability. Three key components of sustainable water management are social justice, economic optimization, and environmental

preservation, all of which support sustainable development ideals. The recovery of the water ecosystem and environmental preservation are central to sustainable urban water management. Urban Water Management involves the fields of water supply, urban drainage, wastewater treatment and sludge handling (Onuoha *et al.*, 2020; Oyebode and Coker, 2021). Pollutants released from domestic wastewater, agricultural runoff, and industrial discharge must be controlled in order to implement water conservation because these contaminants harm aquatic habitats and lower water quality (UNICEF, 2022). In order to properly manage natural water cycles, rainwater collection techniques must be continuously used in conjunction with groundwater recharge initiatives and the installation of sustainable urban features like constructed wetlands and permeable pavement systems. Climate change also complicates the balance of water availability by causing unpredictable rainfall patterns and long-lasting droughts that require people to use a variety of water sources and drought-resistant infrastructure. Artificial intelligence can be applied to hygienic conditions and effective urban water management in developing countries (William *et al.*, 2023a; Ogarekpe *et al.*, 2023; William *et al.*, 2023b).

In order to achieve water sustainability, policies involving community involvement and targeted investments in underprivileged areas must be put into place. Public awareness campaigns and community ownership initiatives are both necessary for long-term behavioral improvements in conservation practices and water resource management (Kone, 2023; Okoye *et al.*, 2021). Achieving urban water sustainability requires cooperation between several parties and a strong institutional structure. Governments, commercial organizations, and local communities must work together to implement innovative practices, support infrastructure development, and enforce regulations (NIMET, 2023). Public-private partnerships that improve services and community-based management organizations that supervise the upkeep of water resources are examples of integrated sustainability initiatives. For carrying out community water management initiatives, integrated water resources management and its IWRM methodology offer helpful global examples. Several facets of water sustainability were shown in Figure 1.

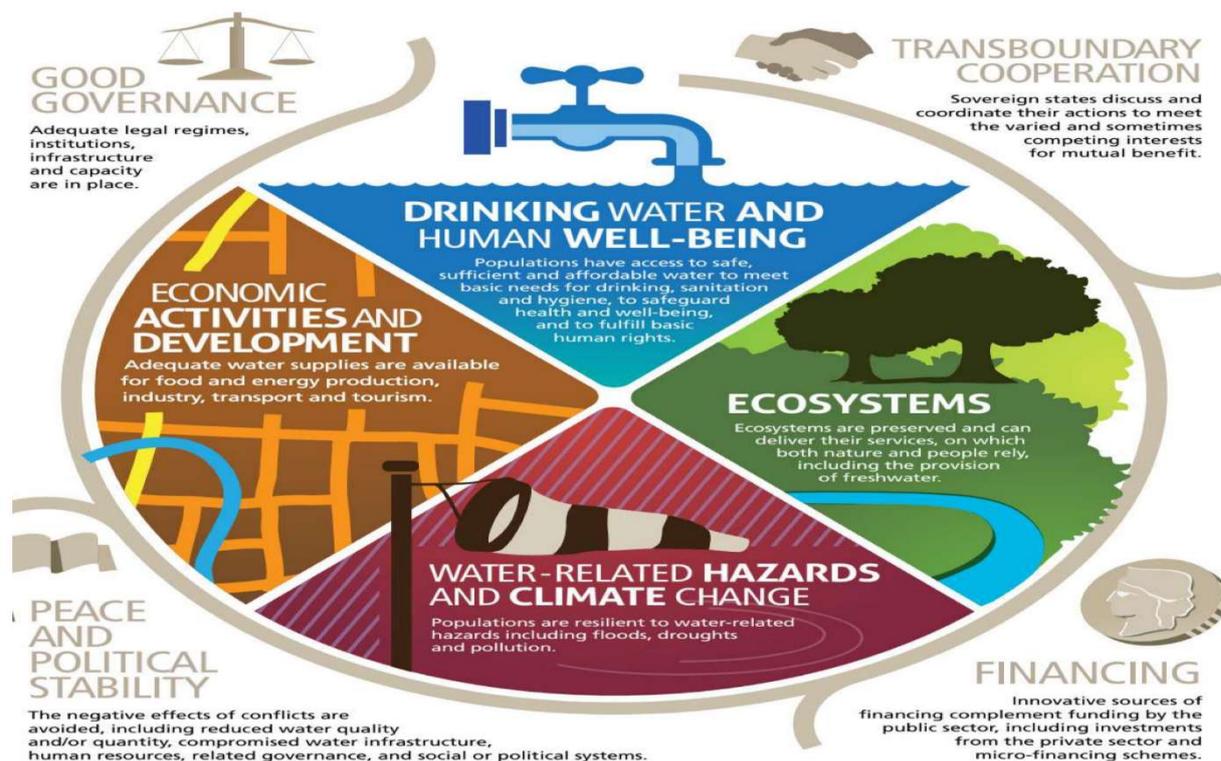


Figure 1: Aspects of Water Sustainability

**Water Management Practices in Urban Areas**  
 In highly populated places, urban water management includes a wide range of techniques intended to guarantee effective water supply, fair distribution, pollution control, and sustainable resource use. These methods are essential for resolving water scarcity, infrastructure deficiencies, and environmental degradation in quickly expanding areas like Idemili South, Anambra State. In order to construct resilient systems that can satisfy current and future needs, effective urban water management blends supply-side interventions, demand-side tactics, governance frameworks, and technological advancements.

**Supply-Side Management Practices**

Supply-side strategies for improving water accessibility include diversifying water sources and expanding infrastructure. The centralized management of water distribution through pipelines operates as the main water delivery method for urban areas that use treated water from reservoirs or treatment plants. (Adekola *et al.*, 2021) The lack of dependable centralized water supply in Idemili South forces residents to depend on boreholes and wells together with rainwater harvesting as their main water resources. Borehole wells exist largely throughout the region despite the long-term threats they create by extracting too much groundwater

from the earth. The managed aquifer recharge (MAR) techniques comprising percolation ponds and injection wells help restore depleted groundwater reserves. Small-scale dam construction and inter-basin water transfer techniques serve occasionally to increase water supply but require thorough environmental and social impact reviews. The practice of waste management includes wastewater recycling for reuse that transforms treated sewage or industrial effluent into non-potable resources used for irrigation and street cleaning and cooling system operations. The practice saves water and simultaneously reduces harmful releases into rivers as well as streams. The water purification method of desalination demands significant amounts of energy to operate while remaining suitable mainly for coastal cities instead of landlocked regions.

**Demand-Side Management Practices**

Water availability through supply-side approaches matches with demand-side methods that work on efficient usage and waste reduction. Water pricing methods along with meters work as effective conservation tools because they provide penalty rates for high users while maintaining reasonable costs for poor households (Ezekwe *et al.*, 2022). Educational programs teach the local population simple water conservation habits which start with leak detection along with the use of efficient fixtures

and low-water irrigation delivery methods through drip systems. Members of the industrial sector decrease consumption and recycle process water through water auditing and cleaner production methods. Urban industries should adopt closed-loop cooling systems which decrease their water intake. Precision irrigation systems with soil moisture sensors help control agricultural water usage by making flood irrigation unnecessary in agricultural areas prominent in urban regions.

#### **Challenges of Urban Water Management Implementation**

Urban water management still faces obstacles despite these tactics, including a lack of funding, outdated infrastructure, political interference, and

low public knowledge. Additionally, rapid development that often exceeds planned leads to unregulated neighborhoods with inadequate water and sanitation infrastructure. To solve these problems and ensure inclusive and effective procedures, sustained investment, capacity building, and community involvement are required. Because present methods enable up to 60% of treated water to go after production, treated water leaks account for significant losses. Customers are forced to pay money on water tankers and boreholes as their alternate sources since water pumping operations suffer from power outages during the erratic electricity supply. Figure 2 indicates a typical aging water infrastructure.



Figure 2: Aging Water Infrastructure

#### **Poor Governance and Institutional Weaknesses**

The combination of inadequate institutional setup with split water management systems leads to severe inefficiencies. The combination of overlapping authority between various water boards at the federal state and local levels produces bureaucratic hurdles through lack of coordination between them. The corruption together with poor management of funds redirects money allocated for infrastructure upgrades toward different purposes and promotes unregulated borehole drilling and illegal water vendor activities without enforcement. Urban planning failures generate a problem of uncontrolled urban spread which creates informal settlements that lack formal water resources and thus compel residents to use dangerous water sources.

#### **Water Pollution and Environmental Degradation**

The water supply in Nigerian urban areas becomes more polluted because of industrial emissions alongside faulty waste dumping and farming

activities. Several industrial facilities discard untreated wastewater into rivers as well as groundwater where dangerous heavy metals and toxic chemicals endanger human health. Diseases like cholera and dysentery can flourish in contaminated water settings caused by people who defecate outside or improperly manage sewage systems. Deforestation and watershed erosion diminish reservoirs' capacity to hold water, while droughts and floods brought on by climate change jeopardize supply dependability. Pollution and environmental harm coexist, making water purification treatments more costly and difficult to implement. Example scenario of water pollution was shown in Figure 3.

#### **Financial Constraints and Economic Barriers**

Advancement is slowed back by insufficient government funding and insufficient cost recovery procedures, despite the fact that proper water management requires significant capital expenditure. Due to poor tariff payment rates and widespread nonpayment patterns across their service

areas, state water companies experience losses. Because political authorities are reluctant to raise taxes, realistic pricing models impede their ability to regulate electricity costs. Without sufficient revenue, utilities are unable to make necessary infrastructure improvements, therefore they

continue to operate inefficiently. Due to general hazards and regulatory uncertainty, critical infrastructure projects continue to get insufficient funding from the private sector. Figure 3 indicates water pollution scenario and Figure 4 shows a typical rapid urban center..



Figure 3: Water Pollution. Source: (Blair, 2023)



Figure 4: Rapid Urbanization. Source: Human Development Reports

### Rapid Urbanization and Population Growth

Nigeria's water distribution infrastructure are currently under tremendous strain due to the country's unparalleled urban population expansion. Idemili South's cities suffer from unchecked urban growth that surpasses the required advancement of their water supply infrastructure. Because wealthy communities may afford private borehole systems while impoverished districts must utilize contaminated creek water or pay exorbitant amounts to water vendors, there is an imbalance in water service. Scarcity of water resources becomes more intense as industries and agriculture increases their

water requirements thus creating conflicts between users as a result. A rapid urbanization setting was presented in figure 4.

### Climate Change and Water Scarcity

Nigeria's water problems are getting worse due to climate variability, which is causing supply disruptions from intense flooding, extended droughts, and irregular rainfall patterns. Droughts lower groundwater recharge rates and surface water levels, while floods contaminate water supplies and harm infrastructure. Many urban areas are vulnerable to severe shocks due to the absence of



2025c). The study's quantitative component uses a descriptive survey design to gather quantitative data regarding water availability and demand patterns as well as infrastructure problems in particular localities. The qualitative part uses case studies and in-depth stakeholder interviews to determine the elements affecting water governance at the institutional and policy levels. Figure 6 shows a map of the study region. The research strategy is separated into three successive approaches in order to maintain strict methodological standards. A thorough review of the literature is the first step in developing theoretical underpinnings based on current research findings about urban water sustainability. The first phase is to identify important study locations by selecting parameters that examine water supply stability, pollutant causes, resource preservation strategies, and known research restrictions (NIMET, 2023; Akpa *et al.*, 2025; Awomeso *et al.*, 2019, Ogunfowokan, 2018; Oyebode and Waterway, 2023; Onyango and Kiarie, 2024, Caretta *et al.*, 2025, Shuaib *et al.*, 2021, Ezekwe *et al.*, 2022). In order to gather primary data, the second phase of the project combines home surveys with field observations and key informant interviews.

#### **Data Collection Methods (Primary & Secondary Data)**

The study collects primary information through structured interviews with households in addition to key informant interviews (KIIs), focus group discussions (FGDs) and field survey observations. Researchers have conducted surveys among 400 selected respondents from diverse areas between urban and peri-urban settlements in Idemili South which gathered data about water access points along with distribution habits and speed of delivery and perception of quality of water. The questionnaire includes structured and semi-structured sections for collecting participant demographics and water consumption patterns and community issues which allows standardization for statistical analysis. The project employs key informant interviews that gather expert insights from policymakers together with water utility officials and environmental regulators and community leaders for understanding governance gaps and institutional capacity alongside policy barriers. The interviews provide qualitative insights which surveys on their own cannot identify. Research meetings with women's groups and farmers and small-scale industrial operators lead to participatory insights regarding water accessibility problems and agricultural practices and pollution threats that affect women. Field observation activities support data verification through documentation of the standard of water

infrastructure as well as locations of pollution sources and methods used to obtain water in chosen communities. Several institutions contribute secondary data through reports along with journals and water utility records and climate data to support field findings. The Anambra State Water Corporation (ASWC) along with the Ministry of Water Resources maintains records of past water deliveries together with infrastructure maps and policy documents while NESREA (National Environmental Standards and Regulations Enforcement Agency) reports show data concerning regulatory compliance and pollution rates. Research literature about urban water management together with case studies from Nigeria along with comparative regions enables assessment of Idemili South's problems in relation to international standard practices (NIMET, 2023; Apeh *et al.*, 2026, Oyebode *et al.*, 2025d; Oyebode, 2022, Adewumi *et al.*, 2011). Before surveying the study, population accuracy is strengthened through preliminary tests performed outside the targeted area to streamline questions and make them less confusing. Activities focused on enumerator training which detail proper ethical data collection practices enable reduced biases and improve data quality. Secondary data sources go through consistency checks against one another to reduce any conflicting information.

#### **Sampling Techniques**

A multi-stage sampling methodology has been implemented to gather representative data in all the different areas and methods of water usage for Idemili South's diverse population. Research findings include quantitative and qualitative findings through a sampling approach that uses probability methods alongside non-probability approaches. Stratified random sampling enables the research to achieve proportional representation among LGA communities (Nnobi, Ojoto, Alor, and Oba) as well as settlement types consisting of urban core, peri-urban, and rural-urban fringe locations. The sample population first receives stratification according to density area types and water accessibility variables where each subdivision receives numbers proportionate to its size. The researchers adopt systematic random sampling by using current neighborhood household lists from local authorities to choose the fifth household in each stratum for reducing bias in selection processes. The survey includes 400 selected households based on calculations from the Cochran formula to achieve 95% confidence with 5% margin of error while adjusting factors related to a finite population.

A total of twenty-five participants were chosen through purposive sampling for in-depth interviews divided among water utility managers (5), local

government officials (5), environmental regulators (5), community leaders (5) and water vendor representatives (5). The selection method reaches all organizational entities who affect water management decisions. The researcher used maximum variation sampling to select participants for six focus group discussions containing 8-10 members from diverse groups such as female household leaders, young representatives and

farmers, artisans, small business owners. Through judgmental sampling the project identified 15 crucial assessment points consisting of five borehole clusters, five Nkisi River sites and five public drinking water outlets which were chosen after initial site assessment to represent various pollution risks and usage patterns.

Table 1: Demographic Characteristics of Survey Respondents

Variable	Category	Frequency (n=400)	Percentage (%)
Gender	Male	212	53.0
	Female	188	47.0
Age Group	18–30 years	128	32.0
	31–45 years	165	41.3
	46–60 years	82	20.5
	Above 60 years	25	6.2
Educational Level	No formal education	38	9.5
	Primary education	75	18.8
	Secondary education	182	45.5
	Tertiary education	105	26.2
Occupation	Farming	92	23.0
	Trading/Business	135	33.8
	Civil service	58	14.5
	Artisan/Industry	74	18.5
	Unemployed	41	10.2
Household Size	1–3 persons	112	28.0
	4–6 persons	203	50.8
	7+ persons	85	21.2

Table 2: Current State of Urban Water Supply in Idemili South

Indicator	Measurement	Data Source	Benchmark (WHO/NESREA)	Compliance Status
Piped Water Coverage	25% of households	Household survey (n=400)	80% (SDG 6.1 target)	Severe deficit
Supply Frequency	2-7 days/week (erratic)	Utility records + resident reports	Daily supply	Chronic instability
Borehole Dependence	53% of middle/high-income households	Survey (stratified sampling)	-	Unsustainable reliance
Groundwater Depletion	1.5-2 meters/year decline	Hydrogeological measurements	<0.5m/year (safe)	Critical overdraft
Surface Water Pollution	41% of samples > WHO fecal limits	Water quality tests (n=15 sites)	0 CFU/100ml	Hazardous contamination
Vendor Pricing	300-500% above utility rates	Market surveys (n=50 vendors)	-	Exploitative
Industrial Effluents	Lead: 4-8mg/L (vs. 0.05mg/L limit)	NESREA compliance tests	0.05mg/L	Severe violation
Dissolved Oxygen	<2mg/L (Nkisi River dry season)	Field spectrophotometry	>5mg/L	Ecological damage
Wet Season Rainfall	17% reduction (2013-2023)	NiMet climate data	Historical averages	Climate stress
Tariff Reinvestment	12% of revenues to infrastructure	Anambra Water Corp. audit	60% (best practice)	Institutional failure

## Results and Discussion

The data analysis scheme establishes methodological rigor by using numerous inquiry processes that support finding verification through triangulation. The logistic regression modeling technique analyzes water insecurity predictors through evaluation of household size and income level and water source distance variables. The QGIS analysis tool displays water system locations and quality details through geographical data to identify access and pollution areas across space. The field-tested water quality data is compared to standards set by WHO and NESREA using PCA to analyze multidimensional parameters that include heavy metals and pH and turbidity levels resulting in interpretable contamination factors.

### Demographic Characteristics of Respondents

The population makeup of surveyed individuals sets essential background information for analyzing water accessibility and utilization practices within Idemili South. Household surveys with standardized questionnaires were given to 400 randomly chosen respondents from urban and peri-urban areas where key demographic groups were properly represented in table 1.

### Description of Data Collection

The questionnaire used for collecting demographic information followed a structured format that

interviewers conducted through face-to-face meetings. Stratified random sampling was employed by Enumerators to achieve equal representation throughout the populations of different ages and genders and residential areas. The selection of households followed systematic random principles to interview every fifth home in the chosen areas. The survey instrument contained closed-ended questions about gender and age and education and occupation and household size so respondents used KoboToolbox to provide digital responses thereby reducing potential errors.

### Current State of Urban Water Supply in Idemili South

The urban water supply system in Idemili South shows severe deficiencies in infrastructure alongside accessibility and quality issues which affects many rapidly changing urban zones in Nigeria. Download our study to see how residents use multiple feeble water service systems from both public establishments and private interests and informal networks that raise sustainability issues. Anambra State Water Corporation piped network which was designed for urban cores has declined to supply water to less than 25% of households because of structural decay and unplanned urban development over many decades. Water customers in areas that

maintain operational pipeline networks encounter unstable water delivery patterns which fall between two and seven days each week thus resulting in 68% of residents drawing additional water from different sources based on our survey findings.

Private borewell extraction operates as the primary water supply for 53% of middle and high-income households but it continues to produce damaging effects on aquifer water reserves. Hydrogeological data shows that water tables in densely drilled areas such as Nnobi and Alor drop between 1.5 and 2 meters yearly. The population in peri-urban areas who have limited resources mainly depends on Nkisi River tributaries together with insufficiently managed public boreholes for their water supply. Testing reveals that 41% of these points have total fecal coliform counts exceeding WHO standards by up to 100 times. Affordability crises in the water sector become worse due to multiple informal water vendors who charge excessive prices amounting to 300-500% above governmental rates and consume 22-35% of the income from poor households confirmed through expenditure surveys. The industrial water requirements in the area around the Onitsha-Owerri Road significantly worsen existing challenges because of agro-processing and manufacturing industries. Over 80% of small industries dump their untreated wastewater into storm drains along the Onitsha-Owerri Road while heavy metals (lead and chromium) exceed NESREA's 0.05mg/L permissible limits by measuring 4-8mg/L in the wastewater. The river pollution has resulted in turning sections of the Nkisi River biologically nonviable because dry season dissolved oxygen readings fall below 2mg/L mark. Climate stressors have an additional destructive effect on the water system. The examination of rainfall data from 2013 to 2023 reveals a 17% decrease in wet period moisture levels alongside elevated flood risk caused by rising built-up zone hard surfaces that now cover 39% of the area. The pressures from declining seasonal water supply and destructive runoff that could be used for water storage result in a dangerous dilemma. Governance failures perpetuate these issues. The confusion in overlaps between the Anambra State Water Corporation, Idemili South LGA and the River Basin Development Authority creates spaces where no one entity is responsible for water management issues. Water tariff revenue stands at only 12% after conducting financial audits but the Department of Water Corporation has a maintenance backlog of ₦2.3 billion. People within the study communities trust formal government systems less than personal remedies as shown by 73% of respondents during FGD discussions. The comprehensive water crisis needs immediate coordinated measures to reduce

operational leaks and find new water sources while also reforming governance structures by restructuring payment methods and implementing water pollution regulations. The subsequent sections evaluate the mentioned obstacles under sector-based models to propose unified approaches. Table 2 presented current state of urban water supply in Idemili south

### Discussion

Water usage in Idemili South exists in three distinctive areas of domestic and industrial and agricultural zones presenting distinct sustainability barriers. The typical domestic water usage needs between 40 to 60 liters per day for a person but water-affected areas consume less than 20 liters. The drinking water routine of families mainly consists of private borehole extraction for two-thirds of population but the other three sections source their water from vendors or untreated streams which causes high sickness rates associated with water pollution. The demand for water by small industrial operations ranges from 10,000 to 50,000 liters per day and they obtain most of their supply through unlicensed boreholes in conjunction with immediate river water extraction. A significant number of facilities lack proper wastewater treatment facilities that enable harmful compounds to mix with river and drain systems. The irrigation method employed by farmers for agriculture leads to 60% to 60 percent water loss during dry seasons. The contamination of Nkisi River water and shallow well water occurs through pesticide pollution in the environment because farmers use these two water sources. Fundamental requirements emerged from the analysis through which authorities need to maintain real estate properties better and enhance industrial oversight while teaching farmers how to use drip irrigation techniques.

### Challenges Affecting Sustainable Water Management

Water resource sustainability management in Idemili South meets various barriers consisting of infrastructure issues and institutional and environmental barriers together with socio-economic issues. Different overlapping barriers prevent efforts to establish secure water systems which deliver equitable service to the area's growing number of residents. The central causes of these issues stem from both old structures and insufficient water infrastructure systems. Severe deterioration afflicts the piped water network because the original design was based on limited population levels but today distribution pipes lose water through corrosion and lack of maintenance at a 60% rate. The physical breakdown of infrastructure coincides with

failing power systems which shut down water pumping stations until quickly require backup energy supply. Unregulated private boreholes have become a crucial survival method but stand as a sustainability risk because the extraction of groundwater reaches 1.5-2 meters every year in areas with excessive drilling. The LGA sustains saltwater intrusion in its coastline areas because of the non-sustainable extraction activities. Table 3

presented water access disparities by household income survey data: n=400 households and Table 4: presented water usage patterns for domestic, industrial, and agricultural purposes.

Table 3: Water Access Disparities by Household Income Survey data: n=400 households

Income Quartile	Primary Water Source	Daily Supply (hours)	Cost as % of Income	Reported Waterborne Illnesses (past year)
Low ( $\leq$ ₦30k/month)	Vendors (45%), Streams (32%)	1.2 $\pm$ 0.8	28.5%	62%
Middle (₦30-80k)	Boreholes (58%), Public taps (27%)	3.5 $\pm$ 1.2	14.7%	38%
High ( $\geq$ ₦80k)	Private boreholes (82%)	24/7 (with storage)	6.3%	11%

Table 4: Water Usage Patterns for Domestic, Industrial, and Agricultural Purposes

Sector	Daily Water Use	Primary Sources	Key Issues
Domestic	40-60 liters/person	Boreholes (53%), vendors (30%), streams (17%)	Shortages, high costs, contamination
Industrial	10,000-50,000 liters/factory	Boreholes (65%), river withdrawals (35%)	Pollution, unregulated extraction
Agricultural	500-1,000 liters/hectare (dry season)	Rivers (70%), wells (30%)	Wasteful flooding methods, pesticide runoff

The existing flaws in established institutions lead to multiple water management deficits. The various entities responsible for water service governance in Anambra State create overlapping authority ranges which conduct unnecessary administrators while leaving key areas without proper oversight. Many problems exist in financial management of water supplies because system improvements receive only a tiny fraction (12%) of collected water fees as these funds are mostly lost to corruption involved in infrastructure upgrades. Monitors fail to enforce regulations since they give 80% of small industries free passage to terminate untreated wastewater when NESREA standards are mandatory. The absence of contemporary water quality and usage surveillance tools prevents policymakers from taking evidence-based decisions. External environmental factors make existing system issues even worse. Multiple pollution sources have produced contaminated water which laboratory testing confirms exceeds WHO fecal coliform standards at 41% of examined points. The Nkisi River functions as a water source but accepts industrial discharges that deliver lead (4-8mg/L) along with chromium and pesticides brought by agricultural drainage. Climate change affects southeastern Nigeria through unpredicted rainfall

behavior that causes both reduced wet season precipitation by 17% and dangerous flooding problems that damage infrastructure and pollute water resources.

The socio-economic conditions create new obstacles for maintaining sustainable management schemes. Peri-urban regions experience accelerated urbanization which surpasses the development of water infrastructure to serve 35% of residents who lack official water access. Households struggling with poverty lose 22-35% of their income when they obtain their water from vendors thus creating water affordability problems and women and girls experience prolonged and risky trips to remote water sources for water collection. The reluctance of cultures toward wastewater reuse and rainwater harvesting acts as a barrier for adopting new alternative water solutions. Manmade problems intensify one another since water infrastructure breakdown results in overdrawn groundwater sources and elevated pumping costs as pollutant-contaminated water makes existing treatment expenses higher. Testing integrated interventions should aim to solve technical issues and governance problems while following the subsequent policy

suggestions. Full-scale reforms of the water sector are needed to stop the worsening water security problems in Idemili South because various challenges reinforce each other.

### **Government and Community Efforts in Water Management**

The government's attempts to deliver urban water are spearheaded by the Anambra State Water Corporation (ASWC), which has recently concentrated on rehabilitating the Obosi water plant and expanding water pipes to serve peri-urban inhabitants. Research conducted in the field shows that budgetary restrictions together with delayed contractors have caused 68% of infrastructure improvements to be discontinued from their original plan. State authorities implemented new regulations through the 2021 Water Sector Law but poorly enforce the law because fewer than 15% of commercial boreholes are licensed with minimal punishments for industrial polluters. Local government authorities built 15 solar-powered boreholes that reached six communities within 2020-2023 as part of their rural-urban transition zone initiatives. The 40% system failure rate happens within 18 months of installation because both maintenance plans and technical expertise are insufficient to sustain operations. The UNICEF WASH program succeeded in improving sanitation facilities throughout 22 schools but this represents only 28% of the educational facilities in the Idemili South LGA. The flood control efforts of the Lower Niger River Basin Development Authority at the federal level have shown restricted success due to delayed completion of 3 out of 8 planned retention basins up to 2024. Since 2019 fourteen water user associations (WUAs) have been established across different community areas. The grassroots members of Nnobi and Ojoto operate communal borehole maintenance together with rainwater harvesting projects and pollution monitoring activities along the Nkisi River. Local water user associations that use participatory budgeting obtain maintenance funds from member contributions of ₦500-₦1000 per month which leads to 78% equipment functionality standards higher than state-installed system standards at 52%. Traditional institutions have brought back indigenous water conservation methods by establishing prohibitions on seasonal fishing as well as safeguarding spiritual water sources. The women-led collectives developed the "Water Mothers" initiative in Alor which trained volunteers provide educational services about water purification and preservation methods to more than 3000 households during 2022.

The initiatives encounter fundamental issues within their organizational structure. The weak

communication between government levels triggers projects to replicate in particular areas where some communities still receive inadequate services since five communities exist without formal water systems although they share proximity of under five kilometers with treatment facilities. Community projects normally confront obstacles to expand beyond the pilot phase because they receive limited financial backing alongside minimal technical help. Integrated planning remains absent during climate shocks because emergency response missed an opportunity to use established community distribution networks during the 2023 floods. Strategic alliances between different public and private entities appear promising as solutions to combine existing capabilities. The new community liaison unit at ASWC established co-management agreements for 8 water facilities which together with the Idemili Water Alliance comprised of 17 stakeholders including industries and religious groups and universities have started advocating for sustainable water policies. Appropriate funding and institutionalization of the collaborative models would create a unified water governance structure from the fragmented intervention system today. The combination of governmental resources and community local knowledge proved most successful by reducing illegal dumping by 40% through joint enforcement between youth patrols and Local Government Area teams in the Nkisi River Monitoring Taskforce management model. Establishing synergy between current tactics and finding ways to remove structural barriers that prevent equitable social inclusion and sustainable finance are necessary for future success.

### **Sustainability Perspectives**

The sustainability of the nation's water resources is threatened both in terms of quantity and quality. Rivers are the major transporters of domestic and industrial wastes generated which are discharged into them untreated. Such wastes are increasingly accumulated in reservoirs created downstream for water supply. Improving the water catchment systems is essential for areas with no other reliable water sources. The conservative capability of existing end-use technologies for water services does not conform to the principles of best practices. Prepaid water meters should be a precondition for prequalification for water service to consumers and punitive measures should be in place to deal with illegal water connections and vandalism of water installations. The regulatory framework will require the regulator to apply a wide variety of tools and employ a degree of selectivity in jurisdiction and responsibilities. How the regulator meets the above responsibilities is through the application of various tools, best illustrated as regulatory inputs and

outputs as in figure 7. Figure 8 presented way of handling challenges of urban water management through nature-based solutions. Figure 9 also indicates environmental, social and governance aspects of sustainability. Figure 10 is an example of urban water management.

### Sustainable Urban Water Management: Concepts and Trends

The planning and delivery of water services (supply, wastewater, and stormwater) in urban settings is known as urban water management.

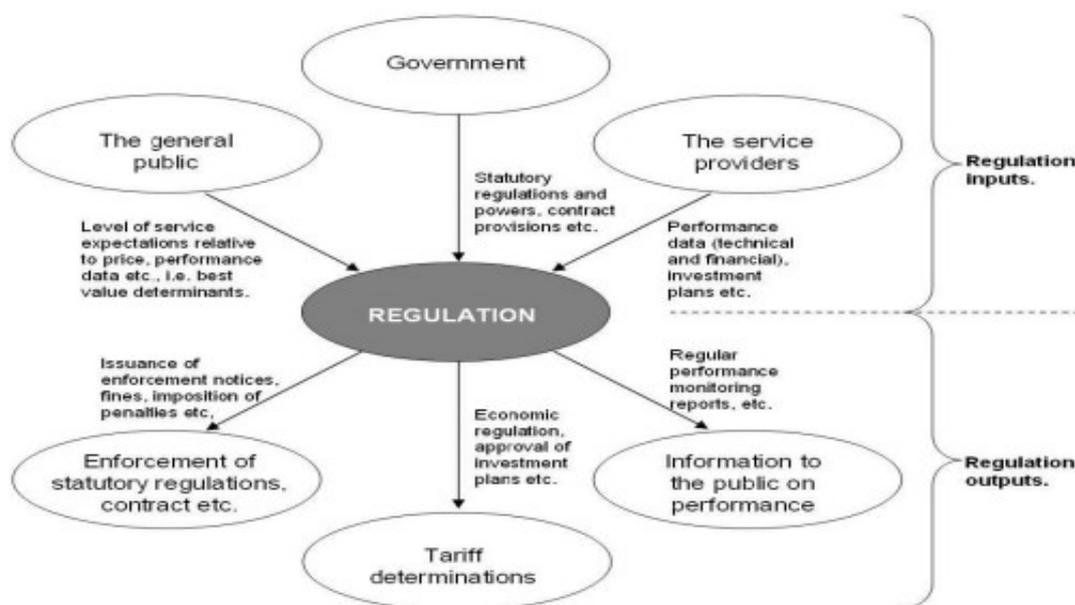


Figure 7: Regulation inputs and outputs

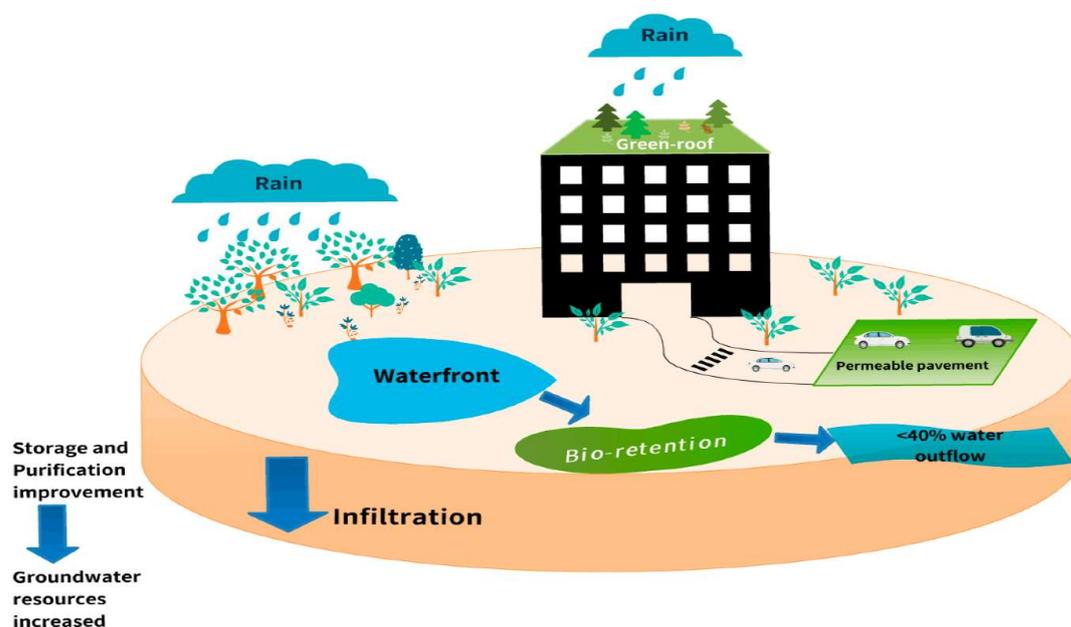


Figure 8: Handling Challenges of Urban Water Management in Chinese Sponge Cities via Nature-Based Solution

Source: (Qi et al., 2020)



Figure 9: Environmental, social and governance aspects of sustainability

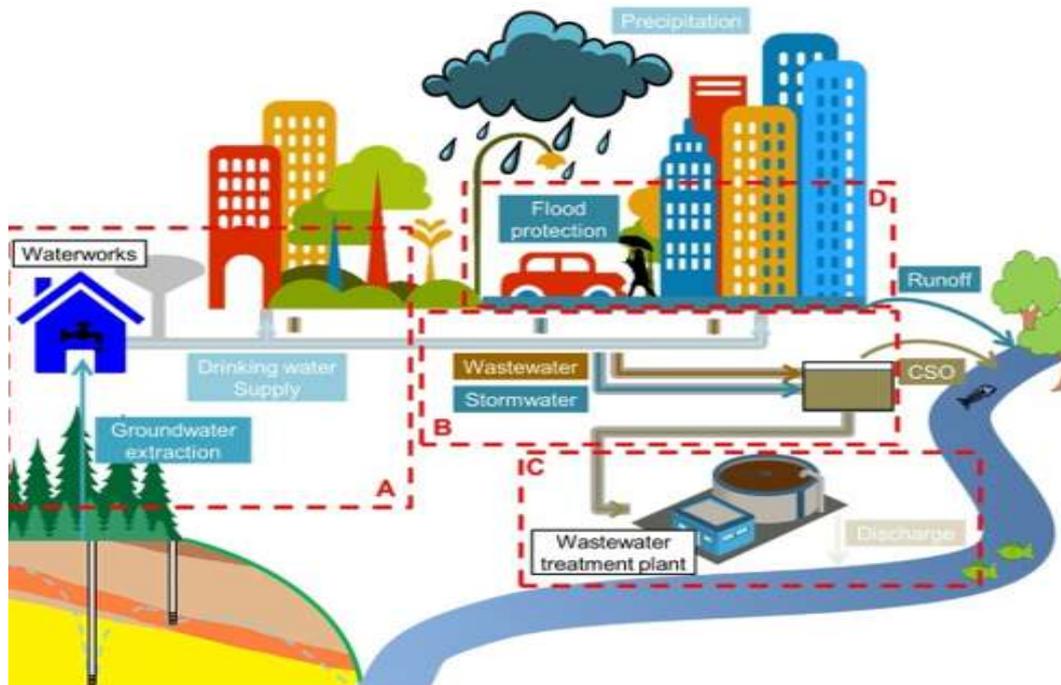


Figure 10: Urban water management

Figure 11 shows the Nigerian Water Resource Management Structure

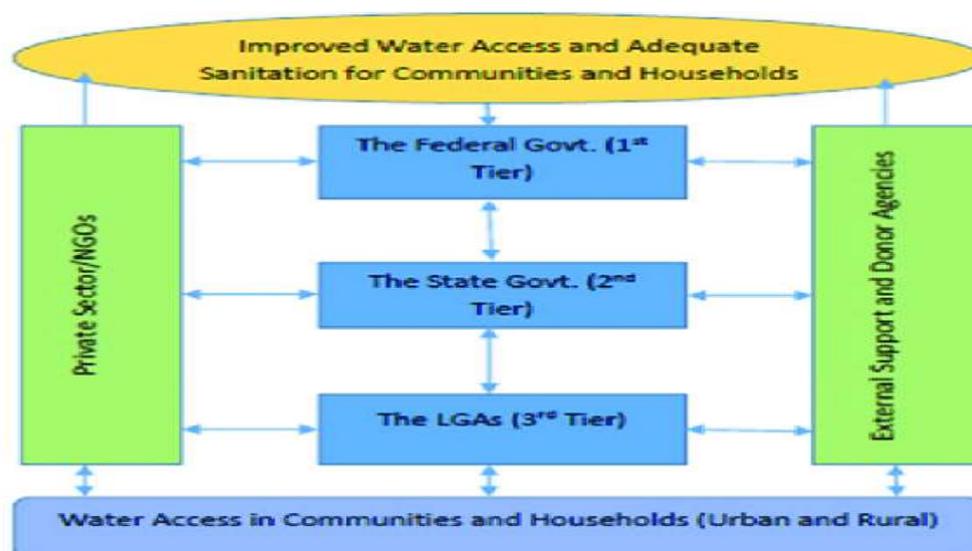


Figure 11: Water Resource Management Structure in Nigeria  
Source: (Meldrum, 2019)

### Conclusion

This study's rigorous investigation of the complex water management challenges has shown a crisis that includes institutional shortcomings, environmental degradation, infrastructure decline, and social disparity. The findings paint a vivid picture of a dysfunctional water system, where unchecked industry taints essential water supplies, antiquated infrastructure cannot meet basic needs, and climate change exacerbates scarcity through erratic rainfall and flooding. Sustainability perspectives can be properly realized through implementing smart water management systems can enhance the efficiency, reliability, and sustainability

### Recommendations for Sustainable Urban Water Management

A number of comprehensive interventions are recommended to address water concerns through infrastructure projects, governance systems, and environmental safeguards in conjunction with community participation activities. Installing smart water technologies requires the use of metering systems to minimize non-revenue water losses and tracking devices to monitor groundwater extraction levels. Stricter enforcement of current groundwater extraction and industrial discharge regulations, increased funding for water infrastructure, better tracking systems for financial accountability, and clear directives for government officials to handle overlap issues are all essential. While groundwater management is encouraged by the use of water abstraction licensing systems, tiered water bill rates

of urban water systems. Technologies like remote sensing and smart metering can improve monitoring and management of water resources. Green infrastructure, such as permeable pavements and rain gardens, can also be used to manage stormwater runoff and reduce urban flooding. Over-reliance on groundwater has led to alarming rates of depletion, and a lack of integrated control has allowed pollution and uneven access to continue unchecked. The gap between public awareness of water challenges and actual conservation efforts demonstrates a crisis of trust in institutional solutions, underscoring the need for more participatory and transparent governance systems.

should boost revenue generation while helping those with low incomes. It is essential to include climate adaptation considerations in water planning processes. Funding programs that support protective water structures and rainwater collection facilities in home and community settings can accomplish this. via water-sensitive locations, farmers should progressively transition from flood irrigation to drip

irrigation systems and water-efficient irrigation techniques, which should be taught via farmer education programs. Community engagement must be the foundation of all interventions. All current grassroots water management initiatives should establish organized local water management organizations so that women and youth can actively participate in all facets of decision-making. To prevent aquifer contamination and dissolution from

degrading water quality, immediate action is required.

### Conflict of Interest

The authors declare that there is no conflict of interest.

### REFERENCES

- Adewumi, I. K., Oyebode, O. J., Igbokwe, K. C., & Aluko, O. G. (2011). Water footprints in four selected Breweries in Nigeria. In *Towards life cycle sustainability management* (pp. 171-181). Dordrecht: Springer
- Akpa, C., Nworie, C. D., Obasi, P. N., Omoruyi, N., & Ugbor, C. C. (2025). Assessment of the heavy metal induced environmental pollution in Abakaliki mining district using geochemical analysis of soils and stream sediments. *International Journal of River Basin Management*, 1-21.
- Adiele, J. G. (2023). Improving the productivity of cocoyam for food security: A review. *CENTENNIAL*, 256.
- Adekola, P. O., Iyalomhe, F. O., Paczoski, A., Abebe, S. T., Pawłowska, B., Bąk, M., & Cirella, G. T. (2021). Public perception and awareness of waste management from Benin City. *Scientific Reports*, 11(1), 306.
- Apeh, S., Oyebode, O. J., & Peter, O. F. (2026). Modelling Total Dissolved Solids Effects on Electrical Conductivity and Biochemical Oxygen Demand in River Benue, Makurdi. *ABUAD Journal of Engineering Research and Development (AJERD)*, 9(1), 28-37.
- Blair, J. J. (2023). Natural Resources Defense Council (NRDC). In *The palgrave handbook of global sustainability* (pp. 2525-2532). Cham: Springer International Publishing.
- Awomeso, J. A., Taiwo, A. M., Idowu, O. A., Gbadebo, A. M., & Oyetunde, O. A. (2019). Assessment of water quality of Ogun River in southwestern Nigeria. *Ife Journal of Science*, 21(2), 375-388.
- Caretta, M. A., Pepa, M., & Totin, E. (2025). Layered crises: Climate change, water insecurity and irrigation in the Sahel. In *Water and Land in the Sahel* (pp. 80-91). Routledge.
- Ezekwe, I. C., & others. (2022). Borehole Water Quality in Southeast Nigeria. *Environmental Monitoring and Assessment*, 194(3), 1-18.
- Kalu, U. C., & Origbakpor, C. E. (2023). Understanding the Roles of NESREA in the Management of Medical Waste in Nigeria: Challenges and Prospects. *AJLHR*, 7, 124.
- Kone, T. S. (2023). *Assessing the impact of the coronavirus pandemic on Local Economic Development (LED) initiatives in Thulamela Local Municipality* (Doctoral dissertation).
- Meldrum, A. L. (2019). Water justice and its dynamic links to water resource Management, water security and conflict in Nigeria. *Global Journal of Engineering Sciences*, 1(4), GJES-MS.
- NESREA. (2019). *National Effluent Limitations Regulations*.
- NiMet. (2023). *Annual Climate Report for Anambra State*.
- Ogarekpe, N. M., Nnaji, C. C., Oyebode, O. J., Ekpenyong, M. G., Ofem, O. I., Tenebe, I. T., & Asitok, A. D. (2023). Groundwater quality index and potential human health risk assessment of heavy metals in water: A case study of Calabar metropolis, Nigeria. *Environmental Nanotechnology, Monitoring & Management*, 19, 100780.
- Ogunfowokan, A. O. (2018). *Industrial Water Pollution in Southwest Nigeria*. University of Ibadan.
- Olajuyigbe, A. E. (2020). Urban Water Infrastructure Challenges in Nigerian Cities. *Journal of Water Resource Management*, 34(5), 1789-1806.
- Okoye, C. O., & others. (2021). Industrial Effluent Management in Nigeria. *Environmental Science and Pollution Research*, 28, 12345-12358.
- Oni, A. A., & Aizebeokhai, A. P. (2017). Impacts of groundwater development on poverty reduction and alleviation in Nigeria. *J. Inform. Math. Sci*, 9(2), 455-484.
- Onyango, J., & Kiarie, R. (2024). Empowering Health and Wellness in Rural Kenya: An Examination of Nutrition Knowledge, Dietary Practices, and Treatment Management among Adults with Hypertension and Type 2 Diabetes Mellitus.
- Onuoha, D. C., & others. (2020). Groundwater Governance in Nigeria. *Water Alternatives*, 13(2), 456-475.
- Onyenechere, E. C. (2019). Water Policy Implementation Gaps. *Development Policy Review*, 37(S2), O178--O196.
- Qi, Y., Chan, F. K. S., Thorne, C., O'donnell, E., Quagliolo, C., Comino, E., ... & Feng, M. (2020). Addressing challenges of urban water management in Chinese sponge cities via nature-based solutions. *Water*, 12(10), 2788.
- Oyebode, O. J., & Coker, A. O. (2021, March). Management of infrastructures in water sector: a veritable tool for healthcare and

- sustainable development in Nigeria. In *IOP conference series: materials science and engineering* (Vol. 1036, No. 1, p. 012008). IOP Publishing.
- Oyebode, O. J. (2022). Design of water retaining structures and application of environmental engineering for 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.
- Oyebode, O. J., & Waterway, O. (2023). Characterization of Wastewater and Evaluation of Recycling Technologies Using Analytical Hierarchical Process for a University Community. *Nature Environment & Pollution Technology*, 22 (1).
- Oyebode, O. J., Oyebode, F. A., Okokpujie, I. P., Ikumapayi, O. M., Jegede, J. T., Afolalu, S. A., ... & Coker, A. O. (2025). Real World Implementations of Green Energy Solutions and Sustainable Water Resources. *NIPES JSTR SPECIAL ISSUE*, 7(2), 3773-3779.
- Oyebode, O. J., Apeh, S., Afolalu, S. A., Bayode, O. A., Okokpujie, I. P., & Udeagbara, S. G. (2025). Utilization of Integrated Water Resources Management and Environmental Engineering Techniques for Sustainable Green Energy. *NIPES JSTR SPECIAL ISSUE*, 7(2), 3780-3787.
- Oyebode, O. J., Dada, J. B., Afolalu, S. A., Aliyu, S. J., Ajisegiri, E., Adediran, A. A., & Oladimeji, S. O. (2025). Development and Performance Evaluation of Pilot-Scale Model Integrated with Wastewater Treatment Plant Using STOAT. *NIPES JSTR SPECIAL ISSUE*, 7(2), 2953-2962.
- Oyebode, O. J., Oyebode, F. A., Okokpujie, I. P., Ikumapayi, O. M., Jegede, J. T., Afolalu, S. A., and Coker, A. O. (2025). Real World Implementations of Green Energy Solutions and Sustainable Water Resources. *NIPES JSTR SPECIAL ISSUE*, 7(2), 3773-3779.
- Oyebode, O. J., Jegede, J. T., Apeh, S., Adetunla, A. O., Afolalu, S. A., & Ikumapayi, O. M. (2025). Wastewater Management, Use of Stormwater and Green Infrastructure Management in Nigeria: Challenges and Way Forward. *NIPES JSTR SPECIAL ISSUE*, 7(2), 3788-3794.
- Shuaib, S. B., Adesanya, E. O., Afolabi, K. O., Jimoh, S. B., & Raji, M. (2021). Work Skills Required by Secondary School Graduates in Sugarcane Production Enterprises for Economic Security in Kwara State, Nigeria. *Journal of Education in Developing Areas*, 29(1), 15-28.
- Suleiman, R. M., Raimi, M. O., & Sawyerr, O. H. (2019). A deep dive into the review of national environmental standards and regulations enforcement agency (NESREA) act. *Suleiman Romoke Monsurat, Raimi Morufu Olalekan and Sawyerr Henry Olawale (2019) A Deep Dive into the Review of National Environmental Standards and Regulations Enforcement Agency (NESREA) Act. International Research Journal of Applied Sciences*. pISSN, 2663-5577.
- William, P., Oyebode, O. J., Ramu, G., Gupta, M., Bordoloi, D., & Shrivastava, A. (2023, August). Artificial intelligence based models to support water quality prediction using machine learning approach. In *2023 International Conference on Circuit Power and Computing Technologies (ICCPCT)* (pp. 1496-1501). IEEE.
- William, P., Oyebode, O. J., Ramu, G., Lakhapal, Sun-water., Gupta, K. K., & Al-Jawahry, H. M. (2023, June). Framework for IoT based real-time monitoring system of rainfall water level for flood prediction using LSTM network. In *2023 3rd International Conference on Pervasive Computing and Social Networking (ICPCSNS)* (pp. 1321-1326). IEEE.
- World Health Organization. (2022). *Guidelines for drinking-water quality: incorporating the first and second addenda*. World Health Organization.UN-Habitat. (2021). *Water Governance in African Cities*.
- Herrfährdt-Pähle, E., Houdret, A., Dombrowsky, I., Cullmann, J., Mukherji, A., Unver, O., & Varady, R. (2025). Empowering global water governance: taking the 2023 UN Water Conference outcomes forward to address the current water crises. *Water International*, 50(1), 4-10.UNICEF. (2022). *WASH in Nigerian Schools*. United Nations Children's Fund.
- Uwazie, U. M. (2022). Traditional Water Management Systems. *African Journal of Indigenous Knowledge Systems*, 21(1), 23-41.