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# FRESHWATER POLLUTION IN NIGERIA: CHALLENGES, CONTROL STRATEGIES, AND PROSPECTS OF GREEN REMEDIATION TECHNOLOGIES

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## ABSTRACT

This study reviews studies on freshwater pollution in Nigeria, examining its causes, impacts, and the potential of green remediation technologies as sustainable solutions. Drawing on findings from previous studies, it identifies the major sources of freshwater pollution, including industrial discharges, agricultural runoff, and domestic waste. It discusses their adverse effects on public health, biodiversity, and economic development. The research reviews existing control strategies, emphasizing the need for stronger regulatory frameworks and public awareness. Special attention is given to green remediation approaches such as phytoremediation, constructed wetlands, and biofiltration, which present eco-friendly alternatives to traditional methods. Despite the promising prospects, challenges such as limited technical expertise, inadequate funding, and space constraints hinder the widespread adoption of these solutions. The study concludes by recommending strategic actions to promote green technologies, including increasing research, public-private partnerships, and capacity building to ensure effective water management and pollution control in Nigeria.

**KEYWORDS:** Fresh Water, Green Remediation, Public Health, Water Pollution,Wastewater.

## INTRODUCTION

Freshwater pollution is a growing global concern, posing a significant threat to environmental sustainability, public health, and economic development. Rapid industrialization, urban expansion, agricultural intensification, and poor waste management practices have contributed significantly to the contamination of rivers, lakes, and aquifers worldwide. The United Nations Environment Programme (UNEP, 2022) reports that approximately 80% of the world's wastewater is discharged into the environment without adequate treatment, leading to the accumulation of pollutants such as heavy metals, pathogens, plastics, and pharmaceuticals in freshwater ecosystems. This situation not only endangers aquatic biodiversity but also

compromises the quality of water available for human consumption, agriculture, and industrial use. Consequently, there is an urgent call for sustainable remediation strategies that are environmentally friendly, efficient, and economically feasible.

In Nigeria, the freshwater pollution crisis mirrors the global trend but is exacerbated by weak regulatory enforcement, inadequate infrastructure, and rapid population growth. Key sources of pollution may include, but are not limited to, discharges from fast food industries, oil and gas operations, abattoirs, artisanal mining, and urban sewage, which release large volumes of untreated or partially treated effluents into rivers and streams. According to Taiwo *et al., (2018),* major water bodies, including the River Niger, Benue, Ogun, and Cross River, have recorded alarming levels of contaminants, such as nitrates, phosphates, lead, chromium, and other hazardous substances. They argue that these pollutants pose significant risks to human health, causing diseases such as cholera, typhoid, and cancer, and threaten food security through their impact on agriculture and fisheries. Despite the existence of water quality standards, enforcement remains inadequate, and remediation efforts are either outdated, expensive, or environmentally unfriendly.

Several scholars have examined the nature and impacts of freshwater pollution in Nigeria and beyond. Okoh *et al.,* (2017) emphasized that the heavy metal content in Nigeria's surface water often exceeds WHO permissible limits due to industrial and agricultural discharges, making most freshwater bodies unsafe for domestic and recreational use. In the same vein, conventional remediation technologies such as chemical precipitation, ion exchange, and membrane filtration are often expensive, energy-intensive, and generate secondary pollutants, which complicate their applicability in low-resource settings. As a result, these researchers advocate for the exploration of cost-effective and sustainable alternatives that can be adapted to local conditions in developing nations.

This study seeks to bridge the existing gap in the literature by providing a comprehensive analysis of empirical studies on freshwater pollution in Nigeria, evaluating the effectiveness of current control strategies, and exploring the prospects of integrating green remediation technologies into national water management frameworks. While numerous studies have examined pollution sources and traditional remediation methods, few have critically assessed the practical challenges, implementation prospects, and policy implications of green remediation technologies in the Nigerian context. This research aims to fill this void by offering data-driven insights and contextual strategies that could inform sustainable water resource management in the country.

**CASE STUDIES**

Akinmoladun *et al.,* (2017) conducted a study to assess the impact of industrial effluents on river water quality in southwestern Nigeria. Water samples were collected from different locations around industrial zones, and various physicochemical properties of the water were analyzed. Key parameters, including pH, temperature, turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), and heavy metal concentrations, were measured using standard laboratory methods. The results indicated a significant deterioration in water quality due to the discharge of industrial effluents, with notable increases in BOD, turbidity, and concentrations of heavy metals like lead (Pb), cadmium (Cd), and mercury (Hg). The pollution levels were found to exceed environmental safety limits, posing serious health risks to both aquatic life and humans. The researchers concluded that industrial activities were a major contributor to

freshwater pollution in the region. They recommended implementing stricter regulations on industrial effluent discharge, promoting green remediation methods such as phytoremediation using native plants, and developing more efficient wastewater treatment infrastructure to mitigate the effects of pollution.

Olorunfemi *et al.,* (2019) conducted an assessment of water quality and pollutant sources in the Lagos Lagoon, one of Nigeria's most important water bodies. The study focused on identifying the key sources of pollution affecting the lagoon, including industrial effluents, sewage, and runoff from urban areas. Water samples were collected from different locations along the lagoon, and parameters such as pH, dissolved oxygen (DO), BOD, heavy metals, and microbiological contamination were analyzed. The study found that the water quality of the Lagos Lagoon was heavily impaired, with high levels of pollutants, particularly organic matter, nutrients, and heavy metals. The primary sources of pollution were identified as untreated sewage, industrial waste, and urban runoff. The authors concluded that the pollution in the Lagos Lagoon posed serious risks to both aquatic ecosystems and the health of the surrounding population. The researchers recommended implementing effective waste management practices, stricter regulation of industrial effluents, and utilizing green remediation techniques, such as constructed wetlands, to treat contaminated water in the lagoon.

Nwachukwu *et al.,* (2021) explored the potential of bioremediation as a green method for cleaning petroleum-contaminated water in Nigeria. The study focused on the use of indigenous bacterial species capable of degrading petroleum hydrocarbons in contaminated water bodies. Water samples were collected from areas affected by oil spills in the Niger Delta region, where petroleum contamination of water is a pressing issue. The researchers isolated native bacteria strains and tested their effectiveness in degrading various hydrocarbons, including benzene, toluene, and xylene. The results showed that the indigenous bacteria were highly effective in breaking down the petroleum contaminants, with degradation rates of up to 75% within a few weeks. The study concluded that bioremediation using native bacteria could be an effective and environmentally friendly method for addressing petroleum contamination in Nigerian water bodies. The author recommended expanding the use of bioremediation techniques in oil spill response efforts, alongside government support for research into other green remediation approaches, such as phytoremediation and bioremediation with fungi.

## SOURCES OF WASTEWATER

**Industrial Discharges:** Industrial waste remains a significant contributor to freshwater contamination in Nigeria. Various sectors such as food processing, textile production, petrochemical, and pharmaceutical industries often release wastewater, either untreated or inadequately treated, into rivers, lakes, and streams. These discharges often contain hazardous substances, including heavy metals (e.g., lead, mercury, cadmium), oils, dyes, detergents, and volatile organic compounds. Such pollutants not only harm aquatic ecosystems but can also accumulate in the food chain, posing serious long-term health threats to humans. In major industrial hubs such as Lagos, Port Harcourt, and Kano, many factories circumvent environmental regulations due to weak enforcement and widespread corruption, exacerbating the pollution crisis. The ongoing discharge of such harmful waste has severely degraded vital water sources, rendering them unfit for drinking, farming, or recreational purposes.

**Agricultural Runoff:** The widespread use of chemical inputs in agriculture

significantly contributes to freshwater degradation. Rainfall and irrigation often wash excess fertilizers and pesticides from fields into nearby water bodies. This runoff introduces large amounts of nitrates, phosphates, and synthetic chemicals into aquatic ecosystems, triggering eutrophication. In this process, nutrient overload leads to excessive algae growth, reduced oxygen levels, and the death of aquatic life. In rural parts of Nigeria, both small-scale and commercial farmers frequently apply agrochemicals without adequate knowledge of their environmental impact. In addition, animal farming contributes to the pollution of rivers and streams through the release of pathogens and organic waste, aggravating the overall contamination of freshwater resources.

**Domestic and Municipal Wastewater:** Wastewater from homes and poorly managed municipal systems is another major source of water pollution in Nigeria. In many urban and suburban areas, the lack of proper sanitation facilities results in raw sewage and greywater being discharged directly into open drains and waterways. These effluents are rich in biological contaminants such as faecal bacteria, viruses, and protozoa, as well as everyday household substances like soaps, oils, detergents, and plastic waste. With most cities lacking centralized sewage treatment facilities, human waste often finds its way into rivers and streams, increasing the risk of diseases such as cholera, typhoid, and hepatitis. The issue is further compounded by unplanned settlements and the uncontrolled dumping of solid waste, particularly during the rainy season, when floodwaters carry pollutants straight into freshwater systems.

## IMPACTS OF FRESHWATER POLLUTION

**Public Health Hazards:** One of the most immediate and devastating impacts of freshwater pollution in Nigeria is the rise in waterborne diseases and general deterioration of public health. Contaminated water sources often harbor pathogens such as *Escherichia coli*, *Salmonella*, Vibrio cholerae, and a wide range of viruses and protozoa, which are responsible for illnesses like cholera, dysentery, typhoid fever, and hepatitis A. These diseases are particularly rampant in urban slums, rural areas, and internally displaced persons (IDP) camps, where access to clean water and sanitation is limited (WHO, 2020). The situation worsens during the rainy season, when floods spread contaminants into wells, boreholes, and rivers used for domestic purposes. Children under five and the elderly are especially vulnerable, with high mortality rates recorded annually due to diarrheal diseases linked to polluted water.

**Decline in Aquatic Biodiversity:** Freshwater pollution significantly disrupts aquatic ecosystems, leading to a decline in biodiversity and the collapse of fragile food webs. Pollutants such as heavy metals, hydrocarbons, and persistent organic pollutants are toxic to aquatic flora and fauna, causing physiological stress, reproductive failure, and mortality in fish, amphibians, invertebrates, and plankton species. Nutrient overload from agricultural runoff promotes eutrophication, leading to algal blooms that block sunlight and reduce oxygen levels in the water, a phenomenon known as hypoxia. These anoxic conditions lead to fish kills and the disappearance of sensitive species, leaving behind only pollution-tolerant organisms and upsetting the ecological balance (Ihuoma *et al.,* 2020).

**Economic Consequences:** The economic impact of freshwater pollution is far-reaching, affecting livelihoods, industrial productivity, and national development. In the agricultural sector, polluted water used for irrigation can damage crops and contaminate food supplies, resulting in reduced yields and market rejection of

produce, especially in export-oriented farming. For fishermen, declining fish populations in polluted rivers result in a loss of income and food insecurity for dependent communities (Ezeonu & Ume, 2023). According to the World Bank Development Report (2024), countries with poor water quality lose up to 1.5% of their GDP annually due to pollution-related costs. In Nigeria, this figure is likely higher given the scale of informal sector dependence on natural water resources and the weak institutional frameworks for environmental management.

**Threat to Food Security:** Freshwater pollution poses a direct threat to food security in Nigeria, particularly for rural communities that rely on subsistence farming and fishing. When contaminated water is used to irrigate crops, it introduces harmful substances into the food chain, leading to the accumulation of heavy metals and pathogens in vegetables, fruits, and cereals. Consuming such contaminated produce poses serious health risks and diminishes the nutritional quality of food (Okoh *et al.,* 2017).

**Diminished Access to Clean Water:** Freshwater pollution significantly restricts the availability of safe drinking water, particularly in regions where surface water is the primary source for domestic use. Rivers, lakes, and streams contaminated with sewage, chemicals, and solid waste are often rendered unfit for human consumption, even after basic filtration or boiling. In states like Delta, Rivers, and Bayelsa, residents are increasingly dependent on sachet water and private boreholes, which are not only expensive but also sometimes contaminated due to the percolation of pollutants into groundwater reserves (Ezeh & Ezeh, 2019).

## CONTROL STRATEGIES

Controlling freshwater pollution in Nigeria requires a comprehensive and integrated approach that addresses both the sources of contamination and the systemic gaps in regulation, infrastructure, and public awareness. The following paragraphs explore critical strategies which are, but not limited to, combating freshwater pollution in Nigeria:

**Strengthening Environmental Regulations and Enforcement:** A robust legal and institutional framework is fundamental to controlling freshwater pollution. Although Nigeria has existing environmental laws, such as the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act and various sectoral guidelines, however, that enforcement remains weak due to inadequate funding, corruption, and limited technical capacity. Strengthening these frameworks requires updating outdated regulations, improving inter-agency coordination, and empowering regulatory bodies with the resources and autonomy to carry out inspections and impose sanctions.

**Investment in Wastewater Treatment Infrastructure:** The lack of centralised and functional wastewater treatment facilities is a significant contributor to freshwater contamination in Nigeria. Building and rehabilitating wastewater treatment plants, especially in urban centers and industrial zones, is essential for preventing the direct discharge of untreated effluents into rivers and streams. Municipalities must be equipped with modern sewage treatment technologies, such as activated sludge systems, trickling filters, or constructed wetlands, depending on local needs and capacities (Adewumi *et al.,* 2018).

**Adoption of Sustainable Agricultural Practices:** Agricultural pollution can be significantly reduced by promoting eco-friendly farming methods and reducing reliance on chemical inputs. Strategies such as integrated pest management (IPM), organic farming, crop rotation, and the use of biofertilizers help minimize nutrient and pesticide runoff (Ihuoma *et al.,* 2020).

Buffer strips and vegetative barriers along riverbanks can also filter out pollutants before they reach water bodies. Extension services must be strengthened to educate farmers about the environmental consequences of agrochemical misuse and to promote soil testing and precision application of fertilizers.

**Public Awareness and Community Participation:** Engaging the public in pollution control efforts is critical for long-term sustainability. Many cases of freshwater contamination in Nigeria stem from poor waste disposal habits, open defecation, and a lack of awareness about the health and ecological impacts of polluted water. Educational campaigns by civil society organizations, faith-based institutions, and local media can play vital roles in community clean-up drives, and school-based water education programs can foster a culture of environmental responsibility (Olalekan *et al.,* 2019).

**Promotion of Green Remediation and Nature-Based Solutions:** Emerging green technologies offer sustainable and cost-effective alternatives for pollution remediation. Phytoremediation, for example, uses plants such as *Vetiveria zizanioides* and *Eichhornia crassipes* (water hyacinth) to absorb and degrade pollutants from contaminated water bodies. Constructed wetlands and vegetated swales can serve as natural wastewater filters, reducing the load of nutrients, sediments, and pathogens entering rivers and lakes (Akanmu *et al.,* 2021).

## GREEN REMEDIATION STRATEGIES

Green remediation technologies are rapidly gaining global recognition as environmentally sustainable alternatives to conventional methods of pollution control. These strategies emphasize the use of natural systems, materials, and renewable processes to remediate contaminated environments with minimal secondary pollution and energy input. Below are green remediation strategies with viable application in Nigeria's freshwater management systems:

**Phytoremediation**: Phytoremediation involves the use of green plants to remove, stabilize, or transform contaminants in soil and water. In freshwater ecosystems, plants such as *Eichhorniacrassipes* (water hyacinth), *Typhalatifolia* (cattail), and *Vetiveriazizanioides* (vetiver grass) have demonstrated the ability to absorb heavy metals, organic compounds, and nutrients from polluted water through processes like phytoextraction, rhizofiltration, and phytodegradation (Akanmu *et al.,* 2021). These plants are cost-effective, readily available in Nigeria, and adaptable to a wide range of hydrological conditions. Phytoremediation is particularly useful in managing eutrophication caused by agricultural runoff, as it reduces nitrate and phosphate concentrations, thereby preventing harmful algal blooms.

**Constructed Wetlands**: Constructed wetlands mimic natural wetland ecosystems to treat wastewater and stormwater in a controlled environment. They consist of engineered basins filled with substrates like gravel and soil, planted with emergent vegetation that facilitates the filtration, adsorption, and microbial breakdown of pollutants. Horizontal subsurface flow wetlands and vertical flow wetlands are among the common designs applicable in Nigeria (Adewole *et al.,* 2022). These systems can remove suspended solids, organic matter, pathogens, and nutrients, making them highly effective for treating domestic and light industrial wastewater before discharge.

**Biofiltration Systems**: Biofiltration is a green remediation technique that uses natural biological processes to degrade contaminants in water as it passes through a filter medium composed of organic or

inorganic materials. In Nigeria, biofilters made from locally available materials such as coconut husk, rice husk, sawdust, and sand have shown promise in removing microbial pathogens, dyes, heavy metals, and nutrients from wastewater (Iwuozor *et al.,* 2023). These systems operate by facilitating microbial activity and physical adsorption within the filter bed, making them highly effective in treating greywater and small-scale industrial effluents.

**Nano-Based Remediation Technologies**: Recent advancements in nanotechnology have introduced nano-based green remediation as an innovative strategy for tackling freshwater contamination. Materials such as nano zero-valent iron (nZVI), titanium dioxide ($TiO_2$), and bio-nanocomposites synthesized from plant extracts are increasingly used to degrade organic pollutants and immobilize heavy metals (Archibong *et al.,* 2024). In Nigeria, research into the use of nZVI supported on activated carbon (nZVI-AC composites) has shown promising results in removing lead and nitrates from industrial wastewater. These nanoparticles exhibit high surface area and reactivity, enabling rapid pollutant removal at low concentrations.

**Algal Remediation (Phycoremediation)**: Phycoremediation is the use of microalgae and macroalgae to remove pollutants from wastewater through bioaccumulation, biosorption, and metabolic transformation. Algae such as *Chlorella vulgaris*, *Spirulina platensis*, and *Scenedesmus* species are known for their ability to uptake heavy metals, ammonia, nitrates, phosphates, and even organic toxins from polluted water sources (Udokang *et al.,* 2021). Algae-based remediation systems can be integrated into wastewater lagoons or photobioreactors and offer dual benefits: water purification and biomass production.

## CHALLENGES OF IMPLEMENTATION

**Limited Technical Expertise:** The successful implementation of green remediation technologies often requires specialized knowledge in environmental science, biotechnology, engineering, and ecology. In Nigeria, there is a shortage of skilled professionals trained in designing, operating, and maintaining green systems such as constructed wetlands or nano-based remediation setups. This gap hinders scalability and sustainability, particularly in rural or underserved areas.

**Inadequate Funding and Investment:** Green technologies, although cost-effective in the long run, often require significant initial capital for design, materials, and setup. In Nigeria, environmental projects are generally underfunded, and the private sector is often hesitant to invest in experimental or unfamiliar technologies. Limited access to environmental financing and a lack of incentives discourage innovation and deployment at scale.

**Poor Policy Framework and Regulatory Support:** While Nigeria has environmental laws in place, there is a lack of specific policies promoting green remediation methods. Regulatory agencies often focus on conventional pollution control measures and may not recognize or support newer, eco-friendly alternatives. The absence of standards for green technologies further complicates their mainstream adoption.

**Low Public Awareness and Acceptance:** Many communities and stakeholders are unaware of the benefits and functioning of green remediation technologies. This leads to skepticism and resistance, particularly when unfamiliar techniques like phycoremediation or nano-remediation are introduced. Without adequate sensitization and education, these solutions may be rejected or poorly maintained by beneficiaries.

**Land Use and Space Constraints:** Some green remediation systems, such as constructed wetlands and phytoremediation setups, require ample space to function effectively. In densely populated or urban areas, acquiring land for such installations is a challenge due to competing needs for housing, infrastructure, and commercial development.

## CONCLUSION

Freshwater pollution in Nigeria represents a significant environmental, health, and economic challenge, but green remediation technologies offer a promising and sustainable solution. Approaches such as phytoremediation, constructed wetlands, biofiltration, nano-based technologies, and algal remediation provide effective means to address water contamination while promoting biodiversity, reducing the environmental footprint, and fostering long-term ecological resilience. However, the successful implementation of these strategies hinges on overcoming key challenges, including limited technical expertise, inadequate funding, weak regulatory frameworks, and low public awareness. With concerted efforts from the government, private sector, and local communities, Nigeria can harness the potential of green technologies to mitigate freshwater pollution, ensuring clean water access for future generations and supporting sustainable development goals. By prioritizing research, public education, and investment in green innovations, Nigeria can pave the way for a cleaner, healthier environment and a more resilient water management system.

## RECOMMENDATIONS

The study hereby proffers recommendations as follows:

1. Non-governmental organizations should invest more in Research and Development (R&D) to adapt and optimize green remediation technologies suitable for Nigeria's environmental conditions.
2. The government should strengthen policy and regulatory frameworks to incentivise the adoption of green technologies and ensure compliance with water treatment standards.
3. Relevant MDAs should increase public awareness and community involvement through educational campaigns and local participation in maintaining green remediation systems.
4. Well-meaning individuals and corporate entities should invest in capacity building and skills development to train professionals in the design, implementation, and maintenance of green remediation technologies.
5. The government should create viable environments to foster public-private partnerships (PPPs) to mobilize resources and expertise for implementing and sustaining green remediation systems in water management.

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