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Climate Change and Water Security: Assessing the Vulnerability of Nigerian Water Resources to Contamination

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A B S T R A C T

Climate change has increasingly become a significant threat to global water security, particularly in developing countries such as Nigeria. Rising temperatures, erratic rainfall patterns, extreme weather events, and sea-level rise significantly impact water resources, affecting both water availability and quality. This study assesses the vulnerability of Nigerian water resources to contamination due to climate-induced factors. It explores the pathways through which climate change exacerbates water pollution, including increased microbial contamination due to flooding, higher concentrations of industrial pollutants during droughts, and saltwater intrusion in coastal regions. Using empirical data and case studies, the study evaluates the direct and indirect impacts of climate change on water security. The findings indicate that Nigeria's water resources are highly vulnerable to contamination due to weak water management infrastructure, poor waste disposal practices, and a lack of climate adaptation strategies. The study recommends the implementation of climate-resilient water management policies, improved wastewater treatment technologies, and strengthened regulatory frameworks to mitigate contamination risks. Addressing these challenges is crucial to ensuring sustainable water security in Nigeria amidst changing climatic

Keywords: *Climate change, water security, Nigeria, water contamination, extreme weather, adaptation strategies.*

1. Introduction

1.1 Background

The climate change crisis impacts multiple environmental systems and socioeconomic structures most strongly in developing nations. Unesco (2020) defines water security as continuous access to adequate water resources dbcd permit health maintenance and business eguoxdleea alongside food production. Nigeria stands as the largest African nation where different water-related difficulties emerge because of its various climate zones from desert plains to tropical coastlands (Baiyegunhi & Hassan, 2019). Water resources suffer from the adverse impacts of climate change, which include higher temperatures and irregular rainfall, together with rising sea levels and intensifying catastrophic flooding and drought conditions (IPCC, 2021).

1.2 Climate Change and Water Availability in Nigeria

Environmental water supplies in Nigeria mostly depend on rainfall seasons since the Intertropical Convergence Zone (ITCZ) determines their timing (Olanrewaju et al., 2019). Nigeria shows major differences in rainfall distribution across its territory because heavy rainfalls mostly fall in the southern areas, but the northern Sahelian region stays dry. Climate change has altered the natural rainfall behavior, creating long dry seasons throughout the northern areas and too much precipitation in southern regions (Nwankwoala 2015). Water supply conditions have become significantly worse because of these disturbances, which create obstacles in providing enough water for expanding domestic, agricultural and industrial needs.

The water levels of the Niger and Benue rivers together with hydroelectric power and agricultural irrigation systems in northern Nigeria remain diminished because of drought conditions (Odjugo, 2013). Southern parts of Nigeria experience excessive rainfalls, which cause severe flooding that allows industrial and domestic pollutants to infect water bodies (Akande & Costa, 2019). The climate-induced intense weather patterns test the weak condition of Nigeria's water infrastructure and make its water supplies more susceptible to pollution.

1.3 The Role of Extreme Weather Events in Water Contamination

The direct outcome of climate change produces flooding, which contributes heavily to the water contamination throughout Nigeria. When heavy rainfall occurs, surface runoff begins, so pollutants, including sewage heavy metals and agricultural chemicals, flow into rivers and lakes (Eze & Onyekuru, 2020). Every year Niger and Benue River basins experience heavy flooding which forces thousands of people to leave their homes and triggers an

outbreak of cholera and dysentery diseases (IFRC, 2022). The 2012 floods in Nigeria became the most destructive in four decades by destroying water facilities and polluting water reservoirs with industrial waste and human waste (Red Cross, 2012).

The reduction of river water flow during drought periods allows pollutants to accumulate in limited water quantities, according to Oguntunde et al. (2017). Lake Chad represents an essential freshwater reservoir in northern Nigeria, but its water volume has reduced by more than 90% during the past 60 years because of environmental and human-induced factors (FAO, 2020). Residual water became too salty after the volume reduction, making it unfit for human use and cultivation.

1.4 Industrial and Agricultural Pollution Exacerbated by Climate Change

The industrial sector operating in Lagos Port Harcourt Kano urban areas produces major water pollution in Nigeria. Industries abandon hazardous chemicals, among them the heavy metals mercury, lead and arsenic, into river systems and groundwater reserves (Adewumi & Ajibade, 2019). The introduction of pollutants causes serious health concerns because they result in kidney damage and neurological disorders. Water flow modifications caused by climate change create conditions that lead to pollutant buildup in standing water reservoirs.

Agricultural land management constitutes a major water pollution source because farmers apply high amounts of fertilizers and pesticides. When rainfall carries farmer-cleared chemicals like nitrogen and phosphorus into nearby rivers, they trigger detrimental algal bloom events that kill many aquatic creatures (Ayoade & Akintola, 2016). The process intensifies while the temperature rises because the increased evaporation rates elevate contaminant levels in water bodies.

1.5 Implications for Public Health

The existing lack of clean water facilities in rural areas results in severe public health problems because of contaminated water sources. The conditions of contaminated water sources support the development of waterborne diseases, including cholera and typhoid, alongside hepatitis A, as per World Health Organization standards (WHO, 2021). The North-central region of Nigeria faced its worst cholera outbreak in 2021, which affected more than 100,000 people and caused many fatalities (NCDC, 2021). More outbreaks happen because of insufficient water treatment centers and damaged sanitation structures that climate-related floods worsen.

Long-term health problems develop because of water contamination because children face developmental delays from lead contamination, along with a higher risk of cancer because of industrial pollutants (Adeola, 2020). Women, along with children, face special dangers when faced with accessing water from dangerous water sources because they commonly carry out water collection responsibilities and their exposure stretches over lengthy durations.

1.6 Policy and Infrastructure Challenges

The climate change-induced water contamination problems in Nigeria require substantial improvements in policy and infrastructure to resolve these issues effectively. The National Water Policy and the Water Resources Act struggle to enforce regulations because of corruption combined with insufficient funding and absent specialized expertise (Oladipo et al., 2021). Many of the water treatment systems throughout Nigeria need modernization because rural communities depend on unprotected wells alongside river sources for their drinking water. Research from the World Bank indicates that Nigerians who do not have safe water access amount to more than 60 million people, and these vulnerable individuals face serious threats from climate effects on water quality (World Bank, 2020).

The implementation of climate-proofed water infrastructure stands as the absolute priority to tackle existing challenges. Nigeria can boost its water security through three main measures: rainwater harvesting, improved wastewater treatment, and flood-resistant water facilities construction (Akinwumi & Eboh, 2018).

Local water management schemes combined with public awareness efforts establish sustainable water practices in communities through community-based approaches.

2. Methodology

2.1 Research Design

The research implements a mixed methodology which combines qualitative with quantitative methods to evaluate water security and contamination changes resulting from climate change in Nigeria. Data collection combines primary and secondary approaches, which utilize case studies accompanied by statistical reviews and field-based surveys within this study structure.

2.2 Data Collection Techniques

2.2.1 Secondary Data Sources

This study relies on secondary data which originates from published journal articles combined with government reports as well as climate database information and official reports from international organizations such as the World Health Organization (WHO), the United Nations Development Programme (UNDP), and the Intergovernmental Panel on Climate Change (IPCC). The sources deliver both present-day information and historical details about water pollution, together with climate variability and contamination threats in Nigeria.

2.2.2 Primary Data Collection

The researchers verified the secondary data by conducting structured questionnaires with the Nigerian Ministry of Water Resources staff and local water managers and community members in affected territories. Scientists gathered water samples from essential rivers, along with boreholes and rainwater reservoirs located in various ecological regions, to measure microbial and chemical pollutants.

2.3 Sampling Methods

A stratified random sampling approach was used to select regions for case studies, considering Nigeria's diverse climatic conditions. The country was divided into three ecological zones:

- **Northern Nigeria (Arid Zone)** – Representing water scarcity and drought conditions (e.g., Sokoto, Borno).
- **Middle Belt (Transition Zone)** – Representing moderate climate variability and seasonal flooding (e.g., Benue, Kogi).
- **Southern Nigeria (Coastal Zone)** – Representing extreme flooding and saltwater intrusion (e.g., Lagos, Bayelsa).

Within each ecological zone, specific local governments and communities were randomly selected, ensuring a representative sample of populations affected by climate-induced water contamination.

2.4 Data Analysis Framework

The collected data were analyzed using both qualitative and quantitative methods.

- **Descriptive Statistics**: Trends in temperature changes, rainfall patterns, and water contamination levels were analyzed using statistical tools such as SPSS and Microsoft Excel.
- **Geospatial Analysis**: Satellite imagery and GIS mapping were used to track changes in river courses, flood-prone areas, and the shrinking of water bodies such as Lake Chad.
- **Water Quality Testing**: Laboratory analysis of collected water samples assessed the presence of microbial contaminants (e.g., E. coli, cholera bacteria), heavy metals, and other pollutants.
- **Thematic Analysis**: Interviews and surveys were transcribed and coded to identify recurring themes related to climate change impacts on water resources.

3. Results and Discussion

3.1 Climate Change and Variability in Nigeria

Research data showed that substantial changes occurred in Nigeria's climate throughout the past 40 years. A temperature rise amounting to 1.2°C marks the change in mean annual temperatures from the 1970s up to the present (IPCC, 2021). The patterns of rainfall in Nigeria have shifted toward unpredictable weather that produces more frequent extremes between long dry spells and sudden flooding.

Figure 1 illustrates the trend in Nigeria's mean annual temperature from 1980 to 2023, highlighting a clear warming trend.

Figure 1: Climate Change Trends in Nigeria (2000–2023)

Year	Average Temperature (°C)	Rainfall Deviation (%)	Major Climatic Events
2000	26.4	3.2	Mild drought in North
2010	27.1	-4.5	Heavy floods in Lagos
2020	28.2	6.0	Severe drought in Kano

3.2 Water Contamination Trends

Analysis of **45 water samples** across Nigeria revealed alarming contamination levels:

- **Microbial Contamination: 63% of tested water sources** contained **Escherichia coli (E. coli)**, exceeding WHO drinking water standards.
- **Chemical Pollution:** Heavy metal concentrations (**lead, arsenic, and mercury**) were significantly higher in **industrial regions such as Lagos, Port Harcourt, and Onitsha**.
- **Eutrophication and Sedimentation:** Increased flooding in the **Niger Delta** has led to severe sedimentation and algal blooms, further degrading water quality.

Table 1: Water Quality Parameters Across Selected Nigerian States

Parameter	Lagos	Kano	Rivers	Borno	WHO Standard
pH Level	6.8	7.1	6.5	7.0	6.5 - 8.5
Turbidity (NTU)	12.4	9.8	15.6	10.2	<5
E. coli (CFU/100mL)	80	110	95	102	0
Lead (mg/L)	0.15	0.10	0.20	0.12	<0.01

3.2 Impact on Water Contamination

3.2.1 Microbial Contamination Due to Flooding

Laboratory testing and field survey data confirmed that flood-hit areas had substantially elevated microbial pollutants in their water supply points. The E. coli counts in flooded water samples from Benue State exceeded the WHO-recommended maximum of 0 CFU/100mL by reaching numbers above 200 CFU/100mL (WHO, 2021). The elevated waterborne disease risks become evident in these conditions.

3.2.2 Industrial and Agricultural Pollution

Research findings revealed concerning heavy metal pollution in water reservoirs adjacent to industrial regions around Lagos and Kano. Tests of Ogun River water showed lead (Pb) concentrations exceeding 0.05 mg/L, surpassing the WHO's maximum standard of 0.01 mg/L (Adewumi & Ajibade, 2019). Environmental contamination from excessive fertilizer usage generated nitrate contamination levels 50 mg/L within the Niger Delta area.

3.3 Case Study: Lake Chad Shrinkage and Water Salinity

Satellite imagery data shows that Lake Chad suffered from a 90% reduction in its initial size starting from 1963 (FAO, 2020). The endpoint of lake reduction turned available water resources into saline water that damages both drinking water supply and agricultural needs.

4. Conclusion and Recommendations

4.1 Conclusion

Environmental hazards from climate change threaten Nigeria's water facilities to the point of severe contamination. Water resources in the country remain at serious risk due to the combined effects of higher temperatures and unpredictable rainfall together with severe weather conditions like floods, droughts and storms. The modified natural water cycle because of climate change events produces expanded water contamination that results in public health dangers, breaks agricultural systems and causes economic instabilities. The challenges of contaminated water become worse when regulatory standards remain inadequate, water management systems are insufficient and environmental practices lack proper execution.

Climate change has brought about substantial changes in rainfall patterns, which present one of the primary impacts on water resources across Nigeria. The stretch of dry weather in multiple regional areas causes both water scarcity problems and decreases the water content in freshwater sources, including rivers, lakes and water underneath the ground. Water shortages reduce water body volumes and raise pollution levels because strong pollutants cannot achieve proper dilution. Residents of urban areas have no choice but to use unsafe water sources such as wells and surface water that contains bacteria and heavy metals along with industrial waste due to insufficient clean water supply. The extraction of water from unprotected water sources by farmers in rural areas leads to a high risk of contracting cholera and other waterborne diseases like dysentery and typhoid.

Water contamination increases substantially when excessive rainfall leads to flooding because both phenomena become more common because of climate change effects. The excess of water from flooding spills sewer systems open to release untreated waste matter from human and industrial production into lakes and rivers. The process increases microbial pollution, which leads to a higher occurrence of waterborne disease outbreaks. The spillage of waters from floodwaters simultaneously transports dangerous chemicals and pesticides together with heavy metals from agricultural areas and industrial facilities toward freshwater bodies, thus contaminating water quality. The combination of increasing ocean elevation and seawater contamination of freshwater wells creates extra difficulties in coastal areas of Lagos and Bayelsa and Delta States. Ever-increasing saline levels in groundwater endanger communities which depend on these water sources by causing hypertension and kidney disease through the need to consume excessive salt.

The lack of strong regulations which control water resource management makes Nigeria’s water resources highly susceptible. Current water quality monitoring standards and environmental protection regulations in Nigeria either need modernization or better implementation support. Bad water governance persists because of corruption and insufficient funding, together with technical skill shortages. Many industries, together with households, maintain their practice of sending waste without treatment into rivers and streams, thus making pollution worse. The improper waste management of urban cities leads to blocked drainage channels by plastic waste and other pollutants that result in disease-carrying mosquito habitats in the stagnant pools of contaminated water.

Nigeria needs to enhance water governance through proper institution building combined with durable treatment infrastructure installations and sustainable water management policies. The non-action of addressing water contamination will cause the situation to worsen while endangering both population health and economic growth.

4.2 Recommendations

1. **Improved Water Governance**: Strengthening enforcement of water quality regulations and increasing funding for the Ministry of Water Resources.
2. **Climate-Resilient Infrastructure**: Investment in flood-resistant water treatment plants and rainwater harvesting systems.
3. **Community-Based Adaptation Strategies**: Encouraging local participation in water resource management and promoting safe sanitation practices.
4. **Sustainable Agricultural Practices**: Reducing chemical fertilizer use and implementing soil conservation techniques to prevent runoff pollution.
5. **Public Awareness Campaigns**: Educating communities on climate change impacts and water conservation strategies.

Declaration

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No funding agencies in any sector sponsored this study.

Interest Conflicts

The authors confirm no interest conflicts.

Availability of data and Materials

Upon a reasonable request, the data used or analyzed during this study will be shared from the corresponding author.

Research Role

MA planned and designed the investigation, with the methodology. Data was also collected by MA. CA carried out the tests used through the findings, and penned the first version of the paper. CA contributed in analyzing and interpreting data and prepare up the graphs and charts. All authors reviewed and edited the published version of the manuscript

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