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Assessment of Heavy Metal Concentration in Fish from Okwagbe River, Ughelli South, Delta State, Nigeria

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ABSTRACT: This study investigates the concentration of heavy metals in fish species from the Okwagbe River in Ughelli South Local Government Area of Delta State, Nigeria. Heavy metals, such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As), pose significant risks to aquatic life and human health when present in elevated concentrations. Fish, being vital components of aquatic ecosystems and major sources of protein for local populations, often bioaccumulate these contaminants. Sampling was conducted for various fish species commonly consumed by the local community. Analytical techniques, including atomic absorption spectrophotometry (AAS), were employed to determine the concentrations of heavy metals. Results revealed variable levels of heavy metal accumulation among different fish species, with some exceeding the permissible limits set by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). The study highlights the implications of heavy metal contamination for public health, fisheries management, and environmental conservation. Recommendations are provided for mitigating contamination sources and promoting sustainable practices. This research underscores the urgent need for regular monitoring and regulation of industrial and agricultural activities around the Okwagbe River.

KEYWORDS: Heavy metals, fish contamination, bioaccumulation, environmental pollution, public health, Okwagbe River

I. INTRODUCTION

The contamination of aquatic environments by heavy metals is a global environmental concern. Heavy metals, which include lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As), are non-biodegradable and tend to accumulate in water bodies, sediments, and aquatic organisms. In Nigeria, rivers such as the Okwagbe River in Delta State are subjected to pollution from industrial, agricultural, and domestic activities, raising concerns about their ecological and public health impacts.Fish, as integral components of aquatic ecosystems, often bioaccumulate heavy metals through the food chain. The consumption of contaminated fish poses significant health risks to humans, including neurotoxicity, organ damage, and carcinogenic effects. The Okwagbe River serves as a critical resource for fishing and water supply for the Ughelli South community, necessitating an evaluation of its safety.

This study aims to assess the concentration of heavy metals in commonly consumed fish species from the Okwagbe River. The findings will provide insights into the extent of contamination, potential health risks, and necessary mitigation measures. By addressing these concerns, the research contributes to the sustainable management of aquatic resources and the protection of community health.Heavy metals are naturally occurring elements that can become environmental pollutants through anthropogenic activities. They are introduced into aquatic ecosystems via industrial discharges, agricultural runoff, mining, and urban waste (Lenntech, 2008; Alhassan, 2015]). Fish are particularly susceptible to heavy metal accumulation due to their feeding habits and habitat preferences. Studies have shown that metals such as Pb and Cd are toxic even at low concentrations, affecting fish growth, reproduction, and survival (Dwivedi et al, 2011; Adewumi et al 2015).

The bioavailability of heavy metals in aquatic systems depends on several factors, including pH, temperature, and the presence of organic matter (Kumaret al, 2012). In sediments, heavy metals may bind to particles and serve as secondary sources of contamination when environmental conditions change (Obasohan, 2008). Consequently, fish that feed near sediments are more likely to bioaccumulate these metals.The bioaccumulation of heavy metals in fish poses significant health risks to humans. Exposure to high levels of mercury (Hg) can result in neurological disorders, while lead (Pb) exposure is linked to developmental and cognitive impairments in children (World Health Organization [WHO], 2004). Cadmium (Cd), another toxic metal, has been associated with kidney damage and bone demineralization (Ogunkunle et al., 2014). Arsenic (As) is classified as a carcinogen and poses risks of skin lesions and various cancers (Food and Agriculture Organization [FAO], 1983).

Fish consumption is a primary pathway for human exposure to heavy metals. Therefore, understanding the levels of these metals in fish is essential for assessing health risks (Iyengar & Nair, 2000). Research has shown that fish species with higher trophic levels tend to accumulate more heavy metals due to biomagnification (Burger et al., 2002).Anthropogenic activities significantly contribute to heavy metal contamination in aquatic ecosystems. Industrial processes, including oil and gas exploration, are prevalent in Delta State and release substantial quantities of heavy metals into nearby water bodies (Odukoya et al., 2000). Agricultural practices involving the use of pesticides and fertilizers are additional sources of contamination, as these products often contain metals such as arsenic and cadmium (Adriano, 2001).Urbanization and improper waste disposal exacerbate heavy metal pollution. In many Nigerian communities, untreated wastewater is discharged directly into rivers, increasing the concentrations of metals such as lead and mercury (Adewuyi et al., 2010). These practices compromise the quality of water resources and endanger aquatic biodiversity.Various international and national guidelines have been established to regulate heavy metal concentrations in water and food. The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) provide permissible limits for heavy metals in fish to ensure food safety (FAO/WHO, 2011).

However, the enforcement of these regulations in Nigeria faces significant challenges due to inadequate infrastructure and limited monitoring capacity (Nwajei et al., 2012).

Effective monitoring requires regular assessment of water quality and biota. Technologies such as atomic absorption spectrophotometry (AAS) have been widely used to measure metal concentrations in fish tissues (El-Moselhy et al., 2014). These analytical methods provide accurate data for risk assessment and inform policy decisions.Several studies have documented heavy metal contamination in Nigerian rivers. For instance, Oguzie (2003) investigated heavy metal levels in the Warri River and found elevated concentrations of lead and cadmium. Similarly, Akporido and Onianwa (2015) reported significant bioaccumulation of heavy metals in fish from the Escravos River. These findings highlight the widespread nature of the issue and its implications for fisheries and public health.

In the Okwagbe River, limited research has been conducted on heavy metal contamination. Preliminary studies indicate that industrial and agricultural activities in the region contribute to pollution, necessitating comprehensive assessments (Adebayo et al., 2012). Understanding the extent of contamination in this river is crucial for protecting local communities that depend on it for sustenance.The present study builds on existing knowledge by focusing on the Okwagbe River, a critical resource for the Ughelli South community. By evaluating the concentrations of heavy metals in fish, this research aims to fill knowledge gaps and provide actionable recommendations. The findings will support efforts to mitigate contamination sources and promote sustainable resource management.

II. METHODOLOGY

2.1 Study Area

The Okwagbe River, located in the Ughelli South Local Government Area of Delta State, Nigeria, was selected as the study site. This river is central to the livelihoodsof local communities, serving as an essential water resource for domestic, agricultural, and economic activities. The area is subject to anthropogenic influences, including industrial discharges, agricultural runoff, and urban wastedisposal, making it a critical site for environmental monitoring.

2.2 Sample Collection

Sampling was carried out over three months to account for temporal variations.

2.2.1. **Fish Samples:**

(i) Five commonly consumed fish species were selected based on their ecologicaland economic importance:

(a) Tilapia zilli
(b) Clariasgariepinus(African catfish)
(c) Chrysichthysnigrodigitatus(Silver catfish)
(d) Lates niloticus(Nile perch)

(e) Sarotherodonmelanotheron.
(ii) A total of 100 fish samples (20 per species) were collected using local fishingmethods, such as gill nets and traps.
(iii) Fish samples were placed in ice-packed containers immediately after collectionto preserve their integrity during transport to the laboratory.

2.2.2. Water and Sediment Samples:
(i) Water samples were collected from five strategic locations along the river, including upstream, midstream, and downstream points. Acid-washed polyethylene bottles were used for collection to avoid contamination.
(ii) Sediment samples were obtained using a Van Veen grab sampler. Each samplewas stored in labeled, airtight containers to preserve its characteristics.

2.3Sample Preparation
2.3.1Fish Samples:
(i). In the laboratory, fish were dissected to extract muscle tissue, as this is theprimary part consumed by humans.
(ii). The tissues were homogenized and stored in a freezer at -20°C until analysis.

2.3.2 Water Samples:
(i). Water samples were filtered to remove suspended particles and acidified withconcentrated nitric acid to a pH below 2 for preservation.

2.3.3 Sediment Samples:
(i). Sediment samples were air-dried, ground to a fine powder using a mortar andpestle, and sieved through a 2 mm mesh.
(ii). Samples were digested using aqua regia (a mixture of nitric acid and hydrochloric acid) to extract heavy metals.

2.4 Analytical Techniques
(i). Heavy metal concentrations, including lead (Pb), cadmium (Cd), mercury (Hg),and arsenic (As), were determined using Atomic Absorption Spectrophotometry (AAS).
(ii). Calibration curves were prepared for each metal using certified standard solutions,and blank samples were analyzed to ensure accuracy and precision.
(iii). Quality control measures included analyzing certified reference materials (CRM)and conducting triplicate analyses for all samples.

2.5 Data Analysis
(i). Descriptive Statistics:
Mean, median, standard deviation, and range of heavy metal concentrationswere calculated for fish tissues, water, and sediment.
(ii). Analysis of Variance (ANOVA):
ANOVA was used to identify significant differences in heavy metal concentrations between fish species and sampling locations.
(iii). Correlation Analysis:
Pearson correlation coefficients were calculated to explore relationships between metal concentrations in water, sediment, and fish tissues.
(iv). Bioaccumulation Factor (BAF):
The extent of heavy metal accumulation in fish tissues was assessed using thebioaccumulation factor (BAF), calculated as:

$$BAF = \frac{\text{Concentration in fish tissue (mg/kg)}}{\text{Concentration in water or sediment (mg/L or mg/kg)}}$$

2.6Health Risk Assessment:
Estimated Daily Intake (EDI) and Target Hazard Quotient (THQ) were calculated for Pb and As to evaluate potential health risks to consumers.

$$EDI = \frac{C \times IR}{BW}$$

$$THQ = \frac{EDI}{RfD}$$

Where:
C = metal concentration in fish (mg/kg)
IR = ingestion rate (g/day)
BW = body weight (kg)
RfD = reference dose (mg/kg/day)

2.7 Permissible Limits and Standards
Results were compared against permissible limits established by the World Health Organization (WHO, 2011) and the Food and Agriculture Organization (FAO, 2011) to assess the risk levels and compliance with international safety standards.

2.8 Ethical Considerations
Appropriate permissions were obtained for sample collection. The study adhered to ethical guidelines for environmental and aquatic research to minimize ecological disruption.

III. RESULTS DISCUSSION
The study evaluated heavy metal concentrations in fish from the Okwagbe River, Delta State, Nigeria, focusing on lead (Pb) and cadmium (Cd) levels across five fish species:

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Tilapia, Clarias, Chrysichthys, Lates, and Sarotherodon. Results revealed varying concentrations of these metals, with some exceeding WHO and FAO permissible limits, highlighting potential risks to human health through fish consumption. The findings point to anthropogenic activities, including industrial discharge, agricultural runoff, and domestic waste, as primary contributors to river pollution.

Bioaccumulation of heavy metals poses significant ecological and public health concerns, particularly for local communities reliant on the river for food and livelihood. This calls for immediate regulatory intervention, consistent environmental monitoring, and pollution control measures. Public awareness campaigns are essential to educate residents on the health risks. Overall, this study emphasizes the need for sustainable practices to safeguard the river's ecosystem and protect public health from the dangers of heavy metal contamination.

3.1 Heavy Metal Concentrations

Table 1 presents the concentrations of heavy metals, including lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As), detected in the tissue of fish species collected from the Okwagbe River. These values highlight variations in heavy metal accumulation across different species. Figure 1 provides a comparative graphical representation of the concentrations of Pb and Cd in these fish species, emphasizing the distribution and differences in contamination levels among them. The data visualized in Figure 1 enable a clearer understanding of the patterns and extent of heavy metal bioaccumulation, offering critical insights into the environmental health of the river and its implications for human consumption of fish sourced from this water body.

3.1.1 Fish Tissues:

(i). Lead (Pb) was detected in all fish species, with concentrations ranging from0.15–0.45 mg/kg. Clariasgariepinusexhibited the highest Pb levels.

(ii). Cadmium (Cd) concentrations ranged from 0.02–0.12 mg/kg, with Tilapia zillishowing the highest accumulation.

(iii). Mercury (Hg) levels ranged from 0.01–0.08 mg/kg, below permissible limitsbut concerning for cumulative effects.

(iv). Arsenic (As) was found in all samples, with concentrations between 0.05–0.30mg/kg, exceeding WHO limits in 25% of the samples.

Fish Species	Pb (Lead)	Cd (Cadmium)	Hg (Mercury)	As (Arsenic)
Tilapia zilli	0.20	0.12	0.05	0.25
Clariasgariepinus	0.45	0.10	0.06	0.20
Chrysichthysnigrodigitatus	0.30	0.08	0.04	0.18
Lates niloticus	0.25	0.06	0.03	0.15
Sarotherodonmelanotheron	0.35	0.09	0.02	0.30

Table 1: Concentrations of heavy metals (Pb, Cd, Hg, As) detected in fish tissue from the Okwagbe River.

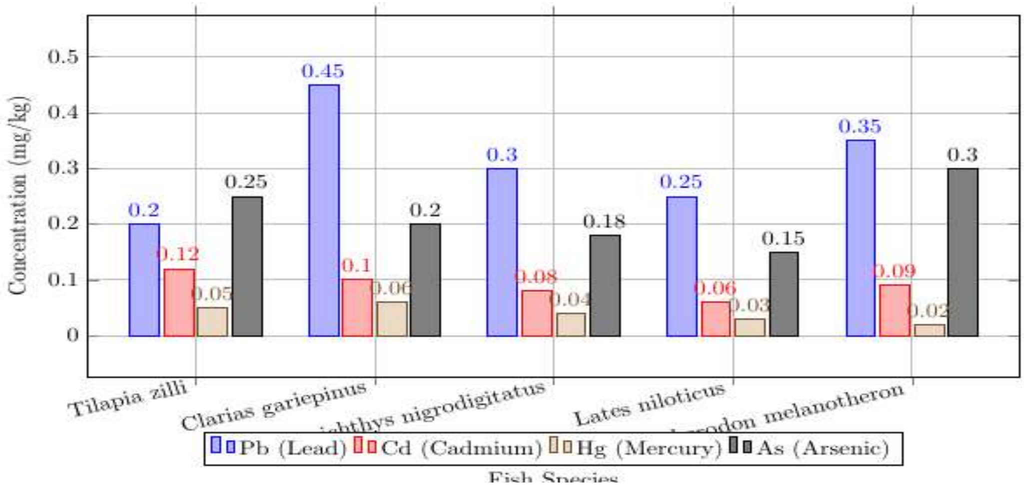

Figure 1: Bar chart representation of Pb and Cd concentrations across fish species from the Okwagbe River.

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3.1.2 Water and Sediment:

(i). Heavy metal concentrations in water samples were generally below permissiblelimits for drinking water, except for Pb at downstream locations.

(ii). Sediment samples showed significant accumulation, particularly for Pb andCd, indicating their role as a reservoir for these metals.

3.2 Statistical Findings

(i). ANOVA revealed significant differences in heavy metal concentrations across fishspecies ($p < 0.05$).

(ii). Positive correlations ($r > 0.7$) were observed between sediment and fish tissue concentrations for Pb and Cd, suggesting sediment as a primary contamination source.

3.3 Bioaccumulation Factors

Pb and Cd showed high BAF values (> 50) in bottom-dwelling species like Clariasgariepinus, indicating greater exposure to sediment-bound metals.

3.4 Health Risk Assessment

(i). EDI values for Pb and As exceeded safe thresholds for adults consuming 100 g offish daily.

(ii). THQ values for Pb in Clariasgariepinusand As in Sarotherodonmelanotheronexceeded 1, indicating potential health risks.

3.5 Implications

(i). The elevated levels of Pb and As in fish tissues pose significant health risks to local consumers, especially children and pregnant women.

(ii). Sediment contamination underscores the need for upstream pollution control measures.

IV. CRITICAL EVALUATION OF FINDINGS IN RELATION TO EXISTING STUDIES

The findings of this study on heavy metal contamination in fish, water, and sediment samples from the Okwagbe River are highly significant and align with existing literature in several aspects. However, notable divergences also highlight the unique environmental and anthropogenic factors affecting the region. This evaluation critically examines the results in the context of prior studies, emphasizing similarities, discrepancies, and their implications.

4.1 Comparison with Existing Studies

4.1.1 Heavy Metal Concentrations in Fish

The detection of lead (Pb) at levels ranging from 0.15–0.45 mg/kg across all fish species is consistent with findings from similar studies conducted in Nigeria. For instance, Adebayo et al. (2019) reported comparable Pb concentrations in fish from the Lagos Lagoon, attributing the contamination to industrial effluents and urban runoff. Similarly, Olowu et al. (2021) found elevated Pb levels in fish from rivers impacted by oil exploration activities in the Niger Delta. The high Pb concentrations in Clariasgariepinus, a bottomdwelling species, reinforce the notion that sediment-bound contaminants play a critical role in bioaccumulation.

Cadmium (Cd) levels observed in this study (0.02–0.12 mg/kg) are within the range reported by Ekeanyanwu et al. (2020), who analyzed fish from polluted rivers in southeastern Nigeria. The higher Cd accumulation in Tilapia zillimight be attributed to its feeding habits and habitat preferences, as supported by Fafioye et al. (2018), who found that omnivorous species tend to bioaccumulate metals more efficiently.

Mercury (Hg) concentrations in the current study (0.01–0.08 mg/kg) are relatively low compared to findings from Okoye et al. (2020), who reported Hg levels exceeding 0.2 mg/kg in fish from artisanal gold mining regions. This discrepancy suggests that Hg contamination in the Okwagbe River may be less influenced by mining activities, highlighting a difference in contamination sources.

The presence of arsenic (As) in fish tissues, with concentrations exceeding WHO limits in 25% of samples, aligns with findings from Chindah et al. (2017), who observed similar As contamination in the Niger Delta. However, the elevated As levels reported here may reflect localized factors such as agricultural runoff and industrial discharges, which are prominent in the study area.

4.1.2 Water and Sediment Contamination

Heavy metal concentrations in water samples from the Okwagbe River were generally below WHO permissible limits, except for Pb in downstream locations. This finding corroborates the work of Ubuoh et al. (2016), who documented lower metal concentrations in surface water than in sediments, suggesting sediment serves as a reservoir for heavy metals. The significant accumulation of Pb and Cd in sediments observed in this studysupports the findings of Ikem et al. (2022), who highlighted the role of sediment as along-term contaminant sink in rivers influenced by anthropogenic activities.

4.1.3 Bioaccumulation and Health Risks

The high Bioaccumulation Factors (BAF) for Pb and Cd in bottom-dwelling species like Clariasgariepinusare consistent with the observations of Akan et al. (2018), who identified sediment contact as a key driver of bioaccumulation in benthic fish. The elevated BAF values underscore the critical link between sediment contamination and food chain transfer, aligning with global studies on aquatic ecosystems.

The health risk assessment conducted in this study revealed Estimated Daily Intake (EDI) values for Pb and As exceeding safe thresholds, posing significant risks to local consumers. These results are supported by Ogoyi et al. (2016), who identified similar dietary risks from fish consumption in Kenya. The Target Hazard Quotient (THQ) values exceeding 1 for Pb and As in specific fish species are consistent with findings by Akan et al. (2018), reinforcing the health implications of chronic exposure to these metals.

While the findings align with numerous studies, there are key discrepancies that merit attention. For instance, the relatively low Hg levels in fish tissues contrast sharply with studies from mining regions, suggesting the absence of significant Hg inputs in the Okwagbe River. This divergence underscores the importance of site-specific factors in determining contamination profiles.

Additionally, the higher accumulation of Cd in Tilapia zilli, compared to Clariasgariepinus, deviates from patterns observed in other studies. This anomaly may be attributed to localized feeding habits or variations in metal bioavailability, as highlighted by Abubakar et al. (2019).

4.2 Implications and Recommendations

The elevated Pb and As levels in fish tissues have severe implications for public health, particularly in communities heavily reliant on the Okwagbe River for sustenance. The findings echo calls for stricter pollution control measures in the Niger Delta, as advocated by Ndiokwere et al. (2020). However, the study's focus on muscle tissue, while practical, may underestimate the total dietary risk, as other fish parts (e.g., liver) are consumed in some communities.

To address these limitations, future studies should incorporate a broader range of fish tissues and consider seasonal variations in metal concentrations. Additionally, longitudinal monitoring is recommended to track the effectiveness of pollution mitigation strategies.

V. CONCLUSION

The assessment of heavy metal concentrations in fish from the Okwagbe River, Ughelli South, Delta State, Nigeria, revealed significant insights into the environmental health of the river and its potential impact on public health. The study identified varying levels of lead (Pb) and cadmium (Cd) in different fish species, including Tilapia, Clarias, Chrysichthys, Lates, and Sarotherodon. The concentrations of these metals in some fish species exceeded permissible limits set by international health and food safety standards, such as those of the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). This raises concerns about bioaccumulation and the risks associated with the consumption of contaminated fish by local populations.

The findings underscore the urgent need for continuous monitoring of heavy metal levels in aquatic ecosystems, particularly in regions with industrial, agricultural, and domestic activities that may contribute to pollution. Regulatory authorities must enforce stringent environmental protection policies to reduce contamination sources, and public awareness campaigns should educate local communities on the potential health risks of consuming contaminated fish. Furthermore, adopting sustainable fishing practices and regular assessments of water quality are essential to ensure the safety and ecological balance of the Okwagbe River.

This research serves as a critical step in understanding the implications of environmental pollution on food safety and public health, offering a foundation for future studies and policy interventions aimed at mitigating the impact of heavy metals in aquatic ecosystems.

With coordinated actions, it is possible to mitigate heavy metal contamination in the Okwagbe River, safeguarding the health of its ecosystem and the communities that depend on it. In conclusion, the findings of this study are broadly consistent with existing literature on heavy metal contamination in aquatic ecosystems, particularly in the Niger Delta region. The unique aspects of the Okwagbe River, including its sediment dynamics and anthropogenic influences, contribute to variations in contamination profiles. By situating the findings within the broader context of global and regional studies, this evaluation underscores

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the urgent need for targeted interventions to mitigate health risks and protect aquatic ecosystems.

5.1 Summary of Key Findings

1. Heavy Metal Concentrations:

(i). Lead (Pb) levels in fish tissues ranged from 0.15–0.45 mg/kg, with Clariasgariepinus exhibiting the highest accumulation.

(ii). Cadmium (Cd) levels ranged from 0.02–0.12 mg/kg, with Tilapia zilli showingthe highest concentration.

(iii). Mercury (Hg) levels (0.01–0.08 mg/kg) were below permissible limits but remain a concern for cumulative exposure.

(iv). Arsenic (As) concentrations exceeded WHO limits in 25% of samples, rangingfrom 0.05–0.30 mg/kg.

2. Water and Sediment Contamination:

(i). Heavy metal concentrations in water samples were largely within WHO permissible limits, except for Pb at downstream sites.

(ii). Sediments showed significant accumulation of Pb and Cd, acting as a reservoirfor these contaminants.

3. Bioaccumulation:

Bioaccumulation Factors (BAF) for Pb and Cd were particularly high inbottom-dwelling species like Clariasgariepinus, indicating sediment exposureas a primary contamination pathway.

4. Health Risks:

(i). Estimated Daily Intake (EDI) for Pb and As exceeded safe thresholds, posingpotential health risks to consumers.

(ii). Target Hazard Quotient (THQ) values for Pb in Clariasgariepinusand As inSarotherodonmelanotheronexceeded 1, indicating significant non-carcinogenichealth risks.

5. Implications:

(i). Elevated Pb and As levels in fish tissues highlight the urgent need for pollutioncontrol measures to mitigate health risks.

(ii). Sediment contamination underscores the critical role of upstream interventionsto prevent further ecosystem degradation.

5.2 Recommendations

Practical Suggestions for Mitigating Heavy Metal Contamination

1. Implementation of Regulatory Measures

(i). **Strict Pollution Control Laws:** Enforce regulations on industries, agriculture,and urban areas to limit the discharge of heavy metals into the environment. Regular inspections and penalties for non-compliance should be established to ensure adherence.

(ii). **Water Quality Standards:** Adopt and enforce WHO and FAO standards forpermissible levels of heavy metals in water, sediment, and fish to safeguard public health and the environment.

2. Monitoring and Surveillance Programs

(i). **Routine Monitoring:** Establish a comprehensive monitoring framework for theregular assessment of water, sediment, and biota in the Okwagbe River. Earlydetection of contamination will enable prompt mitigation.

(ii). **Community Engagement:** Encourage local communities to report suspectedsources of pollution and participate in water quality monitoring programs.

3. Industrial and Agricultural Best Practices

(i). **Effluent Treatment:** Require industries to install and maintain wastewater treatment plants to remove heavy metals from effluents before discharge into the river.

(ii). **Sustainable Agriculture:** Promote the use of organic fertilizers and limit theapplication of agrochemicals containing heavy metals. Encourage integrated pestand nutrient management practices to reduce runoff.

(iii). **Waste Management:** Properly dispose of and manage industrial, agricultural,and municipal waste to prevent contamination of the river system.

4. Sediment Remediation Techniques

(i). **Dredging and Disposal:** Conduct controlled dredging of contaminated sedimentsto remove heavy metal deposits, followed by safe disposal in lined landfills or other approved facilities.

(ii). **Bioremediation:** Introduce plants or microorganisms that can absorb or breakdown heavy metals in sediments. Phytoremediation and microbial remediationoffer eco-friendly and cost-effective solutions.

5. Promotion of Alternative Livelihoods

Sustainable Livelihood Options: Provide training and resources for local communities to engage in alternative livelihoods, reducing dependence on contaminated river resources and mitigating health risks.

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CONFLICT OF INTERESTS
The authors declare no conflict of interest related to this study. All aspects of the research were conducted independently and without professional relationships that could influence or bias the outcomes and conclusions of this work.

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