International Journal of Functional Research in Arts and Humanities (IJFRAH)

Vol. 3 No. 2 (2024)

Risk Assessment of Heavy Metals and Endocrine Disruptive Compounds in Water, Sediment, and Biota in Igbariam, Anambra State

Idigo Mediatrix Amara

Department of Political Science, Chukwuemeka Odumegwu Ojukwu University, Igbariam, Anambra State, Nigeria

Abstract

Riverine communities across Nigeria's Niger-Benue and associated tributary systems, including the Anambra (Omambala) River system bordering Igbariam, face documented risks of heavy metal and endocrine disruptive compound (EDC) contamination linked to agricultural runoff, artisanal and small-scale mining activity upstream, inadequate wastewater management, and, in some catchments, oil and gas-related activity. This paper presents a risk assessment framework for evaluating heavy metal and endocrine disruptive compound contamination in water, sediment, and biota within the Igbariam area of Anambra State, synthesizing established environmental risk assessment methodologies with findings drawn from comparable published studies of Nigerian surface water systems. Rather than presenting original laboratory sampling data, which was outside the scope of this desk-based study, the paper develops and specifies a comprehensive risk assessment protocol, encompassing sampling design across water, sediment, and biota matrices, target contaminant selection informed by regional land-use and industrial activity patterns, appropriate analytical methods, and the calculation of standard risk indices, including hazard quotients, hazard indices, and bioaccumulation factors, that would be required to generate a rigorous, site-specific risk characterization for the Igbariam area. The paper reviews documented contamination patterns and associated ecological and human health risks reported in comparable Nigerian riverine and tributary systems, and uses this comparative evidence to identify the specific heavy metals (including lead, cadmium, mercury, and chromium) and endocrine disruptive compound classes (including phthalates, bisphenol A, and certain organochlorine pesticide residues) most warranting priority investigation in the Igbariam context. The paper concludes that a formally executed empirical risk assessment following the proposed framework is warranted given the documented contamination patterns in comparable regional

water systems and the direct human exposure pathways associated with the Igbariam community's reliance on local water resources for domestic and agricultural use.

Keywords: Heavy metals, endocrine disruptive compounds, risk assessment, Igbariam, water quality

1. Introduction

Water quality degradation linked to heavy metal and endocrine disruptive compound contamination represents a significant and growing environmental health concern across Nigeria's river systems, driven by a combination of agricultural chemical runoff, inadequate industrial and municipal wastewater treatment, artisanal mining activity, and improper disposal of plastics and consumer products containing endocrine-active compounds. Igbariam, situated within Anambra State and bordered by the Anambra (Omambala) River system, is a community whose residents rely substantially on local surface water and associated aquatic biota for domestic water use, fishing, and agricultural irrigation, creating direct and multiple exposure pathways should contamination be present.

This paper develops a risk assessment framework for evaluating heavy metal and endocrine disruptive compound contamination across water, sediment, and biota matrices in the Igbariam area. Given that original field sampling was outside the scope of this desk-based study, the paper's contribution is twofold: first, to specify a rigorous, matrix-appropriate methodological protocol suitable for executing such a risk assessment; and second, to synthesize comparative evidence from published studies of contamination patterns in similar Nigerian riverine systems in order to identify priority contaminants and likely risk pathways warranting particular attention in any subsequent empirical study of the Igbariam area specifically.

The paper proceeds as follows: section two reviews relevant literature on heavy metal and endocrine disruptive compound contamination in Nigerian water systems; section three presents the theoretical and regulatory framework underlying environmental risk assessment; section four outlines the proposed sampling and analytical methodology; section five discusses comparative

contamination patterns and their implications for the Igbariam context; and section six concludes with recommendations.

2. Literature Review

2.1 Heavy Metal Contamination in Nigerian Surface Waters

Published studies of Nigerian river systems, including the Niger, Benue, Ogun, and various tributary systems in the South-East and South-South geopolitical zones, have documented elevated concentrations of heavy metals including lead, cadmium, chromium, mercury, and arsenic in water, sediment, and fish tissue samples, frequently exceeding World Health Organization and Nigerian Federal Ministry of Environment guideline thresholds in localized hotspots linked to upstream mining, industrial discharge, and agricultural runoff. These studies consistently identify sediment as a significant long-term reservoir for heavy metal accumulation, with concentrations in sediment often substantially exceeding corresponding water column concentrations due to metal adsorption onto particulate matter.

2.2 Endocrine Disruptive Compounds in Nigerian Aquatic Systems

A smaller but growing body of Nigerian environmental research has begun to document the presence of endocrine disruptive compounds, including phthalate esters, bisphenol A, and organochlorine pesticide residues such as DDT metabolites, in surface water and sediment samples from various Nigerian river systems, linked to plastic waste degradation, agricultural pesticide application, and inadequate wastewater treatment infrastructure. These compounds are of particular concern given documented associations with reproductive and developmental effects in aquatic organisms even at low concentrations, distinguishing their risk profile from the more straightforward dose-response relationships typically associated with heavy metal toxicity.

2.3 Bioaccumulation and Human Exposure Pathways

Literature on bioaccumulation dynamics in Nigerian freshwater fish populations documents the biomagnification of both heavy metals and certain lipophilic endocrine disruptive compounds through aquatic food webs, with implications for human exposure risk in communities that rely substantially on local fish consumption. Studies specifically addressing communities along the

Anambra River system and comparable South-East Nigerian tributaries have noted the significance of this exposure pathway given the centrality of fishing and local fish consumption to riparian community diets and livelihoods.

3. Theoretical and Regulatory Framework

This paper adopts the U.S. Environmental Protection Agency's (USEPA) human health and ecological risk assessment framework as its primary methodological anchor, which structures risk characterization around four sequential stages: hazard identification, dose-response assessment, exposure assessment, and risk characterization. This framework is widely applied internationally, including in Nigerian environmental risk assessment literature, and provides the structural basis for the sampling and analytical protocol proposed in section four.

Risk characterization within this framework is typically operationalized through standardized indices, including the hazard quotient (HQ), calculated as the ratio of estimated exposure to a reference dose below which adverse effects are not expected, and the hazard index (HI), representing the sum of hazard quotients across multiple contaminants to characterize cumulative risk. For bioaccumulative contaminants, the bioaccumulation factor (BAF) and biota-sediment accumulation factor (BSAF) provide standardized measures of contaminant transfer from environmental matrices into biological tissue. These indices, applied consistently across the water, sediment, and biota matrices specified in the proposed methodology, would allow the Igbariam risk assessment to generate internationally comparable, regulatorily relevant risk characterizations.

4. Proposed Sampling and Analytical Methodology

This paper proposes a stratified sampling design encompassing multiple sampling stations along the Igbariam stretch of the Anambra River system, selected to capture variation across upstream, community-proximate, and downstream locations, with sampling conducted across water, sediment, and biota (fish tissue) matrices at each station to allow comparative analysis of contaminant distribution and bioaccumulation across these three environmental compartments. Water and sediment sampling should follow standard USEPA or equivalent Nigerian Federal

Ministry of Environment protocols for heavy metal analysis via inductively coupled plasma mass spectrometry (ICP-MS) or atomic absorption spectroscopy (AAS), while endocrine disruptive compound analysis in all three matrices should employ gas chromatography-mass spectrometry (GC-MS) or liquid chromatography-tandem mass spectrometry (LC-MS/MS) methods appropriate for the specific target compound classes identified in section five.

Biota sampling should prioritize fish species documented as significant components of local community diet, given their relevance to the human exposure pathway central to the risk characterization stage of the USEPA framework. Seasonal sampling, capturing both dry and rainy season conditions, is recommended given the documented influence of seasonal hydrological variation on contaminant mobilization and dilution in comparable Nigerian river systems. Following laboratory analysis, hazard quotients, hazard indices, and bioaccumulation factors should be calculated for each identified contaminant and compared against WHO, USEPA, and Nigerian regulatory guideline thresholds to generate the final risk characterization.

5. Comparative Contamination Patterns and Implications for Igbariam

5.1 Priority Heavy Metals

Based on comparative evidence from published studies of similar Nigerian riverine systems affected by agricultural runoff and, in some catchments, artisanal mining activity, lead, cadmium, mercury, and chromium emerge as priority heavy metals warranting particular investigative attention in the Igbariam context, given their documented association with agricultural chemical inputs, sediment accumulation dynamics, and established toxicological significance for both aquatic ecosystem health and human health via fish consumption and domestic water use pathways.

5.2 Priority Endocrine Disruptive Compounds

Given documented land-use patterns in the Igbariam area, including agricultural activity and community-generated plastic waste, phthalate esters, bisphenol A, and organochlorine pesticide residues emerge as priority endocrine disruptive compound classes warranting investigation, consistent with contamination patterns documented in comparable Nigerian agricultural-riparian

communities. The distinct low-dose, non-monotonic dose-response characteristics documented in the endocrine disruption literature suggest that even contaminant concentrations below conventional heavy-metal-style toxicological thresholds may warrant risk characterization attention for this compound class.

5.3 Human Exposure Pathway Significance

The comparative literature underscores that the primary human exposure pathways of concern for a community such as Igbariam are likely to be domestic water consumption, where treatment infrastructure is limited, and local fish consumption, given the documented centrality of fishing to riparian community diets and livelihoods in the wider Anambra River system. This suggests that the proposed risk assessment should place particular analytical emphasis on the biota matrix and the associated bioaccumulation and biomagnification indices, alongside conventional water quality parameters.

5.4 Implications for Environmental and Public Health Policy

Should an empirical risk assessment following the proposed framework identify hazard quotients or hazard indices exceeding acceptable regulatory thresholds, the findings would carry direct implications for local public health messaging regarding water use and fish consumption advisories, as well as for upstream land-use and wastewater management policy within the wider Anambra River catchment. This underscores the practical importance of executing the proposed empirical study rather than relying solely on the comparative regional literature synthesized in this paper.

6. Conclusion and Recommendations

This paper has developed a risk assessment framework for evaluating heavy metal and endocrine disruptive compound contamination in water, sediment, and biota in the Igbariam area of Anambra State, synthesizing established USEPA risk assessment methodology with comparative evidence from published Nigerian riverine contamination studies to identify priority contaminants and exposure pathways warranting site-specific empirical investigation. Given the absence of original sampling data within the scope of this study, the paper's contribution lies in

specifying a rigorous, replicable methodological protocol rather than presenting a completed risk characterization.

The paper recommends: first, a formally funded, multi-season empirical sampling campaign should be conducted following the stratified, multi-matrix design proposed in section four, given the documented contamination risks in comparable regional water systems; second, particular analytical priority should be given to lead, cadmium, mercury, and chromium among heavy metals, and to phthalates, bisphenol A, and organochlorine pesticide residues among endocrine disruptive compounds, based on the comparative evidence reviewed; third, biota sampling and bioaccumulation analysis should be prioritized given the significance of local fish consumption as a human exposure pathway; and fourth, findings from any subsequent empirical study should be directly integrated into local public health advisory and upstream catchment management policy, given the direct relevance of such findings to community water use and fish consumption practices.

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