



SPATIO-TEMPORAL DISTRIBUTION OF HEAVY METALS IN OBIOKPOK NSIT RIVER, AKWA IBOM STATE, NIGERIA: INFLUENCE OF DREDGING ACTIVITIES AND ECOLOGICAL IMPLICATIONS

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ABSTRACT

The study investigated the spatial and temporal distribution of iron (Fe), copper (Cu), and zinc (Zn) in Obiokpok Nsit River, Akwa Ibom State, Nigeria, with emphasis on the influence of dredging activities and the associated ecological implications. Water samples were collected monthly from three sampling stations representing varying levels of anthropogenic disturbance between September 2023 and January 2024. Heavy metal concentrations were determined using standard analytical procedures recommended by the American Public Health Association (APHA), while contamination status was evaluated using World Health Organization (WHO) standards. The results revealed elevated concentrations of the investigated heavy metals across all sampling stations throughout the study period. Mean iron concentrations ranged from 1.10 – 4.11 mg/L, copper ranged from 0.87 – 3.42 mg/L, while zinc ranged from 3.71 – 6.32 mg/L. Spatial variations were significant ($P < 0.05$) for all the heavy metals measured, whereas, temporal analysis demonstrated moderate monthly fluctuations. The study demonstrates that dredging related disturbances contribute to heavy metal mobilization and persistence within Obiokpok Nsit River. Continuous environmental monitoring, stricter regulation of dredging activities, and implementation of sustainable management strategies are therefore necessary to reduce further contamination and protect the ecological integrity of the river system.

Keywords: Heavy-metals; Obiokpok Nsit River; dredging; ecological implications

INTRODUCTION

In many developing countries, particularly within sub-Saharan Africa, freshwater systems serve as major sources of livelihood for rural communities that depend directly on aquatic resources for food security and income generation (Arimoro & Keke, 2017; Edokpayi *et al.*, 2018). Despite their ecological importance, freshwater environments are increasingly threatened by anthropogenic activities that alter water quality and disrupt ecological balance. Among the various contaminants affecting aquatic ecosystems, heavy metals remain one of the most persistent and ecologically significant pollutants due to their toxicity, non-biodegradability, environmental persistence, and bioaccumulative characteristics (Tchounwou *et al.*, 2012; Jaishankar *et al.*, 2014). Elevated concentrations of metals such as iron (Fe), copper (Cu), and zinc (Zn) may impair physiological functions in aquatic organisms, reduce biodiversity, and pose long term ecological and public health risks (Zheng *et al.*, 2020).

Sand dredging has become particularly widespread in many Nigerian rivers because of increasing demand for construction materials associated with urbanization and infrastructural development. Dredging operations disturb bottom sediments, increase turbidity, alter hydrological conditions, and promote the resuspension of previously deposited contaminants into the water column (Olawusi & Ogbemudia, 2015). Sediments often function as reservoirs for heavy metals; therefore, continuous sediment disturbance may enhance metal mobility, bioavailability, and ecological exposure within aquatic systems (Lemus *et al.*, 2024).

Previous studies conducted in different parts of Nigeria have reported elevated concentrations of heavy metals in rivers impacted by dredging, urban discharge, and other anthropogenic activities (Iwegbue *et al.*, 2013; Benson *et al.*, 2016 and Izah and Angaye 2016).

The study investigated the spatial and temporal distribution of iron (Fe), copper (Cu), and zinc (Zn) in Obiokpok Nsit River, Akwa Ibom State, Nigeria.

MATERIALS AND METHODS

The Study Area

Obiokpok Nsit River (Figure 1) is located within Nsit Ibom Local Government Area of Akwa Ibom State, southern Nigeria. The river serves as an important freshwater resource for several surrounding communities where it supports artisanal fisheries, transportation, domestic water usage, sand mining, and other socioeconomic activities. The river system forms part of the extensive freshwater network within the Niger Delta region, an area characterized by high biological productivity and increasing anthropogenic pressure on aquatic ecosystems. Station 1 (4°48'57.66"N, 7°55'8.00"E) (Upstream); a low disturbance zone with relatively limited dredging activities. Station 2 (4°48'59.21"N, 7°55'8.10"E) (Midstream); characterized by moderate dredging activities. Station 3 (4°48'57.78"N, 7°55'9.39"E) (Downstream): An area of intensive dredging intensity.

The study area experiences a humid tropical climate marked by distinct wet and dry seasons. The surrounding vegetation is predominantly composed of secondary rainforest and riparian vegetation, although portions of the riverbanks have been altered by human activities including farming, settlement expansion, and dredging operations.

The selection of Obiokpok Nsit River for this study was based on its ecological importance, increasing exposure to dredging activities, and the limited availability of scientific data regarding heavy metal contamination within the system. The river therefore provides a suitable environment for evaluating the influence of anthropogenic disturbances on the spatial and temporal distribution of heavy metals in freshwater ecosystems.

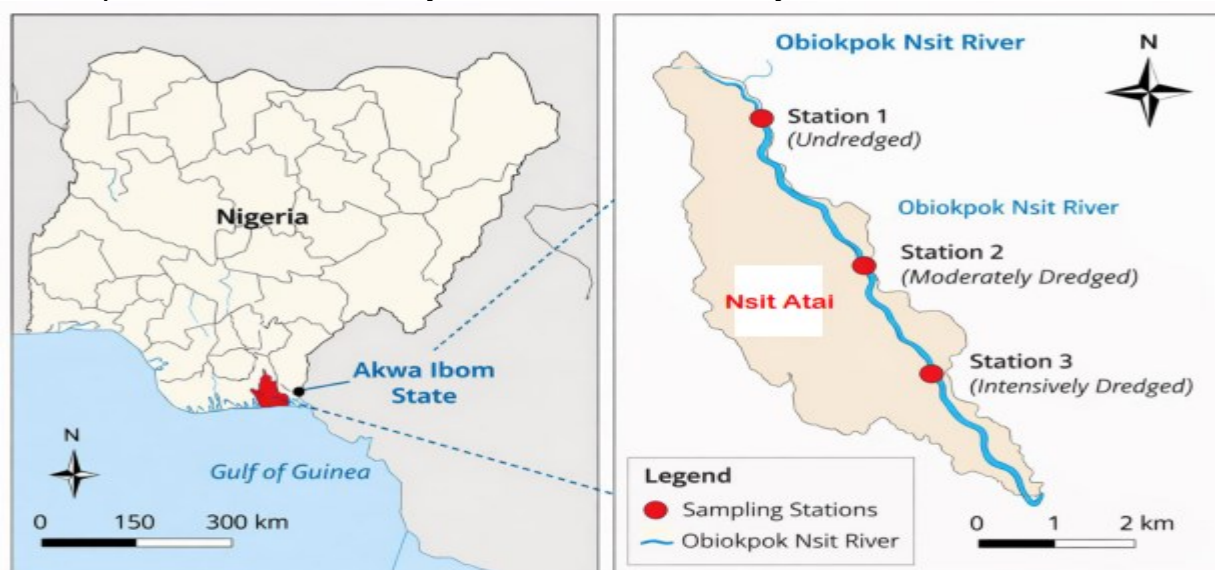


Figure 1. Map of the Obiokpok Nsit River; showing sampling stations in Akwa Ibom State, South-South Nigeria.

Sampling Design and Sample Collection

Three sampling stations were established along Obiokpok Nsit River based on the intensity of dredging activities and the level of observable anthropogenic disturbance within the study area. The stations were selected to represent different environmental conditions along the river continuum.

Water samples were collected and analyzed for heavy metals (iron, copper, and zinc) according to American Public Health Association (APHA, 2005), monthly between September 2023 and January 2024.

Statistical Analysis

One way analysis of variance (ANOVA) was used to determine significant spatial and temporal differences in heavy metal concentrations among sampling stations and sampling months. Where significant differences existed, Duncan Multiple Range Test was used for mean separation at ($p > 0.05$)

RESULTS AND DISCUSSION

Heavy Metal Concentrations (mg/L) in Obiokpok Nsit River

The findings of this study (Table 1) revealed substantial heavy metal contamination within Obiokpok Nsit River, with concentrations of Fe, Cu, and Zn exceeding recommended freshwater guideline limits across all sampling stations. This contamination pattern may be attributed to the combined effects of natural geochemical weathering processes and anthropogenic disturbances, particularly dredging and related sediment resuspension activities within the river system (Chapman, 1996; Varol & Şen, 2012).

Table 1: Heavy metal concentrations (mg/L) in Obiokpok Nsit River

Parameter	Station 1	Station 2	Station 3	WHO Limit
Fe	3.71 ± 0.18^a	2.28 ± 0.07^b	1.92 ± 0.17^c	0.3
Cu	1.78 ± 0.08^b	1.07 ± 0.10^c	3.25 ± 0.06^a	1
Zn	5.93 ± 0.08^a	4.53 ± 0.26^b	5.99 ± 0.12^a	3

Means along the same row bearing different superscripts differ significantly at ($P < 0.05$)

Monthly Variation in iron (Fe) Concentrations Across Sampling Stations in Obiokpok Nsit River from September 2023 to January 2024

The elevated iron concentrations observed at Station 1 may partly reflect natural geological contributions arising from weathering and runoff processes within the surrounding catchment area. However, the concentrations recorded during the present study exceeded permissible freshwater limits, suggesting that natural inputs alone cannot explain the observed enrichment. Similar higher iron concentrations have been reported in Nigerian freshwater systems affected by anthropogenic activities including dredging, urban runoff, and sediment disturbance (Iwegbue *et al.*, 2013). Iron concentrations showed slight increases during November before declining moderately towards January, whereas copper concentrations remained consistently elevated at Station 3 throughout the sampling months (Figure 2).

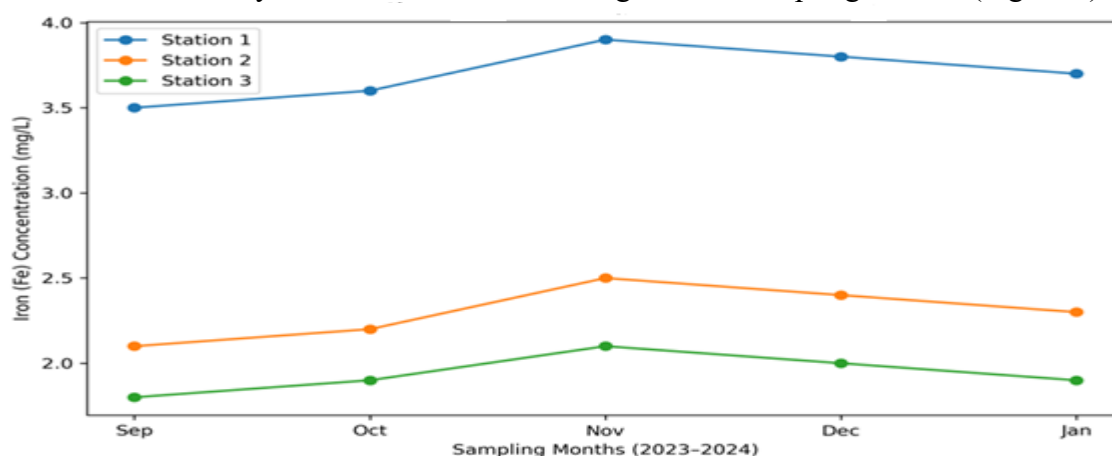


Figure 2: Monthly variation in iron (Fe) concentrations across sampling stations in Obiokpok Nsit River from September 2023 to January 2024

Monthly Variation in Copper (Cu) Concentrations Across Sampling Stations in Obiokpok Nsit River Between September 2023 and January 2024

The spatial distribution pattern of copper revealed significantly higher concentrations at Station 3, the zone characterized by intensive dredging activities. Copper concentrations increased markedly within the dredging zone, suggesting strong anthropogenic influence associated with sediment disturbance and contaminant mobilization. The high copper concentrations observed in the present study (Figure 3) agree with findings reported by Olawusi Peters and Ogbemudia (2015), who observed increased heavy metal concentrations in Nigerian inland waters exposed to dredging activities. Mechanical dredging operations disturb bottom sediments and enhance the release of previously adsorbed metals into the water column, thereby increasing metal bioavailability and ecological exposure. Similar observations have also been reported in freshwater ecosystems within the Niger Delta region where continuous sediment disruption contributed to increased metal concentrations in surface waters (Izah & Angaye, 2016; Benson *et al.*, 2016).

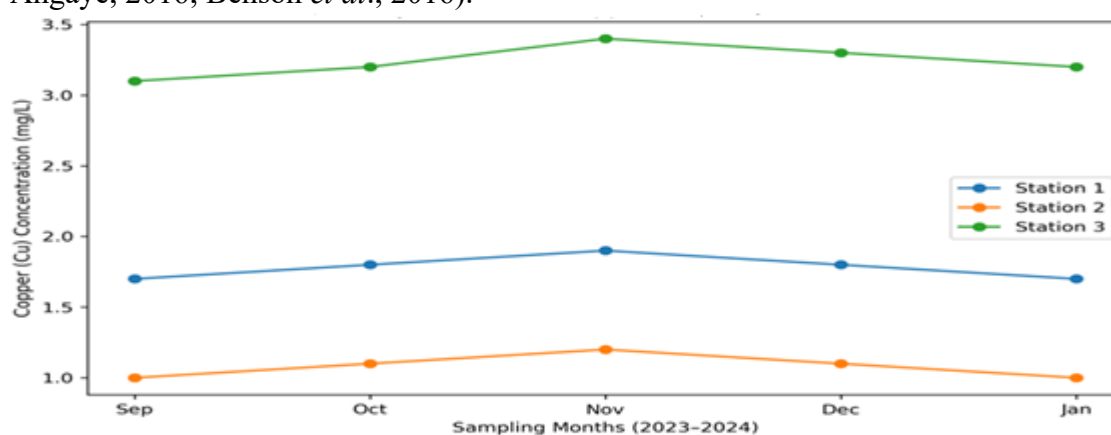


Figure 3: Monthly variation in copper (Cu) concentrations across sampling stations in Obiokpok Nsit River between September 2023 and January 2024

Monthly Variation in Zinc (Zn) Concentrations Across Sampling Stations in Obiokpok Nsit River From September 2023 to January 2024

Zinc concentrations remained consistently high across the sampling stations, suggesting the influence of mixed contamination sources within the river system. The relatively high zinc concentrations recorded at both Station 1 and Station 3 may reflect combined contributions from runoff, sediment disturbance, domestic activities, and other localized anthropogenic inputs. Similar patterns of zinc enrichment have been reported in Nigerian freshwater ecosystems subjected to multiple pollution sources (Ogbeibu & Oribhabor, 2002; Arimoro & Ikomi, 2008). Although zinc is considered an essential trace element, high concentrations throughout the study (Figure 4) may adversely affect aquatic organisms through physiological stress and disruption of metabolic activities.

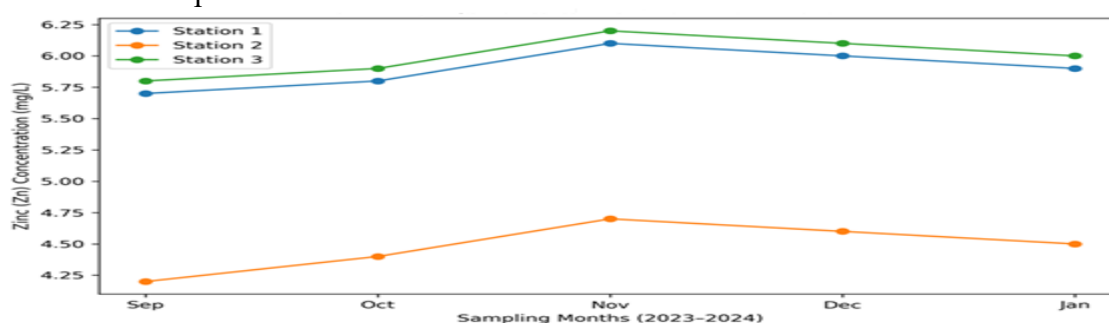


Figure 4: Monthly variation in zinc (Zn) concentrations across sampling stations in Obiokpok Nsit River from September 2023 to January 2024

Temporal analysis showed that heavy metal concentrations remained constantly higher throughout the study period despite moderate monthly fluctuations. The temporal pattern observed in this study is comparable to reports by Nwineewii and Edem (2021), who documented significantly higher heavy metal contamination in Niger Delta freshwater systems exposed to prolonged anthropogenic activities. Similarly, Edokpayi *et al.* (2018) noted that continuous discharge of contaminants into aquatic environments may sustain elevated heavy metal concentrations even during periods of reduced surface runoff. The relatively stable contamination trends observed in the present study therefore indicate that dredging activities may continuously redistribute sediment associated metals within the aquatic ecosystem, thereby limiting natural recovery processes.

From a public health perspective, the findings of this study are also important because communities surrounding Obiokpok Nsit River depend on the river for fishing, domestic activities, and other livelihood related purposes. Prolonged exposure to contaminated water and aquatic organisms may increase the risk of heavy metal accumulation within human tissues through trophic transfer pathways. Previous studies have shown that chronic exposure to higher heavy metal concentrations may contribute to neurological disorders, organ damage, and other long term health complications (Jaishankar *et al.*, 2014; Zheng *et al.*, 2020).

CONCLUSION AND RECOMMENDATIONS

The study demonstrated that Obiokpok Nsit River is experiencing considerable heavy metal contamination associated primarily with anthropogenic disturbances, particularly dredging activities occurring within the river system. The concentrations of iron (Fe), copper (Cu), and zinc (Zn) recorded during the study period exceeded recommended freshwater guideline limits across most sampling stations, indicating significant deterioration in water quality and environmental conditions within the aquatic ecosystem.

Generally, the findings of this study highlight the urgent need for continuous environmental monitoring and effective regulation of dredging activities within Obiokpok Nsit River. Sustainable management practices, stricter environmental compliance measures, and periodic assessment of water quality are necessary to reduce further contamination and protect the ecological integrity of the river system. Future studies should also investigate heavy metal accumulation in sediments and aquatic organisms in order to provide a more comprehensive understanding of contamination pathways and ecological risks within the aquatic environment.

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