African Journal of Environment and Natural Science Research
ISSN: 2689-9434
Volume 7, Issue 1, 2024 (pp. 128-145)
www.abjournals.org

# WATER QUALITY ASSESSMENT AND HEAVY METAL LEVELS IN MUDSKIPPER (*PERIOPHTHALMUS PAPILIO*), SEDIMENTS AND WATER OF MANGROVE SWAMPS, RIVERS STATE, NIGERIA

**Efekemo Oghenetekevwe[1*], Davies Ibienebo C.[2], and Orororo Clement O.[3]**

[1]Department of Chemical Sciences, Biochemistry Programme, Edwin Clark University, Kiagbodo, Delta State, Nigeria.

[2]Department of Fisheries, University of Port Harcourt, P.M.B. 5323, Choba, Port Harcourt, Nigeria.

[3]Department of Chemical Sciences, Chemistry Programme, Edwin Clark University, Kiagbodo, Delta State, Nigeria.

[*]Corresponding Author's Email: davies.chris@uniport.edu.ng

**Cite this article:**

Efekemo O., Davies I. C., Orororo C. O. (2024), Water Quality Assessment and Heavy Metal Levels in Mudskipper (Periophthalmus Papilio), Sediments and Water of Mangrove Swamps, Rivers State, Nigeria. African Journal of Environment and Natural Science Research 7(1), 128-145. DOI: 10.52589/AJENSR-CZHQPC9M

**Manuscript History**

Received: 13 Oct 2023

Accepted: 9 Feb 2024

Published: 1 Mar 2024

**ABSTRACT:** *A study was conducted to determine the physicochemical parameters of surface water and heavy metal concentrations in the mudskipper (Periophthalmus papilio) fish, sediments, and water collected from the Ikpukulu, Kalio, and Ogoloma swamps of Okrika Local Government Area, Rivers State, Nigeria and analysed using standard methods. All samples were collected for six months from three stations in 2023. The results indicate that pH and temperature values were significantly lower across stations in terms of physicochemical properties than standards. However, there was a significant increase in electrical conductivity, total dissolved solids, and salinity. Ikpukulu had the highest EC (1917 uS/cm), while Kalio had the highest salinity (333.3 ppm). All stations had significant decreases in dissolved oxygen (DO) and biological oxygen demand (BOD), with Ogoloma having the lowest values (DO: 3.2 mg/L, BOD: 2.9 mg/L). Copper and chromium levels were significantly higher than the standards in all stations, while cadmium levels were not significantly different from those in the standards. As compared with the standards, copper levels in water samples were considerably higher, especially in Ogoloma (2.03 mg/kg). Ogoloma had a higher concentration of chromium. Cadmium levels decreased significantly at all stations for the mudskipper (P. papilio). The copper levels in Ogoloma and the chromium levels in Ikpukulu were significantly higher than those in standards. The results of the study suggest an increase in heavy metal concentrations in the mangrove swamp region, emphasising the need for proactive measures to mitigate activities that may adversely affect the aquatic ecosystem and the communities that depend on it.*

**KEYWORDS:** Heavy metals; mudskippers; water quality; sediment; Niger Delta.

Article DOI: 10.52589/AJENSR-CZHQPC9M
DOI URL: https://doi.org/10.52589/AJENSR-CZHQPC9M

## INTRODUCTION

Environmental pollution, which can either be natural or man-made, has been an issue of great concern since the advent of civilization, industrialization, and urbanization (Ajibade et al., 2021). It affects land, air and water. The most often polluted environment is the aquatic system. Surface water and sediments contain the most pollutants, with the sediments serving as a repository. This repository is markedly significant because contaminants in the air, soil or land ultimately end up in water bodies via local precipitation, surface water run-offs, leaching of rocks and solid waste deposition (Ambade et al., 2021). Also, industrial waste; sewage; agrochemicals such as fertilizers and pesticides; unconstrained release of effluents from mines, smelters, aerial deposition, mineral and petroleum exploration; and exploitation all contribute greatly to surface water pollution (Kanellopoulos et al., 2021).

Heavy metals are natural elements characterized by their high atomic mass and high density and possess a specific density of more than 5 g/cm$^3$ (ATSDR, 2003). Some metals are beneficial to both plants and animals but at high concentrations, they can be regarded as toxic. Heavy metals are also regarded as trace elements because even at small concentrations they can be toxic; some examples are arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb) (Gezahegn *et al.,* 2017). Heavy metals such as selenium, copper and zinc perform functions that are indispensable for various biological processes, as they are involved in very important metabolic processes in the body (Koller & Saleh, 2018).

Heavy metals are made available in our environment through anthropogenic activities such as waste disposal, fossil fuel burning, industrial activities, application of pesticides, fertilizers, manure and countless man-made products and chemicals. In the atmosphere, their concentration is increased through activities such as smelting and burning of coal, waste, and oil refining (Okonkwo et al., 2021). Heavy metals discharged from shipping activity either intentionally or unintentionally, as well as from gas-producing plants have contributed to the contamination of the marine environment. All of these have resulted in the contamination of our environment/biosphere, resulting in their accumulation in plants, animals, and aquatic life (Okonkwo et al., 2021)

Oil spillage activity is one of the known sources of heavy metal pollution, both on land and in the aquatic environment (Choudhury et al., 2021). Crude oil has a heavy metal content. The oil spillage to our environment can result from extraction, refining, transportation and storage, accidents, poor maintenance and deliberate acts (due to sabotage and oil bunkering). It also can occur as a result of natural occurrences like earthquakes and hurricanes (Ukhurebor et al., 2021). Heavy metals are taken into the body via inhalation, ingestion and skin absorption. Bioaccumulation of heavy metals in water and bodies of organisms depends on the ability of the organisms to accumulate metals and heavy metal concentration in sediment, as well as the eating habits of these organisms (Ali & Khan, 2018).

Metal contamination in marine waters and sediments remains a global threat to biodiversity and humans (Bashir et al., 2020; Debnath et al., 2021). Sediments usually contain heavy metals and as such are used for their analysis. They are naturally occurring materials that are broken down by the process of weathering and erosion. The heavy metals and sediments form complexes (Yusuf & Osibanjo, 2006). Aquatic organisms have been used as pollution indicator species to monitor heavy metals in water (Odekina et al., 2021).

One of the aquatic organisms that can be used as a pollution bioindicator in mangrove forests is the mudskipper fish (*Periophthalmus spp*). This is because mud, one type of mangrove forest substrate, accumulates a lot of nutrients and minerals, including heavy metal pollutants (Okonkwo *et al.*, 2021). Consequently, the bodies of the mudskipper fish, which live immersed in mud and jump on the mud, are very tolerant to inorganic and organic pollutants. Therefore, mudskippers potentially accumulate the heavy metals disposed of from industry, agriculture, domestic and transportation activities. Thus, this fish is very suitable as a marine bio-indicator species (Davies & Okonkwo 2021).

This study is aimed at determining the physico-chemical concentration of water and heavy metal concentration in bodies of mudskipper, water and sediments from Ikpuluku, Kalio and Ogoloma in Okrika Local Government Area, Rivers State. The mudskipper is a fish which has great economic and dietary value/importance. Monitoring of the aquatic environment must be carried out to reduce the incidences of health problems due to the consumption of these aquatic lives and also to maintain the stability of the aquatic ecosystem.

## MATERIALS AND METHODS

### Study Area

The study area in Okrika Local Government Area, Rivers State was surveyed using samples collected from three sampling stations. The study area encompasses Ikpukulu, Kalio, and Ogoloma in Okrika Local Government Area, Rivers State, Nigeria. The sampling stations were chosen based on hydrodynamics and topographies of the study area. Station 1 (Ikpukulu), with coordinates of N04044’3.671” E00701’30.214, was located near the Akubiakiri settlement, dominated by mudflats and tidal current dump sites, littered with oil sheen and abandoned artisanal refining sites.

Station 2 (Kalio) was situated at the mouth of Abuloma Creek with coordinates of N04045’42.440” E00704’6.715 dominated by red mangrove, black mangrove, and a few strands of Nympa palm. The area was also dominated by industrial wastes, effluence from bunkering activities, and human and animal wastes. Station 3 (Ogoloma), with coordinates of N04044’11.797” E00704’38.520, was situated at the junction along the Woji Elelewo creek system connecting the Bonny River. The bottom was characterized by an extensive mudflat, fringing mangrove swamp, and a highly populated coastal settlement with an obvious illegally refined product landing site.

Article DOI: 10.52589/AJENSR-CZHQPC9M
DOI URL: https://doi.org/10.52589/AJENSR-CZHQPC9M

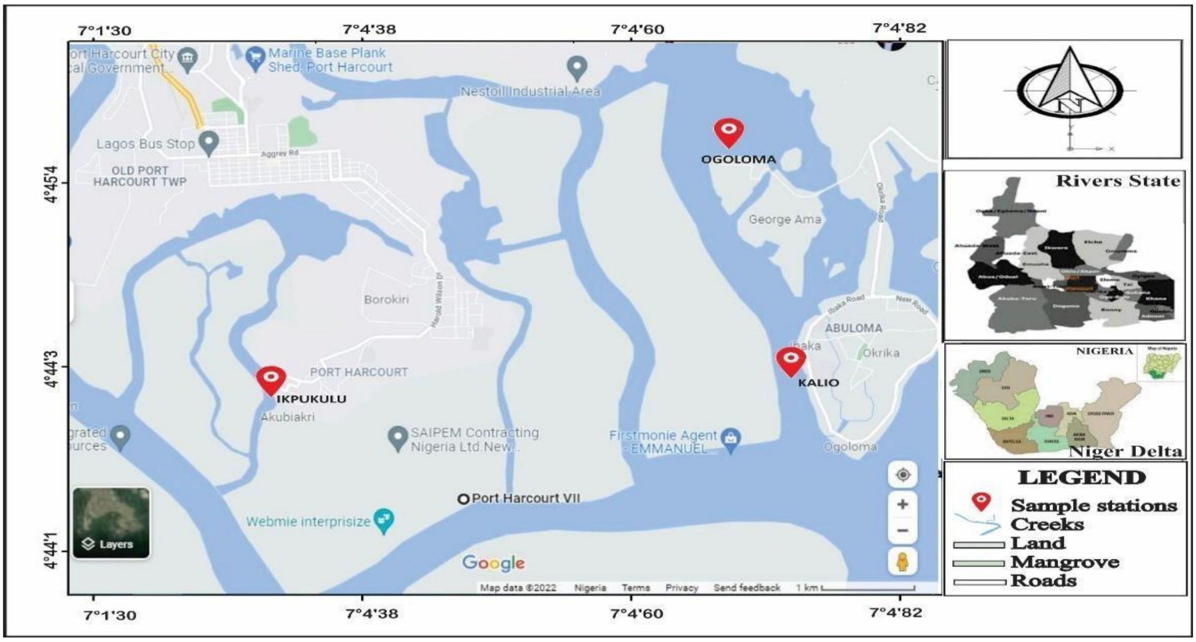

**Figure 1:** Map of Port Harcourt Showing Study Area

The section of the river where samples were collected is bombarded with human, animal, and domestic waste and run-off and it is visible on the shoreline by residents for artisanal fishing.

## Sample Collection

### Determination of Physicochemical Parameters

Physicochemical parameters were assessed through the utilization of an in-situ Handheld Multimeter. The water's pH, temperature, salinity (ppt), and total dissolved solids (TDS) (ppt) were gauged employing the Milwaukee Model pH600 for pH and a Laboratory Benchtop meter 860033-model for temperature, salinity, and TDS. Dissolved oxygen (DO) levels were determined using Winkler's method. For the Biochemical Oxygen Demand (BOD), a water sample was acquired using a BOD bottle and subsequently subjected to laboratory analysis through the 5-day BOD test (APHA, 2000). Adequate precautions were taken to ensure the proper charging of the monitoring device using a suitable charger. Before testing, a relevant gas sensor (probe) was affixed, and protective gear was worn to mitigate potential environmental hazards.

### Sampling and Digestion of the Sampled mudskipper (*Periophthalmus papilio*)

Mudskipper (*P. papilio*) samples were procured from Ikpukulu, Kalio, and Ogoloma in Okrika, utilizing locally crafted fishing traps. The collection took place for six months in 2023 from three primary fishing zones. The collected fish, totalling fifteen samples with an average length of 20.6 ± 0.81cm and weight of 80.52 ± 0.74g, were promptly preserved in ice packs in the field to maintain freshness before transportation to the laboratory. Notably, the chosen mudskipper species is closely linked to mangroves and peri-tidal ecosystems, representing one of the most frequently consumed fish species from the dam throughout the year.

Subsequent analysis involved the weighing and triplicate digestion of shellfish muscles using the APHA (2000) methods. In this process, concentrated nitric acid was introduced to each

Article DOI: 10.52589/AJENSR-CZHQPC9M
DOI URL: https://doi.org/10.52589/AJENSR-CZHQPC9M

weighed fish muscle, followed by heating at 100˚C. Hydrogen peroxide was then added until the absence of brown fumes was observed. The resulting solutions of digested fish samples underwent filtration using Whatman 0.42 μm filter paper directed into 50 mL volumetric flasks containing distilled-deionized water. The filtrate was meticulously transferred to pre-cleaned plastic bottles, ensuring the attainment of precise and dependable results throughout the procedure.

### Sampling and Digestion of Sediment Samples

Sediment samples were systematically collected from the bottom surface of Okrika, with three grabs randomly taken from both the banks and mid-creek. These samples were homogenized and carefully placed in clean polyethene bags. Recognizing the significance of the surface layer in facilitating metal exchange between sediments and water, as well as its role as a reserve for benthic organisms, emphasizes the importance of this sampling approach.

To preserve the integrity of the samples, they were stored in an icebox and subsequently transported to the laboratory. Upon reaching the lab, the samples were thawed at room temperature and then transferred to pre-acid cleaned evaporating beakers. The sediment was subjected to a thorough process involving drying in an oven, grinding, and sieving.

Digestion of the sediment samples was conducted using a mixture of concentrated nitric acid and hydrochloric acid in a 1:3 ratio. Approximately 2 g of dry sediment was accurately weighed and placed into a 50 mL acid-cleaning beaker. A freshly prepared mixture of HNO3 and HCl was introduced to the sediment, and the resultant mixture was gently boiled over a water bath. Following digestion, the sample underwent filtration using Whatman 0.42 μm filter paper into a 50 mL volumetric flask, ready for analysis of heavy metals using Atomic Absorption Spectrometry (AAS). As a quality control measure, a blank solution was meticulously prepared. This comprehensive process ensures the reliability and accuracy of the obtained heavy metal concentrations in the sediment samples.

### Sampling and Digestion of Water

Water sampling procedures, as per the methodology outlined by Chris et al. (2023), involved collecting samples from the creek beneath the water's surface. The sampling process ensured representation from three distinct locations within the creek. Homogenization of each sample was carried out and the resultant homogenized samples were then divided into three separate 500 ml plastic bottles. Prior to sampling, the plastic bottles underwent meticulous cleaning and rinsing with distilled water to prevent contamination. To enhance accuracy, these cleaned bottles were immersed in the creek before actual sample collection. Following collection, 2 mL of nitric acid was added to each sample to minimize the potential adsorption of metals. Proper labelling, including the sampling date and location, was applied to each bottle.

For preservation, the labelled samples were transported to the laboratory and stored at 4˚C until further analysis. In the laboratory, water samples were subjected to triplicate digestion using concentrated nitric acid (Analytical Grade), following the established method. This comprehensive sampling and analysis approach adheres to standardized protocols, ensuring the reliability and precision of the obtained results in assessing metal concentrations in the water samples.

### Analysis of Heavy Metals

Metal concentrations for chromium, cadmium, and copper were determined using Atomic Absorption Spectrophotometers (AAS), following the established procedures outlined by the American Public Health Association **(APHA, 2000)**. This method ensures precision and accuracy in the analysis of metal content in the samples.

### Statistical Analysis

To assess variations in heavy metal concentrations in sediment and benthic fauna between wet and dry seasons, one-way analysis of variance (ANOVA) was employed at a significance level of 0.05. The standard errors were calculated to provide additional insights into the precision of the measurements. IBM SPSS Statistics 20 and Microsoft Excel 2010 served as the platforms for conducting all statistical analyses, ensuring robust and reliable results.

## RESULTS AND DISCUSSION

### Physicochemical Parameters across the Stations

The results of the physicochemical parameters in water at Ikpuluku, Kalio, and Ogoloma stations exhibit variations, with some values exceeding recommended standards, indicating potential environmental concerns and the impact of anthropogenic activities (Figure 1 to 7).

### pH

Hydrogen ion concentrations were consistent across Ikpuluku, Kalio, and Ogoloma, all measuring 5.6, significantly lower than WHO and U.S. EPA standards. There is no significant ($p>0.05$) difference in the value ($5.6\pm0.07$) of pH across the three stations (Ikpuluku, Kalio & Ogoloma) respectively (Figure 2).

The consistently low pH (5.6) in the studied area indicates potential environmental stress, possibly due to anthropogenic activities like oil spills, domestic waste, and artisanal refining. This low pH affects aquatic life by affecting nutrient availability, metabolic rates, reproductive success, harm to fish and aquatic organisms, and the risk of reduced biodiversity (Thanigaivel et al., 2023). However, low pH can affect the solubility and availability of essential nutrients in water, hindering the growth and development of aquatic organisms that rely on specific nutrient concentrations (Mahowald et al., 2018). It may also disrupt metabolic rates and reproductive success, leading to suboptimal growth and reproduction. According to Nilsen et al. (2019), prolonged exposure to low pH may lead to physiological stress, reduced survival rates, and adverse effects on health.

The overall health of an aquatic ecosystem is closely tied to biodiversity, and consistent low pH conditions may contribute to a reduction in species diversity. Consistent acidity may disrupt the balance of the ecosystem, leading to long-term consequences.

Fishes, being a key component of aquatic ecosystems, are particularly vulnerable to changes in pH, negatively impacting their physiological processes, behaviour, and population dynamics

(Chris et al., 2023). Addressing the sources of acidity and implementing measures to restore pH balance is crucial for sustaining a healthy and biodiverse aquatic environment.

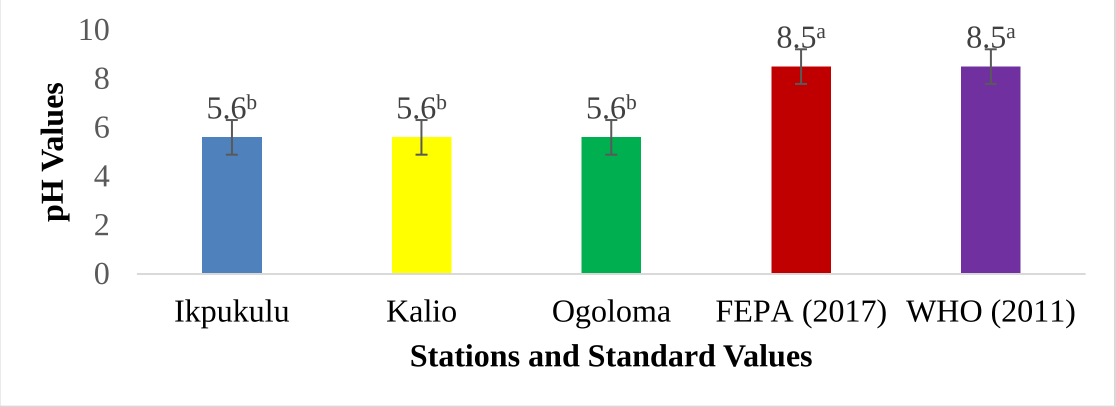

**Figure 2:** Showing a Comparative Value of pH across the Stations and Stipulated Standard Values; *a, b, c: Means Values with Different Superscripts are Significantly Different ($p<0.05$).*

**Temperature**

Figure 3 shows that Stations 1 and 3 had similar values of 29.1°C, and Station 2 had 28.8°C. There is no significant difference between the three stations, values consistent with reported temperatures in the Niger Delta, significantly lower than WHO and FEMA standards.

Similar temperatures across stations may be influenced by local climate conditions and exposure to solar radiation. The slight differences could result from varying degrees of mangrove cover. Temperature affects metabolic rates, reproduction, and habitat preferences of aquatic organisms (Saenger & Holmes, 2018). Consistent low temperatures may limit metabolic processes crucial for fish survival (Sutton et al., 2018) with potential impacts on the reproductive success and growth rates of fish. Lower temperatures may also influence the distribution and abundance of certain species.

The water temperature obtained from surface water from this study is also similar to the report of Odekina et al. (2021) and Adesakin et al. (2020) who recorded water temperatures ranging from 27.7 to 31$^{o}$C from water bodies in the Niger Delta, Nigeria. The variation of water temperature recorded could be attributed to high atmospheric temperature and exposure to direct solar radiation, low relative humidity, and reduction in the number of suspended particles which occurred as a result of high-water transparency and heat from sunlight increasing (Davies & Okonkwo, 2021). Adesakin et al. (2020) stated that aquatic organisms can be adapted to such changes in temperature and can even withstand changes outside this range.

Article DOI: 10.52589/AJENSR-CZHQPC9M
DOI URL: https://doi.org/10.52589/AJENSR-CZHQPC9M

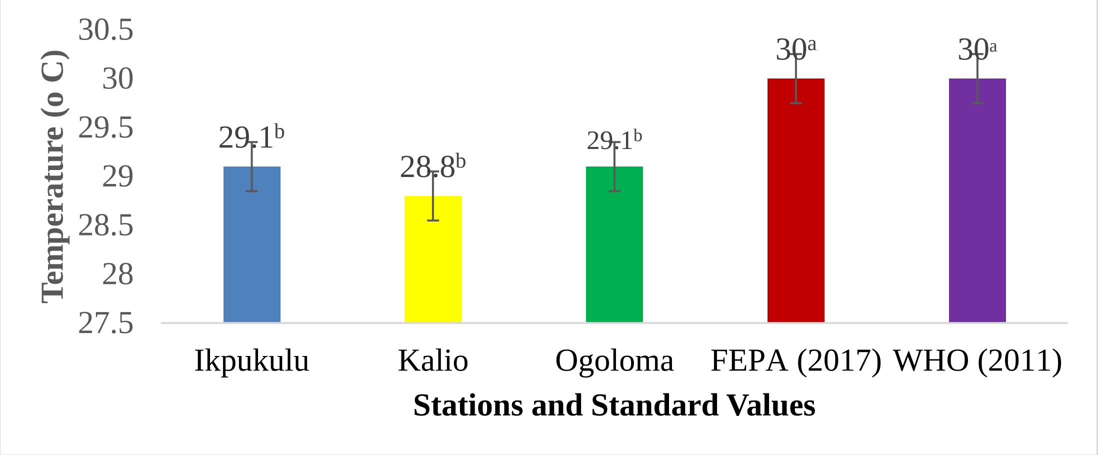

**Figure 3:** Showing Temperature (ºC) Values across the Stations and Standard Values

**Electrical Conductivity**

Station 1 had the highest (1917uS/cm), similar to Station 2 (1824.6uS/cm), and Station 3 had the least (1245.6uS/cm), as seen in Figure 4. All values are significantly higher than standards. High conductivity indicates elevated dissolved inorganic substances, exceeding WHO limits.

Variation in conductivity may stem from differences in industrial activities, agricultural runoff, and anthropogenic pollution. Elevated conductivity levels indicate increased ion content, potentially affecting osmoregulation in aquatic organisms. This can lead to stress and reduced survival rates. High conductivity levels pose a risk to fish health, potentially affecting their ability to regulate internal ion concentrations and leading to osmotic stress.

Electrical conductivity is the measurement of the degree of ions in water. It affects the taste and has a significant impact on the user's acceptance of the water (Adesakin et al., 2020). This range of electrical conductivity values (1245.6 to 1917.6 µS/cm) recorded from the stations is generally higher than the permissible limit by WHO (2011) for normal natural water bodies. Higher conductivity indicates that the water receives a high amount of dissolved inorganic substances in ionized form their surface catchments (Mezgebe et al., 2015).

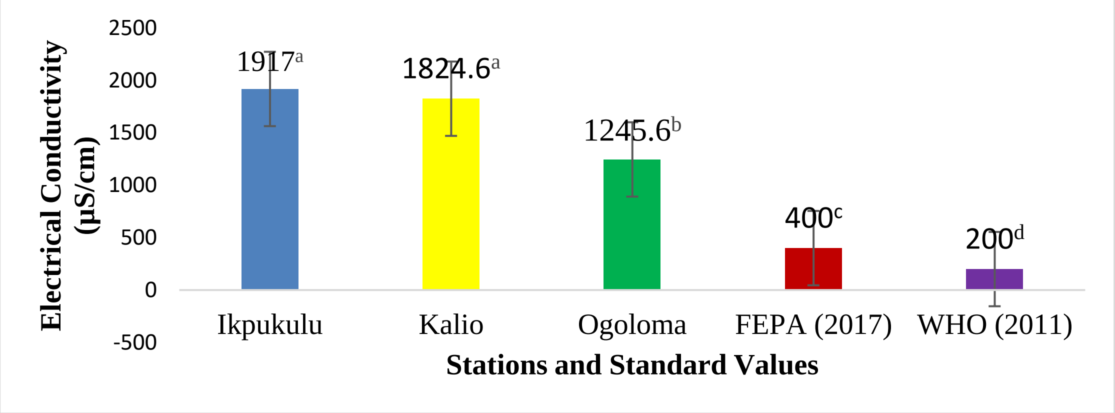

**Figure 4:** Shows the Value of Electrical Conductivity (EC) across the Stations and the Standards

Article DOI: 10.52589/AJENSR-CZHQPC9M
DOI URL: https://doi.org/10.52589/AJENSR-CZHQPC9M

## Total Dissolved Solids (TDS)

From Figure 5, Stations 1, 2, and 3 recorded values of 7300.7mg/L, 9248.6mg/L, and 3856.3mg/L, respectively. All values are significantly higher than standards. Station 2 had the highest total dissolved oxygen.

Higher total dissolved solid (TDS) levels, resulting from agricultural runoff, human activities, and suspended particles, can indicate water quality changes that affect the composition and diversity of aquatic communities. These changes can have cascading effects on the overall health of aquatic ecosystems, with some species being more sensitive to increased TDS, while others may be more tolerant (Cunillera-Montcusí et al., 2022).

Fishes are particularly sensitive to changes in water quality, and elevated TDS levels can affect their osmoregulation, behaviour, reproduction, and overall population dynamics. Fishes, being ectothermic animals, are highly influenced by their aquatic environment's temperature and chemical composition. Increased TDS can alter their feeding habits, migration patterns, and general activity, which may affect the overall functioning of the aquatic ecosystem (Bal et al., 2022). According to Arenas-Sánchez et al. (20216), changes in water quality can also influence the abundance and distribution of aquatic organisms, leading to potential imbalances in the ecosystem.

The specific implications of TDS changes can vary depending on the magnitude and duration of changes, the sensitivity of the local ecosystem, and the overall environmental context. Regular monitoring and comprehensive ecological assessments are essential to understand and manage potential impacts on aquatic environments.

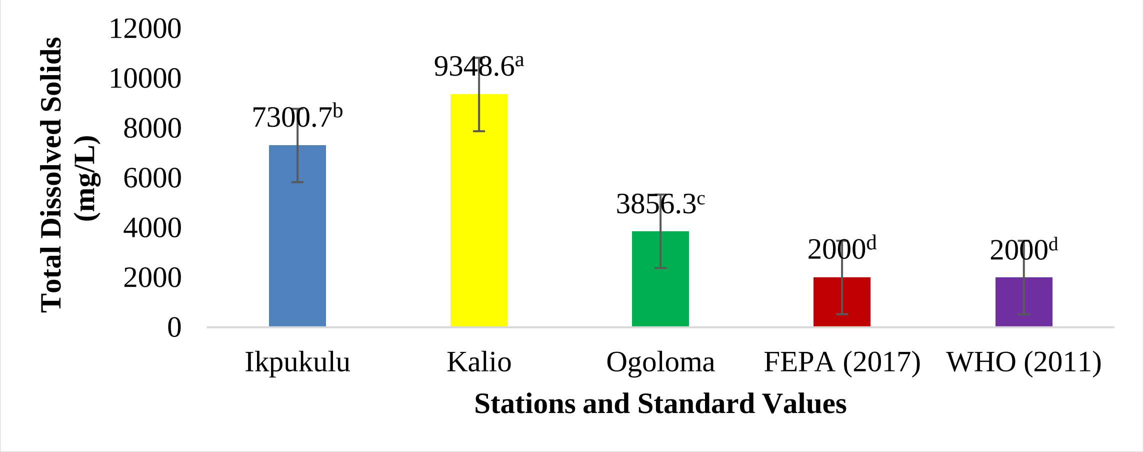

**Figure 5:** Showing the Total Dissolved Solids across the Stations and Standard Values

## Salinity

Salinization is attributed to human activities, altering ion content in freshwater ecosystems. From Figure 6, there were significant differences in salinity levels among the three stations. All stations had salinity levels significantly higher than standards.

Elevated salinity levels may result from anthropogenic sources, such as industrial discharges and seawater intrusion. Increased salinity can lead to reduced species diversity and altered community structures in freshwater ecosystems (Hintz & Relyea, 2019). Fish and other aquatic

Article DOI: 10.52589/AJENSR-CZHQPC9M
DOI URL: https://doi.org/10.52589/AJENSR-CZHQPC9M

organisms adapted to lower salinity may face challenges in osmoregulation, affecting their distribution and abundance (Freire & Prodocimo, 2019).

From this study, the salinity ranges between 2.13 and 2.17%o. This gradient was not in conformity with the situation obtainable by (Akankali et al., 2020). The salinity values were also within the WHO (2011) guideline set for the maximum tolerable limit of salinity for brackish water. The concentration of salt may have resulted from the oceanic waters and the decreasing influence of the river and runoff-derived freshwater (Davies & Ekpenusi, 2021).

The salinity levels in this study were significantly higher than the standard acceptable limit. Salinization can reduce population and organisms' fitness through sublethal effects, e.g., oxidative stress, delayed growth, reduced feeding efficiency, and increased drift (Clement & Kotalik, 2016). It can affect ecosystem structure and function by altering trophic interactions, biochemical cycles and leaf decomposition (Miguel et al., 2018).

Water pollution due to anthropogenic sources, which include heavy metals or pesticides, industrial waste and sewage, has contributed to an increase in salinity levels. These human activities alter the total concentration of major ions (salinity) and the composition of these ions in freshwater ecosystems. The ion content of inland surface waters is determined by several natural factors including rainfall, rock weathering, seawater intrusion and aerosol deposits (Miguel et al., 2018).

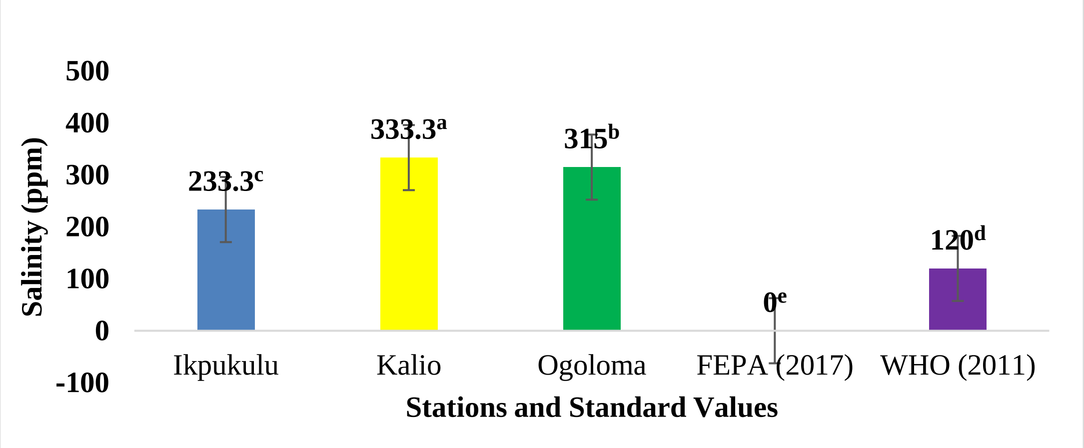

**Figure 6:** Showing a Comparative Value of Salinity across the Stations and Standard Values

## Dissolved Oxygen (DO)

From Figure 7, there is no significant difference between Stations 2 (3.4mg/L) and 3 (3.2mg/L), both significantly different from Station 1 (5.6mg/L). All stations are significantly higher than the standards. Variations in dissolved oxygen (DO) levels observed in the study can be attributed to fluctuations in water temperature and human activities. Dissolved oxygen is critical for fish metabolism and serves as a determinant for suitable habitats for different species. In this study, the recorded DO values ranged between 3.2 and 5.6 mg/L, falling below the acceptable standards for drinking water set by WHO (2011) and those documented by various researchers for polluted water bodies in the Niger Delta (US EPA, 2001).

These values were notably lower than the WHO's acceptable limit of 6 mg/L, indicating a potential concern for aquatic health. The observed decrease in DO values might be indicative of bacterial activity, as excessive bacteria can deplete dissolved oxygen. The influence of temperature on DO levels is noteworthy, as warmer water tends to hold less oxygen compared to colder water (Davies & Ekperusi, 2021). Hence, the high-water temperature in the sources could be a contributing factor to the observed low DO values.

While low dissolved oxygen may not pose a direct health hazard to humans, its effects on other water chemicals can have repercussions for the aquatic environment (Adesakin et al., 2020). The presence of high organic content, stemming from sources such as human feces, decaying domestic waste, sawmill residues, and plant materials, contributes to the recorded low DO levels. Addressing these factors is crucial for maintaining the ecological balance of the aquatic environment and sustaining the health of the swamps under consideration.

The observed variations in physicochemical parameters across the studied stations underscore the complex interplay of natural factors and human activities in shaping aquatic environments.

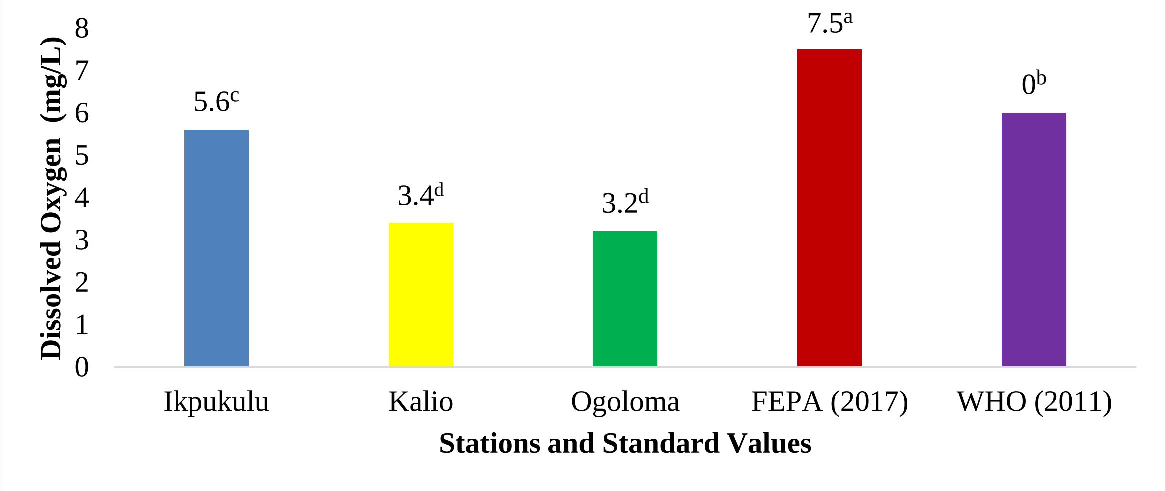

**Figure 7:** Showing the Value of Dissolved Oxygen across the Stations and Standards

## Biological Oxygen Demand (BOD)

All three stations showed significantly lower values than the standards (Figure 8). Station 1 had the highest BOD. Lower BOD values suggest less organic pollution or efficient decomposition processes (Wen et al., 2017). Low BOD indicates a healthier environment with reduced oxygen demand from decomposing organic matter. While low BOD is generally positive, excessively low levels may indicate reduced microbial activity, potentially affecting nutrient cycling (Ward et al., 2017).

The observed variations in physicochemical parameters across the studied stations underscore the complex interplay of natural factors and human activities in shaping aquatic environments (Belhouchet et al., 2023). The ecological implications suggest potential risks to fish populations, emphasizing the need for sustainable environmental management practices to mitigate adverse effects on aquatic ecosystems. Regular monitoring and implementation of conservation measures are crucial for maintaining the health and biodiversity of these sensitive habitats.

The BOD measures the amount of oxygen utilized by microorganisms such as bacteria to oxidize organic matter available within the water (Davies & Ekperusi, 2021). The BOD values recorded in this study were within the range of 2.9 to 3.33mg/L. However, the range obtained from this study was below the WHO guideline set for the maximum tolerable limit of BOD in drinking water, for fisheries and aquatic life. The variations in the BOD values could be attributed to the effect of higher temperature, salinity, and putrefaction of substances deposited in the river (Onojake *et al.*, 2017). The values of BOD obtained in this study were less than 10 mg/L as stipulated by WHO, implying that the water body was fairly useful. The variations observed could be attributable to the dump heap within the area.

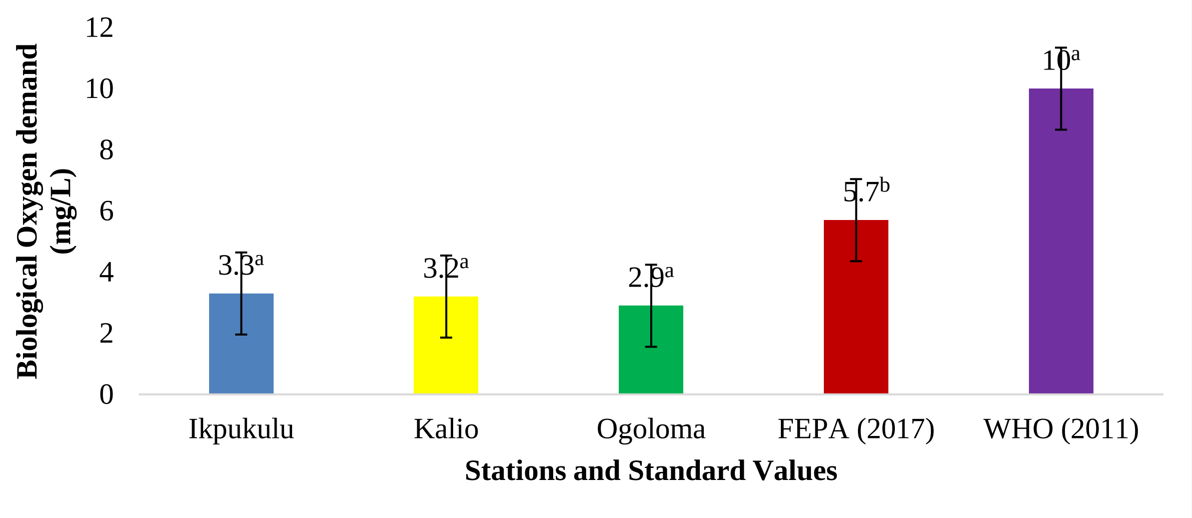

**Figure 8:** Showing Values of Biological Oxygen Demand across the Stations and Standards

## Sediment Metal Concentrations

The concentration of heavy metals for cadmium, copper and chromium for the three stations was shown in the bar charts (Figure 9). Cadmium (Cd), which was denoted with blue color, had similar sediment concentration across the three stations, but when the cadmium concentration of the stations was compared to the standards, there was no significant difference ($p<0.05$). For copper (Cu), the three stations Ikpukulu, Kalio and Ogoloma showed significant differences in sediment concentration, when each of their values was compared to the standards; Ikpukulu had similarities with U.S. EPA but was significantly different from WHO. Kalio and Ogoloma showed a significant difference ($p<0.05$) when their values were compared to the controls, U.S. EPA and WHO. For chromium (Cr), the three stations showed no significant difference ($p<0.05$) in value, but comparing them to the standards, there was a significant difference.

The consistent concentration of Cadmium (Cd) across stations suggests a common sediment source. Potential reasons include natural geological processes or shared anthropogenic inputs like industrial discharges or agricultural runoff. Significant variations in the Copper (Cu) concentration may be linked to localized industrial activities or point sources in Kalio and Ogoloma. Human activities, such as artisanal refining in Ogoloma, might contribute to higher copper levels. Ikpukulu's similarity to the U.S. EPA standards could indicate a lower anthropogenic impact.

Uniform levels of Chromium (Cr)may stem from natural geological sources. However, elevated levels compared to standards indicate potential anthropogenic influences requiring

Article DOI: 10.52589/AJENSR-CZHQPC9M
DOI URL: https://doi.org/10.52589/AJENSR-CZHQPC9M

further investigation (Tóth et al., 2016). Elevated metal concentrations in sediment pose risks to benthic organisms and may enter the food chain, impacting human health through fish consumption. Communities around Ikpukulu might experience lower risks due to sediment conformity to standards, whereas Kalio and Ogoloma face potential health risks.

The high significant values of the heavy metals across the three stations could be attributed to an avenue for the recontamination of the water channel as a result of turbulence or bioturbation in the sediment (Okonkwo *et al.*, 2020). The level of these metals suggests varied intense anthropogenic influence due to industrial and urban advancement within the catchments along the creeks. These levels of chemical distribution in interstitial waters in the Niger Delta may influence the diversity of life present or adapted to the water channels, while the sediments act as a sink for contaminants in the aquatic ecosystem (Davies & Ekperusi, 2021). All heavy metals were higher than the acceptable limits, according to WHO (2011) and U.S. EPA (2007).

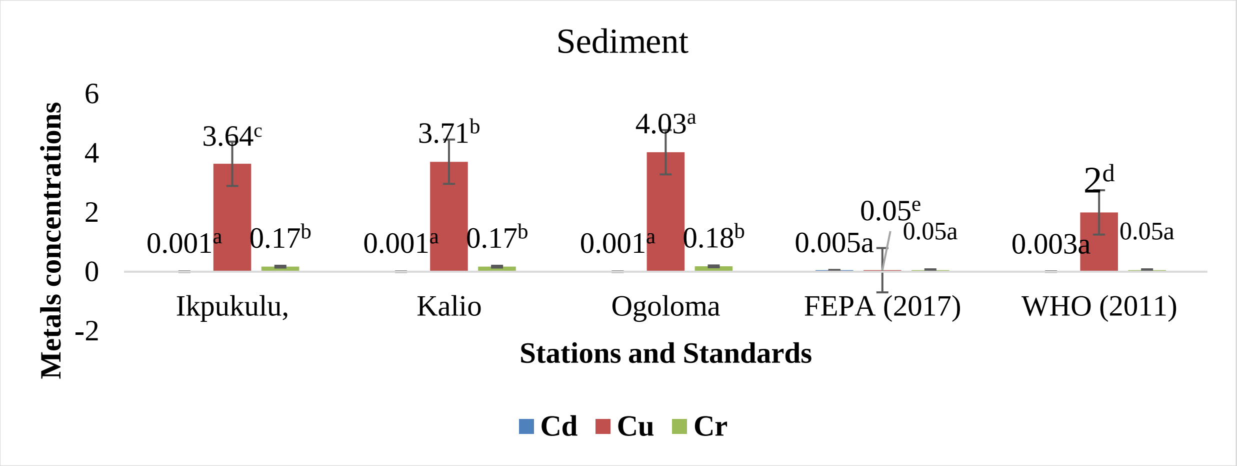

**Figure 9:** Mean Concentrations of Heavy Metal from Sediments across the Stations (mg kg$^{-1}$)
*a, b, c: Means Values with Different Superscripts on the Same Bar Colour are Significantly Different (p<0.05)*

## Water Metal Concentrations

The concentration of heavy metals, cadmium, copper and chromium, contained in the water of the three stations were shown in the chart, with cadmium denoted blue, copper red and chromium green (Figure 10). The concentration of cadmium in water at the three stations showed significant ($p<0.05$) similarity, but comparing the values to the standards, there was a significant decrease in stations ($p<0.05$). Copper concentration was similar for Ikpukulu and Kalio, but they were both significantly lower when values were compared to that of Ogoloma. These values of the station were compared to the control, Ikpukulu and Kalio, which were statistically similar and showed significant differences to U.S. EPA and WHO, but Ogoloma showed no significant difference to WHO though significantly different from U.S. EPA. For chromium, Ikpukulu and Kalio showed no significant difference from each other, but comparing their values to Ogoloma, there was a significant difference. Comparing the values of the stations to the standards, Kalio and Ikpukulu were similar to the standards, but Ogoloma was significantly different ($p<0.05$) from both standards.

Similar concentrations of Cadmium (Cd) across the stations but lower than the standards may indicate common water sources. Dilution effects or reduced anthropogenic inputs in these water bodies might explain the lower levels. However, lower levels of Copper (Cu) in Ikpukulu and Kalio, with higher concentrations in Ogoloma, suggest localized anthropogenic inputs, possibly related to industrial or refining activities. Water mixing, dilution, or point-source contamination could explain the variations.

Significant differences in the Chromium (Cr) between Ikpukulu/Kalio and Ogoloma indicate distinct contamination sources. Anthropogenic activities, particularly in Ogoloma, contribute to higher chromium levels. Water quality variations indicate potential ecological risks for aquatic life, with implications for the health of fish and other organisms. Elevated metal levels in water bodies, particularly in Ogoloma, pose risks to the communities relying on these waters for domestic use and fisheries.

The high level of these metals in water above normal limits, in contrast with WHO (2011) and U.S. EPA, is due to high anthropogenic activities in these stations which lead to the releasing of these toxicants into the water channels causing an increase in heavy metal contents. As suggested in previous studies, most anthropogenic influences such as mining, agricultural wastes, disposal of untreated and partially treated industrial effluents, fossil fuels, petroleum exploration, indiscriminate use of heavy metal-containing fertilizer, pesticides in agricultural fields and oil spillage can play a relevant role and these have been implicated in the metal contamination of the waters in the three stations (Ogoloma, Kalio and Ikpuluku).

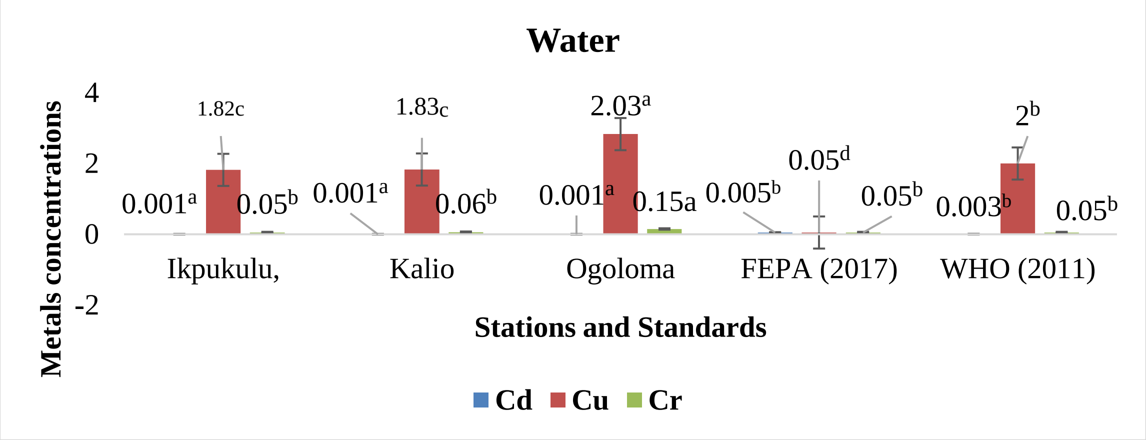

**Figure 10:** Mean Concentrations of Heavy Metal from Water across the Stations (mg kg$^{-1}$); *a, b, c: Mean Values with Different Superscripts on Same Bar Colour are Significantly Different (p<0.05)*

### Metal Concentrations in Fish (*P. Papillio*)

Figure 11 shows the concentration of heavy metals, cadmium, copper and chromium contained in *P. Papillio*. Cadmium showed no significant difference when values were compared across the three stations, but comparing them to the standards, there was a significant increase ($p<0.05$) for WHO, though they were all similar to U.S. EPA. For copper, Ikpukulu and Kalio were both statistically similar but, compared to Ogoloma, they showed a significant decrease ($p<0.05$). Comparing the stations to both standards, they all showed a significant increase ($p<0.05$). For chromium, Kalio and Ogoloma were significantly similar; both were significantly lower ($p<0.05$) than Ikpukulu, but comparing the values of the station to the standards, the stations were all significantly increased ($p<0.05$).

Article DOI: 10.52589/AJENSR-CZHQPC9M
DOI URL: https://doi.org/10.52589/AJENSR-CZHQPC9M

The study reveals consistent Cadmium (Cd) concentrations across the stations, with elevated levels compared to standards, suggesting a shared exposure source. Mangrove-associated mudskippers may accumulate metals from both water and sediment. The concentrations of Copper (Cu) in Ikpukulu and Kalio, with a significant decrease in Ogoloma, suggest localized contamination sources. Anthropogenic activities in Ogoloma likely contribute to higher copper levels.

Significant increases in Chromium (Cr) in all stations, compared to standards, indicate potential bioaccumulation. The similarity between Kalio and Ogoloma may be due to shared environmental conditions. Elevated metal concentrations in fish suggest potential risks to human health through dietary exposure. Mangrove-associated fish, vital for local diets, may contribute to metal exposure in nearby communities, warranting health advisories and further studies.

Cd, Cr, and Cu in water come from domestic effluent discharge, weathering of minerals and soils, and urban storm-water runoffs containing these heavy metals (Odekina et al., 2021). The high concentrations of these metals in mudskipper fish follow the same progression as that of the sediments, indicating that fish can survive on both sediments and water, leading to contamination (Yusuf & Osibanjo, 2006).

The study qualifies the mudskipper as a bioindicator species, similar to other benthos known for bioaccumulating organic pollutants in tissues and organs. Understanding these variations is crucial for assessing potential risks to human health and ecological well-being in the studied locations. Continuous monitoring and targeted interventions are essential for safeguarding community health, preserving aquatic ecosystems, and ensuring sustainable resource use.

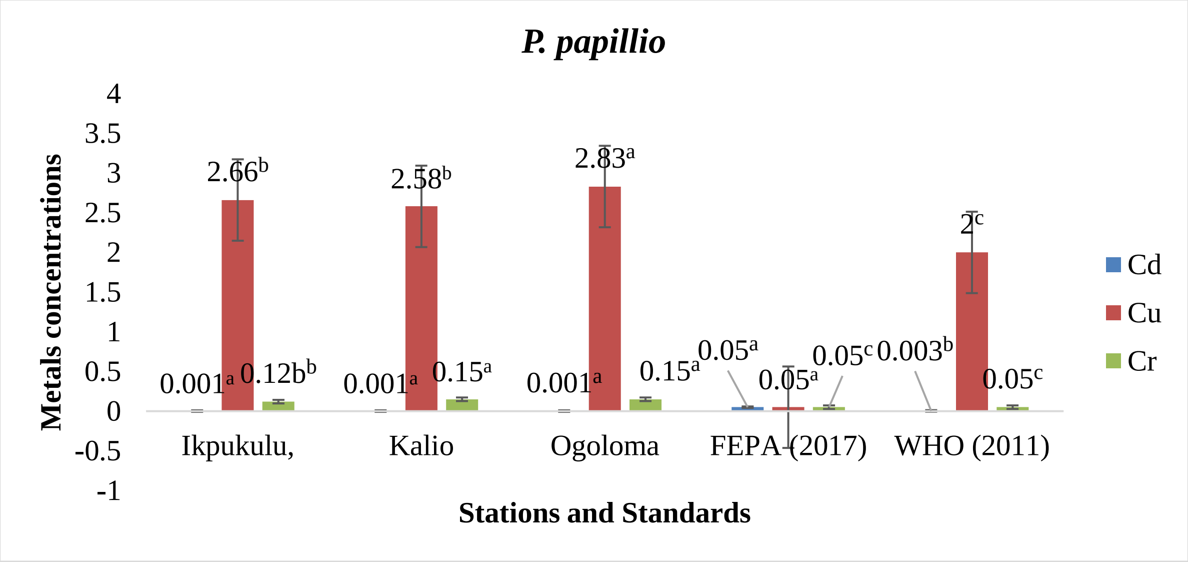

**Figure 11:** Mean Concentrations of Heavy Metal from *P. papillio* across the Stations (mg kg$^{-1}$); *a, b, c: Means Values with Different Superscripts on same Bar Colour are Significantly Different (p<0.05)*

## CONCLUSION

The study examines physicochemical parameters and heavy metal concentrations in the Ikpukulu, Kalio, and Ogoloma regions of the Okrika Local Government Area, Rivers State, Nigeria. Key parameters such as pH, temperature, electrical conductivity, TDS, salinity, dissolved oxygen, and BOD are analyzed to understand potential ecological implications and human health risks. Low pH levels are attributed to anthropogenic activities, while similar temperatures are influenced by local climate conditions and mangrove cover. Electrical conductivity variations suggest industrial and agricultural influences, while elevated TDS levels suggest agricultural runoff. Salinity variations reveal potential anthropogenic sources affecting freshwater ecosystems. Dissolved oxygen levels and BOD values indicate potential microbial activity and organic pollution. Metal concentrations in sediment, water, and fish show variations, indicating complex interactions between natural and anthropogenic factors. Elevated metal levels pose risks to benthic organisms and human health through fish consumption. The study emphasizes the need for sustainable environmental management practices and continuous monitoring to mitigate adverse effects on aquatic ecosystems and safeguard human health.

## REFERENCES

Adesakin, T. A., Oyewale, A. T., Bayero, U., Mohammed, A. N., Aduwo, I. A., Ahmed, P. Z. & Barje, I. B. (2020). Assessment of bacteriological quality and physicochemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. *Heliyon*, 6(8):e04773.

Ajibade, F. O., Adelodun, B., Lasisi, K. H., Fadare, O. O., Ajibade, T. F., Nwogwu, N. A., ... & Wang, A. (2021). Environmental pollution and their socioeconomic impacts. In *Microbe mediated remediation of environmental contaminants* (pp. 321-354). Woodhead Publishing.

Akankali, J. A., & Davies, I. C. (2020). Analysis of heavy metals concentration in different media of Iwofe Creek, Niger Delta, Nigeria. *International Journal of Scientific and Research Publications*, *10*(04), 2250-3153.

Ali, H., & Khan, E. (2018). Trophic transfer, bioaccumulation, and biomagnification of non-essential hazardous heavy metals and metalloids in food chains/webs—Concepts and implications for wildlife and human health. *Human and Ecological Risk Assessment: An International Journal*.

Ambade, B., Sethi, S. S., Kurwadkar, S., Kumar, A., & Sankar, T. K. (2021). Toxicity and health risk assessment of polycyclic aromatic hydrocarbons in surface water, sediments and groundwater vulnerability in Damodar River Basin. *Groundwater for Sustainable Development*, *13*, 100553.

American Public Health Association (APHA). (2000). Standard methods for the examination of water and wastewater. 18th ed Washington, DC.

Arenas-Sánchez, A., Rico, A., & Vighi, M. (2016). Effects of water scarcity and chemical pollution in aquatic ecosystems: State of the art. *Science of the Total Environment*, *572*, 390-403.

ATSDR (2003). Draft toxicological profile for nickel. Atlanta, Georgia, United States. US Department of Health and Human Services. Agency for Toxic Substances and Disease Registry.

Bal, A., Panda, F., Pati, S. G., Anwar, T. N., Das, K., & Paital, B. (2022). Influence of anthropogenic activities on redox regulation and oxidative stress responses in different phyla of animals in coastal water via changing in salinity. *Water*, *14*(24), 4026.

Bashir, I., Lone, F. A., Bhat, R. A., Mir, S. A., Dar, Z. A., & Dar, S. A. (2020). Concerns and threats of contamination on aquatic ecosystems. *Bioremediation and biotechnology: sustainable approaches to pollution degradation*, 1-26.

Belhouchet, N., Inal, A., Nait-Mohand, H., Belkacem, Y., & Chenchouni, H. (2023). Assessment of pollutants in coastal waters, sediments, and biota of marine ecosystems in Algeria, North Africa. *Regional Studies in Marine Science*, 103355.

Chris, D. I., Wokeh, O. K., Lananan, F., & Azra, M. N. (2023). Assessment of Temporal Variation of Water Quality Parameters and Ecotoxic Trace Metals in Southern Nigeria Coastal Water. *Polish Journal of Environmental Studies*, *32*(5).

Clement W. H. , Kotalik, C. 2016. Effect of major ions on benthic communities:an experimental assessment of the US environmental Protection agency aquatic life benchmark for conductivity. Freshw. Sci. 35, 126-138).

Cunillera-Montcusí, D., Beklioğlu, M., Cañedo-Argüelles, M., Jeppesen, E., Ptacnik, R., Amorim, C. A., ... & Matias, M. (2022). Freshwater salinisation: a research agenda for a saltier world. *Trends in Ecology & Evolution*.

Davies, I. C. and Ekperusi, A. O. (2021). Evaluation of Heavy Metal Concentrations in Water, Sediment and Fishes of New Calabar River in Southern Nigeria. *Journal of Limnology and Freshwater Fisheries Research*, 7(3):207-218.

Davies, I. C. and Okonkwo, S. E. (2021). Analyses of Some Heavy Metal and Nutrients of Water Samples from Ajegunle Creek in Lagos. *International Journal of Environment and Pollution Research*, 9;1:7-26

Debnath, A., Singh, P. K., & Sharma, Y. C. (2021). Metallic contamination of global river sediments and latest developments for their remediation. *Journal of environmental management*, *298*, 113378.

Freire, C. A., & Prodocimo, V. (2019). Special challenges to teleost fish osmoregulation in environmentally extreme or unstable habitats. In *Fish osmoregulation* (pp. 249-276). CRC Press.

Gezahegn, W.W., Srinivasulu, A., Aruna, B., Banerjee, S., Sudarshan, M., Narayana, P.V.L. & Rao, A.D.P. (2017). Study of Heavy Metals Accumulation in water. *Journal of Environmental Sciences*, 27: 43-54

Hintz, W. D., & Relyea, R. A. (2019). A review of the species, community, and ecosystem impacts of road salt salinisation in fresh waters. *Freshwater biology*, *64*(6), 1081-1097.

Kanellopoulos, T. D., Kapetanaki, N., Karaouzas, I., Botsou, F., Mentzafou, A., Kaberi, H., ... & Karageorgis, A. P. (2022). Trace element contamination status of surface Hintzmarine sediments of Greece: an assessment based on two decades (2001–2021) of data. *Environmental Science and Pollution Research*, *29*(30), 45171-45189.

Koller, M., & Saleh, H. M. (2018). Introductory chapter: Introducing heavy metals. *Heavy metals*, *1*, 3-11.

Mahowald, N. M., Hamilton, D. S., Mackey, K. R., Moore, J. K., Baker, A. R., Scanza, R. A., & Zhang, Y. (2018). Aerosol trace metal leaching and impacts on marine microorganisms. *Nature communications*, *9*(1), 2614.

Miguel C. A., Ben K. & Raff S. (2018). Salt in fresh waters: causes effects and prospects-introduction to the theme issue. The royal society publishing, 374(1764):20180002)

Nilsen, E., Smalling, K. L., Ahrens, L., Gros, M., Miglioranza, K. S., Picó, Y., & Schoenfuss, H. L. (2019). Critical review: grand challenges in assessing the adverse effects of contaminants of emerging concern on aquatic food webs. *Environmental Toxicology and Chemistry*, *38*(1), 46-60.

Odekina, M.U., Davies I C., Akoko S., & Vincent-Akpu I. F. (2021). Bioaccumulation of Heavy Metals in *Periophthalmus papillio*, Sediment and Interstitial Water from Isaka-Bundu Water Front in Rivers State. *Academic Journal of Current Research.* 8(11):19-38.

Okonkwo, S. E., Davies I. C., & Okere M.C. (2021): Assessment of Physicochemical Characteristics and Phytoplankton of a Polluted Tidal Creek In Ajegunle, Lagos. *British Journal of Environmental Sciences* 9(1): 51-69.

Onojake, M. C., Sikoki, F. D., Omokheyeke, O., & Akpiri, R. U. (2017). Surface water characteristics and trace metals level of the Bonny/New Calabar River estuary, Niger delta, Nigeria. *Applied Water Science*, *7*, 951-959.

Saenger, P., & Holmes, N. (2018). Physiological, temperature tolerance, and behavioural differences between tropical and temperate organisms. In *Pollution in tropical aquatic systems* (pp. 69-95). CRC Press.

Sutton, A. O., Turko, A. J., McLaughlin, R. L., & Wright, P. A. (2018). Behavioural and physiological responses of an amphibious, euryhaline mangrove fish to acute salinity exposure. *Copeia*, *106*(2), 305-311.

Thanigaivel, S., Vickram, S., Dey, N., Jeyanthi, P., Subbaiya, R., Kim, W., ... & Karmegam, N. (2023). Ecological disturbances and abundance of anthropogenic pollutants in the aquatic ecosystem: Critical review of impact assessment on the aquatic animals. *Chemosphere*, *313*, 137475.

Tóth, G., Hermann, T., Da Silva, M. R., & Montanarella, L. J. E. I. (2016). Heavy metals in agricultural soils of the European Union with implications for food safety. *Environment international*, *88*, 299-309.

U.S. EPA (Federal Environmental Protection Agency). (2007). National Guidelines and Standards for Industrial Effluents and Water Quality Tests U.S. EPA (Nigeria) Official Gazette, Nigeria.

U.S. EPA (U.S. Environmental Protection Agency). 2001. OPPTS 870.8355. Combined Chronic Toxicity/Carcinogenicity Testing of Respirable Fibrous Particles. EPA 712-C-01-352. Washington, DC U.S. EPA.

Ukhurebor, K. E., Athar, H., Adetunji, C. O., Aigbe, U. O., Onyancha, R. B., & Abifarin, O. (2021). Environmental implications of petroleum spillages in the Niger Delta region of Nigeria: a review. *Journal of Environmental Management*, *293*, 112872.

Ward, D. M., Nislow, K. H., & Folt, C. L. (2010). Bioaccumulation syndrome: identifying factors that make some stream food webs prone to elevated mercury bioaccumulation. *Annals of the New York Academy of Sciences*, *1195*(1), 62-83.

Wen, Y., Schoups, G., & Van De Giesen, N. (2017). Organic pollution of rivers: Combined threats of urbanization, livestock farming and global climate change. *Scientific reports*, *7*(1), 43289.

World Health Organization. (2011). *WHO guidelines on preventing early pregnancy and poor reproductive health outcomes among adolescents in developing countries*. World Health Organization.

Yusuf, K. A., & Osibanjo, O. (2006). Trace Metals in Water and Sediments from Ologe Lagoon, Southwestern. *Biological Sciences-PJSIR*, *49*(2), 88-96.