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Research Article

Assessment Of Heavy Metal Toxicity Load (HMTL) For Water Quality Improvement: A Case Study of *NVUNA* River In ITUKU Community, Enugu State, Nigeria

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Abstract
Water pollution from human activities remains a global concern, predominantly due to toxic heavy metals that pose significant health risks. This study assessed the heavy metal toxicity load (HMTL) in water and sediment from the Nvuna River in Ituku Ozalla, Enugu State, Nigeria. Six water samples were analyzed for physicochemical properties and four heavy metals using atomic absorption spectrophotometry. The HMTL and Metal Index (MI) were calculated to evaluate contamination levels. Results showed water pH ranged from 7.23 to 8.03, while sediment pH ranged from 7.50 to 8.10, indicating alkaline conditions. Conductivity values were 31.02–36.84 µS/cm in water and 30.37–37.49 µS/cm in sediment. Turbidity, total solids, nitrate, and sulfate levels were within WHO limits. Heavy metal analysis revealed no detectable levels of lead (Pb), cadmium (Cd), or arsenic (As). However, mercury (Hg) levels in water (0.001–0.002 mg/L) exceeded the WHO permissible limit (0.001 mg/L). The MI values were 1.5 for water and 29 for sediment, while HMTL ranged from 1.455 to 119.31 mg/L, with an average of 43.165 mg/L. The findings highlight severe mercury contamination, with 88% of the heavy metal load needing removal for water to be safe for consumption. Elevated MI and HMTL values indicate significant risks to drinking water safety and aquatic ecosystems, underscoring the urgent need for remediation to restore water quality in the study area.

Keywords: HMTL; MI; Heavy metal; water quality, health risks

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Introduction

The sixth Sustainable Development Goal (SDG) of the UN is clean water and sanitation. The most basic requirements for maintaining good health and wellness in humans are having access to clean water, adequate sanitation, and regular hygiene (United Nations, 2023). The demand for water is rising due to factors such as urbanization, rapid population growth, and the expanding water needs of the energy, industrial, and agricultural sectors (Grönwall *et al*, 2020). The UN estimates that by 2030, billions of people would lack access to these basic services if enormous efforts are not made to improve access to water resources (United Nations, 2023). Despite its vital role in providing safe drinking water, the recognition of surface water's importance remains incomplete at both global and national levels. Water, as an indispensable element for life on Earth, plays a pivotal role in socio-economic growth and sustainable development (Okudo *et al*., 2023). The mismanagement of water resources, compounded by a range of human activities, poses a serious threat to water quality worldwide (Reza *et al*, 2010; Islam *et al.*, 2014). Surface water, a crucial natural resource supporting human health, socio-economic development, and ecosystems, has recently faced escalating contamination issues (Egbueri *et al*, 2020). The contamination of water resources by heavy metals, originating from natural sources and human activities, has emerged as a prominent global concern (Egbueri *et al*, 2020).

Therefore, an in-depth understanding of surface water quality, its evolution, and the associated drivers is imperative for ensuring long-term sustainability (Obasi *et al*, 2020). Heavy metal pollution in water is a significant environmental issue due to its potential ecological and human health repercussions (Kumar *et al*, 2021). The presence of heavy metals, characterized by high atomic weights and densities, can result in toxic effects even at low concentrations due to their persistence and cumulative nature in the environment (Kumar *et al*, 2021). These metals, including lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), arsenic (As), and nickel (Ni), often found in industrial effluents, can disrupt aquatic ecosystems and bioaccumulate in the food chain, posing threats to both aquatic organisms and humans (Lambert *et al*., 2000; Rahman *et al*., 2013; Ali *et al*., 2020).

The contamination of water bodies by heavy metals stems from diverse sources, including industrial discharges, agricultural runoff, and natural geological processes (Sharma *et al*., 2009). This contamination exerts detrimental effects on both environmental stability and human well-being, potentially leading to physical, muscular, and neurological disorders (Saha *et al*, 2019; Ali *et al*., 2020).

Consequently, assessment of heavy metal toxicity in water quality is essential to mitigate ecological damage and safeguard public health (Egbueri, 2018; Kalhor *et al*, 2019).). Despite the significance of heavy metal toxicity, an evaluation of the Heavy Metal Toxicity Load (HMTL) model's application in quantifying toxic elements in surface water within Nigeria, particularly Enugu State, remains lacking. The HMTL model offers a unique approach to assess toxic element concentrations, estimate required removal percentages, and enhance the suitability of surface water for consumption (Proshad *et al*., 2021).

2.0 Methods

2.1 Description of the Study Area

Nvuna river provides drinking water as well as aquatic environment that supports an all year-round farming though irrigation for residents of Ituku Ozalla in Enugu State. In the past, there had been reports (Ede, 2021) of toxic effluent being discharged into the river from a company located in Ituku that produces ethanol.

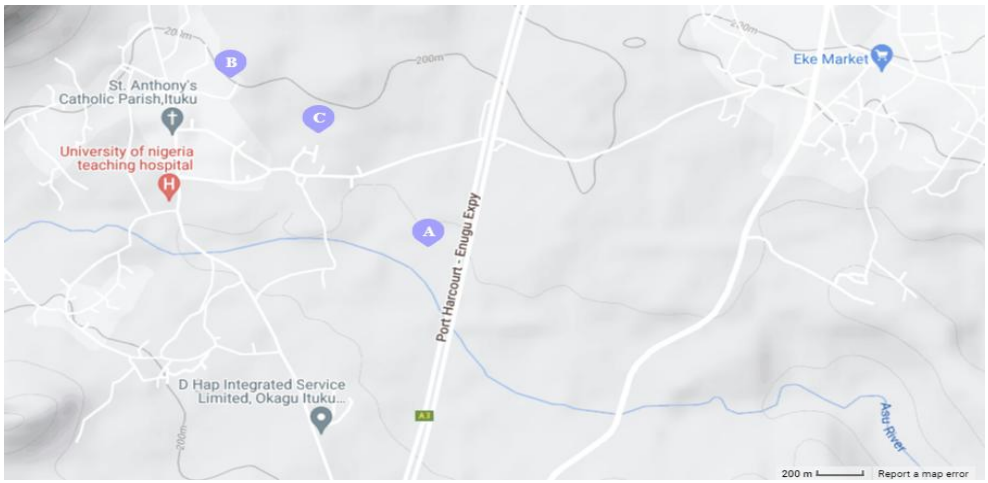

Figure 1: Sampling Locations along *Nvuna* River in Ituku.

Coordinates of the three locations - A(6°17′00″N, 7°27′53″E), B(6°17′27″N, 7°27′24″E), C(6°17′18″N, 7°27′37″E)

2.2 Collection of Water and Sediment

The water and sediment samples were collected in December, 2023 during the dry season from three different sampling locations: *Nvuna* express (A), *Nvuna* Ogbuanu (B) and *Nvuna* Umuowo (C) as indicated in figure 3.1. Six samples were collected comprising of three water and three sediment samples from the three locations. The water collection process involves the cleaning of sampling bottles, sampling pole, masking tape, marker and GPS locator. Clean 75 cl sampling bottles were used to collect the water samples. The bottles were submerged just below the water surface, taking care not to disturb the sediment or bottom of the water body. They were filled completely, avoiding any air bubbles. The sediment samples were collected by disturbing the sediment and submerging the water bottles to collect sample. The sediment samples were separated by decantation. Properly labelled sampling bottles were sealed tightly to prevent any leakage or contamination during transportation, and were stored in a cool and dark place (American Public Health Association (APHA, 2017).

2.3 Collection of Fish Samples

The fish samples were collected according to APHA (2017) procedure. The fish samples were collected by trapping with net. The net was positioned in an area where fish are likely to be present. It was properly anchored and positioned to intercept fish swimming along their natural path. The net was allowed to remain in place for a sufficient period; monitored periodically to check for fish entanglement or capture. After an appropriate duration, the net was carefully retrieved to avoid damaging the captured fish. Care was taken to handle the fish carefully during collection to minimize stress and injury. The fish samples were properly labelled and preserved overnight by freezing. Two fish samples were collected from the river during the dry season. The fish samples were collected from location B – *Nvuna* Ogbuanu.

2.4 Collection of Grass Samples

The elephant grass (*Pennisetum purpureum*) samples were collected from two locations along the river during the dry season. The locations are *Nvuna* express and *Nvuna* Ogbuanu. The grass samples were authenticated by Prof. C.S. Eze of the Department of Applied Biology, Enugu State University. The samples were collected by cutting the stems close to the ground using a pair of scissors (Tcacenco *et al*, 1992). An amount, 10 g each of the grass samples were kept in clean and airtight waterproof bags (APHA., 2017), and properly labelled.

2.5 pH

The process of determining the pH involved the following steps. Equipment to be used were cleaned and calibrated. The equipment included a pH meter, pH electrode, reference electrode, and calibration solutions. The pH meter was calibrated using standard buffer solutions of known pH values. This step ensures the accuracy and reliability of the pH measurements. Representative water sample was taken at room temperature. The pH electrode and reference electrode were rinsed with distilled water to remove any contaminants. They were immersed in a storage solution or a pH 7 buffer solution to condition them before use. The electrodes were immersed into the water sample, ensuring that they were fully submerged and not touching the sides or bottom of the container. The pH reading was allowed to stabilize on the pH meter display. The pH reading from the pH meter was recorded. The electrodes were rinsed with distilled water after each measurement to remove any residue. They were stored in a storage solution or a pH 7 buffer solution to prevent drying out and maintain their performance (APHA, 2017).

2.6 Conductivity

To determine the conductivity of a water sample, the following steps were followed. All the necessary equipment was cleaned and calibrated. These included a conductivity meter, conductivity cell or probe, and calibration solutions. The conductivity meter was calibrated using standard calibration solutions of known conductivity values. This step ensures the accuracy and reliability of the conductivity measurements. Representative water sample was at room temperature. The conductivity cell or probe was rinsed with distilled water to remove any contaminants. The electrodes were immersed in a storage solution or a conductivity standard solution to condition them before use. The conductivity reading from the conductivity meter was recorded. The electrodes were rinsed with distilled water after each measurement to remove any residue. They were stored in a storage solution or a conductivity standard solution to prevent drying out and maintain their performance (APHA, 2017).

2.7 Turbidity

Turbidity, which measures the cloudiness or haziness of a fluid caused by suspended particles, was assessed using a turbidimeter. A turbidimeter is a portable device used to measure the turbidity of water. Water sample was collected in a clean container. The turbidimeter probe was inserted into the water sample. The turbidimeter emitted light into the water sample and measured the amount of light scattered by the suspended particles. The turbidimeter provided a digital readout of the turbidity level in NTU (Nephelometric Turbidity Units) (APHA, 2017)

2.8 Total Solid (TS)

A 100 ml beaker was washed, dried and weighed. A volume, 50 ml of the water sample was added to the weighed beaker and heated to dryness in an oven at 103 ^{o}C for 1 hr. The dried beaker was transferred into a desiccator to cool for 1 hr. The difference in weight is a measure of the TS (APHA, 2017).

$$\text{TDS (mg/l)} = \frac{(W2 - W1) \times 1000 \times 1000}{volume\ of\ sample}$$

Where W_2 and W_1 are the final and initial weights, in grams, of the beaker respectively

2.9 Total Suspended Solids (TSS)

A filter paper was dried in the oven, and its initial weight measured. A volume, 50 ml of water sample was filtered through the filter paper. The filter paper was dried in an oven at 40 ºC. The final weight of the filter paper was taken (APHA, 2017).

$$\text{TSS (mg/l)} = \frac{(W2 - W1) \times 1000 \times 1000}{volume\ of\ sample}$$

Where W_2 and W_1 are the final and initial weights, in grams, of the filter paper respectively

2.10 Sulphate

A volume, 100 ml of water sample was measured into a 250 ml conical flask. A volume, 5 ml of conditioning reagent was added, and the solution mixed in the stirring apparatus. Conditioning reagent was prepared by mixing 12.5 ml of glycerol with 7.5 ml conc. HCl, 75 ml distilled water, 25 ml absolute ethanol and 18.75 g of NaCl. While stirring, 5 g of barium chloride crystals was added, and the timer set. After stirring at a constant speed, the absorbance was measured in the second minute at 425 nm. The Sulphate concentration was calculated based on a sulphate standard curve. A calibration curve was prepared using standard sulphate solutions of known concentrations. The curve relates the absorbance to the concentration and was used to determine the sulphate concentration in the sample (APHA., 2017).

$$y = 135.7X + 5.724$$

where y is sulphate concentration (mg/L); X is absorbance at 425nm

2.11 Nitrate

A number of test tubes were set up in a rack, and a volume, 10 ml of the sample were added to the test tubes. The rack was set in a cool water bath. A volume, 2 ml of NaCl solution was added. The solution was mixed thoroughly by swirling and allowed to cool. A volume, 0.5 ml of brucine sulphanilic acid reagent solution was added, and the test tubes swirled again, placed inside a boiling water bath that maintains the temperature not less than 90 ºC and allowed to stay for 20 minutes. The tubes were removed from the bath, and allowed to cool in a cool water bath. The absorbance was read at 411nm. The Nitrate concentration was calculated based on a Nitrate standard curve. A calibration curve was prepared using standard nitrate solutions of known concentrations. The curve relates the absorbance to the concentration and is used to determine the nitrate concentration in the sample (APHA., 2017).

$$y = 5.547X + 0.0299$$

where y is nitrate concentration (mg/L) and x is absorbance.

2.12 Heavy Metal determination

Digested samples were analyzed for Lead (Pb), mercury (Hg), arsenic (As) and Cadmium (Cd) by using Atomic Absorption Spectrophotometer-230FCS (APHA., 2017). An amount, 1 g each of ground fish and grass samples were digested. The Spectrophotometer was calibrated using different concentrations (1ppm, 5 ppm and 10 ppm) of stock heavy metals. The different concentrations were prepared by serial dilution of 100 mg/L stock of each of the following metals: Pd, Cd, Hg and As. A calibration graph was prepared for each metal before analysis. The heavy metal analysis was done for the fish, grass, water and sediment samples. For each experiment, a run including blank, reference materials and samples were analyzed in duplicate to eliminate any batch-specific error (Proshad *et al*, 2020).

2.13 Metal Index (MI)

The Metal Index (MI) is used for determining the degree and level of heavy metals present in any water source (Goher *et al.*, 2014). The water's quality decreases with increasing metal concentration relative to its MAC value. A warning threshold of MI value >1 is established by Bakan *et al.* (2010). The following formula was used to determine the MI (Tamasi *et al*, 2004):

$$MI = \sum_{i=1}^{n} \frac{Ci}{MACi}$$

Where C_i is the concentration (mean values) of the ith heavy metals analysed,

MAC_i is the maximum allowed concentrations of the ith heavy metals

2.14 Bioconcentration Factors of Heavy Metals

The bioconcentration factors (BCF) of the heavy metals obtained in fish samples were calculated using equation:

$$BCF = \frac{C\ organism}{C\ sediment\ or\ water}$$

Where, C organism = concentration of metals in the fish species and C sediment = concentration of metals in the sediment (Adeosun *et al*., 2015).

2.15 Heavy Metal Toxicity Load (HMTL)

The heavy metal toxicity load (HMTL) measures the amount of heavy metal present in the water that may affect human health. It provides an idea to the regulatory authority about the extent of treatment required to treat the water which is suitable for human use. This technique also helps to document an effective treatment and management plan. HMTL was evaluated by multiplying the measured concentration of heavy metals with its hazard intensity as shown below:

$$HMTL = \sum_{i=1}^{n} C \text{ x } HIS$$

where C is the concentration of heavy metal; n is the number of heavy metals and HIS is the hazard intensity score which is obtained from the ATSDR (Agency for Toxic Substances and Disease Registry [ATSDR], 2022; Proshad *et al.*, 2020). HIS is allocated based on the frequency of incidence of toxic metals as a harmful substance on the National Priorities List sites maintained by ATSDR, the toxicity level of studied metals, and the prospect of human contact. The highest HIS for toxic metal is 1800 points, with 600 points each for the

frequency of NPLs, toxicity, and the possibility of physical contact (Ayejoto *et al.*, 2022).

2.16 Statistical Analysis

To assess the statistical significance of the findings, a comprehensive statistical analysis was conducted using Microsoft Excel 2016 and Matplotlib 3.7.0 on Jupyter Notebook 6.5.4. Descriptive statistics, including mean and standard deviation, were calculated for all measured parameters.

3.0 Results

3.1 Physicochemical Parameters of the Water Samples

Table1 shows that the water has an alkaline pH; contains dissolved and suspended solids. The water samples analyzed in Table 1 demonstrate good quality, meeting World Health Organization (WHO) standards for drinking water. All physicochemical parameters, including pH, conductivity, turbidity, total solids, total dissolved solids, total suspended solids, nitrate, and sulphate, are within the recommended limits. Specifically, the pH levels are slightly alkaline, averaging 7.63, while conductivity, turbidity, and total solids are relatively low. Additionally, nitrate and sulphate levels are well below the recommended limits, averaging 1.38 mg/L and 29.02 mg/L, respectively. Overall, the water samples appear to be safe for consumption based on these parameters.

Table 1: Physicochemical Parameters of the Water Samples

Parameters	Concentrations (Mean ± STD)	WHO
pH	7.63 ± 0.40	6.5 –8.5
Conductivity (µS/cm)	33.93 ± 2.91	400
Turbidity (NTU)	0.18 ± 0.04	5.00
TS (mg/L)	130 ± 30.82	1000
TDS (mg/L)	73.33 ± 30.55	500
TSS (mg/L)	56.66 ± 25.17	500
Nitrate (mg/L)	1.38 ± 0.15	50
Sulphate (mg/L)	29.02 ± 7.11	500

3.2 Physicochemical Parameters of the Sediment Samples

Table 2 shows that the sediment has an alkaline pH; contains dissolved and suspended solids. The sediment samples analyzed in Table 2 generally exhibit physicochemical parameters within acceptable limits, aligning with World Health Organization (WHO) guidelines. The mean pH level of 7.80 indicates slightly alkaline conditions, while conductivity and turbidity values are relatively low. Total solids, total dissolved solids, and total suspended solids were also within recommended limits, averaging 60 mg/L, 60 mg/L, and 50 mg/L, respectively. Furthermore, nitrate and sulphate concentrations are below the recommended limits, averaging 1.33 mg/L and 35.15 mg/L, respectively. Overall, the sediment samples appear to be relatively uncontaminated, meeting WHO standards for environmental safety.

Table 2: Physicochemical Parameters of the Sediment Samples

Parameters	Concentrations (Mean ± STD)	WHO
pH	7.80 ± 0.30	6.5 – 8.5
Conductivity (µS/cm)	33.93 ± 3.56	400
Turbidity (NTU)	0.19 ± 0.05	5.00
TS (mg/L)	60 ± 34.64	1000
TDS (mg/L)	60 ± 40.07	500
TSS (mg/L)	50 ± 30.00	500
Nitrate (mg/L)	1.33 ± 0.42	50
Sulphate (mg/L)	35.15 ± 6.43	250

3.3 Heavy Metal Concentration in the Water Samples

Table 3 shows that out of the four heavy metals analysed, only mercury was detectable in water samples. The water samples analyzed in Table 3 showed negligible concentrations of heavy metals, with levels below or comparable to World Health Organization (WHO) guidelines. Lead (Pb) and cadmium (Cd) were not detectable, while arsenic (As) was also below detection limits. Mercury (Hg) was present in very low concentrations, averaging 0.0015 mg/L, which was slightly above the acceptable limit of 0.001 mg/L set by WHO. Overall, the water samples appear to be free from significant heavy metal contamination, indicating a low risk to human health and the environment.

Table 3: Heavy Metal Concentration in the Water Samples

Metal	Concentration (mg/l) Mean ± STD	WHO (mg/l)
Pb	N.d.	0.05
Hg	0.0015 ± 0.0005	0.001
Cd	N.d.	0.003
As	N.d.	0.05

N.d. stands for not detectable

3.4 Heavy Metal Concentration of Sediment Samples

Table 4 shows that out of the four heavy metals analysed, only mercury was detectable in the sediment samples. The sediment samples analyzed in Table 4 show varying concentrations of heavy metals, with some metals present in detectable amounts. Lead (Pb), cadmium (Cd), and arsenic (As) were not detectable, indicating low levels of contamination. However, mercury (Hg) was present in a concentration of 0.029 mg/L, which exceeds the WHO guideline of 0.001 mg/L. This suggests that the sediment may be contaminated with mercury, potentially posing an environmental risk.

Table 4: Heavy Metal Concentration of the Sediment Samples

Metal	Concentration (mg/L) Mean ± STD	WHO (mg/L)
Pb	N.d.	0.05
Hg	0.029 ± 0.045	0.001
Cd	N.d.	0.003
As	N.d.	0.05

N.d. stands for not detectable

3.5 Metal Index (MI) of Heavy Metals in Water and Sediment Samples

Table 5 shows that, based on the MI classification, the water samples were slightly affected by metal contamination, while the sediment samples were seriously affected. The classification is based on the Metal Index Categorization/ classification by Caeiro *et al.* (2005). The water samples have an MI value of 1.5, classified as Class III, suggesting that they are only slightly affected by heavy metal contamination. In contrast, the sediment samples have a significantly higher MI value of 29, classified as Class VI, indicating that they are seriously affected by heavy metal contamination. This disparity highlights the potential for sediment to act as a sink for heavy metals, posing a greater environmental risk compared to the water samples.

Table 5: Metal Index of Heavy Metals in Water and Sediment Samples

Sample	MI	Class	Properties
Water	1.5	III	Slightly affected
Sediment	29	VI	Seriously affected

3.6 Heavy Metal Concentration in the Fish Samples

Table 6 shows that out of the four heavy metals analysed, only mercury was detected in the fish samples. Lead (Pb), cadmium (Cd), and arsenic (As) were not detectable, indicating very low levels of contamination. Mercury (Hg) was present in a very low concentration of 0.0002 mg/kg, which is significantly below the Food and Agriculture Organization (FAO) guideline of 0.5 mg/kg. Overall, the fish samples appear to be safe for human consumption, with heavy metal concentrations well within acceptable limits.

Table 6: Heavy Metal Concentration in the Fish Samples

Metal	Concentration (mg/kg) Mean ± STD	FAO (mg/kg)
Pb	N.d.	0.2
Hg	0.0002 ± 0.0000	0.5
Cd	N.d.	0.05
As	N.d.	0.5

N.d. stands for not detectable

3.7 Bioconcentration Factors of Heavy Metals in Fish Samples

Table 7 shows the bioconcentration factors of lead, mercury, cadmium and mercury in the fish samples. The Bioconcentration Factors (BCFs) presented in indicate the extent to which heavy metals accumulate in fish tissues. The BCF values for lead (Pb), cadmium (Cd), and arsenic (As) are zero, suggesting that these metals are not bioaccumulating in the fish samples. In contrast, the BCF value for mercury (Hg) is 0.133, indicating a low level of bioaccumulation. Though low, this could potentially pose a health risk upon human consumption.

Table 7: Bioconcentration Factors of Heavy Metals in Fish Samples

Metal	Concentration in Fish	Bioconcentration Factor
Pb	N.d	0
Hg	0.0002 ± 0.0000	0.133
Cd	N.d	0
As	N'd	0

3.8. Heavy Metal Concentration in Grass Samples

Table 8 shows that out of the four heavy metals analysed, only mercury was detected in the grass samples. The grass samples analyzed showed low concentrations of heavy metals, indicating a relatively uncontaminated environment. Lead (Pb), cadmium (Cd), and arsenic (As) were not detectable, suggesting very low levels of contamination. Mercury (Hg) was present in a low concentration of 0.0015 mg/kg, which is below the Food and Agriculture Organization (FAO) guideline of 0.03 mg/kg. Overall, the grass samples appear to be safe, with heavy metal concentrations within acceptable limits.

Table 8: Heavy Metal Concentration in Grass Samples

Metal	Concentration (mg/kg) Mean ± STD	*FAO (mg/kg)
Pb	N.d.	0.3
Hg	0.0015 ± 0.0006	0.03
Cd	N.d.	0.02
As	N.d.	0.5

*FAO/WHO maximum permissible limits for heavy metals in vegetables (Ezeonyejiaku *et al*, 2023)

3.9. Heavy Metal Toxicity Load (HMTL) of Water and Sediment Samples

Table 9 shows that the HMTL is greater than the permissible toxicity load for water and sediment from three locations: Nvuna Express, Nvuna Ogbuanu, and Nvuna Umuowo. The results show that mercury (Hg) is the primary contributor to the toxicity load, with concentrations ranging from 1.455 to 119.31 mg/L. The total toxicity load is 129.495 mg/L, with an average of 43.165 mg/L. To reduce pollution, an 88% removal of toxic metals is recommended. The Hazard Intensity Score (HIS) ranges from 1317 to 1675, indicating a significant level of toxicity. The permissible toxicity load for mercury is 1.455 mg/L, according to the Agency for Toxic Substances and Disease Registry (ATSDR, 2022).

Table 9: Heavy Metal Toxicity Load of Water and Sediment Samples

	Toxicity of Heavy Metals in mg/L				
Location	Cd	Pb	As	Hg	Heavy Metal Toxicity Load (HMTL)
Nvuna Express	0	0	0	1.455	1.455
Nvuna Ogbuanu	0	0	0	8.730	8.73
Nvuna Umuowo	0	0	0	119.31	119.31
Total	0	0	0	129.495	
Percentage removal of toxic metal to reduce pollution	0	0	0	88%	
*Hazard Intensity score (HIS)	1317	1531	1675	1455	
Permissible toxicity load (mg/L)	3.951	1.531	1.675	1.455	

*(ATSDR, 2022) Range: 1.46 to 119.31, Average: 43.165

4.0 Discussion

The pH values for the water and the sediment samples indicate that the water is alkaline. The values obtained are within the WHO (2017) approved pH range of 6.5 – 9.2 for drinking water. The pH measurement reflects the acidity or alkalinity of the water sources that can produce sour or alkaline tastes (Addisie, 2022). The pH of drinking water has no immediate direct effects on human health but has some indirect health effects by bringing changes in other water quality parameters such as solubility of metals and survival of pathogens (Zabed *et al.,* 2014). High levels of pH can affect egg production

in fish, cause skin and eye irritation to humans (Ojo *et al*, 2012). The pH in rivers can be due to wastewater, municipal discharge, heavy rainfall and agricultural runoff (Vivien *et al*., 2012).

The conductivity values obtained were within the WHO (2017) recommended limit of 400 µS/cm for drinking water. This shows that the water from *Nvuna* river was not significantly ionized and had a lower degree of ionic concentration activity, due to small dissolved particles. The turbidity values for water and sediment samples were less than the WHO (2017)-recommended threshold of 5 NTU. However, Ken-Onukuba *et al.* (2021) in 'Water quality assessment of Ekulu and Asata Rivers in Enugu Area, Southeastern Nigeria', reported higher turbidity values in river Ekulu and Asata located in Enugu Urban area. Human activity is a major factor contributing to turbidity (Li and Xia, 2023).

The values obtained for total solid (TS) level of water and sediment samples are within the WHO (2017) approved limit for drinking water of 1000 mg/L. The total dissolved solid (TDS) and total suspended solids (TSS) for water and sediment samples are also within the WHO (2017) approved limits of 500 mg/L for each parameter respectively. Generally, this indicates low level of pollution by dissolved and suspended contaminants (Ken-Onukuba *et al.*, 2021). The results obtained are in contrast to those of Alum *et al.*, (2023) in 'Assessment of Pollution Status of River Ajali in Enugu State using water quality index', who reported high TDS.

Nitrate and sulphate levels in the water and sediment samples were found to be within the WHO (2017) permissible limits. Similar nitrate levels, ranging from 1.1367 to 0.8417 were recorded by Sadiq *et al.* (2022). The presence of nitrate in a river can be attributed to wastewater discharge from settlements and runoff from farmlands (Damo *et al*, 2013). Sulphate concentration in natural water ranges from a few to a several hundred mg/L but no major negative impact of sulphate on human health is reported (Fadaei *et al*, 2014). Sulphates can occur naturally or be introduced through municipal or industrial discharges (Ujah *et al*., 2023).

Out of the four heavy metals analysed only mercury was detected in the water and sediment samples. The presence of arsenic, lead and cadmium were not detected. The average mercury level in both water and sediment samples exceed the WHO recommended limit of 0.001 mg/L for mercury in drinking water. Mercury releases from natural sources, such as volcanic eruptions and geothermal activity, and anthropogenic sources, such as fossil fuel burning, metal mining, and industrial emissions enter the aquatic ecosystems are primarily by riverine input and atmospheric deposition. Mercury exposure leads to neurological issues, kidney impairment, and a correlation with infertility (Choy *et al*., 2003). The nervous system is highly sensitive to mercury (Bellanger *et al*., 2013), causing various health problems, including alterations in brain functions, shyness, tremors, memory problems, and irritability. Similarly, high values for mercury in water had been reported by Atama *et al.* (2020) in 'Heavy metal analysis of three urban rivers in Enugu, Nigeria'. Achukwu *et al.* (2012) in 'Mercury Contamination of Fish Consumed in Enugu, Southeast Nigeria' reported that the level of mercury of water bodies in Enugu metropolis and South-East Nigeria is significantly higher than the WHO recommended values. Data from the three locations reveal that the sediment samples have a higher mean mercury content than the water samples. *Nvuna* Umuowo records the highest mercury level of 0.08 mg/L for the sediment sample.

The Metal Index values corroborate the contrast in mercury level as it indicates that the water samples were slightly affected while sediment samples were seriously affected by heavy metal contamination. According to Metal Index values, both water and sediment samples are seriously threatened with metal pollution for drinking and aquatic usage (MI > 1) (Goher *et al.*, 2014). Sediment samples have reasonably high mercury concentrations compared with their stream waters, which could be due to the settling and adsorption of various inorganic and organic mercurial salts in the water (Ishaq *et al.*, 2013).

The amount of harmful metals present in a body of water and the proportion that has to be removed before the water is acceptable for human consumption are displayed by the heavy metal toxicity load (HMTL) model. It evaluates the concentration of hazardous metals in water that are harmful to human health. According to Proshad *et al*. (2021), it provides the regulatory body with information regarding the extent of treatment required to bring a water source up to acceptable drinking water standards. The application of a suitable therapy and intervention strategy is aided by this statistical indication. According to Kumar *et al.* (2019), the HMTL is therefore thought to be a technique for figuring out the pollutant levels in the water that pose a non-carcinogenic risk. This study's average HMTL value of 43.165 was greater than the permissible toxicity load of 1.455, indicating that the amount of hazardous components in the water was at its highest (Proshad *et al.*, 2021). Similar results were recorded by Ayejoto *et al.* (2022). Continuous water contamination can cause the HMTL value to increase (Ayejoto *et al*., 2022). The total toxicity load of the heavy metals indicates that 88% of the heavy metal load must be removed for the water resources to be fit for human consumption.

The result of heavy metal analysis of the two fish samples revealed that lead, Cadmium and Arsenic were not detected. Mercury was detected in only one of the fish samples. The concentration of mercury detected was below the Food and Agriculture Organisation (FAO) permissible limit for mercury in fish. Achukwu *et al.*, (2021) in 'Mercury Contamination of Fish Consumed in Enugu, Southeast Nigeria' pointed out the significantly high empirical values of mercury in the local fish species. According to them, fish consumed in Enugu has levels of mercury which are significantly higher than the WHO recommended values. Fish products have been shown to contain varying amounts of heavy metals, particularly mercury and fat-soluble pollutants from water pollution (Center for Food Safety and Applied

Nutrition, 2022). The presence of mercury in fish is a health concern for people who eat them, especially for women who are or may become pregnant, nursing mothers, and young children. Fish and shellfish concentrate mercury in their bodies, often in the form of methylmercury, a highly toxic organomercury compound (Park *et al.*, 2008). Mercury is known to bioaccumulate in humans, so bioaccumulation in seafood carries over into human populations, where it can result in mercury poisoning. Mercury is dangerous to both natural ecosystems and humans because it is a metal known to be highly toxic, especially due to its neurotoxic ability to damage the central nervous system.

The bioconcentration factor of mercury in the fish sample was relatively lower than the 1.00 recommended limits of WHO/FEPA (Mustapha *et al.*, 2021) indicating no significant accumulation of mercury in the fish samples. Heavy metal analysis of grass samples indicates that out of the four heavy metals (Pb, Hg, Cd, As) only mercury was detected. The mean concentration of mercury in the samples ranged from 0.0009 - 0.0021 mg/L. These values are relatively lower than the 0.03 mg/L FAO permissible limit for mercury in vegetables (Ezeonyejiaku *et al*., 2023).

The presence of mercury in water, sediment, fish and grass samples in the study area could be attributed to burning of fossil fuels and dumping of industrial effluents which may be ascribed to manufacturing activity going on in the area. Previous reports had linked the pollution of *Nvuna* river to industrial effluents from an alcohol manufacturing company in the study area (Ede, 2021). However, the non-detectable levels of the other heavy metals, usually tied to industrial activities (Alloway, 2013), suggests that there could be other sources of the observed mercury in the environment. According to the USEPA (2002) medical waste incinerators contribute 13 % (the fourth-largest source) of the anthropogenic mercury emissions to the environment. Also, hospitals contribute 4 to 5% of the total wastewater mercury load in some communities. Location C- Nvuna Ogbuanu - recorded the highest level of mercury (0.08mg/L) for both water and sediment samples. The nearness of this location to a hospital suggest a possible source of the observed mercury.

5.0 Conclusion

The findings of this research suggest the possibility that the water quality in the study area is not up to standard. The water has greater amounts of mercury than the WHO's permitted limit for drinking water. Because of the potential negative effects on the residents, these higher amounts of mercury may not be suitable for human consumption. Regulatory agencies might need to intensify their observation of water bodies, particularly the evaluation of drinking water in the area being studied. It is also necessary to impose penalties on people or businesses that contribute to environmental damage. This will significantly lower the rate at which individuals in the study area are exposed to contaminants such as heavy metals. It is imperative to regularly assess the amounts of heavy metals in seafood and food crops and look into how these metals vary with the seasons. The total heavy metal toxicity load (HMTL) measurement shows that the amount of mercury present is higher than the permissible level. The heavy metal contamination needs to be removed for the water to be safe to drink. According to the study's findings, 88% of the mercury in the water supplies must be removed before it is safe for human consumption. It is intended that this estimate would help the planning authority determine which treatment technique will be most effective.

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