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Potential Health Risk Assessment of Dumpsite Soil of Nwangele River in Amaigbo, Imo State

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Abstract

Human health is seriously endangered by heavy metals, particularly when they are found in water supplies. A large number of people living around Nwangele River depend on surface water for a variety of needs, including drinking, cooking, and washing. These population are in seriously danger of heavy metal contamination from the surface water due to the solid waste disposal site's close proximity. The surrounding environment may suffer if heavy metals are found in water bodies. It may have an effect on aquatic life, upset the balance of the food chain, and have permanent ecological repercussions. Therefore, determining the heavy metal concentrations in the surface water close to the location of the dumpsite will help lessen the effects on the ecosystem through proper treatment. The study therefore evaluates the potential health risk of siting a dumpsite close to Nwangele River in Amaigbo, Imo state, Nigeria. The heavy metal levels in the soil and water samples were assessed using an atomic absorption spectrometry (AAS), which was following by a physicochemical analysis of both samples. The potential health risk of these metals were determined using the hazard quotient (HQ), lifetime cancer Risk (LCR), and lifetime average daily dose (LADD). It was observed that iron (Fe) and zinc (Zn) were numerically high but were of non-carcinogenic risk when compared to WHO regulatory limits. On other hand, lead (Pb) and cadmium (Cd) which appeared to be numerically low exceeded the WHO permissive limits for metals in soil and were of carcinogenic risk. The proximity to the dumpsite appears to significantly influence on the concentrations of heavy metals in the surface water. Downstream points, particularly in Okumpi and Onuezuze, consistently showed higher levels of lead, cadmium, and nickel, with corresponding increases in LADD, HQ, and LCR values. These findings suggest that the waste disposal site may be contributing to the contamination of the water sources, posing a carcinogenic health risk, particularly in downstream areas where heavy metals have accumulated to higher levels. Therefore, regular monitoring and potential remediative measures may be necessary to protect public health and mitigate the risks of prolonged exposure to these contaminants.

Keywords: Dumpsite Soil, Environmental Contamination, Nwangele River, Health Risk Assessment

Full length article **Corresponding Author*, e-mail: benedict.nlemchukwu@uaes.edu.ng; benpriest2021@gmail.com, Doi # https://doi.org/10.62877/16-IJCBS-25-27-21-16

1. Introduction

Siting dumpsites near surface water poses significant potential health risks which could lead to the contamination of drinking water and the spread of infectious diseases, exposure to from toxic chemicals and heavy metals [1]. Protecting human health and ecosystems requires careful planning, waste management, and mitigation strategies which include: proper site selection, monitoring, and remediation efforts. It's essential to avoid placing dumpsites near water sources to reduce these risks and ensure the safety of both human populations and the environment [2]. A health risk assessment of dumpsite soil near a river involves identifying contaminants, understanding the exposure pathways, assessing the potential health impacts, and recommending mitigation strategies [3]. The goal is to protect human health, minimize environmental damage, and restore the affected areas through comprehensive testing, monitoring, and risk management to mitigate potential adverse health outcomes and reduce long term advance environmental effects [1-3]. Consuming contaminated water can cause gastrointestinal diseases, neurological damage, or even cancer, depending on the contaminants present. When waste materials decompose, they can release toxic substances, known as leachates into the surrounding soil and groundwater [4]. These leachates often contain harmful chemicals such as heavy metals (e.g., arsenic, mercury, lead), organic compounds (e.g., pesticides, solvents), and pathogens [5]. If the dumpsite is near a water source used for drinking, these contaminants can seep into the water, potentially leading to water contamination [65]. Secondly, waste in dumpsites, particularly if it includes medical or human waste, can harbor harmful bacteria (e.g., *Escherichia coli*, *Salmonella* spp., *Vibrio cholerae*) and viruses (e.g., hepatitis A, rotavirus) that can enter surface water causing waterborne diseases like cholera, dysentery, gastroenteritis, and typhoid fever when consumed or used for recreational purposes (e.g., swimming or fishing) [66]. Heavy metals (lead, cadmium, mercury) and organic pollutants (such as polychlorinated biphenyls, or PCBs) can enter surface water through leachates from the dumpsite [6]. These substances can accumulate in the tissues of aquatic organisms (fish, crustaceans, etc.), and subsequently bioaccumulate along food chain. People who consume contaminated fish or other aquatic organisms may be exposed to these toxic substances. For example, mercury poisoning can cause neurological damage, kidney damage, and developmental delays in children [7]. Furthermore, surface water contaminated by a nearby dumpsite can be used for irrigation, leading to contamination of crops. Chemicals such as pesticides, herbicides and heavy metals can be absorbed by plants, resulting in contaminated food products. Consuming contaminated crops can lead to long-term health risks such as poisoning, neurological damage, and other chronic illnesses. Ingestion of contaminated water by livestock can also affect the food chain and the health of animals [8-9]. Increased risk of respiratory problems can arise especially with industrial chemical waste, volatile organic compounds (VOCs) can evaporate into air and affect air quality [10-11]. Inhalation of VOCs can cause respiratory problems, such as asthma, bronchitis, and even lung cancer in long term. Waste sites, particularly open dumps, can release dust particles that may be inhaled by people living nearby. These particles can contain harmful substances which include heavy metals and pathogens, contributing to respiratory and cardiovascular issues [12-13]. Surface water contaminated by waste from a nearby dumpsite poses a significant risk to recreational water activities (e.g., swimming, boating, and fishing). Pathogens, chemicals, and hazardous materials can be ingested or come into contact with skin, leading to infections, rashes, or systemic health issues [14-15]. Direct exposure to toxic leachates in the water can cause burns, allergic reactions, or more serious long-term health effects.

Long-term Health impacts from chronic exposure to contaminated water, whether through consumption, direct contact, or consumption of contaminated food (e.g., fish), can lead to chronic health conditions [16]. These may include cancers, reproductive problems, kidney damage, liver damage, and developmental issues in children. Many chemicals found in dumpsites, such as phthalates, dioxins, and certain pesticides, can act as endocrine disruptors, interfering with hormone function and leading to reproductive and developmental problems [17]. Finally, Pollutants from the dumpsite can disrupt the local ecosystem [18-19]. Contaminants in the water can kill aquatic life or disrupt their reproductive cycles. Over time, the balance of the aquatic food chain can be damaged, affecting biodiversity [20-21]. Toxic substances in water can also affect plants and animals that rely on the surface water for habitat and food, leading to broader ecological impacts [22]. Communities living near dumpsites are often the most vulnerable particularly if they lack the resources to address water pollution (e.g., access to clean drinking water, healthcare, etc.) [23]. Low-income or marginalized populations may suffer disproportionately from health effects of contaminated surface water [24]. The placement of dumpsites near water sources often leads to environmental justice issues, where disadvantaged communities bear the burden of negative impacts while others may benefit from cleaner water or land [25-26]. This present study is intended to evaluate potential health risk of dumpsite soil of Nwangele River in Amaigbo, Imo State.

2. Materials and Methods

2.1. Area of Study

The study area is Nwangele River, located in Nwangele, Imo state, Nigeria and the five other rivers in Nwangele Local Government Area. The Nwangele River, located in Nwangele, Imo state, Nigeria, serves as a vital hub for district trade and commerce. As of the 2006 census, its area was 63 km^3 (24 sq mi), and its population was 127,691.

2.2. Sample Collection/ Pre-Treatment

A sterile plastic bottle was used to gather the samples from the surface waters and soil samples. Prior to collecting samples, the plastic bottles used for surface water collection were properly labelled, cleaned, dried and soaked in 10% HCl for 48 hours. Surface water samples from the Nwangele River were collected using the plastic bottle for three different sampling locations: upstream, midstream, and downstream. The samples are then acidified with nitric acid (HNO_3) to a pH of less than 2 to preserve metals in solution and transported to the laboratory for analysis [3].

2.3. Soil sample collection

Using a stainless-steel auger, various soil samples were collected at depth of (0-15 cm) across the solid waste dump site within the solid waste dump site at Nwangele River [27]. Each sample is put into a pre-labelled plastic bag. The sampling locations were chosen to represent various distances from the dumpsite, including directly at the site, 50 meters away, and 100 meters away. These locations were chosen to symbolize different zones and possible pollution sources. In order to get a complete picture of the distribution of heavy metals, there were some considerations for regions with high concentration of human activity with respect to waste disposal and disposal methods.

2.4. Physiochemical Analysis

Water samples were collected from various locations from the five rivers in Nwangele Local Government Area, particularly near the solid waste dumpsites using plastic bottles which had been soaked in a 10% hydrochloric acid solution for 48 hours. Samples were taken at different depths and distances from dumpsite to provide a comprehensive representation of the water quality. Once collected, the water samples underwent filtration through a 0.45-micron filter to remove any particulate matter which was followed by a digestion process with concentrated nitric acid and perchloric acid. After digestion, samples were diluted to a specified volume with deionized water. The diluted samples were then analyzed using an Atomic Absorption Spectrophotometer (AAS) [28]. Calibration curves were established using standard solutions of known concentrations to ensure the accuracy of the measurements. Also, soil samples were collected from the solid waste dump site using a stainless-steel auger. Samples were taken from various depths, typically 0 to 15cm, and placed in pre-labelled plastic bags for identification. Soil samples were air-dried at room temperature and then sieved through a 2 mm mesh to remove larger particles and debris. A representative sub-sample of the sieved soil, approximately one gram, was weighed and subjected to a digestion process using a mixture of concentrated nitric acid, hydrochloric acid, and hydrofluoric acid in a microwave digestion system. After digestion, the soil samples were also diluted with deionized water to prepare them for analysis. The diluted soil samples were analyzed using the AAS. Calibration curves were developed for each metal, and rigorous quality control measures were employed to ensure reliability of results [29].

2.5. Instrumentation

A sample is subjected to atomization during this analytical procedure, which turns its component elements into free, gaseous atoms. When these atoms come into contact with a radiation source, they then absorb light at specific wavelengths. By measuring this absorption, the AAS makes it possible to precisely identify and quantify particular heavy metals using their distinct spectral fingerprints. The device precisely measures the amount of heavy metals such as lead, cadmium, and mercury in environmental samples by calibrating against established standards. The AAS instrument is calibrated using standard solutions with known quantities of each heavy metal (Pb, Cu, Fe, Ni, Mn, Zn, and Cd). A calibration curve is developed for each metal. The digested and diluted samples are drawn into the AAS instrument. The apparatus detects each metal's absorbance at a given wavelength which is equivalent to its concentration in the sample. Quality control measures such as the analysis of blank samples, spiked samples (samples with known additions of metals), and certified reference materials are conducted alongside the samples [30-31]. Heavy metal concentrations acquired via AAS are compared to recognized recommendations and criteria, such as those published by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

2.6. Data Analysis

To assess the proximity of heavy metal contamination in soil and water samples, a systematic approach is employed. This involves measuring the distance from potential pollution sources, such as waste disposal sites, and correlating these distances with the concentrations of heavy metals found in the samples. The potential source of contamination, such as municipal solid waste disposal sites is identified. Sampling locations were points at varying distances from the identified pollution sources which include points directly adjacent to the source and points further away. A GPS coordinates or mapping tools was used to measure the distance from each sampling point to the nearest pollution source. Soil and water samples were collected from each designated location and distances and corresponding heavy metal concentrations for each sample was recorded. Using SPSS software, the association between the variable was established using Pearman's correlation coefficient analysis, and the test statistics were utilized to look for variations in the means at the 5% level of significance. The acquired data was processed using pollution index models [32-33].

2.7. Health Risk Assessment

To assess the potential health risks associated with exposure to heavy metals in both water and soil samples, the parameters measured include: Hazard Quotient (HQ), Lifetime Cancer Risk (LCR), and Lifetime Average Daily Dose (LADD). Each of these parameters provides valuable insights into the potential health impacts of contaminants based on exposure levels, age, and body weight [34-35]. Then the LADD, LCR, & HQ would be determined using the formula

LADD = (EC X IR X EF X ED) / (BW X AT)
LCR = LADD X CSF
HQ= LADD / RfD

3. Results and discussion

The investigation into the levels of heavy metals in soil samples from the solid waste dumpsite in Amaigbo, Imo State, yielded significant findings that raised concerns about environmental contamination and potential health risks on the local population. Study focused on quantifying concentrations of key heavy metals, including lead, cadmium, copper, and zinc which are commonly associated with waste disposal practices and industrial activities [36]. Considering the data from figures (Table 2), concentration of copper, iron, nickel and Zinc were within the WHO permissive limit. However, lead and cadmium concentration were of a serious concern. Lead concentrations ranged from 587 mg/kg to 620 mg/kg which is notably higher than permissible limit of 300 mg/kg set by the Nigerian Federal Ministry of Environment for agricultural soils and other regulatory agencies [37-38]. Also, Cadmium levels exceeded the acceptable limit of 3 mg/kg for agricultural soils. The elevated presence of lead and Cadmium is particularly of public health concern, as they are toxic metals with severe health implications, including neurological damage, developmental delays in children, and various other health issues in adults [39-40]. From the correlation analysis, p-value for lead was 0.270 which was strongest correlation, Manganese was 0.078 (approaching significance but still above the threshold), and 0.196 for Cadmium. This means that based on this specific analysis with a sample size of 15 (3 points per 5 rivers), none of the observed linear relationships between the overall distance of a river system from the dumpsite (Table 1) and its heavy metal concentrations were statistically significant. However, lack of statistically significant results in this specific correlation test does not automatically disprove the influence of the Amaigbo dumpsite on river water quality. According to [41-42], there is a need for a comprehensive understanding of the impact of heavy metal contamination in the solid waste dumpsite. The accumulation of these metals in soil can have detrimental effects on immediate ecosystem, including potential for leaching into surface water and groundwater which could further exacerbate public health risks [43-44].

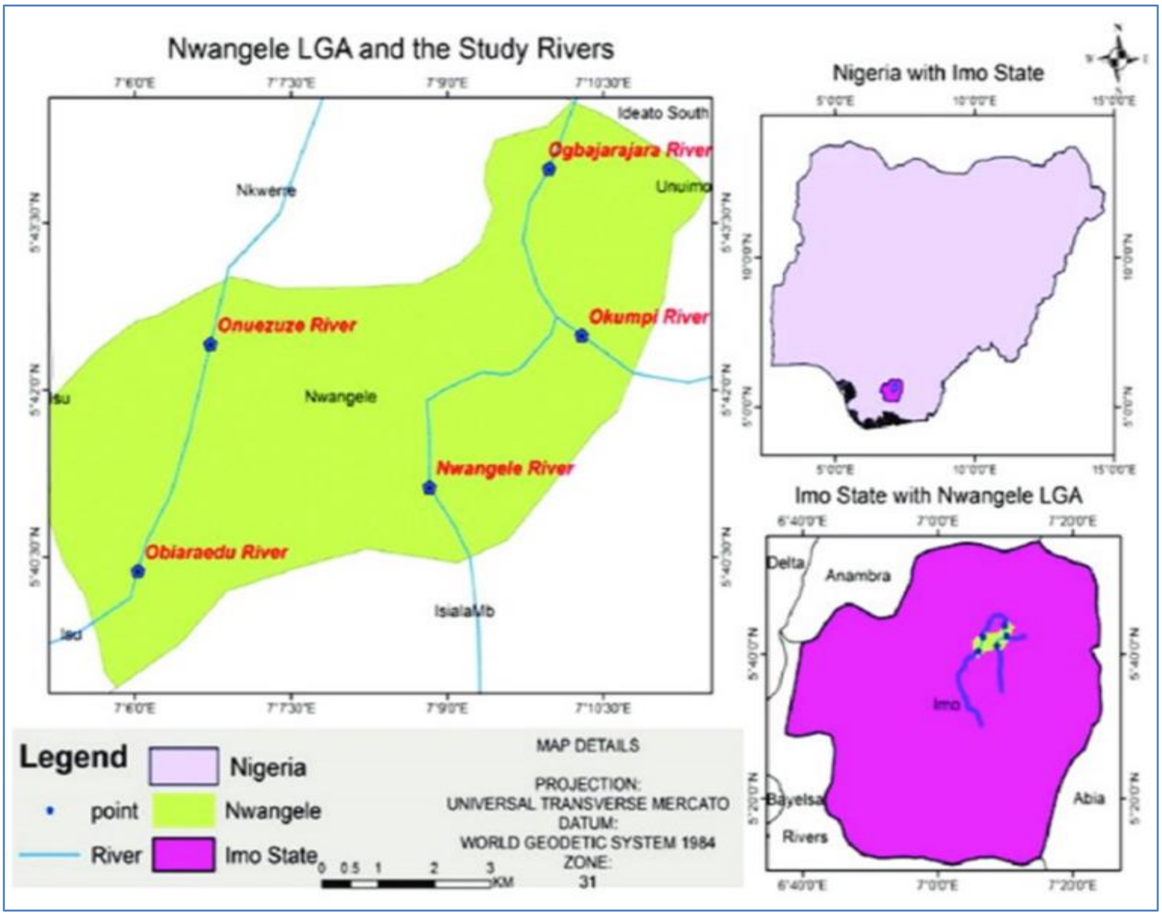

Figure 1: Nwangele River and the study rivers in Nwangele L.G.A. of Imo state, Nigeria
Source: (Joseph *et al*., 2019) [27]

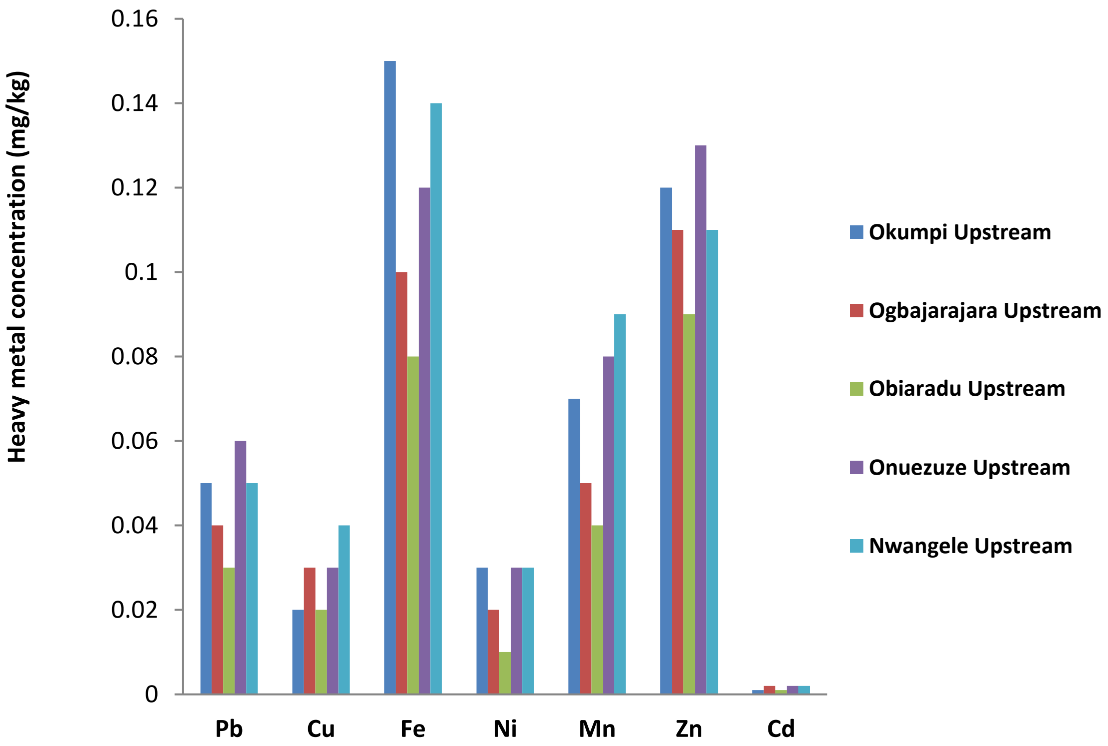

Figure 2: Upstream heavy metal levels

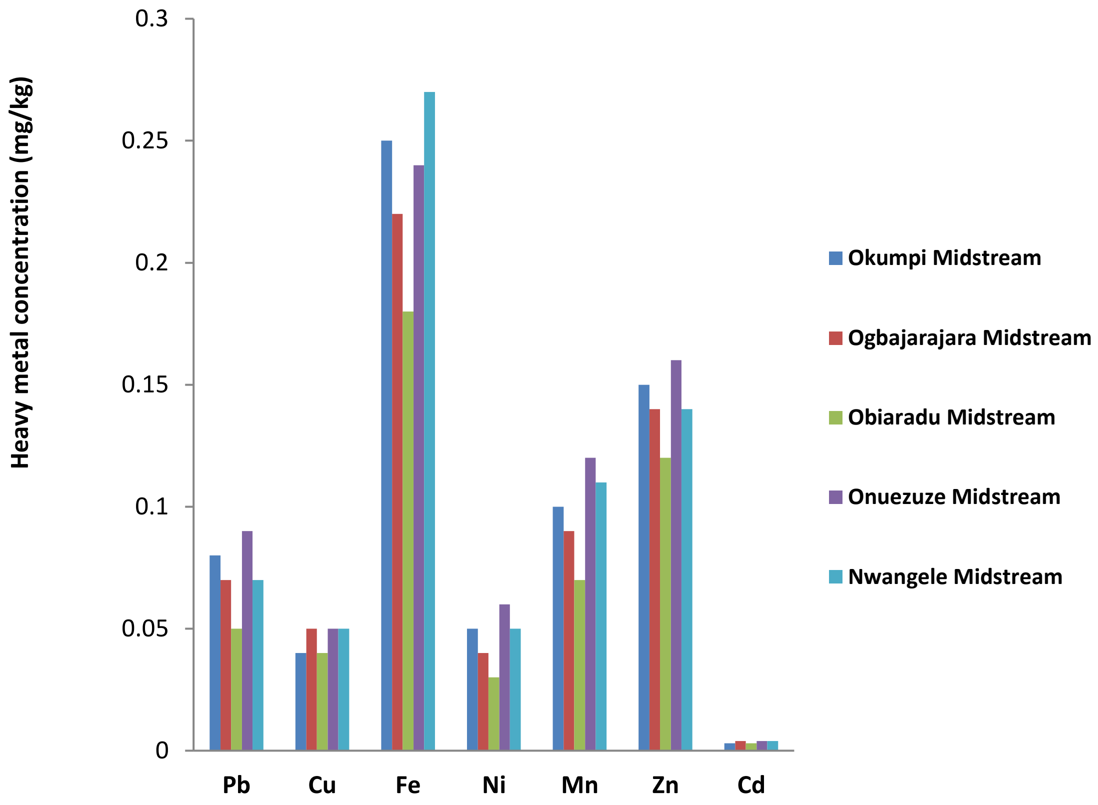

Figure 3: Midstream heavy metal levels

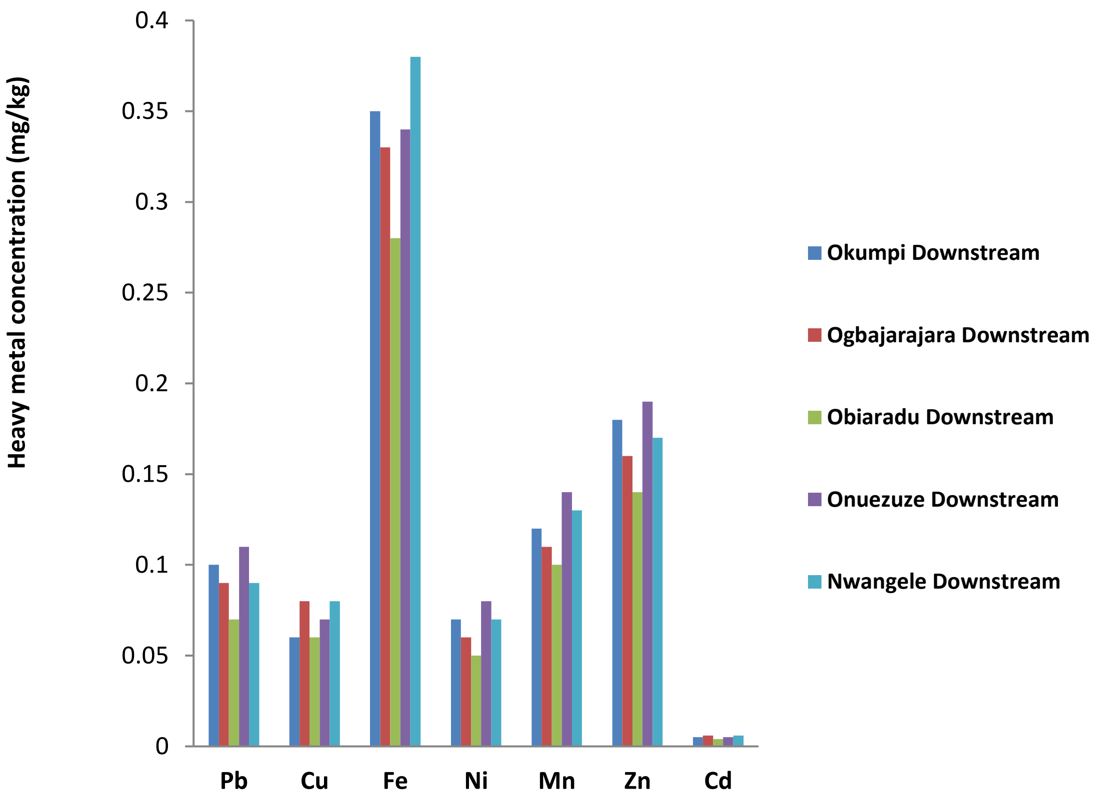

Figure 4: Downstream heavy metal levels

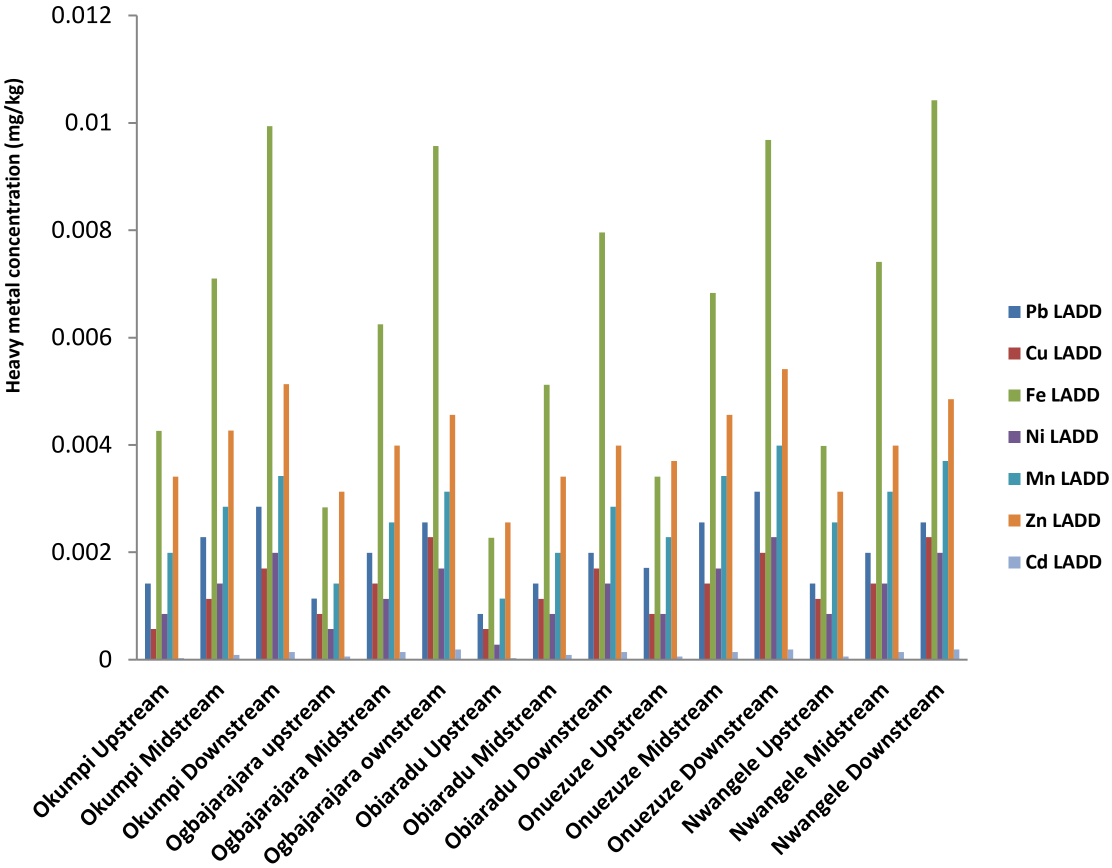

Figure 5: LADD for all sampling points

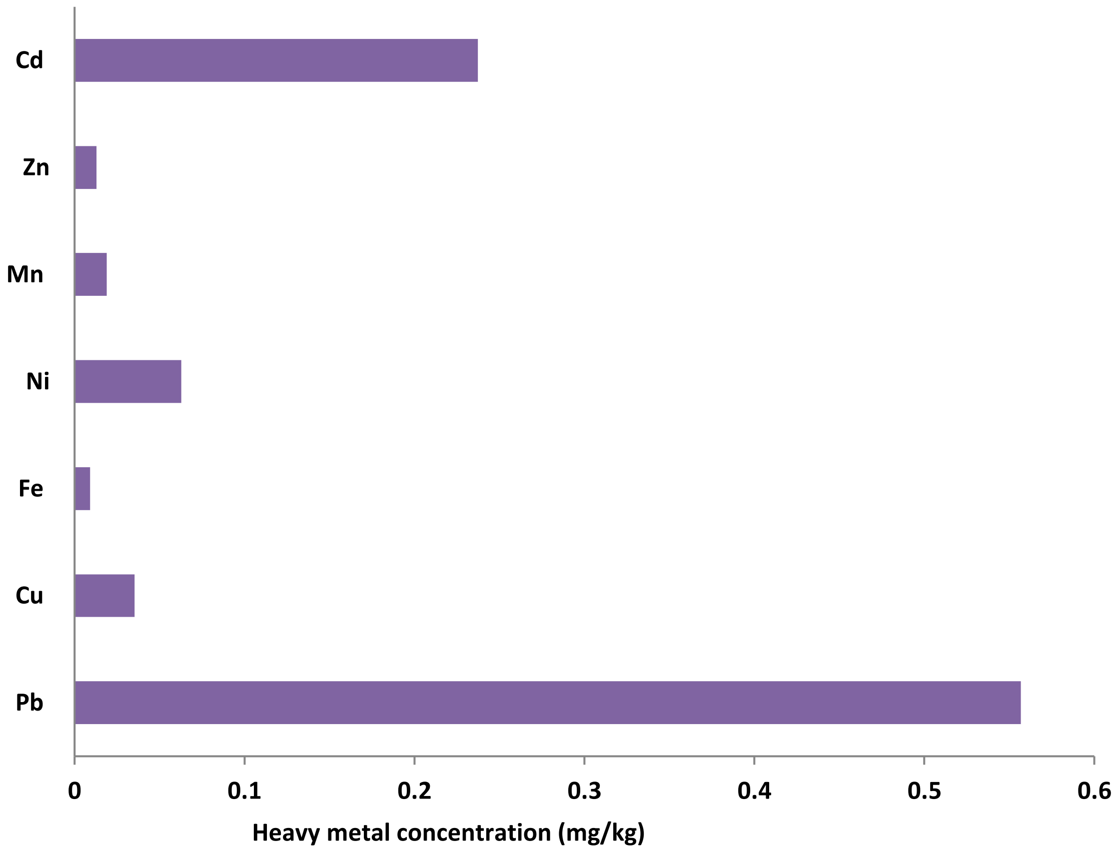

Figure 6: Hazard Quotient for all heavy metals

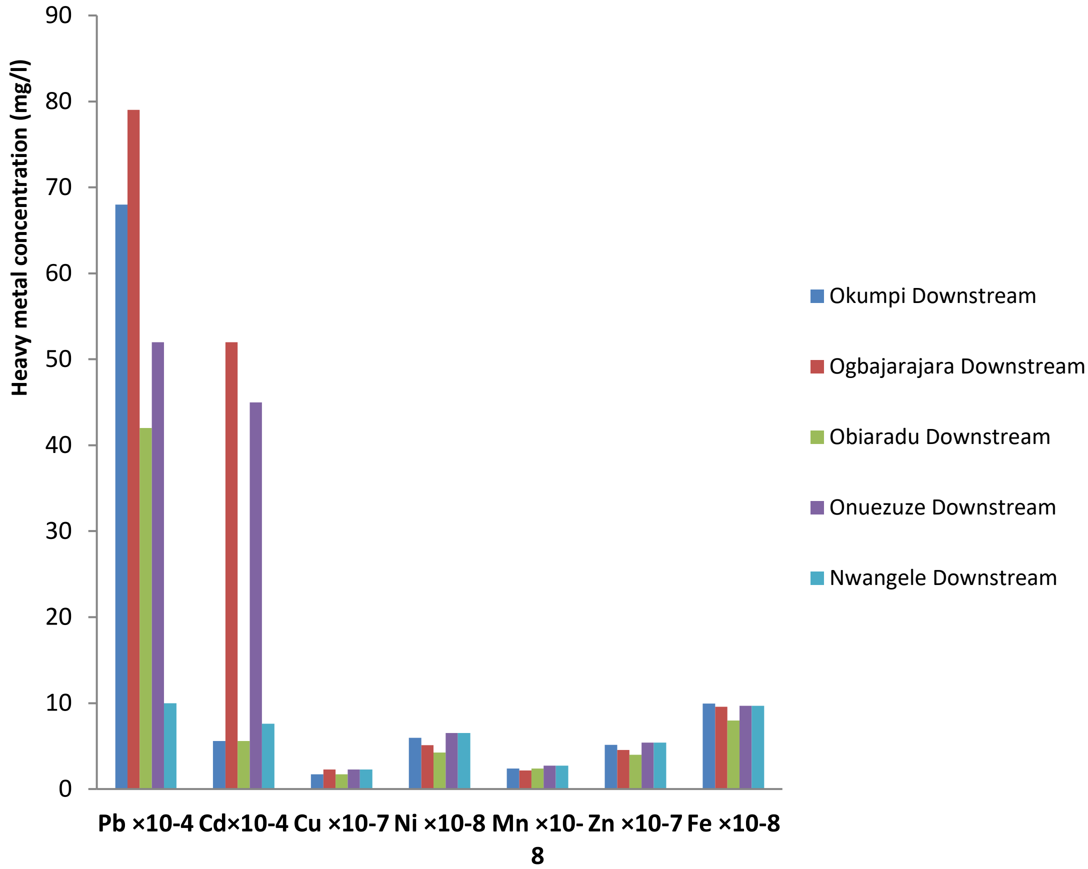

Figure 7: Lifetime cancer risk values for each heavy metal at the different sampling points

Table 1: Distance of the rivers from the dumpsite

Sample ID	Location	Distance from Pollution Source (m)
W1	Nwangele	200
W2	Okumpi	500
W3	Onuezuze	600
W4	Ogbajarajara	650
W5	Obiaredu	1000

Table 2: The level of heavy metals in soil samples of solid waste dumpsite in Amaigbo-Imo State

Sample Point	Pb (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Ni (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cd (mg/kg)
Point A	605	22.3	3500	15.7	78.9	110.5	0.45
Point B	587	20.9	3420	13.5	75.2	108.2	0.40
Point C	612	23.1	3550	16.3	80.1	112.8	0.48
Point D	594	21.5	3460	14.2	76.5	109.6	0.42
Point E	620	24.0	3600	17.0	82.3	115.0	0.50

The comparative analysis of the impact of proximity of waste disposal site to the surface water revealed that manganese had a moderate negative correlation of -0.468 suggesting that as the distance from the dumpsite increased, the concentration of manganese in the surface water tends to decrease [45-47]. However, the significance level of 0.078 indicates that this correlation is not strong enough to be statistically conclusive [48-50]. Similarly, the correlations for zinc and cadmium showed weak negative relationships with proximity, as indicated by Pearson correlation values of -0.178 and 0.354, respectively. These results suggest minimal influence of proximity on their concentrations in surface water. Notably, the correlations for copper and iron were also weak, with values near zero, indicating that their levels in surface water are not significantly affected by the distance from the dumpsite [51-52]. In contrast, the correlation for nickel showed a positive relationship with proximity, indicating that higher concentrations of nickel were observed closer to the dumpsite [53-54]. The finding from this study suggests that the closeness to the dumpsite is an important consideration when evaluating the quality of the water and any potential health risks [55-56]. It further implies that the dumpsite's proximity to residential areas, along with poor waste management procedures, had contributed to heavy metal deposition in the soil [57-58]. Also, other studies have confirmed these observations [59-60].

The findings from the analysis of LADD, HQ, and LCR values for the heavy metals across the various sampling points suggest varying degrees of health risks (Fig. 4, 5 and 6). The concentration of copper, manganese, nickel and zinc were within regulatory limits and were of non-carcinogenic risk. On other hand, lead concentrations consistently increased downstream at Okumpi and Onuezuze. The LADD values were higher in these areas, indicating greater exposure to lead, especially near the dumpsite [2-61]. The hazard quotient (HQ) for lead exceeded the value of 1 in some locations, indicating potential carcinogenic risks to those consuming the water. Although the lifetime cancer risk (LCR) values for lead were relatively low, they still surpassed acceptable safety thresholds at certain points, implying a slight carcinogenic risk over prolonged exposure, particularly in downstream regions [2-62-63]. Cadmium levels were generally low but increased downstream, especially in Okumpi, Ogbajarajara, and Onuezuze. Although the LADD for cadmium was relatively low, its tendency to accumulate over time raises concerns about long-term exposure. The HQ for cadmium remained below 1, indicating minimal carcinogenic risks, but its LCR values though small indicated that chronic exposure could result in carcinogenic outcomes, particularly in areas near the dumpsite [64].

4. Conclusion

The comprehensive examination of the environmental and health implications of the Nwangele River and its nearby solid waste disposal site provided notable discoveries across the various locations sampled. The proximity to the dumpsite appears to significantly influence the concentrations of heavy metals in the surface water. Downstream points, particularly in Okumpi and Onuezuze, consistently showed higher levels of lead, cadmium, and nickel, with corresponding increases in LADD, HQ, and LCR values. These findings suggest that the waste disposal site may be contributing to the contamination of water sources, posing a carcinogenic health risk, particularly in downstream areas where heavy metals have accumulated to higher levels. Regular monitoring and potential remediation may be necessary to protect public health and mitigate the risks of prolonged exposure to these contaminants. The consistency of laboratory results with secondary data and current literature emphasizes the critical need for health risk assessments and intervention methods to reduce exposure to these heavy metals. The findings highlight the crucial relevance of tackling environmental contamination in order to maintain the health and well-being of the local community, emphasizing the need for proper waste disposal techniques and public health initiatives.

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