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Investigation of Heavy Metal Concentration of Nwangele River and its Tributaries in Amaigbo and the Effect on the Inhabitants

Nlemchukwu Benedict N.C[1], Ojiako E.N[2], Anunihu Chinonso Lynda[1], Ukachukwu Veronica Ifeoma[1]*

[1]*Department of Chemistry, University of Agriculture and Environmental Sciences Umuagwo, Imo State, Nigeria.*

[2]*Department of Pure and Industrial Chemistry, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.*

Abstract

Heavy metal contamination of rivers from nearby solid waste dumps sites poses significant environmental and health risks. The study therefore seeks to identify possible environmental health risks of constant heavy metal contamination of Nwangele River and it tributary in Nwangele local government area of Imo State, Nigeria. The surface river was evaluate for its Physicochemical parameters, proximity of waste disposal site to the surface water, living average daily dose for heavy metal and hazard quotient. The results indicated that the concentrations of these heavy metals in the Nwangele River exceeded the permissible limits set by the World Health Organization (WHO) and other regulatory bodies particularly in locations such as Okumpi and Onuezuze. The LADD values were higher in these areas, indicating greater exposure to lead, especially near the dumpsite. The hazard quotient (HQ) for lead, cadmium and Nickel suggest a strong potential risk for cancer to those consuming the water. However, the hazard quotient for Zinc (Zn), Manganese (Mn) and Copper (Cu) remained low, indicating non-carcinogenic risks. These findings suggest that the waste disposal site may be contributing to the contamination of water sources, posing both non-carcinogenic and carcinogenic health risks, particularly in downstream areas where heavy metals have accumulated to higher levels. Generally, study underscores a critical environmental issue. The presence of these metals at concentrations above recommended standards suggests significant pollution, which could have far-reaching implications for public health, agriculture, and the local ecosystem. The findings highlight the urgent need for effective monitoring and management strategies to mitigate heavy metal contamination in the river, ensuring the safety and sustainability of this vital water resource for the surrounding communities.

Keywords: Heavy Metals, Environmental Contamination, Public Health, Nwangele River, Waste Management

Full length article **Corresponding Author*, e-mail: *benedict.nlemchukwu@uaes.edu.ng; benpriest2021@gmail.com*

1. Introduction

The existence of heavy metals in water presents a number of difficulties and is a major concern for the environment and public health. Heavy metal contamination of rivers from nearby solid waste dumps sites poses significant environmental and health risks [1]. The presence of toxic metals like lead, mercury, cadmium, arsenic, and chromium in these waste sites are of poses a serious threat to the environment and is capable of causing an outbreak within the nearby communities [2]. Rainwater or groundwater can percolate through the solid waste, dissolving and carrying heavy metals into nearby rivers. This leachate, when untreated, pollutes water bodies and harms aquatic life. Heavy metals accumulate in the tissues of aquatic organisms (fish, plants, and invertebrates), leading to toxic effects and could disrupt the food chain [3]. Species that consume contaminated organisms (including humans) are at risk of ingesting these metals. Metals like mercury and cadmium can reduce biodiversity, impair reproduction, and harm the physiological functions of aquatic species, leading to population declines or ecosystem imbalances [4]. Heavy metals also can enter water supplies, posing risks to human populations who depend on the river for drinking water or agricultural irrigation [5]. People who use the river for recreational purposes or live near it are at risk of direct exposure to contaminated water [6-7].

Drinking or coming into contact with polluted water can cause various health problems. Chronic exposure to heavy metals can lead to serious health issues such as lead poisoning which can cause neurological damage, especially in children, leading to developmental delays, learning disabilities, and behavioral issues [8-10]. Mercury toxicity can also affect nervous system, kidney function, and can cause memory loss, tremors, and developmental damage in infants and children. Similarly, Cadmium can affect kidney function, leading to bone demineralization, and increases risk of cancer. Arsenic exposure has been reported to cause skin lesions, internal cancers (e.g., lung, bladder), cardiovascular diseases, and neurological issues [9-11]. Wildlife including animals that drink from or live near the contaminated river is also at risk. Heavy metals can cause reproductive failure, neurological damage, and even death in wild species [12-13]. Contamination with heavy metals may not always originate from one place [14]. Spread of pollution and impact on larger ecosystems & communities can occur when discharge from contaminated sites transports metals into nearby rivers, lakes, and groundwater. According to Ihenetu *et al*. [15], it revealed that Nwangele River, which is situated in Southeast Nigeria, has somewhat contaminated water due to heavy metals.

To reduce the level of heavy metal contamination in the river, a number of steps like institutionalizing regular, proper, and timely health education on waste management inside the markets have been used to help market traders reach a proper and good level of waste management practice [16]. Nonetheless these wastes like polythene paper, cabbage, refuse, plastics, bottles, industrial wastes and solid waste are still improperly managed and disposed at Nwangele River and its environs [17-18]. It is obvious that heavy metals do not break down over time; they are resilient in soil and aquatic habitats [19]. This means that contamination can remain present for a long time after it starts. In order to remove or neutralize the metals, remediation and treatment of surface water bodies is essential [20]. Furthermore, heavy metal contamination of rivers can be prevented and mitigated by regular monitoring of water and sediment quality in areas near solid waste dumps [21]. Also, proper management of solid waste, including the prevention of hazardous materials from entering the water bodies, and the treatment of landfill leachate, can minimize the risk of heavy metal contamination [22]. It is therefore essential to assess the heavy metal contamination of Nwangele River in Amaigbo to evaluate the possible environmental and health risks involved [23].

2. Materials and Methods

2.1. Study Area

The study area is Amaigbo community in Nwangele Local Government Area in Imo state, Nigeria (Figure 1). Amaigbo community 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. 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. The samples are then acidified with nitric acid (HNO_3) to a pH of less than 2 to preserve metals in solution and transport. Nwangele River and its four tributaries which are Onuezuze River, Okumpi River, Ogbajarajara River, and Obiaraedu River were sampled at three different sampling locations for upstream, midstream, and downstream [15-24].

2.3. Physicochemical Analysis

Water samples were collected from various locations from Nwangele River in Nwangele Local Government Area, particularly near solid waste dumpsites using the plastic bottles, which had been soaked in a 10% hydrochloric acid solution for 48 hours. The samples were taken at different depths and distances from the 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 following by a digestion process with concentrated nitric acid and per chloric acid. After digestion, the samples were diluted to a specified volume with deionized water. The diluted samples were then analysed using an Atomic Absorption Spectrophotometer (AAS) [25]. Calibration curves were established using standard solutions of known concentrations to ensure the accuracy of the measurements [26].

2.4. Instrumentation for AAS

A sample is subjected to atomization during this analytical procedure, which turns its component elements into free, gaseous atoms. When these atoms come in 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 [27].

2.5. 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 [28]. 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. The 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 run through pollution index models, and a health risk assessment [29].

2.6. Health Risk Assessment

To assess the potential health risks associated with exposure to heavy metals in the water samples, several parameters are commonly measured which include the Hazard Quotient (HQ) and Lifetime Average Daily Dose (LADD) [30]. Each of these parameters provides valuable insights into the potential health impacts of contaminants based on exposure levels, age, and body weight. Estimation of Lifetime Daily Dose (LADD) and Hazard quotient would also be obtained was determined by calculation [31]. It takes into account factors such as the amount of the substance ingested, inhaled, or absorbed through the skin of the worker. Both tools would be adapted. LADD and HQ would be determined using the formula:

1. LADD = (EC X IR X EF X ED) / (BW X AT)
2. HQ= LADD / RfD

i. Exposure Concentration (EC): The average concentration of heavy metal in the water
ii. Exposure Frequency (EF): How often exposure occurs (days/year).
iii. Exposure Duration (ED): The duration of exposure (in years).
iv. Body Weight (BW): The average body weight of the exposed individual (kg).
v. Averaging Time (AT): For non-carcinogens, this is typically the exposure duration in days. For carcinogens, it's the lifetime expectancy in days (generally 70 years × 365 days/year).
vi. Intake Rate (IR): The rate of intake for the medium of exposure (e.g., litters/day for water).
vii. Reference Dose (RfD) (for HQ calculation): Also provided by regulatory agencies, it represents the daily exposure level that is not expected to cause adverse health effects.

3. Results and discussion

3.1. Results

The assessment of the physicochemical parameters of Nwangele River and its tributary reveals significant insights into the water quality and its implications for both human health and the environment. The study measured various parameters, including pH, dissolved oxygen, total hardness, electrical conductivity, nutrient levels, and the presence of heavy metals (Table 1). Comparing the findings against established standard values. The pH of Nwangele River was found to range from 7.2 to 7.8 indicating an alkalinity condition, as the World Health Organization (WHO) recommends a pH range of 6.5 to 8.5 for drinking water which is in line with [32-33]. Dissolved oxygen levels were also evaluated, with findings suggesting that the river may be experiencing reduced oxygen availability. Adequate dissolved oxygen is crucial for the survival of aquatic organisms, and WHO guidelines suggest that levels should remain above 5 mg/L. Low dissolved oxygen can result in hypoxic conditions, which can be detrimental to fish and other aquatic species, leading to a decline in biodiversity [15-34-35]. The total hardness of the river water was assessed, it is important to note that water hardness is classified into categories ranging from soft to very hard.

High hardness levels can affect the usability of water for domestic purposes and may necessitate treatment to make it suitable for consumption [34-35]. Electrical conductivity measurements indicated the concentration of dissolved salts and ions in the river water. Elevated conductivity levels can signal pollution and salinity issues, which can adversely affect both human health and aquatic ecosystems [36-37]. WHO guideline suggests that electrical conductivity should remain below 1500 µS/cm for drinking water (Ibe et al., 2023). Nutrient levels, particularly nitrates and phosphates, were also evaluated, as they serve as indicators of nutrient pollution often stemming from agricultural runoff and wastewater discharge [19]. The WHO recommends that nitrate levels in drinking water should not exceed 50 mg/L, as high concentrations can lead to serious health issues, particularly in infants [38]. Excessive nutrients can also contribute to eutrophication, which harms aquatic life by depleting oxygen levels in the water. From previous studies on surface water pollution, heavy metals such as lead, cadmium, mercury, and arsenic were evaluate for possible contamination and potential toxicity [39]. WHO guidelines specify maximum allowable concentrations for these metals, with lead; for instance, having a limit of 0.01 mg/L.

Elevated levels of heavy metals can pose serious health risks, including neurological and developmental issues [40-41]. The findings from the physicochemical analysis of the Nwangele River indicate potential concerns regarding water quality. If the measured parameters exceed standard values, it suggests that the river may be contaminated, which could have significant implications for public health, agriculture, and the local ecosystem. The results underscore need for continuous monitoring and effective management strategies to protect this vital water resource and ensure its sustainability for future generations. It was observed that the turbidity level was very high, averaging 45 NTU, indicating considerable particulate matter and probable contamination. When compared to secondary data and literature, findings revealed alarming developments. Previous research has shown that high turbidity can harm aquatic ecosystems by decreasing light penetration and affecting photosynthesis [42]. Furthermore, dissolved oxygen levels were discovered to be lower than the suggested standards, which can harm fish and other aquatic creatures, resulting in reduced biodiversity [40]. The literature also highlighted association b/w high turbidity and increased heavy metal concentrations, which validated by laboratory results [43]. The association shows the possibility of heavy metal deposition in the river, posing threats to both aquatic life and human health, especially for communities who rely on the river for drinking water and irrigation. The examination of the physiochemical characteristics of the Nwangele River highlighted concerns about water quality, particularly turbidity and dissolved oxygen levels [44]. The combination of laboratory findings with secondary data emphasizes the critical need for monitoring and remediation activities to safeguard the river's environment and the health of the local residents that rely on it [45]. The study focused on key heavy metals, including lead (Pb), cadmium (Cd), mercury (Hg), and iron (Fe), which are commonly associated with pollution from industrial activities, agricultural runoff, and improper waste disposal (Fig. 2). The results indicated that the concentrations of these heavy metals in the Nwangele River exceeded the permissible limits set by the World Health Organization (WHO) and other regulatory bodies. For instance, lead levels were found to be particularly alarming, with measurements surpassing the WHO guideline of 0.01 mg/L for drinking water.

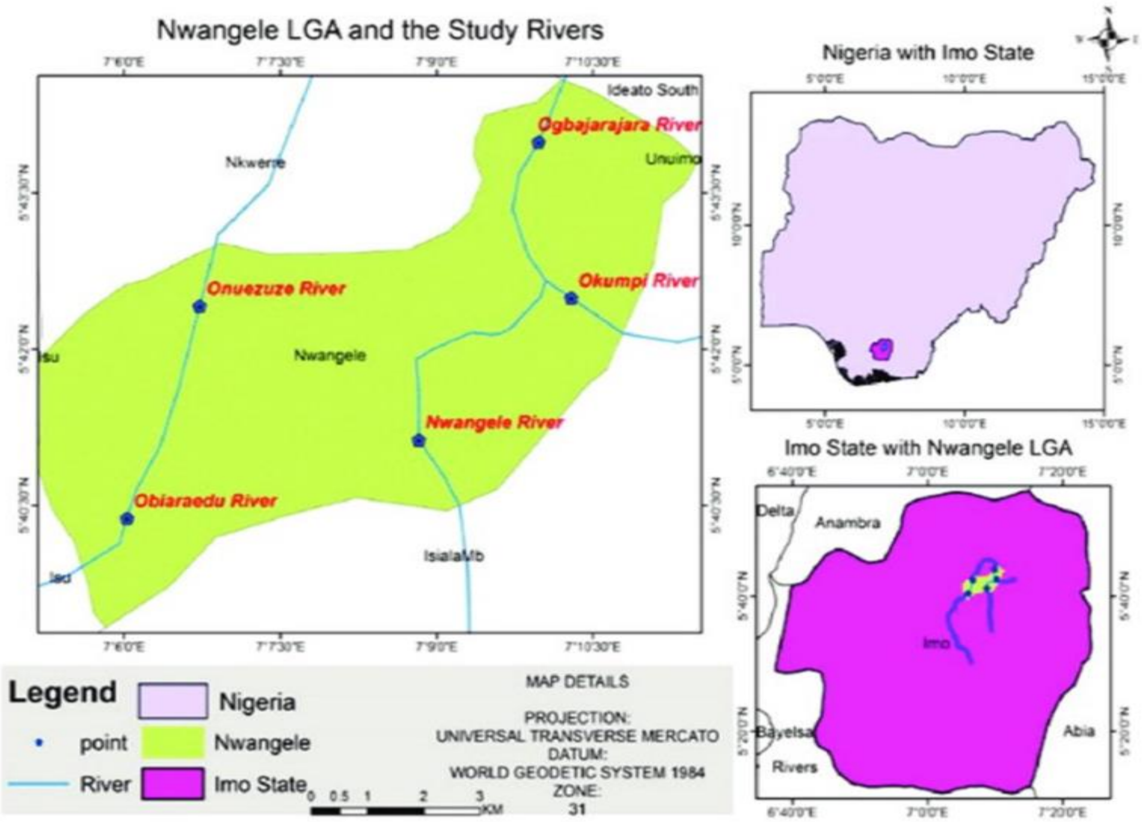

Figure 1: Map of Nwangele L.G.A. with the associated rivers. Source: [15]

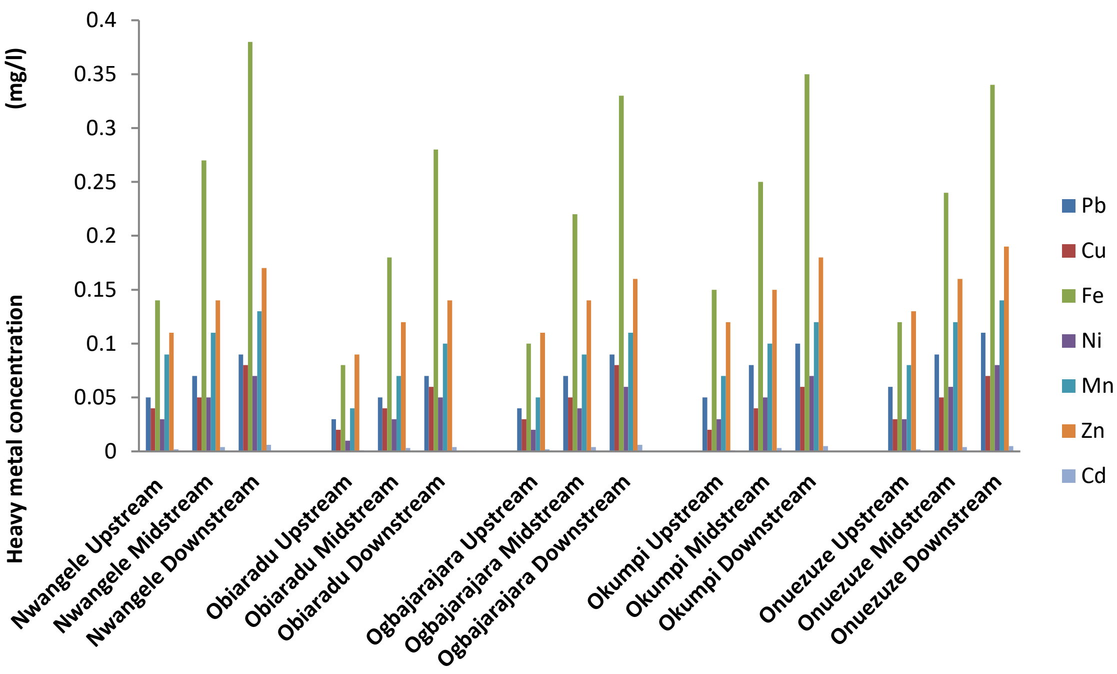

Figure 2: Level of heavy metals in the Nwangele River surface water

WHO Standard for heavy metals:

- Pb: 0.01 mg/L, Cu: 2 mg/L, Fe: 0.3 mg/L, Ni: 0.07 mg/L
- Mn: 0.4 mg/L, Zn: 3 mg/L, Cd: 0.003 mg/L

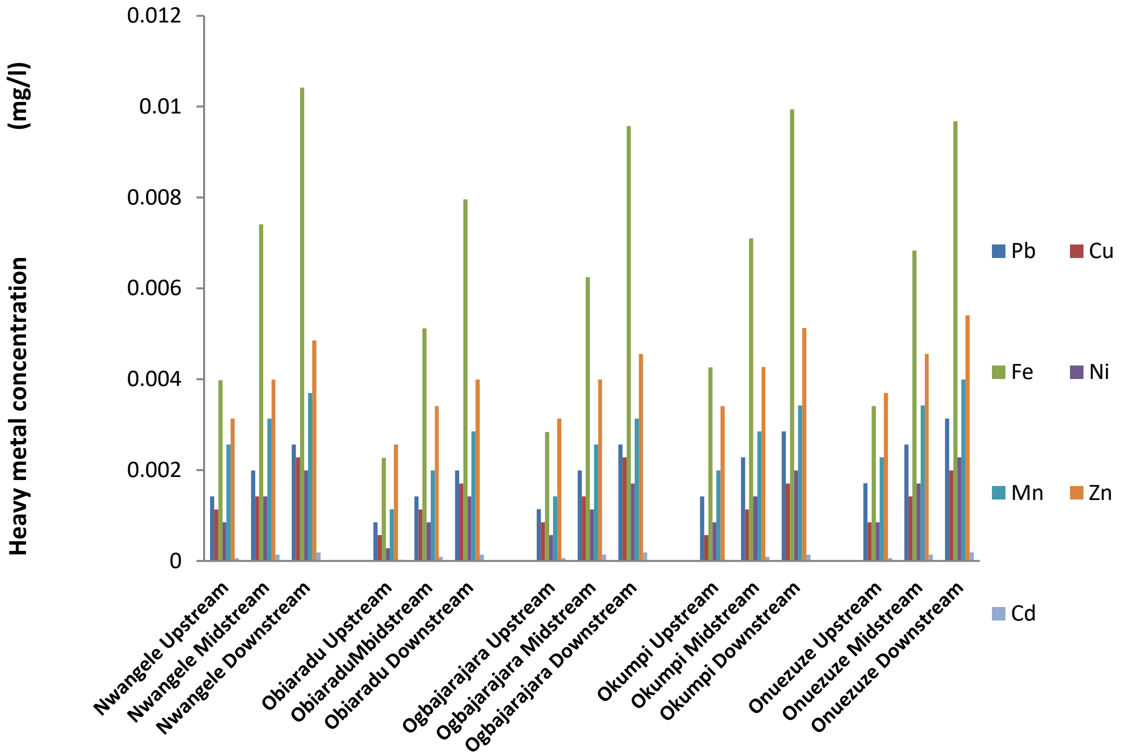

Figure 3: Living Average Daily Dose for all sampling points

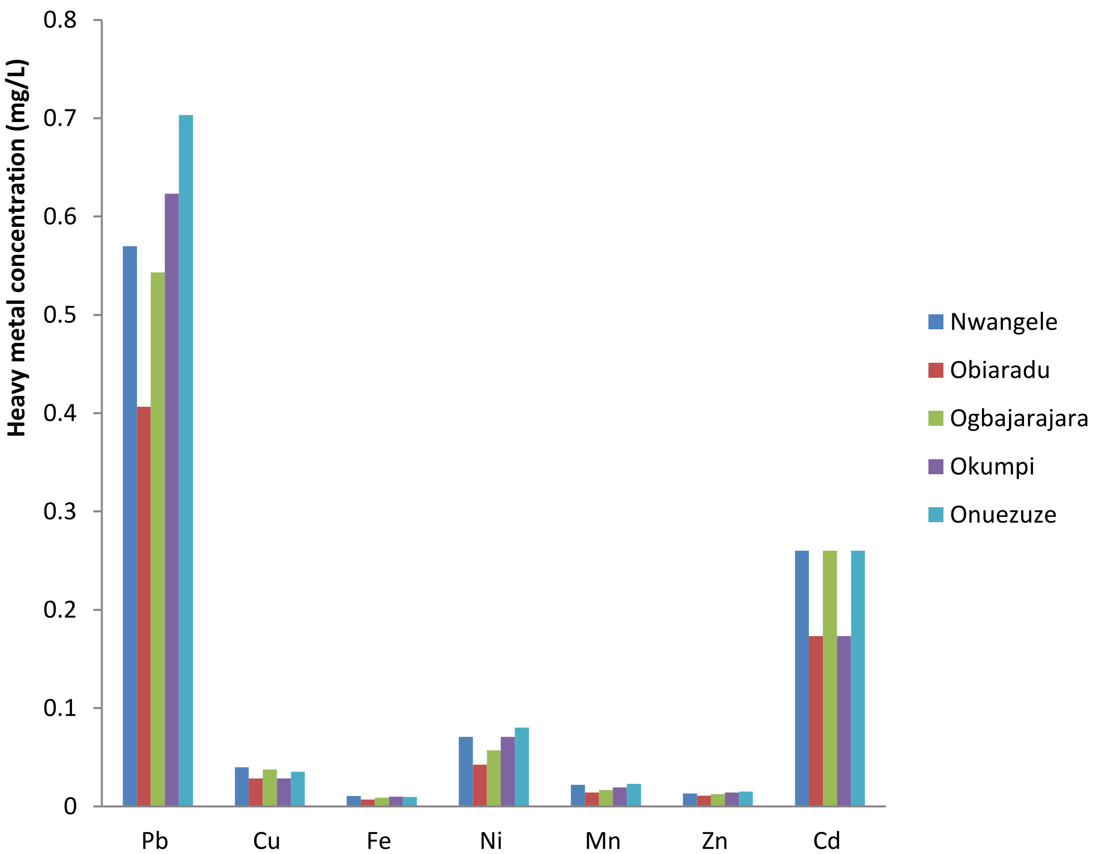

Figure 4: Hazard Quotient for all heavy metals

Elevated lead concentrations can have severe health implications, especially for vulnerable populations such as children, where exposure can lead to developmental delays, cognitive impairments, and various neurological issues. Cadmium levels also exceeded the WHO limit of 0.003 mg/L. Cadmium have been reported as a potential toxic metal that can accumulate in the human body, leading to kidney damage and bone fragility over time [46]. The presence of cadmium in the river water raises significant concerns regarding the safety of water for irrigation and consumption, particularly for communities relying on the river for their daily water needs [47]. The findings from the analysis of LADD and HQ, values for the heavy metals across the various sampling points suggest varying degrees of health risks. The concentration of the metals analysed (Fig. 3 and 4), generally increased downstream, particularly in locations such as Okumpi and Onuezuze. The LADD values were higher in these areas, indicating greater exposure to lead, especially near the dumpsite.

The hazard quotient (HQ) for lead exceeded the value of 1 in some locations, indicating potential carcinogenic risks to those consuming the water. Similarly, the hazard quotient cadmium and Nickel approached 1 at some locations, suggesting a possible risk of carcinogenic health. However, the hazard quotient for Zinc, Manganese and Copper remained low, indicating no significant non-carcinogenic risks at the current levels. Lead and cadmium also exceeded the WHO standard for Lifetime Cancer Risk (Table 3). 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 which is in line with previous studies [48-50]. Zhang et al. [51], suggest that a regular monitoring and potential remediation may be necessary to protect public health and mitigate risks of prolonged exposure to these contaminants.

4. Conclusions

This study provides an empirical data on heavy metal concentrations in the Nwangele River and its tributary. It addresses existing gaps in the literature on environmental contamination in this specific geographic area, providing a more complete picture of the degree of pollution. Secondly, the study performs a complete health risk assessment to determine the potential health concerns associated with heavy metal exposure in the local community. It emphasizes the public health consequences of environmental contamination by investigating the relationship between closeness to pollution sources and health issues such as respiratory problems, skin diseases, and neurological abnormalities which is crucial in increasing the awareness of the risks associated with heavy metals. The present study reveals the high levels of lead and cadmium in the surface water which pose major health concerns to the local population, particularly vulnerable groups. The investigation of physiochemical parameters revealed that turbidity and low dissolved oxygen levels endanger aquatic life and water quality. The close proximity of the waste disposal site to the river was observed to have enhanced contamination concerns, emphasizing the critical need for improved waste management procedures. These findings highlight the vital importance of the continued monitoring, community awareness, and the adoption of successful remediation techniques to protect both environmental health and the community well-being.

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