Comparative Study of Toxic Metal Contamination in Water Bodies of Edo State, Benin City: Identifying the Most Polluted Zones and Associated Risks.

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Abstract- ***Heavy metal contamination in water bodies presents significant environmental and public health risks. This study evaluates the levels of heavy metals in various water sources across Edo State, Benin City Nigeria, including industrial effluents, rivers, reservoirs, and groundwater. The highest contamination was recorded in industrial effluents from the Seven-Up Bottling Company, where iron (Fe) reached 6.68 mg/L, nickel (Ni) 6.65 mg/L, zinc (Zn) 5.65 mg/L, and chromium (Cr) 4.53 mg/L, all exceeding permissible limits. Ikpoba River showed lead (Pb) at 0.09 mg/L, surpassing the WHO standard of 0.01 mg/L, posing a health hazard for communities. The Ikpoba Reservoir had an alarming zinc (Zn) concentration of 116.59 mg/L, far exceeding safe levels. Osse River exhibited chromium (Cr) at 0.11 mg/L and nickel (Ni) at 0.08 mg/L, both above WHO limits. Groundwater near Ikhueniro and Otofure dumpsites contained lead (Pb) at 0.12 mg/L, cadmium (Cd) at 0.04 mg/L, and iron (Fe) at 3.80 mg/L, raising concerns for residents who rely on these sources. These findings highlight industrial effluents and waste disposal sites as primary contributors to heavy metal pollution, necessitating urgent regulatory interventions, improved wastewater treatment, and sustainable waste management practices.***

Indexed Terms- ***Heavy Metal Pollution, Industrial Effluents, Water Contamination, Public Health Risks, Environmental Management***

I. INTRODUCTION

Water pollution caused by heavy metals is a critical environmental and public health issue worldwide, particularly in rapidly urbanizing regions with extensive industrial activities (Alloway, 2013). In Nigeria, Benin City and Edo State are experiencing increasing contamination of water bodies due to industrial discharges, municipal waste, and poor waste management practices (Oboh et al., 2019). The pollution of rivers, reservoirs, and groundwater sources by toxic metals such as iron (Fe), zinc (Zn), lead (Pb), cadmium (Cd), and chromium (Cr) poses significant risks to aquatic ecosystems and human health (Adekoya et al., 2021).

Industrial activities, particularly manufacturing and beverage industries, contribute heavily to the release of toxic metals into the environment (Nwachukwu et al., 2010). For instance, effluents from the Seven-Up Bottling Company in Benin City have been found to contain high concentrations of iron (6.68 mg/L), nickel (6.65 mg/L), and zinc (5.65 mg/L), exceeding permissible limits for safe discharge (Ochu et al., 2025)

Similarly, the Ikpoba River, which receives wastewater from various municipal and industrial sources, has lead (Pb) concentrations of 0.09 mg/L, surpassing the WHO guideline limit of 0.01 mg/L, raising concerns about its suitability for domestic and agricultural use (Osa-Iguehide et al., 2016)

Groundwater sources, which serve as the primary drinking water supply for many communities, are not exempt from contamination. Studies conducted near the Ikhueniro and Otofure dumpsites revealed elevated levels of iron (3.80 mg/L), lead (0.12 mg/L), and cadmium (0.04 mg/L), highlighting the leaching of toxic substances from solid waste into aquifers (Groundwater Quality Near Ikhueniro and Otofure Dumpsites, 2023). The high levels of lead and cadmium in these water sources are of particular concern due to their potential to cause kidney damage, neurological disorders, and developmental impairments in children (Järup, 2003).

The bioaccumulation of heavy metals in aquatic life further exacerbates the risks to human health, as contaminants enter the food chain through fish and other aquatic organisms (Iwegbue, 2011). For instance, fish samples from the Osse River, an important fishing location, have shown chromium (0.11 mg/L) and nickel (0.08 mg/L) concentrations exceeding FAO/WHO recommended limits, indicating potential long-term health hazards for consumers (Igbinedion & Oguzie, 2016).

Given the increasing severity of heavy metal contamination in Edo State, this study aims to identify the most polluted zones by analyzing metal concentrations across various water bodies. The findings will provide crucial insights for environmental policymakers, regulatory agencies, and public health authorities to implement effective pollution control measures and safeguard water quality.

II. DATA COLLECTION AND SAMPLE LOCATIONS

This outlines the sources of data used in this comparative analysis of heavy metal contamination in water bodies across Edo State, Nigeria. The data were obtained from existing studies and reports on industrial effluents, river systems, reservoirs, and groundwater sources. These sources provided insights into the levels of contamination, the types of pollutants present, and their potential environmental and public health impacts.

Data on industrial effluent discharge were collected from studies analyzing wastewater from the Seven-Up Bottling Company in Benin City. The analysis focused on assessing the concentration of heavy metals in wastewater samples collected from multiple discharge outlets of the company. These studies provided information on the extent of industrial pollution and its potential impact on nearby water bodies. (Ochu et., 2025)

Studies on Ikpoba River served as a primary source of data on heavy metal contamination from municipal and industrial sources. Water samples were analyzed to determine the presence and concentration of toxic metals. The river, which serves as a water source for domestic and agricultural use, has been impacted by industrial discharges, urban runoff, and other anthropogenic activities (Osa-Iguehide et al., 2016)

The Ikpoba Reservoir, a significant water supply source, was included in this comparative analysis through studies assessing its water quality. Researchers collected and analyzed water samples to determine heavy metal contamination levels. The reservoir is crucial for drinking water supply and irrigation, making its contamination a significant concern for public health and environmental sustainability (Wangboje & Ekundayo 2013).

The Osse River, located in Edo State, was included in the analysis based on data from studies evaluating pollution from human activities such as agriculture, industrial discharge, and waste dumping. Water samples were analyzed for heavy metal contamination, providing comparative insights into pollution trends affecting the river Igbinedion & Oguzie 2016).

Groundwater quality assessments near the Ikhueniro and Otofure dumpsites provided crucial data for this study. Studies focused on analyzing borehole and well water samples to determine the presence of heavy metals. The proximity of these water sources to dumpsites raised concerns about leachate infiltration and the potential impact on drinking water safety (Asemota et al retrieved from Research Square)

III. RESULTS

Table 1 Industrial Effluent from Seven-Up Bottling Company, Benin City

Heavy metal	Concentration in (mg/L)
Iron (Fe)	6.68
Nickel (Ni)	6.65
Zinc (Zn)	5.65
Chromium (Cr)	4.53
Copper (Cu)	2.87
Manganese (Mn)	2.23
Lead (Pb)	1.55
Cadmium (Cd)	1.49

Source: Analyzing toxic heavy metals in industrial discharge: Implications for public health. *IRE Journals ,2025

Table 2: Ikpoba River Heavy Metal Contamination

Heavy metal	Concentration in (mg/L)
Iron (Fe)	5.76
Zinc (Zn)	2.34
Nickel (Ni)	0.42
Lead (Pb)	0.09
Chromium (Cr)	0.07
Cadmium (Cd)	0.03

Source: Levels of heavy metal concentration in water, sediment and fish in Ikpoba River, Benin City, Edo State Nigeria. International Journal of Chemical Studies, 2016

Table 3 Ikpoba Reservoir Water Quality

Heavy metal	Concentration in (mg/L)
Zinc (Zn)	116.59
Iron (Fe)	5.60
Lead (Pb)	0.07
Nickel (Ni)	0.03
Cadmium (Cd)	0.02

Source: Assessment of heavy metals in surface water of the Ikpoba Reservoir, Benin City, Nigeria. Nigerian Journal of Technology, 2013

Table 4. Heavy Metal Pollution in Osse River

Heavy metal	Concentration in (mg/L)
Zinc (Zn)	4.32
Chromium (Cr)	0.11
Nickel (Ni)	0.08
Leadl (Pb)	0.05

Source: Heavy metals concentration in fish and water of River Osse, Benin City, Nigeria. International Journal of Environmental Bioremediation & Biodegradation, 2016.

Table 5. Groundwater Contamination Near Ikhueniro and Otofure Dumpsites

Heavy metal	Concentration in (mg/L)
Zinc (Zn)	8.52
Iron (Fe)	3.80
Lead (Pb)	0.12
Cadmium (Cd)	0.04

Source: Heavy metal contamination and cancer risk assessment in groundwater near dumpsites: Health implications for vulnerable populations in Nigeria [Preprint]. Research Square.

Table 6.Comprehensive Overview of Heavy Metal Contamination in Water Bodies of Benin City and Edo State, Nigeria with W.H.O accepted standard.

This report consolidates findings from various studies on heavy metal contamination in selected water bodies of Edo State, Nigeria. The data, drawn from industrial effluents, river systems, reservoirs, and groundwater sources, highlight environmental and public health risks associated with heavy metal pollution.

Location	Fe (mg/L)	Ni (mg/L)	Zn (mg/L)	Cr (mg/L)	Cu (mg/L)	Mn (mg/L)	Pb (mg/L)	Cd (mg/L)
Seven-Up Effluent	6.68	6.65	5.65	4.53	2.87	2.23	1.55	1.49
Ikpoba River	5.76	0.42	2.34	0.07	-	-	0.09	0.03
Ikpoba Reservoir	5.60	0.03	116.59	-	-	-	0.07	0.02
Osse River	-	0.08	4.32	0.11	-	-	0.05	-
Ikhueniro/Otofure Groundwater	3.80	-	8.52	-	-	-	0.12	0.04
WHO Limit	0.3	0.07	3.0	0.05	2.0	0.1	0.01	0.003

Figure 1.0 Variations in Heavy Metal Pollution Levels in Water Sources of Benin City and Edo State

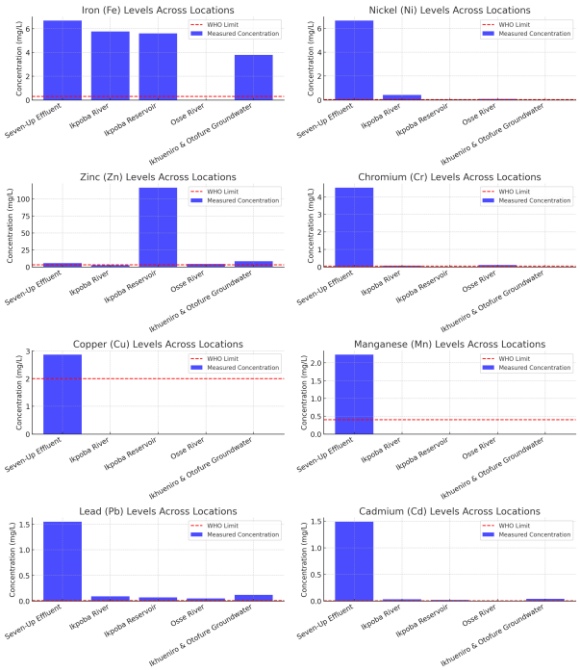
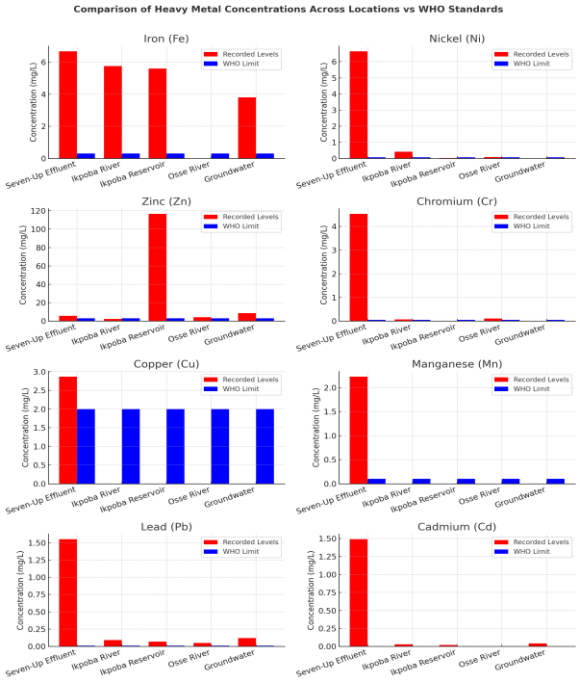


Figure 2.0 Comparison of Heavy Metal Concentrations Across Locations with WHO Standards



IV. DISCUSSION

The data collected from various water sources in Benin City and Edo State reveal significant heavy metal contamination, with multiple sources contributing to pollution levels that exceed WHO permissible limits. Industrial effluents, river systems, reservoirs, and groundwater sources were all found to contain heavy metals at concentrations that pose environmental and public health risks.

A striking observation from the data is the extent to which industrial effluent discharge, particularly from the Seven-Up Bottling Company, contributes to water pollution. The effluent contained high levels of Iron (Fe), Nickel (Ni), Zinc (Zn), and Chromium (Cr), with iron reaching 6.68 mg/L—far exceeding the WHO limit of 0.3 mg/L. The presence of lead (Pb) at 1.55 mg/L and cadmium (Cd) at 1.49 mg/L is particularly concerning, given that both metals are highly toxic even at low concentrations. The effluent discharge into surrounding water bodies poses a serious risk of bioaccumulation in aquatic life, which can subsequently impact human health through the food chain.

The Ikpoba River, which receives wastewater from industrial and municipal sources, also showed elevated levels of heavy metals. Iron, Zinc, Nickel, Lead, Chromium, and Cadmium all exceeded WHO standards. Of particular concern is the lead concentration, which was recorded at 0.09 mg/L—nine times higher than the WHO limit of 0.01 mg/L. This is significant because communities rely on the river for domestic use and irrigation, increasing the risk of lead poisoning and other health-related complications. The presence of chromium and cadmium, both of which are known carcinogens, further underscores the potential dangers posed by contaminated water.

Another critical source of contamination is the Ikpoba Reservoir, which serves as a major water supply in the region. The reservoir exhibited extremely high Zinc (Zn) levels at 116.59 mg/L, which is almost 39 times higher than the WHO limit of 3.0 mg/L. While zinc is an essential trace element, excessive concentrations can lead to adverse health effects, including nausea, vomiting, and disruptions in water quality. The

presence of lead and cadmium further compromises the safety of this water source, making it unsuitable for human consumption without rigorous treatment.

The Osse River, which is exposed to both agricultural and industrial activities, also showed elevated levels of heavy metals, particularly zinc, chromium, nickel, and lead. While the concentrations here were lower than those in the Ikpoba Reservoir, they still exceeded WHO limits. Chromium and nickel, in particular, raise concerns due to their association with allergic reactions and kidney damage. Given that rivers serve as major sources of freshwater for both rural and urban populations, contamination at this level poses a direct threat to public health.

Groundwater contamination was also evident, particularly near the Ikhueniro and Otofure dumpsites, where elevated concentrations of zinc, iron, lead, and cadmium were recorded. Lead contamination in groundwater is especially alarming because groundwater is often considered a safer alternative to surface water. However, the presence of 0.12 mg/L of lead—12 times the WHO limit—makes the water unsafe for drinking. This suggests that leachates from waste dumps are infiltrating groundwater sources, introducing toxic heavy metals into drinking water supplies.

In terms of identifying the most polluted zone, the Ikpoba Reservoir emerges as the most critical area of concern. While the Seven-Up Bottling Company effluent contained high metal concentrations, it represents a point-source pollution, meaning it is localized and can potentially be managed with effective treatment. However, the Ikpoba Reservoir is a major water supply system that receives contaminants from multiple sources, making it the most vulnerable and hazardous water body in the region. The extreme levels of zinc contamination in the reservoir are unprecedented and require immediate intervention to prevent further environmental and health risks.

CONCLUSION AND RECOMMENDATIONS

Overall, the findings highlight the urgent need for stricter wastewater treatment regulations, regular monitoring of water quality, and public awareness campaigns on the dangers of consuming contaminated water. Industrial waste disposal should be closely regulated to ensure compliance with environmental safety standards. Additionally, efforts should be made to explore alternative water sources or enhance the treatment of existing ones to mitigate the risks associated with heavy metal contamination in Benin City and Edo State.

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