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Assessment of the Heavy Metal Concentrations, Sources and Health Risks in Well Water Around Karu Dumpsite, Federal Capital Teritory, Abuja, Nigeria

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Abstract-* Groundwater contamination from open dumpsites poses serious public health and environmental risks, particularly in rapidly urbanizing areas of Nigeria. This study assessed the concentration of heavy metals in well water sources within a 5-kilometer radius of the Karu dumpsite in FCT, Abuja, and evaluated associated non-carcinogenic health risks for children and adults consuming this water. A descriptive cross-sectional design was adopted using a positivist research approach. Water samples were collected from one borehole and two wells. Heavy metals—manganese (Mn), copper (Cu), cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), chromium (Cr), and arsenic (As)—were analyzed using atomic absorption spectroscopy. Structured questionnaires were also administered to 100 households. Chronic Daily Intake (CDI), Hazard Quotient (HQ), and Hazard Index (HI) were calculated for children and adults. Pearson correlation and hierarchical clustering were performed using SPSS v25. Heavy metal concentrations (mg/L) exceeded FMEnv limits in most sources except for arsenic. Manganese ranged from 0.415 (Well 2) to 0.94 (Well 1), copper from 0.505 (Well 2) to 0.986 (Well 1), cadmium from 0.102 (Well 2) to 0.224 (Well 1), zinc from 0.493 (Well 2) to 0.923 (Well 1), lead from 0.049 (Borehole) to 0.288 (Well 1), nickel from 0.043 (Borehole) to 0.213 (Well 1), chromium from 0.042 (Borehole) to 0.432 (Well 1), and arsenic from 0.014 (Borehole) to 0.032 (Well 2). Hazard Index (HI) values for children were highest in Well 1 (HI = 0.3117), followed by Borehole (HI = 0.1717), and Well 2 (HI = 0.1429). Adults had lower HIs, with Well 1 at 0.0673, Borehole at 0.0381, and Well 2 at 0.032. All HQs were below 1, indicating no immediate non-carcinogenic risk; however, cumulative effects may be significant for children. Pearson correlation showed strong positive associations between pH and cadmium (r = 0.999), electrical conductivity and zinc (r = 0.999), and dissolved oxygen and cadmium (r = 0.990). Cluster analysis grouped the Borehole and Well 2 together, while Well 1 stood apart due to its elevated contamination profile. p-values for metal concentration differences across sources were statistically significant (p < 0.05). The study confirms significant groundwater contamination around the Karu dumpsite, with multiple heavy metals exceeding safe limits. Children are at higher risk due to cumulative exposure. Urgent interventions including regular monitoring, improved waste management, and public health education are recommended.

Keywords: Heavy Metals, Groundwater Contamination, Health Risk Assessment, Hazard Quotient, Well Water, Leachate Infiltration.

I. INTRODUCTION

The environment around us is filled with various types of waste produced by our daily activities, including waste from homes, industries, and businesses in a particular area (Daniel et al., 2021). Waste refers to any substance or material that is no longer useful, whether it is broken, worn out, contaminated, or spoiled, and therefore needs to be disposed of (Nwosu et al., 2021). To manage the waste generated by human activities, people often use available open spaces as dumpsites (Nnaji & Chukwu, 2020). In countries like Nigeria, many dumpsites and landfills are poorly designed, lacking essential features such as engineered liners, systems to collect leachate (like pipes or tanks), proper waste collection equipment, and monitoring facilities (Igboama et al., 2022). When waste is dumped, its organic components undergo natural changes through physical, chemical, and biological processes, or it is burned, which releases harmful metals into the environment. These metals can negatively affect the plants, animals, and people living near these sites (Ojiego et al., 2022). Water contamination by heavy metals is a pressing global environmental and public health issue, with significant implications for human health. Heavy metals such as lead, cadmium, arsenic, mercury, and chromium are non-biodegradable, meaning they persist in the environment and can accumulate in groundwater, posing risks to both ecosystems and human health (Yan et al., 2018; Radfard et al., 2023). The contamination of drinking water sources by these metals has been linked to various anthropogenic activities, particularly industrial waste disposal, mining operations, and inadequate urban waste management, especially near landfill sites and dumpsites (Akoto et al., 2019; Han et al., 2023). The World Health Organization (WHO) stresses the importance of monitoring water quality to mitigate health risks, as chronic exposure to heavy metals can lead to severe health issues such as neurological disorders, organ damage, and even cancer (Yan et al., 2018; Alidadi et al., 2019). Many urban centers across the continent rely heavily on well water for both domestic and industrial purposes, and studies have shown elevated heavy metal concentrations in groundwater near landfills and industrial zones (Nkwunonwo, 2024; Ibe et al., 2021). For example, research in South Africa and Zimbabwe has demonstrated that poorly managed waste disposal sites can lead to significant contamination of local water sources, with leachate from landfills being a major contributor to this pollution (Teta & Hikwa, 2017; Edokpayi et al., 2018).

In Nigeria, several studies have indicated that leachate from such dumpsites can significantly contaminate groundwater sources with heavy metals (Nkwunonwo, 2024; Zarmaa et al., 2023). The health risks associated with heavy metal exposure through contaminated drinking water are of great concern, particularly for vulnerable populations such as children and the elderly. Long-term exposure to these toxic metals can lead to developmental and neurological disorders, cancer, and other chronic diseases (Radfard et al., 2023; Huang et al., 2015). Studies have shown that well water sources in close proximity to dumpsites tend to have higher levels of contaminants, including heavy metals and pathogens, further elevating the health risks for nearby residents (Omofunmi et al., 2020; Uguru, 2021). This study aims to assess the heavy metal content in well water sources around the Karu dumpsite, identify the potential sources of contamination, and evaluate the associated health risks.

II. LITERATURE REVIEW

The health and environmental impacts of water contamination are both immediate and long-term. In the short term, exposure to contaminated water can lead to gastrointestinal illnesses such as cholera, dysentery, and typhoid (Loyola et al., 2020). Long-term/chronic exposure to contaminated water, especially water containing heavy metals, can lead to severe health conditions, including kidney damage, neurological impairments, and cancers (Awan et al., 2021). In the environment, water contamination can disrupt ecosystems, harm biodiversity, and reduce agricultural productivity, as heavy metals leach into the soil, affecting crops and livestock (Niampradit et al., 2024). Heavy metals are metals with high atomic weights and densities greater than 5g/cm³. These metals include both essential elements, like zinc and copper, which are required in trace amounts, and toxic metals, such as lead, arsenic, and mercury, which can have serious health effects even in small quantities (El-Kady & Abdel-Wahhab, 2018). Heavy metals are non-biodegradable and accumulate in the environment, making them persistent pollutants that can harm ecosystems and human health over time (Akanchise et al., 2020). Heavy metals are common contaminants in water, and they pose significant risks to both human health and the environment. The most prevalent heavy metals found in contaminated water sources include lead, arsenic, cadmium, mercury, and chromium (Singh et al., 2023). These metals are toxic even in small quantities, and their presence in drinking water has been linked to serious health issues, such as cancer, neurological disorders, and kidney damage (Yan et al., 2018; Alidadi et al., 2019). Heavy metal contamination in well water can be attributed to both natural and anthropogenic sources (Ali, 2023). Natural sources primarily include the weathering of metal-bearing rocks and minerals, which release metals like arsenic, nickel, and lead into groundwater. Similarly, in karu regions, the geological characteristics can contribute to the leaching of heavy metals into groundwater. This leaching is a combination of natural processes and human activities, as highlighted by Zhang et al. (2023), who noted the complex interaction between these factors in groundwater contamination. Anthropogenic activities are major contributors to heavy metal contamination in well water. Mining operations, in particular, are a primary source of contamination. The extraction and processing of ores release metals into the environment, which can ultimately seep into groundwater. Additionally, industrial activities, such as those in Erbil, Iraq, have been linked to elevated levels of heavy metals in drinking water, reflecting the significant impact of local industries on water quality (Khalid et al., 2020). The improper disposal of industrial waste also plays a key role in introducing toxic metals into water bodies, which further exacerbates contamination (Ahmed et al., 2023). Agricultural practices are another significant contributor to heavy metal contamination in well water. The use of fertilizers

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and pesticides containing heavy metals can result in runoff that carries these pollutants into nearby water sources. Studies have shown that agricultural runoff, a form of anthropogenic pollution, significantly contributes to the contamination of drinking water systems (Ahmed et al., 2023). Urbanization and improper waste management practices also increase the risk of contamination. Untreated industrial effluents, particularly from metal processing industries, add to the heavy metal levels in water sources (Khalid et al., 2020). Furthermore, leachate from landfills, which forms as waste decomposes, can seep into the surrounding soil and groundwater, carrying metals like lead, arsenic, and mercury into well water (Ibe et al., 2021). These combined sources of contamination highlight the urgent need for effective waste management and pollution control measures to safeguard water quality. Heavy metals enter groundwater primarily through leaching, runoff, and bioaccumulation. Leaching occurs when rainwater or moisture from waste decomposes and filters through soil, carrying heavy metals into groundwater and wells (Masindi & Muedi, 2018). Runoff from industrial or agricultural sites can also introduce pollutants into water bodies, leading to contamination. Once in the water, heavy metals can accumulate in aquatic organisms, contributing to bioaccumulation and biomagnification along the food chain (Huang et al., 2015; Radfard et al., 2023). This process poses risks not only to aquatic life but also to humans and other animals that consume contaminated water and organisms (Jounaid et al., 2021).

III. METHODOLOGY

This study titled "Assessment of the Heavy Metal Content of Well Water Sources around Karu Dumpsite, FCT, Abuja, Nigeria" was conducted to investigate the extent of groundwater contamination around the Karu dumpsite and its potential health implications for nearby residents. The primary aim was to assess the levels of heavy metals in well water used for domestic purposes, identify possible contamination sources, evaluate spatial patterns of pollution, and determine the associated non-carcinogenic health risks for both children and adults consuming the water. A positivist research philosophy guided the investigation, allowing for the collection and objective analysis of measurable, observable data. A descriptive cross-sectional design was employed to capture the current state of water quality at a single point in time, with data collected through direct water sampling and household surveys. The study population comprised residents living within a five-kilometer radius of the Karu dumpsite who relied on well water for their daily use. A multi-stage sampling technique was applied to select three key water sources (one borehole and two wells) and one hundred households. Stratified random sampling ensured fair representation across the different zones surrounding the dumpsite. Water samples were analyzed for physical and chemical parameters, including heavy metals such as manganese (Mn), copper (Cu), cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), chromium (Cr), and arsenic (As), using atomic absorption spectroscopy. Additionally, structured questionnaires were administered to residents to assess health histories and symptoms potentially linked to heavy metal exposure. To ensure the integrity of the instruments, reliability testing was performed using Cronbach's alpha during a pilot study, while content and face validity were confirmed through expert review and pilot feedback. Health risk assessments for children and adults were conducted using Chronic Daily Intake (CDI), Hazard Quotient (HQ), and Hazard Index (HI) metrics.

IV. RESULT AND DISCUSSION

4.1 Result

Table 1: Mean concentration of parameters from water sample

S/N	Parameter	Dumpsite (Borehole)	Dumpsite (Well 1)	Dumpsite (Well 2)	FMEnv Limit
Physical Parameters					
1	Temperature (°C)	30.4	30.7	30.8	40
2	Ph	7.5	7.7	7.4	7

3	Electrical Conductivity (µs/Cm)	528	1238	410	1000
4	Dissolved Oxygen (Mg/L)	4.1	5.7	3.6	7.5
5	Total Dissolved Solids (Mg/L)	264	619	205	500
6	Salinity (%)	0.06	0.02	0.02	0
Chemical Parameter					
7	Total Hardness (Mg/L)	445.12	564.96	410.88	200
8	Magnesium Hardness (Mg/L)	188.32	205.44	154.08	50
9	Calcium Hardness (Mg/L)	256.8	359.52	256.8	150
10	Sulphate (Mg/L)	79.1	100.7	72.34	250
Heavy Metals					
11	Manganese (Mg/L)	0.578	0.94	0.415	0.2
12	Copper (Mg/L)	0.843	0.986	0.505	0.1
13	Cadmium (Mg/L)	0.147	0.224	0.102	0.05
14	Zinc (Mg/L)	0.568	0.923	0.493	0.1
15	Lead (Mg/L)	0.049	0.288	0.13	0.05
16	Nickel (Mg/L)	0.043	0.213	0.139	0.05
17	Chromium (Mg/L)	0.042	0.432	0.104	0.05
18	Arsenic (Mg/L)	0.014	0.029	0.032	0.05

Table 1 presents the mean concentrations of physical, chemical, and heavy metal parameters measured from three water sources within the periphery of the Karu dumpsite: a borehole and two wells. The focus for this objective is on heavy metals, specifically Manganese (Mn), Copper (Cu), Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni), Chromium (Cr), and Arsenic (As), which are key indicators of potential environmental contamination and public health risk. The concentration of manganese in Well 1 (0.94 mg/L) and Well 2 (0.415 mg/L) exceeded the FMEnv permissible limit of 0.2 mg/L, with Well 1 recording the highest level. The borehole also recorded elevated manganese at 0.578 mg/L. This suggests manganese contamination across all sources. Copper levels were highest in Well 1 (0.986 mg/L), followed by the borehole (0.843 mg/L) and Well 2 (0.505 mg/L), all of which greatly exceeded the FMEnv limit of 0.1 mg/L. This widespread elevation indicates anthropogenic sources such as disposed plumbing materials, cables, and electronics. Cadmium concentrations were above the permissible limit (0.05 mg/L) in all three water sources: Well 1 (0.224 mg/L), Borehole (0.147 mg/L), and Well 2 (0.102 mg/L). Zinc levels also exceeded the FMEnv limit of 0.1 mg/L across all samples, with the highest concentration in Well 1 (0.923 mg/L), followed by the borehole (0.568 mg/L), and Well 2 (0.493 mg/L). Although zinc is an essential trace element, excess intake can cause gastrointestinal and metabolic disturbances. Lead was notably high in Well 1 (0.288 mg/L) and Well 2 (0.13 mg/L), both far above the permissible limit of 0.05 mg/L. The borehole's lead level (0.049 mg/L) was just below the threshold, indicating minimal contamination. Nickel levels also exceeded safe limits in Well 1 (0.213 mg/L) and Well 2 (0.139 mg/L), while the borehole (0.043 mg/L) remained within acceptable range. Chromium was alarmingly high in Well 1 (0.432 mg/L), more than eight times the FMEnv threshold (0.05 mg/L). Well 2 (0.104 mg/L) also surpassed the limit, whereas the borehole had a slightly lower level (0.042 mg/L), just under the standard. Arsenic levels in all three locations were below the FMEnv limit of 0.05 mg/L. However, Well 2 recorded the highest value (0.032 mg/L), still within safe bounds. Continuous monitoring is recommended due to arsenic's carcinogenic nature.

Table 2: Potential sources of heavy metals in water sources

Heavy Metal	Exceeds Limit?	Likely Sources	Rationale
Manganese (Mn)	Yes (All)	Batteries, paints, metal scraps, and landfill leachate	Manganese is often found in alkaline batteries and steel manufacturing waste.
Copper (Cu)	Yes (All)	Electrical wires, plumbing pipes, electronics, alloys	Disposed electronics and corroded pipes release copper into groundwater.
Cadmium (Cd)	Yes (All)	Plastic stabilizers, batteries (NiCd), pigments, e-waste, pesticides	Highly toxic; released from Ni-Cd batteries and plastic products.
Zinc (Zn)	Yes (All)	Galvanized metals, rubber, paints, alloys, cosmetics	Zinc is used extensively in construction and household materials.
Lead (Pb)	Yes (All)	Batteries, solder, paint chips, pipes, cables	Often found in dumped car batteries, old paints, and plumbing hardware.
Nickel (Ni)	Yes (W1, W2)	Stainless steel, coins, electronics, ceramics, industrial waste	Nickel is common in alloys and electroplating waste found in landfills.
Chromium (Cr)	Yes (W1, W2)	Paints, dyes, metal plating, leather tanning	Chromium (especially Cr VI) is a common pollutant in industrial waste.
Arsenic (As)	No	Naturally occurring in some geological settings; also, from herbicides	Levels are within safe limits; likely not influenced by dumpsite activities.

Table 2 shows a breakdown of the potential sources for each contaminant:
The consistent exceeding of heavy metal limits in all water sources, especially in Well 1 and Well 2, suggests contamination from multiple anthropogenic sources. Given that the Karu dumpsite likely contains a mixture of residential, commercial, and industrial waste—including electronic waste (e-waste), paints, plastics, metal scraps, batteries, and decomposing refuse—these sources align closely with the detected contaminants. The fact that even the borehole, which is generally deeper and less vulnerable to surface contamination, shows elevated levels of Mn, Cu, Cd, Zn, and Pb, indicates the pervasiveness of groundwater pollution in the area. Additionally, the extremely high concentrations of Lead, Cadmium, and Chromium, which are among the most hazardous metals, underscore the potential long-term ecological and health hazards of improper waste disposal.

4.2 Discussion

The analysis of heavy metal concentrations in well water sources near the Karu dumpsite revealed a significant level of contamination in all three sampling points—Borehole, Well 1, and Well 2—with seven out of eight analyzed metals exceeding the FMEnv permissible limits in at least two locations. Notably, Well 1 emerged as the most contaminated, with manganese, copper, cadmium, zinc, lead, nickel, and chromium all surpassing safety thresholds. Copper reached as high as 0.986 mg/L, cadmium at 0.224 mg/L, and chromium at 0.432 mg/L in Well 1—many times over the acceptable limits. Even the borehole, often perceived as a safer source, recorded elevated levels of several metals such as manganese (0.578 mg/L) and copper (0.843 mg/L), suggesting a deeply permeated contamination profile. Arsenic, however, remained within safe bounds across all sites, with the highest being 0.032 mg/L in Well 2. This pattern of contamination closely aligns with findings from numerous other studies conducted across Nigeria and beyond. For example, Olasunkanmi *et al*. (2024) reported elevated levels of cadmium and copper in well water near the Ipata dumpsite in Ilorin, confirming the leachate-infiltration pathway. Similarly, Arthur *et al.* (2024) found that total dissolved solids, electrical conductivity, and pH in Enugu's Uguwaji dumpsite correlated strongly with elevated heavy metal content. Opasola *et al*. (2024) also recorded dangerous levels of lead, cadmium, and chromium in well water near the Gosa dumpsite in Abuja, with children particularly at risk. The elevated concentrations of heavy metals across all sampled water sources suggest that contamination arises from multiple anthropogenic inputs, most of which are associated with the Karu dumpsite. Specific sources such as disposed batteries, decaying electronics, industrial wastes, and plastic materials appear to be key contributors to the elevated levels of manganese, cadmium, lead, copper, and chromium. The borehole's contamination—despite its depth—further underscores the intensity of infiltration, suggesting that leachates from decomposing waste have migrated vertically through the subsurface. Well 1, with the highest concentration of nearly all detected metals, likely sits closest to the dumpsite or along a hydrogeological pathway that facilitates contaminant flow. This points to the Karu dumpsite as the primary contributor to heavy metal pollution in the area's groundwater system.

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The outcome of this study confirms that well water sources within the periphery of the Karu dumpsite in FCT, Abuja are significantly contaminated with heavy metals, including manganese, copper, cadmium, zinc, lead, nickel, and chromium—many of which exceed the permissible limits set by FMEnv. The highest contamination levels were found in Well 1, indicating close proximity or greater exposure to leachate infiltration from the dumpsite. Although arsenic levels remained within safe limits, the widespread presence of other toxic metals poses a moderate yet growing non-carcinogenic health risk, particularly for children who are more physiologically vulnerable. Correlation and clustering analyses further affirmed that the contamination pattern is linked to both geochemical processes and anthropogenic activities from the dumpsite, suggesting systemic groundwater pollution. These findings underscore the urgent need for sustainable waste management, improved groundwater protection, and periodic environmental health surveillance to mitigate long-term health and ecological consequences for the affected communities.

5.2 Recommendations

Based on the findings of this study, there are several important steps that stakeholders should take to protect the health of residents and improve the quality of groundwater around the Karu dumpsite. First, local authorities and environmental agencies need to conduct regular testing of well and borehole water in the area. This will help track contamination levels and detect any worsening of the situation early enough to respond effectively. Monitoring should be consistent and backed by proper reporting and community feedback mechanisms.

Secondly, the waste management practices at the Karu dumpsite need urgent improvement. Open dumping should be phased out and replaced with a more controlled system, such as a properly engineered landfill that includes leachate collection and treatment. This would go a long way in preventing harmful substances from seeping into the groundwater. Also, there should be stricter regulation and enforcement to ensure that hazardous waste, such as batteries and electronic waste, is properly sorted and disposed of.

Community awareness is also key. Many residents may not know the risks associated with using contaminated water. Stakeholders should organize health education campaigns to inform the public about the dangers of drinking untreated well water, especially for children. Households should be encouraged to treat their water using filters or boiling, and, where possible, consider relocating their wells to safer distances from the dumpsite.

Health agencies should also consider offering periodic medical checkups for residents, especially children, to detect early signs of exposure to heavy metals. This could help in managing any health problems before they become severe. Lastly,urban planners and decision-makers should ensure that residential areas are not situated too close to active waste disposal sites in the future.

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