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Original Article

Heavy Metals and Microorganisms in Borehole Water Around the Olusosun Dumpsite in Lagos, Nigeria: Occurrence and Health Risk Assessment

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Abstract
Dumpsites are the most cost-effective and widely used method of waste disposal. However, studies have linked dumpsites to groundwater contamination, necessitating a safety assessment of groundwater sources near dumpsites. The safety of borehole water near the Olusosun dumpsite in Ojota, Lagos, Nigeria, was investigated in this study. Water samples were collected at distances of 100, 200, and 300 m from the dumpsite and subjected to conventional heavy metal analysis and microbiological tests. The average daily intake (ADI) and hazard quotient (HQ) of heavy metals were also estimated. The heavy metal analysis revealed that copper (Cu) and iron (Fe) levels exceeded permissible limits recommended by the World Health Organization (WHO) at the three locations, while manganese (Mn), lead (Pb), and cadmium (Cd) concentrations were within non-permissible levels only at the distances of 100 and 200 m. The concentrations of other heavy metals tested, such as zinc (Zn), nickel (Ni), and chromium (Cr), were within tolerable limits. The ADI of heavy metals at the three locations was within acceptable levels. However, the HQ of Cd in all the locations, as well as Pb at the distance of 100 m and Cr at distances of 100 and 200 m, was greater than the threshold of 1. The microbiological analysis revealed that all the water samples had non-permissible bacteria and coliform counts. The results obtained suggest that the borehole water around the dumpsite is grossly contaminated, with contamination levels increasing significantly ($P \leq 0.05$) with closeness to the dumpsite (100 > 200 > 300 m). Therefore, there is a need for heavy metal remediation and disinfection of the dumpsite.
Keywords: Average daily intake, Bacteria, Dumpsites, Groundwater, Lead

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1. Introduction

Dumpsites are the most cost-effective and widely used means of disposing of municipal solid wastes, industrial wastes, and hazardous wastes (1-3). Globally, about 71% of municipal solid wastes are disposed of in dumpsites (4). Waste disposal in a dumpsite entails burying the wastes, which is often done in neglected or unutilized quarries, mining areas, or dug pits (5). A well-planned and well-maintained dumpsite can be a clean and safe means of waste disposal (5).

Unfortunately, dumpsites in developing countries, such as Nigeria, are not well managed, and as a result, they are the main cause of groundwater contamination (6). Physical, chemical, and biological processes combine to break down wastes in poorly managed dumpsites, resulting in chemical-laden leachates (7). Toxic chemicals such as heavy metals, persistent organic pollutants, and microbes are commonly found in leachate (8). As a result, leachate-contaminated groundwater can cause ecological problems such as water blooms and soil salinization, as well as waterborne diseases (9, 10). Therefore, there is a need for periodic monitoring of groundwater around dumpsites to prevent diseases.

The Olusosun dumpsite in Ojota, Lagos, Nigeria, is one of the world's largest dumpsites (11, 12). On a daily basis, the dumpsite receives around 10 000 tons of municipal solid wastes and industrial wastes (13). Several containers, mostly electronic wastes, are also brought to the facility daily. Some of these wastes are treated with chemicals to extract reusable products, resulting in the release of harmful gases. This makes the site an ideal environment for the development of diseases and contamination of the environment, particularly nearby groundwater. Consequently, groundwater sources such as boreholes and wells near the dumpsite need to be continually monitored to prevent disease outbreaks. This becomes more imperative considering that groundwater is the principal source of drinking water in the area (14). However, literature shows that the quality of groundwater around the dumpsite has not been evaluated in recent times. Therefore, this study assessed the occurrence and health risk of heavy metals and microorganisms in borehole water near the Olusosun dumpsite in Ojota, Lagos, Nigeria.

2. Materials and Methods

2.1. Description of the Study Area

This study was carried out around the Olusosun dumpsite in Ojota, Lagos State, Nigeria (Fig. 1). The dumpsite is located between latitude 6° 26’ 28.1688” and longitude 3° 25’ 4.7172” (11). Lagos has a total area of 3577 km², with land areas covering 2798 km² and waterbodies covering 779 km² (15). The vegetation of the state is tropical, and there are several aquatic ecosystems such as lagoons, rivers, and creeks (14). The weather is mostly humid, with a short dry season (14). Lagos is Nigeria’s most populous city and Africa’s second-largest city (16). The city is also a major African financial centre and the economic hub of Nigeria (17). Lagos’ high population and economic activities generate a large amount of waste, most of which is disposed of at the Olusosun dumpsite. The Olusosun dumpsite is surrounded by highly populated communities and commercial centres, with the majority of residents relying on groundwater for drinking and domestic purposes. Therefore, it becomes imperative to constantly monitor the impact of dumpsites on nearby groundwater sources such as boreholes and wells.

2.2. Sample Collection

Water samples were collected from 30 boreholes around the Olusosun dumpsite, 10 of which were sited at the distance of 100 m from the dumpsite, another 10 at 200 m, and the remaining 10 at 300 m from the dumpsite. A sample was collected from each borehole monthly for 3 months (March 2021–May 2021, spanning dry and wet seasons), resulting in a total collection of 90 samples (30 from each location). The samples were put in clean, pre-sterilized 1-L plastic containers (filled to the brim), sealed properly, and transported to the laboratory, where they were kept in a freezer at –4°C before being analyzed for heavy metals and microorganisms.

2.3. Sample Treatment

All frozen samples were allowed to defrost at room temperature (26°C). Water samples were not further processed, but they were thoroughly mixed before being used for heavy metal analysis.

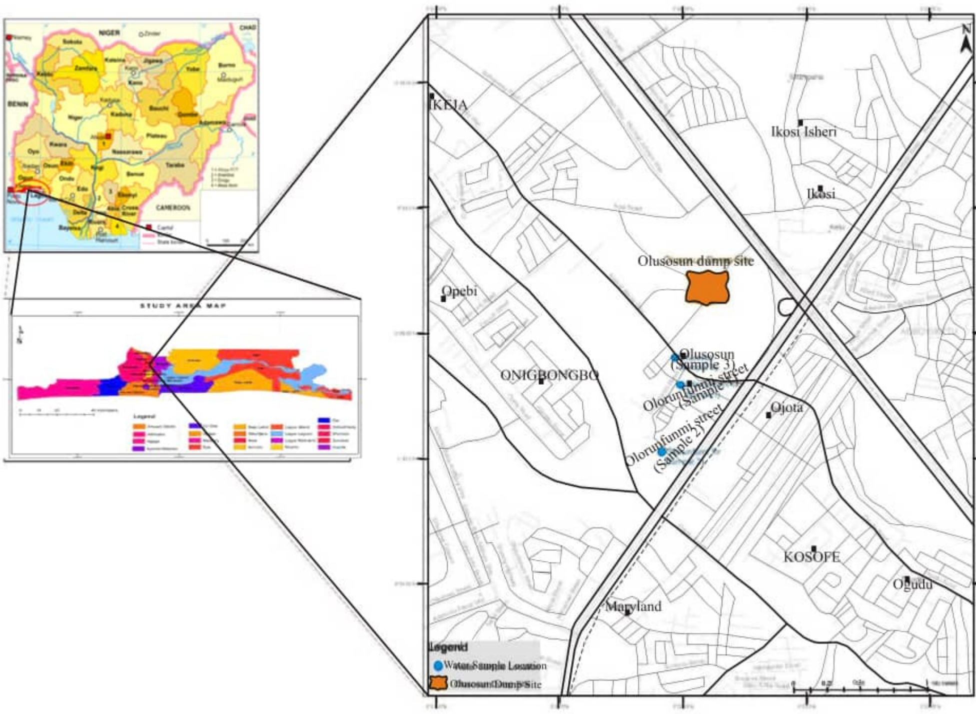

Fig. 1. Locations of Olusosun Dumpsite (drawn using ArcGIS 10.3 software).

2.4. Heavy Metal Analysis

The heavy metal analysis was conducted as outlined by Yahaya et al (14). First, 1 mL of each water sample was poured into a clean 100-mL beaker containing 25 mL of 70% aqua regia (HNO_3 and 3HCl) and 5 mL of diluted hydrogen peroxide. Then, the mixture was digested at 79°C, after which it was allowed to cool, filtered into a 50-mL volumetric flask, and made up to the meniscus mark with deionized water. An atomic absorption spectrophotometer (Alpha-4 Cathodeon) was used to determine the concentration of copper (Cu), lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), iron (Fe), manganese (Mn), and zinc (Zn) in the filtrate.

2.5. Microbial Analysis

The total numbers of bacteria, coliforms, and fungi in the water samples were estimated using the ten-fold serial dilution method. All the media used were prepared according to Azi et al (18) and autoclaved at 120°C for 20 minutes. The bacterial count was determined by filtering 0.1 mL of the water sample on nutrient agar plates in duplicate and incubating it at 37°C for 24 hours. At the end of the incubation, the number of bacterial colonies was counted and expressed as colony-forming units per gram (CFU/g/mL). The fungal counts were determined in the same way, but potato dextrose agar was used as the growth medium.

The coliform population in the water was estimated using a two-step enrichment method. The bacteria-infested filter was initially placed on lauryl tryptose broth, then on M-Endo agar, and incubated for 3 and 22 hours at 34°C, respectively. Then, the number of coliforms was estimated.

2.6. Health Risk Assessment of the Water

Using equations 1 and 2 below, the health risk of drinking borehole water on a daily basis was determined from the average daily intake (ADI) and hazard quotient (HQ) of heavy metals in the water (19).

$$ADI = \frac{Cx \times Ir \times Ef \times Ed}{Bwt \times At} \quad (1)$$

Where:

ADI = average daily ingestion of heavy metals per kilogram of body weight; Cx = concentration of heavy metals in water; Ir = ingestion rate per unit time; Ef = exposure frequency; Ed = exposure duration; Bwt = body weight; At = the average time (Ed x Ef).

According to Yahaya et al (14), the standard values and units of the mentioned variables are as follows: $EF = 365$ days/years; $Ir = 2$L/day; $Ed = 55$ years; $Bwt = 65$ kg; $At = 20075$ days.

$$HQ = \frac{ADI}{RFD} \quad (2)$$

Where: HQ = hazard quotient; RFD = heavy metal oral reference dose.

According to USEPA (20), the RFD (mg/L/day) of Cu = 0.04; Mn = 0.14, Fe = 0.700; Zn = 0.3; Pb = 0.0035; Cd = 0.0005; Ni = 0.020; Cr = 0.0003.

2.7. Data Analysis

Values of the various parameters of the water samples were presented as mean ± standard deviation (SD) using Microsoft Excel. The software was also used to calculate the ADI and HQ of the heavy metals. Statistical analysis was done using the analysis of variance (ANOVA), in which $P \leq 0.05$ was considered statistically significant.

3. Results and Discussion

3.1. Levels of Heavy Metals in the Water Samples

Table 1 shows the concentrations of Cu, Mn, Fe, Zn, Pb, Cd, Ni, and Cr in the borehole water collected from three different locations (labelled A, B, and C) around the Olusosun dumpsite. Cu and Fe were above the World Health Organization (WHO) permissible limits in all the three locations, whereas Zn, Ni, and Cr were within the permissible ranges in all the locations. Mn, Pb, and Cd were above the permissible ranges in locations A and B but were within the permissible limits in location C. Overall, location A had the highest concentrations of heavy metals, followed by B and C, respectively. This result is consistent with those of Odukoya and Abimbola

Table 1. Levels of Heavy Metals in Borehole Water Collected from Three Locations Around the Olusosun Dumpsite in Lagos

Heavy Metal	Location A	Location B	Location C	Recommended Guidelines (21)
Cu	0.923 ± 0.0020[a]	0.303 ± 0.0025[b]	0.301 ± 0.0010[c]	0.05
Mn	0.582 ± 0.0011[a]	0.086 ± 0.0012[b]	0.038 ± 0.0010[c]	0.05
Fe	5.112 ± 0.0015[a]	1.452 ± 0.0015[b]	1.096 ± 0.0010[c]	0.3
Zn	2.991 ± 0.0011[a]	1.797 ± 0.0010[b]	2.233 ± 0.000[c]	5.0
Pb	0.310 ± 0.0012[a]	0.090 ± 0.0012[b]	0.004 ± 0.0015[c]	0.01
Cd	0.020 ± 0.0015[a]	0.003 ± 0.0020[b]	0.002 ± 0.0006[b]	0.003
Ni	0.022 ± 0.0015[a]	0.002 ± 0.0015[b]	0.003 ± 0.0006[a]	0.02
Cr	0.011 ± 0.00577[a]	0.021 ± 0.0015[b]	0.020 ± 0.000[b]	0.05

Values were expressed as mean ± SD and mg/L; values along the row with different superscripts (a, b, or c) differ significantly at $P \leq 0.05$ (ANOVA); WHO: World Health Organization; Location A: 100 m from Olusosun dumpsite; Location B: 200 m from Olusosun dumpsite; Location C: 300 m from Olusosun dumpsite

(22) and Kayode et al (23) who detected non-permissible levels of heavy metals in groundwater around landfills in Lagos, Nigeria. This indicates that the water may not be safe for drinking unless treated. Pb toxicity may increase blood pressure, cause neurological disorders, and lead to multi-organ damage (24). Overexposure to Cu may cause gastrointestinal disorders and liver damage (25). High levels of Fe may cause tissue damage (26). Chronic Cd exposure induces renal tubular damage (27). The concentrations of the heavy metals increased significantly with closeness to the dumpsite, which suggests that boreholes in location A (100 m from the dumpsite) pose more risks to consumers, followed by B and C, respectively.

3.2. Health Risk of the Water

The average daily ingestion (ADI) of Cu, Pb, Cd, Cr, Ni, Fe, Mn, and Zn in borehole water collected from three locations (A, B, and C) around the Olusosun dumpsite are presented in Table 2. Compared with the limits recommended by the WHO, the ADI of all the evaluated heavy metals in all the locations was within the recommended limits. However, the HQ of Cd in all the locations, as well as Pb at the distance of 100 m and Cr at distances of 100 and 200 m, was greater than the threshold of 1 (Table 3). These findings add to the evidence that daily consumption of borehole water in the area can predispose humans to health hazards, especially hazards related to Cd, Pb, and Cr toxicity. Residents above 55 years of age may be more affected because the calculation was based on the life expectancy of resident Nigerians, which is 55 years.

3.3. Levels of Microorganisms in the Water

Table 4 shows the levels of bacteria, coliform, and fungi in the samples of water collected from boreholes at three locations around the Olusosun dumpsite. The concentrations of bacteria and coliforms present in the water in all the three locations were above the WHO permissible limits, in increasing order of closeness to the dumpsite. However, fungi were not detected in all the water samples. The detection of coliforms indicated that the water was contaminated by faecal matter (28). The majority of coliforms are non-pathogenic. However, some strains of coliforms such as *Escherichia coli* can cause diarrhoea (29). Bacteria can cause water-borne diseases such as gastrointestinal illnesses, diarrhoea, cholera, and fever (30). The result of the current study is in line with that of Odukoya and Abimbola (22), who detected abnormal microbial populations in groundwater around two dumpsites in Lagos, Nigeria. Odeyemi et al (31) also observed high microbial populations in groundwater sources near dumpsites in Ekiti, Nigeria.

4. Conclusion

The results demonstrated that water samples from boreholes situated near the Olusosun dumpsite contained high levels of heavy metals, including Cu, Fe, Mn, Pb, and Cd. The water also contained non-permissible levels of bacteria and coliforms. The levels of the mentioned heavy metals and microorganisms increased significantly with closeness to the dumpsite (100 > 200 > 300). Though the ADI of the heavy metals was within the tolerable limits, the HQ of Cd in all the locations, as well as Pb and Cr in

Table 2. Average Daily Intake of Heavy Metals in Borehole Water Collected From Three Locations around Olusosun Dumpsite in Lagos

Location	Cu	Mn	Fe	Zn	Pb	Cd	Ni	Cr
A	0.028	0.018	0.157	0.092	0.010	0.001	0.001	0.0003
B	0.009	0.003	0.045	0.056	0.003	0.0001	0.0001	0.001
C	0.010	0.001	0.069	0.0001	0.0001	0.001	0.0001	0.0001
RDI (22)	0.90	0.05	0.3	5.0	0.21	0.06	0.50	0.20

Values were expressed in mg/day; RDI: recommended daily intake; Location A: 100 m from Olusosun dumpsite; Location B: 200 m from Olusosun dumpsite; Location C: 300 m from Olusosun dumpsite

Table 3. Hazard Quotient of Heavy Metals in Borehole Water Collected From Three Locations around Olusosun Dumpsite, Lagos

Location	Cu	Mn	Fe	Zn	Pb	Cd	Ni	Cr
A	0.70	0.13	0.22	0.31	2.86	2.00	0.05	1.00
B	0.23	0.02	0.06	0.19	0.86	1.20	0.01	3.33
C	0.25	0.01	0.09	0.00	0.03	2.00	0.005	0.34

Location A: 100 m from Olusosun dumpsite; Location B: 200 m from Olusosun dumpsite; Location C: 300 m from Olusosun dumpsite

Table 4. Levels of Bacteria, Coliform, and Yeast in Borehole Water Collected From Three Locations around Olusosun Dumpsite in Lagos

Microbe	Location A	Location B	Location C	Limit (23)
Total bacterial	21000 ± 34.0^{a}	4100 ± 10.61^{b}	1200 ± 100^{c}	≤100 cfu/mL
Total coliform	11000 ± 500^{a}	10.0 ± 4.58^{b}	10.0 ± 3.00^{c}	0 cfu/mL
Total fungi/yeast	BDL	BDL	BDL	0 cfu/mL

Values were expressed as mean ± SD; BDL: below detection level; WHO: World Health Organization; Location A: 100 m from Olusosun dumpsite; Location B: 200 m from Olusosun dumpsite; Location C: 300 m from Olusosun dumpsite some locations, was above the permissible limits. Overall, the results suggest that borehole water near the dumpsite may not be suitable for consumption.

5. Recommendation

The following recommendations are proposed based on the results of this study:

- Boreholes should not be sited near the dumpsite (at least not within 300 m).
- Residents of the area should consider treating borehole water before drinking or domestic use.
- Management of the dumpsite should conduct heavy metal remediation and disinfection of the site.
- The dumpsite should be re-engineered so that it does not discharge leachate into the environment.
- The quality of borehole water in the area needs to be checked on a regular basis to prevent disease outbreaks or health hazards.

Competing Interests

The authors declare that they have no conflict of interests.

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