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Characterization and risk evaluation of water samples collected from boreholes situated around a dumpsite in Obalende, Lagos, Nigeria

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Abstract: Dumpsites are used worldwide for waste disposal because they are cost-effective and have the capacity to contain enormous amounts of waste. However, concerns are rife about the impact of dumpsites on the quality of nearby groundwater. The present study assessed the quality of borehole water near a dumpsite in Obalende, Lagos, Nigeria. Heavy metal, physico-chemical, and microbiological tests were performed on the samples of the water using standard techniques, and the results were compared to the WHO permissible limits. The average daily oral ingestion (ADOI), average daily dermal ingestion (ADDI), and hazard quotient (HQ) of the heavy metals were also estimated. The heavy metal analysis revealed non-permissible levels of zinc, iron, lead, and manganese, while nickel, cadmium, and silicon were within the permissible limits. Physico-chemical analysis showed that turbidity, total suspended solids, total dissolved solids, nitrate, and phosphate were within the permissible limits, but not the pH, electrical conductivity, chloride ion, sulphate and dissolved oxygen. The microbiological examination indicated that the water had high levels of bacteria and coliform counts. The HQ of Zn, Fe, and Pb, mainly through dermal exposure was above the recommended limits (>1). Overall, the results suggest that the water may predispose consumers in the area to Zn, Fe, Pb, and Mn toxicities as well as microbial infections. Consequently, consumers are advised to treat the water before consuming it.

Keywords: Average daily ingestion, bacteria, dumpsite, Lead, Nitrate

1 Introduction

Increasing population expansion and industrialization in Lagos, Nigeria is synonymous with high waste generation (Akande 2018). These wastes include domestic, agricultural, and industrial wastes and may be classified as liquid, solid, or gaseous (Adebayo and Obiekezie 2018). Most of the wastes are disposed of in open dumpsites across the state by private sectors, local governments, and the Lagos State Waste Management Authority. Some wastes are also disposed of indiscriminately within the metropolis and water bodies. The dumpsites are poorly managed and concerns are rife about the possible impact of these dumpsites on the quality of nearby groundwater (Aboyeji and Eigbokan 2016, Oyedele and Oyedele 2017).

The major environmental contaminants in dumpsites are toxic elements and microorganisms. Organic wastes in dumpsites produce microorganisms that degrade them, such as *Bacillus, Escherichia coli, Klebsiella, Proteus, Pseudomonas, Staphylococcus* and *Streptococcus spp., Aspergillus, Fusarium, Mucor, Penicillium,* and *Saccharomyces spp.* (Williams and Hakam 2016, Hamid *et al*. 2019). The decaying wastes produce weak acidic chemicals, which combine with liquids in the waste to form leachate and landfill gas (Hamid *et al*. 2019). Additionally, inorganic wastes such as electronics and food containers contain toxic elements, particularly heavy metals, including Lead (Pb), Mercury (Hg), Arsenic (As), Cadmium (Cd), and Nickel (Ni) (Popoola *et al*. 2019). Over time, the leachate, along with toxic elements and microorganisms, leaches into the soil and groundwater, compromising drinking water quality (Vodyanitskii 2016). Heavy metals generate free radicals in animals and plants and cause oxidative damage (Rehman *et al*. 2018). Microorganisms enter the cells and disrupt the immune function or elicit toxins (Alberts *et al*. 2002).

Groundwater is the commonest source of drinking water in most parts of Lagos (African Groundwater Atlas 2019). This is due to insufficient or inefficient pipe-borne water, comparable to what is obtainable in other regions of Nigeria and developing nations (Yahaya *et al*. 2020a). Furthermore, when properly managed, groundwater is economical, safe, consistent in quality and quantity, and ample for humans (Umar *et al*. 2017). Thus, it becomes imperative to keep regular monitoring of the quality of groundwater around dumpsites to prevent health hazards. Literature searches show that there is a dearth of information on the quality of groundwater around a dumpsite in Obalende, Lagos, Nigeria. Obalende is highly cosmopolitan and one of the most populated areas in the city. This study, therefore, characterized the quality and evaluated the levels and risk of heavy metals in water collected from boreholes situated around a dumpsite in Obalende, Lagos, Nigeria.

2 Material and Methods

2.1 Description of the study area

This study was carried out in Obalende, Lagos, Nigeria (Figure 1). Lagos is the capital of Lagos State, at latitudes of 6°37′N and 6°70′N and longitudes of 2°70′E and 4°35′E. Lagos covers an area of approximately 3,577 km^2, of which land constitutes 2,798 km^2

and water covers 779 km^2 (Wang *et al.* 2018). Lagos is bordered by the Republic of Benin on the west; Ogun State on the east and north; and the Atlantic Ocean on the south. The state is characterized by tropical vegetation, many water bodies, and high rainfall (Yahaya *et al.* 2019a). Obalende is among the most densely populated areas in Lagos, but, unfortunately, there are no government-approved dumpsites in the area. So, residents dump all sorts of waste indiscriminately, mainly along the McGregor canal, under the bridge, in Obalende. This has resulted in heaps of filthy and stinking waste in the area, necessitating an assessment of the effects of these wastes on the nearby drinking water sources.

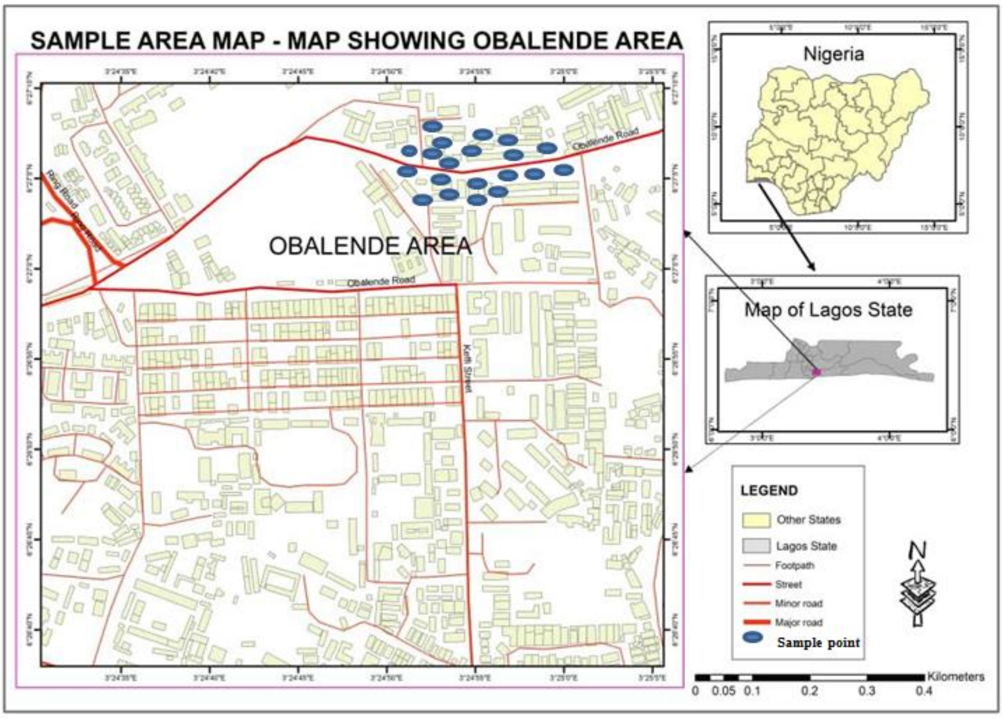

Fig 1: Water sampling locations in the Obalende area, Lagos, Nigeria

2.2 Sample collection

Water samples were collected randomly from ten boreholes situated within dwelling places at about 100 m from the dumpsite in February 2021. The samples were collected in polyethylene terephthalate plastic bottles that had been prewashed with a detergent solution, sterilized with 10% nitric acid for 24 h, and then rinsed with distilled water (Yahaya *et al.* 2020a). The samples were covered tightly and refrigerated at -10 °C in the laboratory.

2.3 Physicochemical and heavy metal analysis

The physicochemical properties of the water were characterized based on the guidelines for measuring water quality as described by APHA (2012). Time-sensitive properties, such as pH, temperature, and electrical conductivity, were measured on-site with a digital pH meter, a mercury-in-glass thermometer, and a conductivity meter, respectively. Other properties such as total suspended solids (TSS), total dissolved solids (TDS), turbidity, dissolved oxygen (DO), chloride, sulphate, nitrate, and phosphate were measured in the laboratory as described by Yahaya *et al*. (2020b).

Heavy metal analysis was carried out as described by Yahaya *et al*. (2019b). One milliliter of each sample was transferred to a pre-washed 100-ml beaker containing an analytical grade of 25 ml of aqua regia mixture (70% HNO_3 and HCl in a ratio of 3:1, respectively) and 5 ml of 30% H_2O_2. The mixture was digested in a digestion vessel at 80 °C until a homogenous solution was obtained. Afterwards, the solution was cooled, filtered through a Whatman No. 42 filter paper into a 50-ml volumetric flask, and diluted to the mark with deionized water. The filtrate was subjected to atomic absorption spectroscopy using a UNICAM spectrophotometer (model 969) to determine the concentrations of zinc (Zn), iron (Fe), sodium (Na), manganese (Mn), lead (Pb), cadmium (Cd), nickel (Ni), and silicon (Si).

2.4 Microbial analysis

The total bacterial counts were estimated using the membrane filtration technique as described by Brock (1984). To this end, 100 ml of each water sample was filtered through a sterile cellulose filter (0.2 µm pore size), and the filter was inoculated into a nutrient agar plate and incubated at 35 °C for 24 h. The total number of bacterial colonies formed on the plate was estimated using a colony counter.

The membrane filtration technique was also used to estimate the coliform count. However, the two-step enrichment method was used for microbial growth. The filters containing the bacteria were inoculated into an absorbent pad saturated with lauryl tryptose broth and incubated at 35 °C for 2 h. The filters were thereafter transferred to an absorbent pad saturated with M-Endo media and incubated at 35 °C for 22 h. The sheen colonies were observed and estimated by a colony counter.

2.5 Risk assessment

The risks of heavy metals in the water samples were estimated using equations 1, 2, and 3 (USEPA, 2003 and 2004).

$$\mathrm{ADOI} = \mathrm{Cx} \times \mathrm{Ir} \times \mathrm{Ef} \times {}^{\mathrm{Ed}}/_{\mathrm{Bwt}} \times \mathrm{At} \cdots\cdots\cdots [1]$$

In equation 1 above, *ADOI* represents the average daily oral ingestion of a heavy metal per kilogram of body weight, *Cx* is the concentration of heavy metals in water, *Ir* stands for the ingestion rate per unit time, *Ef* indicates the exposure frequency, *Ed* is the exposure duration (average life expectancy of a resident Nigerian), *Bwt* means body weight, and *At* is the average time (*Ed* x *Ef*). The standard values for these parameters were adopted from Yahaya *et al*. (2020a).

$$\mathrm{ADD1} = \mathrm{Cx} \times \mathrm{Sa} \times \mathrm{Pc} \times \mathrm{Et} \times \mathrm{Ed} \times {}^{\mathrm{Et}}/_{\mathrm{Bwt}} \times At \cdots\cdots\cdots\cdots [2]$$

In equation 2 above, *ADDI* is the average daily dermal ingestion of heavy metals, *Cx* represents the concentration of heavy metals in water, *Sa* denotes the total skin surface area, *Pc* indicates the chemical-specific dermal permeability constant (cm/h), *Et* is the exposure time (h/day), *Ef* stands for the exposure frequency (days/years), *Ed* reveals the exposure duration (years), *Bwt* is the body weight, and *At* is the average time (*Ed* x *Ef*). The standard values for these parameters were adopted from Yahaya *et al*. (2020a).

$$HQ = \frac{\mathrm{Exposure}}{\mathrm{RFD}} \cdots\cdots\cdots\cdots [3]$$

In equation 3 above, *HQ* represents the hazard quotient via oral or dermal ingestion (no units) and *RFD* stands for oral/dermal reference dose (mg/L/day). Oral/dermal reference doses for the selected heavy metals were adopted from Yahaya *et al*. (2020a).

2.6 Data Analysis

The levels of heavy metals and microorganisms in the water samples were presented as mean ± standard deviation (SD) using Excel software. The *ADOI*, *ADDI*, and *HQ* of the heavy metals were also calculated using Excel.

3 Results & Discussion

3.1 Physico-chemical properties of the water samples

Table 1 shows the physico-chemical properties of the water samples. The pH, electrical conductivity, TDS, chloride ion, sulphate, and DO levels were all within the World Health Organization's (WHO) allowable drinking water limits. However, the turbidity, TSS, nitrate, and phosphate were above the permissible limits. This finding suggests that waste from the dumpsite contaminated the water, making it unsafe to drink. The high TSS showed that the water contained high inorganic and organic materials, resulting in high turbidity. High turbidity is associated with endemic gastrointestinal illness (Mann *et al*. 2007). High levels of phosphate can cause digestive problems (Kumar and Puri 2012). Abnormal concentrations of nitrate can cause blue-eye syndrome in children and pregnant women (Sawyerr *et al*. 2017). Sources of nitrate and phosphate in the water include agrochemicals, human and animal wastes, sewage leaks, detergents in industrial effluents, and run-off from fertilized farmlands (Adesuyi *et al*. 2015). The results of the current study are consistent with those of Odukoya and Abimbola (2010) and Osinbajo *et al*. (2016), who reported abnormal levels of some water quality parameters in groundwater surrounding dumpsites in Lagos. However, the result contradicts Majolagbe *et al*. (2011) and Kayode *et al*. (2018), who found no abnormal levels of nitrate and phosphate in groundwater around some dumpsites in Lagos.

Table 1: Mean physico-chemical properties of the water samples obtained from boreholes around a dumpsite in Obalende, Lagos, Nigeria.

Parameters	Mean Concentrations	Unit	[a] Recommended values for drinking water
pH	6.46±1.163	Unit	5.5-9.0
Turbidity	58.0±0.100	NTU	≤ 5
Electrical conductivity	176.6±0.208	µS/cm	≤ 1500
Total dissolved solid	657.0±3.46	mg/l	≤ 500
Total suspended solid	359.0±1.00	mg/l	≤ 100
Chloride	85.2±0.153	mg/l	≤ 250
Nitrate	103.1±0.058	mg/l	≤ 50
Phosphate	509.0±1.00	mg/l	≤ 0.1
Sulphate	25.46±0.031	mg/l	≤ 750
Dissolved oxygen	5.68±0.025	mg/l	≥1.0

[a] WHO, 2017

3.2 Levels of heavy metals in the water samples

The levels of Zn, Fe, Na, Mn, Pb, Cd, Ni, and Si in the water samples are shown in Table 2. Zn, Fe, Mn, and Pb were detected above the permissible limits, but Na, Cd, Ni, and Si were within the permissible limits. These results again prove that the water might have been compromised and so not suitable for drinking. Hemochromatosis and tissue damage may result from an excess of Fe (Arko *et al*. 2019). High levels of Pb may cause high blood pressure, vitamin D and calcium metabolism imbalances, neurological disorders, and multi-organ damage (Popoola *et al*. 2019). Excess Zn may cause a range of symptoms, including nausea, diarrhea, and headaches (Helen and Othman 2014). Mn toxicity is associated with multi-organ damage and dopaminergic dysfunction (O'Neal and Zheng 2015). The results obtained under the current study are in line with those of Aboyeji and Eigbokhan (2016) and Oyeku and Eludoyin (2010), who detected abnormal concentrations of heavy metals in groundwater around Olososu dumpsite in Lagos, Nigeria. However, Longe and Balogun (2010) found no significant impact of a dumpsite on groundwater in Lagos with regards to heavy metal concentrations.

The risk assessment of the heavy metals further shows that daily intake of water may pose some risks. In particular, the *ADDI* of Zn was beyond the recommended limit (Table 2). Thus, residents are prone to toxic effects of Zn on the skin, such as skin lesions, decreased wound healing, and acrodermatitis (Plum *et al*. 2010). In addition, the *HQ* of oral ingestion of Fe and dermal ingestion of Zn, Fe, and Pb were greater than 1. This suggests that residents that live within the average life expectancy of Nigerians (55 years) are strongly at risk of Fe, Zn, and Pb toxicity. The risk becomes more significant with increasing age.

Table 2: Levels, estimated average daily ingestion and Hazard quotient of heavy metals in water samples obtained from boreholes around a dumpsite in Obalende, Lagos, Nigeria.

Heavy metals	Levels (mg/l) [a]	[b] Recommended values for drinking water	Exposure		Hazard quotient		
			Oral (mg/day)	Dermal (mg/day)	[c] RDI	Oral	Dermal
Zn	6.056±0.0017	5.0	0.186	9.079	8	0.002	30.263
Fe	30.45±0.0020	0.3	0.937	7.607	10	1.329	10.867
Na	1.46±0.0020	30-60	0.92	-	30-60	-	-
Mn	0.08±0.0018	0.05	0.0006	0.005	1.8	0.043	-
Pb	0.097±0.0010	0.01	0.003	0.097	0.21	0.002	27.714
Cd	BDL	0.003	-	-	0.06	-	-
Ni	BDL	0.02	-	-	0.500	-	-
Si	BDL	NA	-	-	-	-	-

[a] Values were expressed as mean ± SD, BDL: below detection levels, NA: not available,
[b] WHO: World Health Organization, 2017; [c] RDI: Recommended daily intake (Yahaya *et al*. 2020a)

The possible sources of Fe in the water include steel and iron scraps, and sewage (Garba and Abubakar 2018). Zn might have been introduced through metal processing, anti-oxidants, detergent/dispersant, vehicle brakes, and tire wear (Jeong 2022). Pb could have been introduced by oil spillage from mechanical workshops, welding, panel beatings, Pb-bearing glass, pottery glazes, batteries, old lead-based paints, lead pipes, and sewage sludge (Tongesay *et al*. 2018). Possible sources of Mn in the water include iron and steel scrap, traffic emissions, glass, dry batteries, and chemicals (Garba and Abubakar 2018).

3.3 Levels of microorganisms in the water samples

Table 3 reveals the levels of bacteria, coliform, and fungi in the water samples. The total bacteria and coliform were detected at levels above the WHO permissible limits, while fungi were not detected. These results further suggest that the water may not be suitable for drinking. Waterborne bacteria may cause diseases such as cholera, diarrhoea, typhoid fever, and dysentery (Philip *et al.* 2017). Excess iron concentration might have increased the turbidity of the water and promoted bacterial growth (Sawyerr *et al*. 2017).

Table 3: Levels of microorganisms (mean ± SD) in the water samples obtained from boreholes around a dumpsite in Obalende, Lagos, Nigeria.

Microorganism	Mean Level (CFU/ml)	Permissible Limit (WHO 2008)
Total bacterial	1011 ± 50.14	≤100 CFU/ml
Total coliform	400 ± 20.00	0 CFU/ml
Total fungi/yeast	ND	0 CFU/ml

ND: not detected; CFU/ml: coliform forming unit per milliliter, WHO: World Health Organization.

High levels of other nutrients in the water, such as nitrate and phosphate, might have also induced bacterial growth (Singh 2013). The detection of coliforms in the water samples indicated that the water was contaminated by organic matter, particularly faecal matter (Adelekan and Ogunde 2012). Certain strains of coliforms such as *Escherichia coli* 0157:H7 can cause urinary tract infections, bacteremia, meningitis, diarrhea, and acute renal failure (Gruber *et al*. 2014, Sawyerr *et al*. 2017). The result of the present study is consistent with those of Adeyemi *et al*. (2007) and Odukoya *et al*. (2013), who detected high microbial populations in groundwater obtained near dumpsites in Lagos, Nigeria.

5 Conclusions

The results have demonstrated that the borehole water is turbid and contains non-permissible levels of TSS, nitrate, phosphate, Fe, Zn, Mn, Pb, and microbial populations (bacteria and coliforms). The *HQ* of Zn, Fe, and Pb, mainly through dermal exposure, was above the threshold of 1. This indicates that daily ingestion of the water may predispose consumers to health risks, particularly those related to Zn, Fe, and Pb toxicities.

From the findings of this study, we recommend that borehole water in the locations be treated before consumption, and boreholes should not be located within 100 m of the diameter of the dumpsite. Residents should be informed about the dangers of drinking contaminated water. The government should devise a strategy to prevent people from dumping wastes in or along the canal. Similar studies like the current study should be carried out periodically in the locations.

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