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Quality and Safety Assessment of Borehole Water around Simpson Transfer Loading Station in Lagos, Southwest Nigeria

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Abstract

The Simpson Transfer Loading Station in Lagos, Nigeria was established to treat and compact waste, thus reducing waste volume before being conveyed to permanent dumpsites and ultimately saving costs. This study was conducted to determine the effects of the facility's operations on nearby borehole water. Physicochemical parameters; total dissolved solids (TDS), pH, alkalinity, acidity, color, hardness, calcium, magnesium, chloride, sulphate, nitrate, phosphate, and electrical conductivity were analyzed using standard methods. Heavy metals; lead, arsenic, copper, cadmium, and chromium were analyzed. The sampled water was assayed for the presence of bacteria, coliforms, and fungi. Possible health risks that might be associated with the ingestion of heavy metals that might be present in the water were also investigated. The results of the physicochemical analysis revealed that TDS, hardness, calcium, chloride, sulphate, nitrate, phosphate, and electrical conductivity exceeded the limits recommended by the World Health Organization. All of the heavy metals analyzed exceeded their tolerable levels. The microbiological examination revealed non-permissible bacteria counts, but coliform and fungi were undetected. The health risk assessment showed that average daily ingestion of the heavy metal was normal, but daily dermal exposure to Pb exceeded the allowable limits. Moreover, the hazard quotient and carcinogenic risk of all the heavy metals exceeded the permissible limits. Except bacteria, all the

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parameters were higher in the wet season than in the dry season. From these results, it can be inferred that the water is not suitable for consumption. Environmental safety needs to be adhered to by the management of the facility.

Keywords: Bacteria, Dumpsite, Hazard quotient, Lead, Total dissolved solids (TDS)

INTRODUCTION

Water is the universal solvent necessary for life. In humans and other animals, water is necessary for the transport and dissolution of vitamins and minerals, the regulation of body temperature, and the functioning of all parts of the body (Kılıç *et al*., 2020). Although water covers more than 70% of the earth's surface, only around 0.3% of the water resources are usable (Kılıç *et al*., 2020). Of the mentioned proportion, 97.2% is salt water while the remaining 2.8% is fresh water, of which 20% is groundwater (Yahaya *et al*., 2020). Groundwater has a nearly balanced salt percentage, making it the best source of fresh water for human consumption (Kolekar, 2017). Besides, groundwater has a widespread occurrence, it is available, has good quality, and has a low production cost (Osibanjo *et al*., 2017; Ojukwu and Nwankwoala, 2022). In an ideal condition, groundwater is pollution-free and cleaner than surface water (Patil and Patil, 2010). However, like other forms of water, groundwater is susceptible to environmental influence and so must be regularly monitored to ensure its suitability for intended purposes (Ritabrata, 2019). Drinking water that does not meet certain standards is a source of disease and associated medical costs (WHO, 2005; USEPA, 2018).

Indiscriminate dumping of solid wastes, chemicals, sewage from homes and industries, and agricultural runoffs are some of the anthropogenic activities that compromise the quality of water sources (Yahaya *et al*., 2022a). One other source of environmental contaminants in water is dumpsites. Dumpsites are the most widely used methods of disposing of municipal solid wastes, industrial wastes, and hazardous wastes because they are effective and cheap (Ferronato and Torretta, 2019; Obiekezie *et al*., 2019). Dumpsites are open grounds where truckloads of waste are deposited, containing mainly industrial, medical, agricultural, electronic, and domestic waste (Ziraba *et al*., 2016). Properly managed dumpsites are hygienic, but poor management may cause organic waste degradation and, coupled with acidic rain, elicit leachate which can percolate into the ground and contaminate groundwater (Omorogieva and Andre-Obayanju, 2020; Ozbay *et al*., 2021). Leachate from dumpsites contains hazardous substances like heavy metals, dissolved organic matter, inorganic macro components, microorganisms, and xenobiotic organic compounds (Daniel *et al*., 2021). Of all the environmental contaminants known to have the capability of marring the sanctity of groundwater, heavy metals are the most studied due to their toxicity, persistency, and non-degradability (Uddin *et al*., 2021). Some heavy metals, including cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), and arsenic (As), are toxic, even at low concentrations, making them a threat to both plant and animal survival (Olayiwola *et al*., 2017; Otomewo, 2022). On the other hand, some heavy metals such as cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn) are beneficial but they become harmful after certain doses (Sabejeje *et al*., 2014). Microorganisms are also a top environmental and health concern worldwide. Some of the microorganisms often detected in dumpsite leachate include *Escherichia coli*, *Enterobacter*, *Bacillus*, *Salmonella*, *Aspergillusniger*, *Aspergillusflavus*, *Rhizopus*, *Serratiamarcescene*, *Klebsiellaaerogenes*, *Staphylococcus aureus*, *Alcaligens* species, and *Proteus* species (Daniel *et al*., 2021). These pathogens have been linked to the outbreaks of typhoid, cholera, diarrhea, and skin rashes, among others (Daniel *et al*., 2021).

Considering the potential health and environmental hazards of dumpsite leachates, there is a need to constantly monitor every dumpsite and related waste management facility to prevent untended hazards to host communities. In Lagos, the Simpson Transfer Loading Station is Lagos State's first waste management facility, commissioned in 2009 to compact waste into smaller volumes for easier evacuation to dumpsites with fewer trucks (Communication Week Media, 2009). It has the capacity to store and treat a minimum of 600 metric tons of waste per day and 1,000 metric tons of waste at full capacity (Communication Week Media, 2009). The facility also serves as a temporary dumpsite where waste is dumped during the day until compaction later in the night. Activities in this facility can potentially impact the environment and groundwater in particular. Yet, there is a dearth of documented studies on the effects of the facility on the environment, which may serve as a guide for the prevention or mitigation of the effects of the facility. This study was, as a result, conceptualized to determine the safety of borehole water for consumption around the facility with regards to physicochemical parameters as well as heavy metal and microbiological contamination.

MATERIALS AND METHODS

Description of the study area

The Simpson Transfer Loading Station is located in Lagos Island, Lagos State, Nigeria (Figure 1). Lagos State, which is in the south-western region of the country, is located at Latitude 6° 27' 55.5192 "N and Longitude 3° 24' 23.2128 "E (LatLong.net, 2022). Lagos is a megacity with high population growth, economic activity, and urbanization. It is the most populated and industrialized city in Nigeria and a major economic hub in Africa. There are at least 33506 companies in Lagos (BusinessList.com.ng, 2022). Thus, there are huge anthropogenic activities in the city, resulting in high utilization of resources and high waste generation. The vegetation of the state is tropical rainforest with a long wet season and several bodies of water, such as lagoons, creeks, estuaries, rivers, and streams (Yahaya *et al.*, 2020).

Lagos Island is located in the Lagos Island Local Government Area (LGA) at Latitude 6° 26' 59.99" N and Longitude 3° 23' 59.99" E (Latitude.to, 2022). The LGA is one of the most populated parts of Lagos with high waste generation, which necessitated the establishment of the Simpson Transfer Loading Station. The facility serves as a temporary storage for waste before being treated, reduced, and transported to various dumpsites across the state. There are concerns, however, that the facility's operations could potentially impact the environment, particularly groundwater. So, groundwater sources around the facility need to be evaluated periodically.

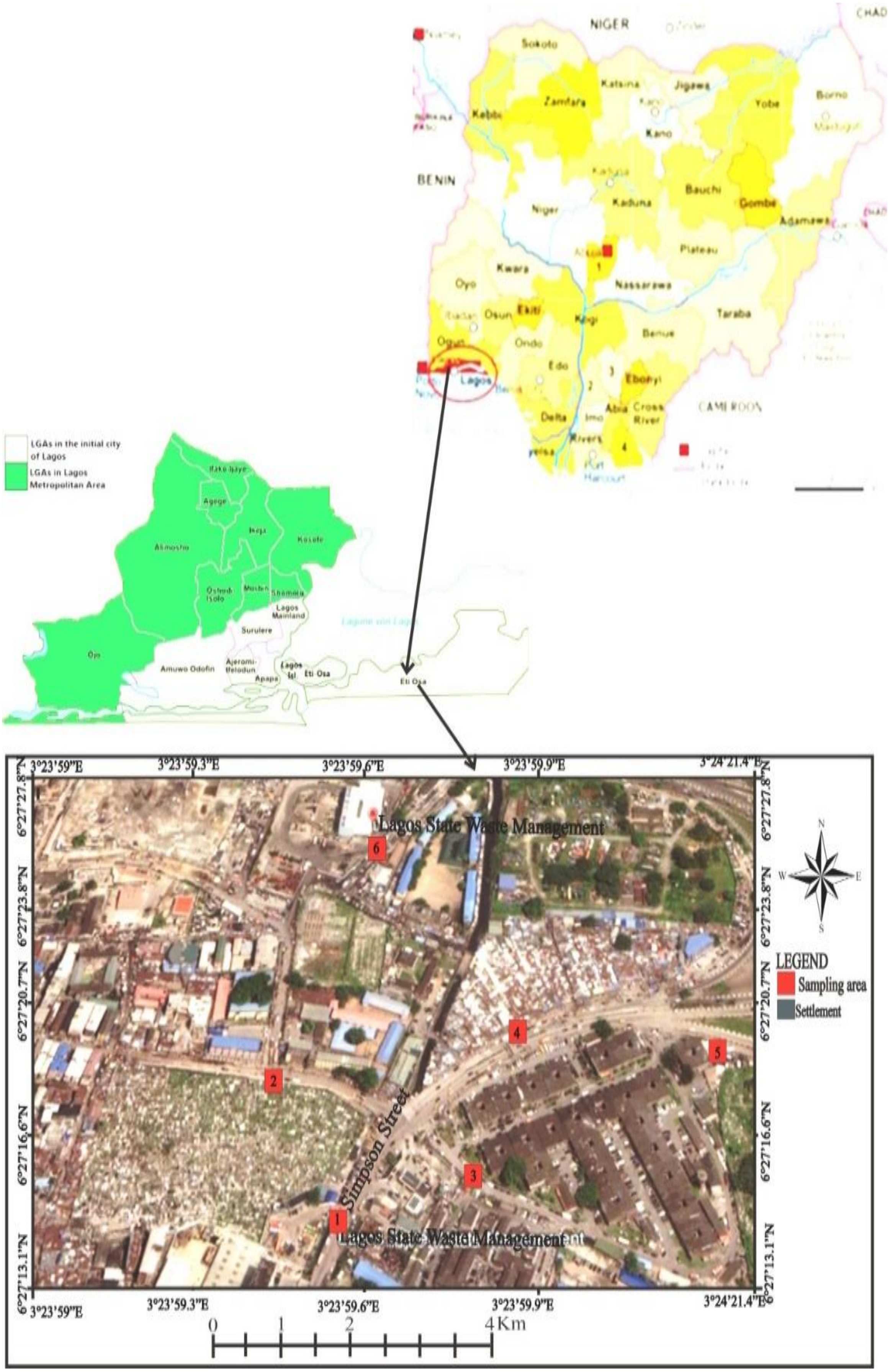

Figure 1: Locations of the study area

Sample collection and preparation

Water samples were collected from boreholes in six streets around the Simpson Transfer Loading Station, namely; Simpson, Batipa, Hawley, Lewis, Okesuna, and Igbosere streets. The sampling was done monthly, from December 2021 to May 2022 (spanning dry and wet seasons), resulting in the collection of thirty-six (36) samples. The samples were put in 1000-mL disinfected polyethylene terephthalate plastic bottles, tightly sealed, and kept in a refrigerator at –4 °C in the laboratory for further use.

Determination of physicochemical parameters

The criteria of the American Public Health Association (2018) were used to determine the physicochemical properties of the sampled water. The pH (as well as alkalinity and acidity) and total dissolved solids (TDS) were evaluated on-site with a Pye Unicam pH meter and an HM Digital TDS meter model TDS-4, respectively, for accuracy. A DR 2000 spectrophotometer (Model 50150) was used to evaluate nitrates, sulfates, calcium, magnesium, and phosphates. An Avial chloride meter (20 x 40 mm) was used to determine chloride. A complex metric EDTA titration was used to determine hardness. Turbidity and electrical conductivity were determined by a turbidimeter and an electrical conductivity meter (EC meter), respectively.

Determination of heavy metals

The heavy metals in the sampled water were determined in accordance with Yahaya *et al.* (2022a). A beaker was filled with 100 mL of the sampled water, 5 mL of concentrated HNO_3, and then tightly sealed to avoid contamination. The mixture was heated slowly at 95 °C until it evaporated to about 21 mL. The solution was left to cool, after which it was poured into a 100-mL volumetric flask and filled up to the meniscus with distilled water. The digest was transferred to a plastic bottle and labelled. The standard stock of each sample was prepared and serially diluted to concentrations of 5 ppm, 10 ppm, 20 ppm, and 25 ppm. These diluents were used to generate a suitable curve, which was used to calibrate the instrument. The diluents were then fed into the UNICAM atomic absorption spectrometer (model 969) to determine the levels of Pb, As, Cd, Cr, and Cu.

Quality control and assurance

Analytical-grade reagents were used throughout. Glass wares were immersed in 10% nitric acid for 24 hours and rinsed with ultrapure water, followed by a 0.5% (w/v) $KMNO_4$ solution, and ultrapure water again. Blank samples were analysed alongside the test samples to check for background contamination. Each sample was analysed three times, and the reproducibility of the same values was ensured at 95% accuracy. Accuracy and precision were verified by using reference material. The blank samples analysed indicated that the analyses were performed within the certified range of 96–100% recovery for the heavy metals that were evaluated.

Health risk assessment

The non-carcinogenic health risks of daily consumption of the water were calculated from equations 1 and 2 (Yahaya *et al.*, 2020).

$$ADI= \frac{CoH \ x \ IR \ x \ EF \ x \ ED}{ABW \ x \ AT} \quad \text{--------------------------------------} \ (1)$$

In equation 1, *ADI* is the average daily ingestion of heavy metals in mg/kg/day, *CoH* is the concentration of heavy metals in water (mg/L), *IR* denotes the ingestion rate per unit time (L/day) = 2, *EF* means exposure frequency (days/year) = 365, *ED* stands for exposure duration (years) = 55 (life expectancy of a resident Nigerian), *ABW* indicates average body weight (kg) = 65, and *AT* is the average time (*Ed* x *Ef*) = 20075.

$$ADDE = \frac{CoH\ x\ ESSA\ x\ AF\ x\ DAF\ x\ EF\ x\ ED}{ABW\ x\ AT} \tag{2}$$

In equation 2: *ADDE* means average daily dermal exposure mg/kg/day; *ESSA* stands for exposed skin surface area (cm^3) = 28,000; *AF* is the adherence factor ($kg/m^2/day$) = 0.7; *DAF* denotes dermal absorption factor (cm/h) = 0.0006 for Cu, 0.0006 for Cd, 0.0002 for Cr, and 0.004 for Pb, and 0.0006 for As.

$$HQ\ for\ Oral = \frac{\mathbf{ADI}}{\mathbf{RFD}} \tag{3}$$

$$HQ\ for\ Dermal = \frac{\mathbf{ADDE}}{\mathbf{RFD}} \tag{4}$$

In equations 3 and 4, *HQ* stands for hazard quotient, while *RFD* represents the reference dose in mg/L/day. The *RFD* (oral/dermal) of Pb, Cd, Cr, Cu, and As are 0.0035/0.000525, 0.0005/0.00001, 0.0003/0.00006, 0.04/0.012, and 0.0003/0.0008, respectively.
The carcinogenic risks of the water were calculated from equations 5 and 6.

$$CR\ for\ Oral = ADI\ x\ CSF \tag{5}$$

$$CR\ for\ dermal = ADDE\ x\ CSF \tag{6}$$

In equations 5 and 6, *CR* stands for carcinogenic risk of oral or dermal exposure to heavy metals in water, and *CSF* represents cancer slope factor (mg/kg/day). The *CSF* for Pb is 0.0085, Cd is 6.3, Cr is 0.5 Cu is 0.00, and As is 1.5. A *CR* value greater than 10^{-6} was considered potentially carcinogenic.

Microbiological analysis

The microbial populations (total bacteria, total coliforms, and fungi) in the sampled water were estimated using the membrane filtering method described by Brock (1983). A sterile cellulose filter was used to filter 100 mL of the sampled water, which was then incubated on nutrient agar medium for 24 hours at 36 °C. The number of bacteria that grew on the medium was counted using a colony counter. The coliform population in the water was estimated using the two-step enrichment method. The filter contaminated with bacteria was first placed on a lauryl tryptose broth medium and subsequently placed on M-Endo media. These two media were incubated for 3 hours and 22 hours, respectively, at 34 °C.The growing coliforms were then counted. The fungal population was also estimated using nutrient agar, but to inhibit bacterial growth, an antibiotic was added to the medium (Babič *et al.*, 2017).

Data analysis

The levels of heavy metals and physicochemical parameters of the sampled water were presented as mean ± standard deviation (SD) using the excel software version 21. The software was also used to calculate the *ADI*, *ADDE*, HQ, and *CR* of heavy metals in the sampled water. Statistical analysis was done using the Student's *t*-test, in which $p \leq 0.05$ was considered statistically significant.

RESULTS

Physicochemical parameters of the water samples

Table 1 reveals the physicochemical parameters of water samples collected from boreholes around Simpson Transfer Loading Station in Lagos. All of the physicochemical parameters were above the limits allowed by the World Health Organization (WHO), except for the pH, acidity, alkalinity, magnesium and sulphate for both dry and wet season. The parameters were significantly ($p \leq 0.05$) higher in the wet season than in the dry season.

Table 1: Mean physicochemical parameters of water samples collected in borehole around Simpson Transfer Loading Station in Lagos

		Concentration		
Parameters	**Unit**	**Dry**	**Wet**	**Limit (WHO, 2017)**
pH	-	6.5±0.17^a	7.4±0.15^b	6.5-8.5
Color	-	Cloudy	Cloudy	-
Odor	-	Foul smells	Foul smells	-
Electrical conductivity	µS/cm^3	3467.24±29.23^a	3850.56±47.5^b	≤1000
TDS	mg/L	1698.94±14.32^a	1872.40±65.3^b	≤1000
Alkalinity	mg/L	0.000^a	50.60±3.14^b	≤200
Acidity	mg/L	22.87±2.31^a	0.000^b	≤200
Hardness	mg/L	422.87±10.50^a	892.47±10.06^b	≤200
Calcium	mg/L	169.33±7.16^a	356.99±5.45^b	≤200
Magnesium	mg/L	61.71±4.14^a	130.02±6.16^b	≤150
Chloride	mg/L	408.58±40.03^a	907.07±51.32^b	≤250
Sulphate	mg/L	37.51±6.30^a	305.43±5.17^b	≤ 750
Nitrate	mg/L	54.85±1.08^a	63.93±1.37^b	≤ 50
Phosphate	mg/L	0.18±0.01^a	1.32±0.10^b	≤ 0.1

Values in the same row with different superscripts are significantly different at $p \leq 0.05$ (Student's-*t*-test)

Levels of heavy metals in the water samples

Table 2 shows the levels of heavy metals (Pb, As, Cu, Cd, and Cr) in the water samples. All of the heavy metals were above the WHO permissible limits during the wet season while the heavy metals were within the permissible limits during the dry season, except Cu.

Table 2: Mean levels of heavy metals in water samples collected in borehole around Simpson Transfer Loading Station in Lagos

	Concentration (mg/L)		
Heavy metal	**Dry season**	**Wet season**	**Limit (WHO, 2017)**
Pb	1.07±0.01^a	2.67±0.02^b	≤ 0.01
As	BDL	0.037±0.01	≤ 0.01
Cu	2.07±0.004^a	2.87±0.13^a	≤ 0.05
Cd	0.002±0.0005^a	0.040±0.001^a	≤ 0.003
Cr	0.014±0.001^a	0.11±0.005^a	≤ 0.05

Values in the same row with the same superscript are not significantly different at $p \geq 0.05$ (Student's-*t*-test)

Non-carcinogenic risks of the water samples

The average daily ingestion (*ADI*), average daily dermal exposure (*ADDE*), and hazard quotients (*HQ*) of the heavy metals in the water samples are depicted in tables 3, 4, and 5. The *ADI* and *ADDE* of heavy metals in water samples were within the recommended dietary intake (*RDI*), except the *ADDE* Pb. This implies that, the *HQ* of all the heavy metals was greater than the threshold of 1.

Table 3: Average daily ingestion (*ADI*) and average daily dermal exposure (*ADDE*) to heavy metals in the water samples obtained from boreholes around Simpson Transfer Loading Station in Lagos

Heavy Metals	Exposure route (mg/day/person) Oral Dry season	 Wet season	 Dermal Dry season	 Wet season	*RDI* (WHO, 2017)
Pb	0.0330^{a}	0.0800^{b}	1.2905^{a}	3.1360^{b}	0.214
As	0.0000^{a}	0.0010^{b}	0.0000^{a}	0.0060^{b}	0.002
Cu	0.0640^{a}	0.0880^{a}	0.3750^{a}	0.5190^{b}	0.900
Cd	0.00005^{a}	0.0010^{b}	0.0003^{a}	0.0070^{b}	0.06
Cr	0.0004^{a}	0.0034^{b}	0.00008^{a}	0.0060^{b}	0.05

RDI= recommended daily intake; values in the same row with different superscripts are significantly different at $p \leq 0.05$ (Student's-*t*-test).

Table 4: Hazard quotient (*HQ*) of heavy metals via oral daily ingestion (*ADI*) of water samples obtained in boreholes around Simpson Transfer Loading Station in Lagos

Heavy metal	Values Dry season	 Wet season
Pb	9.425^{a}	22.85^{b}
As	0.000^{a}	3.333^{b}
Cu	1.600^{a}	2.200^{b}
Cd	0.100^{a}	2.000^{b}
Cr	1.333^{a}	11.33^{b}

Values in the same row with different superscripts are significantly different at $p \leq 0.05$ (Student's-*t*-test)

Table 5: Hazard quotient (*HQ*) of heavy metals via dermal exposure to water samples obtained from boreholes around Simpson Transfer Loading Station in Lagos

Heavy metal	Values Dry season	 Wet season
Pb	2458.0^{a}	5973.3^{b}
As	0.000^{a}	7.500^{b}
Cu	31.25^{a}	43.25^{b}
Cd	30.00^{a}	700.0^{b}
Cr	08.00^{a}	100.0^{b}

Values in the same row different superscripts are significantly different at $p \leq 0.05$ (Student's-*t*-test)

Carcinogenic risks of the water samples

The carcinogenic risk of oral and dermal exposure to carcinogenic heavy metals in the water samples, namely; Pb, As, Cd, and Cr were represented in Tables 6 and 7. The carcinogenic risks of oral and dermal exposure to the heavy metals were greater than the threshold of 10^{-6}.

Table 6: Carcinogenic risks of average daily ingestion (*ADI*) of heavy metals in water samples obtained in boreholes around Simpson Transfer Loading Station in Lagos

Heavy metal	Values Dry season	 Wet season
Pb	0.00028^{a}	0.00068^{b}
As	0.0000^{a}	0.00005^{b}
Cd	0.00031^{a}	0.0063^{b}
Cr	0.0002^{a}	0.0017^{b}

Values in the same row with different superscripts are significantly different at $p \leq 0.05$ (Student's-*t*-test)

Table 7: Carcinogenic risks of dermal exposure to heavy metals in water samples obtained in boreholes around Simpson Transfer Loading Station in Lagos

	Values	
Heavy metal	Dry season	Wet season
Pb	0.0108[a]	0.0266[b]
As	0.0000[a]	0.00015[b]
Cd	0.0019[a]	0.0441[b]
Cr	0.0002[a]	0.0017[b]

Values in the same row with different superscripts are significantly different at $p \leq 0.05$ (Student's-*t*-test)

Microorganisms in the water samples

Table 8 shows the microorganisms detected in the water samples. The water contained non-permissible levels of total bacteria, with water collected in the dry season being more contaminated than the wet season. Meanwhile, coliform and fungi were undetected in the water samples.

Table 8: Microorganisms isolated from water samples obtained in boreholes around Simpson Transfer Loading Station in Lagos

Microorganisms	Dry season	Wet season	Limit
Total bacteria	6.0×10^{-4}	3.0×10^{-1}	≤100CFU/mL
Total fungi	0.00	0.00	≤50 CFU/mL
Total coliforms	0.00	0.00	0.00

DISCUSSION

The Simpson Transfer Loading Station was established in Lagos Island, Nigeria to reduce the volume of waste generated in the area before being transported to dumpsites. This was aimed at reducing the turnover time of waste and the number of trucks loading waste to dumpsites, thereby saving on the cost of managing waste. As it can be seen in Table 1, the physicochemical parameters of borehole water samples collected during dry and wet seasons, including electrical conductivity, TDS, hardness, calcium, chloride, sulphate, nitrate, and phosphate, were above the regulatory limits of the WHO. This suggests that leachate from the facility has contaminated the surrounding groundwater and is therefore not suitable for consumption in its current form. A similar study conducted by Okunowo *et al.* (2020) also reported that leachates from the Abule-Egba dumpsite in Lagos infiltrated surrounding groundwater. Moreover, Majolagbe *et al.* (2011); Alabi *et al.* (2021) reported non-permissible levels of some physicochemical parameters in borehole water obtained around dumpsites in Iju and Iwaya, both in Lagos, respectively. In the same vein, Adeyi and Majolagbe (2014); Yahaya *et al.* (2022a) reported excessive levels of some physicochemical parameters in borehole water around Obalende, Olusosun, and Solus dumpsites in Lagos. However, Ige *et al.* (2022) reported permissible levels of all the physicochemical parameters tested in samples of borehole water obtained around the Igando dumpsite, Lagos. The high concentration of TDS in the water could be caused by the high concentrations of detected inorganic salts; calcium, magnesium, chlorides, and suphate, as well as some dissolved organic compounds (Drinking-water extension, 2019). These salts might have emanated from sewage, municipal and agricultural waste in the facility, as well as chemicals used in the facility for waste treatment and the wastewater disposed into the built environment. At permissible doses, Ca and Mg in drinking water may interact to lower cardiovascular disease, but excessive amounts can increase the risk and mortality of cardiovascular disease (Rapant *et al.*, 2017). Ingestion of large quantities of chlorides or phosphate may cause gastrointestinal symptoms such as stomach discomfort, mucous membrane damage, as well as ulceration in some cases (Kumar and Puri, 2012; Kończak and Janson, 2021). Excessive ingestion of nitrate can result in methemoglonaemia in children, which may progress to mental retardation if the child survives (Isiuku and Enyoh, 2020). Generally, chloride, phosphate, and sulphate anions are acidic and, when ingested in high concentrations, disrupt the acid-base balance, creating more acidic conditions, a process that can result in acidiosis (Enyoh *et al.*, 2018). On the other hand, extreme basic ion concentrations such as potassium, magnesium, and calcium can cause repolarization disturbances, conduction abnormalities, and cardiac arrhythmias (Noordam *et al.*, 2019). The hardness, cloudiness, as well as the high electrical conductivity of the water may be attributed to their high concentration of TDS (Weber-Scannell *et al.*, 2007). Physicochemical parameters were higher during the wet season, possibly because rain water speeds up the breakdown of organic waste and the movement of leachate into the environment.

The non-tolerable levels of Pb, As, Cu, Cd, and Cr detected in the water samples obtained in dry and wet seasons further prove that the water may not be ideal for drinking. This result is consistent with that of Adeyi and Majolagbe (2014); Yahaya *et al.* (2022b), both of whom detected non-permissible levels of selected heavy metals in groundwater near Olusosun and Solus dumpsites in Lagos. Ogunrinola *et al.* (2020) documented excessive concentrations of selected heavy metals in groundwater around Solus dumpsite in Lagos. Ajibola (2016); Olorunfemi *et al.* (2020) also reported leaching of heavy metals from Abule-Egba dumpsite and Ewu-Elepe (Ikorodu) dumpsite, both in Lagos, into the surrounding soil. Some heavy metals perform biological functions in the body, but they become toxic at certain doses (Uddin *et al.*, 2021). Adults exposed to Pb can experience cardiovascular diseases, increased blood pressure and hypertension, decreased kidney function, and infertility, while even low levels of Pb in the blood of children can cause cognitive impairment and anemia (USEPA, 2022). Long-term exposure to As from drinking water can cause cancer, skin lesions, cardiovascular disease, diabetes, as well as cognitive impairment and increased deaths in young adults (WHO, 2018). Short-term exposure to high levels of Cu can cause gastrointestinal problems, while long-term exposure to high doses can cause anemia and disrupt liver and kidney function (WSDOH, 2016). Chronic exposure to Cd above the allowable limits can cause kidney, liver, bone, and blood damage (WQA, 2022). Adverse effects of overexposure to hexavalent Cr include nasal and sinus cancers, kidney and liver damage, skin irritation and ulceration, and eye irritation and damage (USNTP, 2018). Possible sources of Pb in the water include waste containing toys, herbal materials, lead-based paints, metals, lead-acid batteries, cosmetics, and jewelry, among others (NYSDOE, 2010). Detected As in the assayed water samples could have emanated from fossil fuels, agricultural wastes such as arsenical fungicides and herbicides, as well as wood preservatives (Shankar *et al.*, 2014). The presence of Cu ions in the water suggest sources such as industrial waste, electronic waste, and natural metals (Manne *et al.*, 2022). The presence of Cd in the sampled water indicates livestock manures, sludge, plastics, batteries, electroplating, paint, and pigments (Kubier *et al.*, 2019). Cr is widely used in electroplating, stainless steel production, leather tanning, textile manufacturing, and wood preservation, and so Cr in the water could have emanated from waste containing those materials mentioned (USNTP, 2018). The heavy metals were higher during the wet season for the reasons mentioned earlier.

The risk posed by daily consumption of the water was confirmed by its health risk assessment. The average daily dermal exposure (*ADDE*) to Pb via the water exceeded the permissible limits. On top of that, the hazard quotient (*HQ*) and carcinogenic risk (*CR*) of oral and dermal exposure to all the heavy metals exceeded the allowable concentrations. This means that consumers of borehole water who have lived up to 55 years in the area may experience both non-carcinogenic and carcinogenic risks from the evaluated heavy metals. Consumers that have lived beyond the mentioned age may experience more severe symptoms of the risks. This is so because the health risk evaluation was based on the life expectancy of residents in Nigeria, which is 55 years. While most heavy metals induce non-carcinogenic risks through related mechanisms, mainly the generation of reactive oxygen species, each carcinogen among the heavy metals induces cancer through specific mechanisms. Pb causes cancers by interacting with zinc finger proteins, causing oxidative stress that alters cell signaling pathways and induces apoptosis (Muhle and Steenland, 2006). As inhibits DNA replication or repair, it interferes with tissue respiration and oxidative stress (Ebele, 2009). Cd alters signaling events in the cells, causing epigenetic changes that hinder DNA repair and boost apoptosis (Cui *et al*., 2021). Hexavalent Cr undergoes intracellular reduction to trivalent Cr, which ultimately interacts with and causes the DNA damaging events, leading to neoplastic transformation of cells and ultimately cancer (O'Brien *et al*., 2003). After a long time of accumulation around the cell membrane, trivalent Cr can rupture it and cause DNA damage (Wise and Wise, 2012).

The detection of non-allowable bacteria counts in the water samples further buttressed the risk posed by daily consumption of the water. Meanwhile, coliforms and fungi were not detected in the water samples. This result is in line with Ige *et al*. (2022), who detected some quantities of bacteria in borehole water samples collected near Igando dumpsite, Lagos, and like the current study, coliforms were not detected. However, the levels of bacteria detected in the current study were far higher than those detected by Ige and his co-researchers. Contrarily, in addition to bacteria, Oluseyi *et al*. (2014) detected non-permissible levels of coliform and fungi in well water obtained near Oke-Alfa and Olusosun dumpsites, both in Lagos. Adeyemi *et al*. (2007) also detected bacterial species, coliforms, and fungi in groundwater obtained near Odo Iya Alaro landfill in Ojota, Lagos. Food waste, pet feces, absorbent products, sewage, biosolids, glass, metals, plastic, paper, and some organic wastes in the facility could probably be the source of bacteria in the water (Gerba *et al*., 2011). The microbial populations were higher during the dry season because the high temperature and relative humidity provided favorable environmental conditions for microorganisms (Nair, 2021). Though many bacterial species play a beneficial role, some can cause cholera, diarrhea, dysentery, respiratory diseases, gastrointestinal diseases, among others (Yahaya *et al*., 2019). Considering the large quantities of bacteria in the water samples, a study is needed to unravel why coliform and fungi were absent. However, the absence of coliform could suggest the absence of fecal matter.

CONCLUSION

Water samples collected from boreholes near the Simpson Transfer Loading Station contained non-permissible levels of physicochemical properties, namely; TDS, hardness, calcium, chloride, sulphate, nitrate, phosphate, and electrical conductivity. The water also contained non-tolerable levels of heavy metals, including Pb, As, Cu, Cd, and Cr, as well as microbiological populations, mainly bacterial species. The health risk assessment of the water revealed that dermal exposure to Pb as well as the hazard quotient and carcinogenic risk of all the heavy metals detected exceeded the permissible limits. The water was more contaminated during the wet season than during the dry season, possibly due to increased decomposition of organic waste and mobility of the leachate by rain water. Overall, the results showed that the water is not ideal for consumption in its current state.

Based on the study's results, before sinking groundwater, advice from an expert should be sought to find a safe place. Moreover, consumers should ensure proper treatment of water before consumption. Sources of environmental contamination within the facility should be identified, and environmental safety measures compliance should be ensured by the management of the facility. Periodic monitoring of groundwater in the area is also advised.

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