Journal of Civil Engineering, Science and Technology

Volume 16, Issue 2, September 2025, 196-209

GEOSPATIAL EFFECTS OF LANDFILL LEACHATE ON GROUNDWATER PHYSICOCHEMICAL PROPERTIES AROUND OLUSOSUN DUMPSITE, LAGOS, NIGERIA

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Date received: 31/07/2024 Date accepted: 06/08/2025

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DOI: 10.33736/jcest.7511.2025

Abstract — Improper waste disposal is a major environmental concern. Limited resources and technology often force areas like Lagos to rely on dumpsites. However, poorly managed dumpsites can significantly harm the environment and human health. This study investigates the impact of the Olusosun dumpsite on nearby groundwater physicochemical properties. Twenty-five water samples were collected from boreholes surrounding the dumpsite and analysed in the laboratory. GPS coordinates were recorded for each sample. The Inverse Distance Weighting interpolation technique was used for interpolation of results between sampled points, creating a more complete picture of physicochemical properties of water across the study area. Test results of physicochemical properties of samples collected were compared to World Health Organisation (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ) standards. The findings showed that all the water samples had a high lead concentration. More than 50% of the water samples have zinc and copper concentrations higher than WHO and NSDWQ standards. Similarly, 52% of water samples have values outside of the normal range. Results also revealed a higher concentration of physicochemical properties in locations close to the landfill, and this reduces as the distance from Olusosun landfill increases. The study recommends an alternative source of water consumption for residents around the landfill or a proper treatment of groundwater before consumption.

Keywords: landfill, Olusosun dumpsite, groundwater quality, pollution, environmental degradation

1.0 INTRODUCTION

Cities are getting bigger, and the amount of waste generated from these cities is fast outpacing the waste management provisions. This waste is a result of our consumption habits, and throwing it all away isn't the answer. Landfills, the traditional way of dealing with trash, can actually pollute our groundwater, as the US Environmental Protection Agency confirmed in 2008. But there's good news! Trash isn't just useless stuff. With new technologies and better recycling programmes, we can give old materials new life. This reduces waste and creates benefits for society and the economy. There are many challenges to managing waste effectively. The types of trash we throw away keep changing as our lifestyles and manufacturing processes evolve. Occasionally, regulations regarding waste management are either unclear or poorly implemented. And as cities grow, they generate even more trash, making it harder to keep up. There are different ways to classify waste. Biodegradable waste can decompose naturally, while non-biodegradable waste can't. Toxic waste is harmful, while non-toxic waste isn't. Some waste dissolves in water (soluble), and some doesn't (insoluble). Hazardous waste requires special handling because it's so dangerous. Solid waste is simply any unwanted or leftover material we throw away after we're done with it. This can be food scraps (organic waste) or things like plastic bottles and packaging (inorganic waste). Homes, businesses, factories, and schools all produce solid waste. In short, anything solid that someone throws away can be considered solid waste.

Groundwater is the water stored underground. It mostly comes from rain and snow that soaks into the ground and filters through layers of soil. Surface water can also contribute to groundwater through a process called percolation. Here in Lagos, Nigeria, several studies have investigated how dumpsites affect the quality of the water beneath them. The World Health Organisation (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) set guidelines for safe drinking water. Research by Adedibu [1] compared water quality around dumpsites, while Mandindi et al. [2] focused on a specific landfill and did detailed lab tests. Longe and Enekwechi [3] also studied groundwater quality in the Olusosun area. There are several factors that influence how a dumpsite affects nearby groundwater. The types of trash in the landfill (its composition) make a big difference in how likely it is to cause contamination. Highly compacted landfills are less likely to leak liquids that can pollute groundwater. The amount of leachate (the liquid that drains from landfills and can contain contaminants) also plays a role—the more leachate, the higher the risk of contamination. Oyeku and Eludoyin [4] investigated the effect of landfill leachate on groundwater contamination in a case study of Obio-Akpor LGA in Rivers State. They discussed a study in Nigeria that found leachate from a dumpsite seeped into the underlying aquifer, contaminating the groundwater. Iboroma et al. [5] explore how an open dumpsite in Nigeria polluted nearby groundwater with high levels of contaminants. The study revealed that the closer a water source was to the dump site, the higher the level of contamination. Rajesh et al. [6] reviewed various studies on the impact of dumpsites on groundwater. The studies employed different methods to assess the spread of leachate contamination and the resulting groundwater pollution. Climate and rainfall patterns affect how quickly contaminants move through the landfill. Shallow groundwater sources are more at risk of contamination than those located deeper underground. Around the world, people are becoming increasingly concerned about groundwater pollution. Afolayan et al. [7] point out that population growth and rapid industrialisation are putting a strain on our freshwater resources, making them especially vulnerable to contamination from landfills. Pollution can happen when harmful substances like oil, gasoline, trash, pesticides, and fertilisers seep into the ground.

This contamination is a serious threat because groundwater is a vital source of drinking water, alongside sources like lakes, rivers, and streams. Protecting groundwater is essential for ensuring safe drinking water supplies for everyone. Groundwater is the major source of water consumption in many parts of Lagos and particularly around Ojota, where Olusosun landfill is located. This is because the public water supply in Lagos has become ineffective, and only limited parts of Lagos are supplied with public water. There is the need for a concerted effort in preventing groundwater contamination from waste, including governments, communities, organisations, and individuals. Previous studies, however, did not examine the geospatial effect of the landfill on groundwater in the study area. This study investigates the impact of the Olusosun dumpsite in Ojota, Lagos State, Nigeria, on nearby underground water facilities. To assess the impact of the Olusosun dumpsite on nearby groundwater, a multi-step approach was employed, which includes mapping the dumpsite. The precise location and delineation of the Olusosun dumpsite on a map of Lagos was done; Identifying Water Sources—Using GPS technology, we pinpointed the locations of underground water facilities surrounding the dumpsite; Water Sample Collection—Water samples were collected from these identified facilities; Water Quality Analysis—Laboratory tests were conducted to determine the physical and biochemical characteristics of the water samples. Geospatial Analysis: The test results were analysed using geospatial techniques to map potential contamination patterns.

This research addresses the gaps in previous studies by combining both laboratory analysis of water samples and geospatial analysis to map the spread and patterns of groundwater contamination. This comprehensive approach provides a clearer understanding of the impact of dumpsites on groundwater quality in Lagos.

1.1. Study Area

The Olusosun dumpsite in Lagos, Nigeria, is a significant waste management challenge. Located along the Lagos-Ibadan Expressway in Ojota, it occupies roughly 42.7 hectares (105 acres) of land and is estimated to be 7 metres deep (Lagos Waste Management Authority (LAWMA), 2011). Notably, the site previously served as a laterite mine before becoming a landfill in 1992 (Lagos State Government, Nigeria, 2011). Situated between 6°23′N; 2°42′E and 6°41′N; 3°42′E [8], the dumpsite is bordered by Oregun Industrial Estate, Ojota Residential, Ikosi Residential, and Oregun Residential Areas. These surrounding areas, particularly those closest to the landfill, are the focus of this study examining boreholes for potential groundwater contamination. Olusosun is known to be one of the largest dumpsites in Africa, receiving an estimated 10,000 tonnes of waste daily. Its proximity to residential areas and its vast size raise concerns about its environmental impact, making it a crucial site for investigation. The study area is as presented in Figure 1.

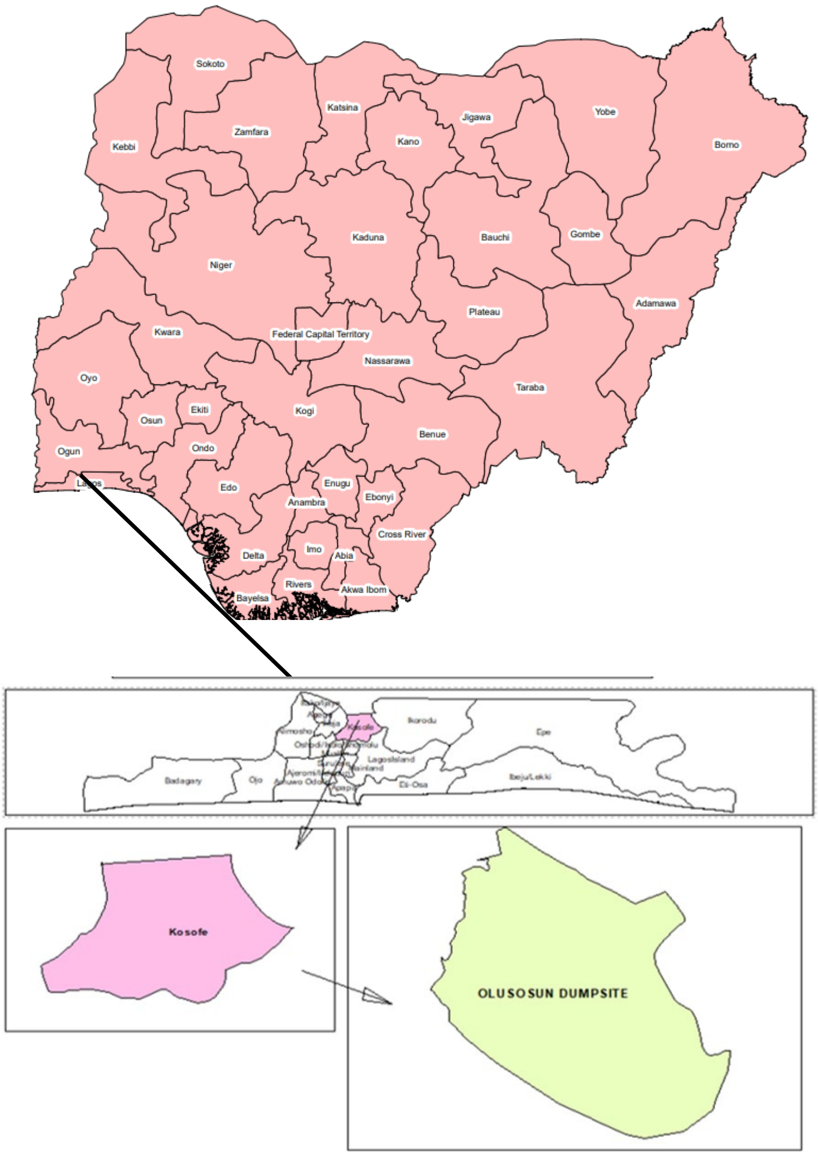

Figure 1 Map of Lagos showing the study area

2.0 MATERIALS AND METHODS

This section deals with the materials and methods deployed in the implementation of the objectives of the study.

2.1. Data Collection

This section explains how the relevant data in this study were acquired in the execution of the aim and objectives of the study.

2.1.1. Sample collection

The study involved collecting leachate and groundwater samples from the Olusosun dumpsite and surrounding areas for laboratory analysis. Due to the dry weather conditions in February, obtaining sufficient leachate and borehole water proved challenging. Sample integrity was protected by collecting water in pre-sterilised 750 ml screw-capped plastic containers to prevent physical, chemical, and microbial contamination. Other standard methodology for groundwater sample collection, such as well purging, sample handling, and documentation [4], was strictly observed to ascertain data reliability. Global Positioning System (GPS) coordinates were recorded for each sample point. To comprehensively assess the study area, we collected a total of 25 borehole water samples. These samples underwent analysis for various physical, chemical, and bacteriological water quality parameters at the University of Lagos Chemical Laboratory Department. See Table 1 for the data collected in this section.

2.1.2. Analysis of the physicochemical characteristics of water

The chemical and physical properties of the water samples were analysed at the University of Lagos Chemical Laboratory Department. This analysis included physical **characteristics (colour** and total hardness); **metals (zinc, iron,** copper, and lead); and **chemical parameters—total dissolved solids** (TDS) and pH. Table 1 contains the various water analyses performed to get the different water parameters. A detailed analysis of the methodologies adopted can be found in the relevant literature cited in the table.

Table 1 Water Physicochemical Characteristics and Method of Analysis

SN	Water Characteristics	Method of Analysis
1	Total Hardness of Water	Rand Water Classification [9]
2	Water Colour	Visual Examination [10]
3	Heavy metals	Flame Photometric [11]
4	Total Dissolved Solid	direct measurements [12]
5	pH	pH mater [13]

The locations of these 25 borehole water sources in relation to the location of the Olusosun landfill are presented in Figure 2. The Inverse Distance Weighting interpolation technique was used to estimate values between sampled points, creating a more complete picture of water quality variations across the study area [14]. Maps were then generated to show the variations of different physical and chemical properties of the water around Olusosun landfill. Further correlation analysis was carried out between parameters and distance to landfill so as to show the contamination severity.

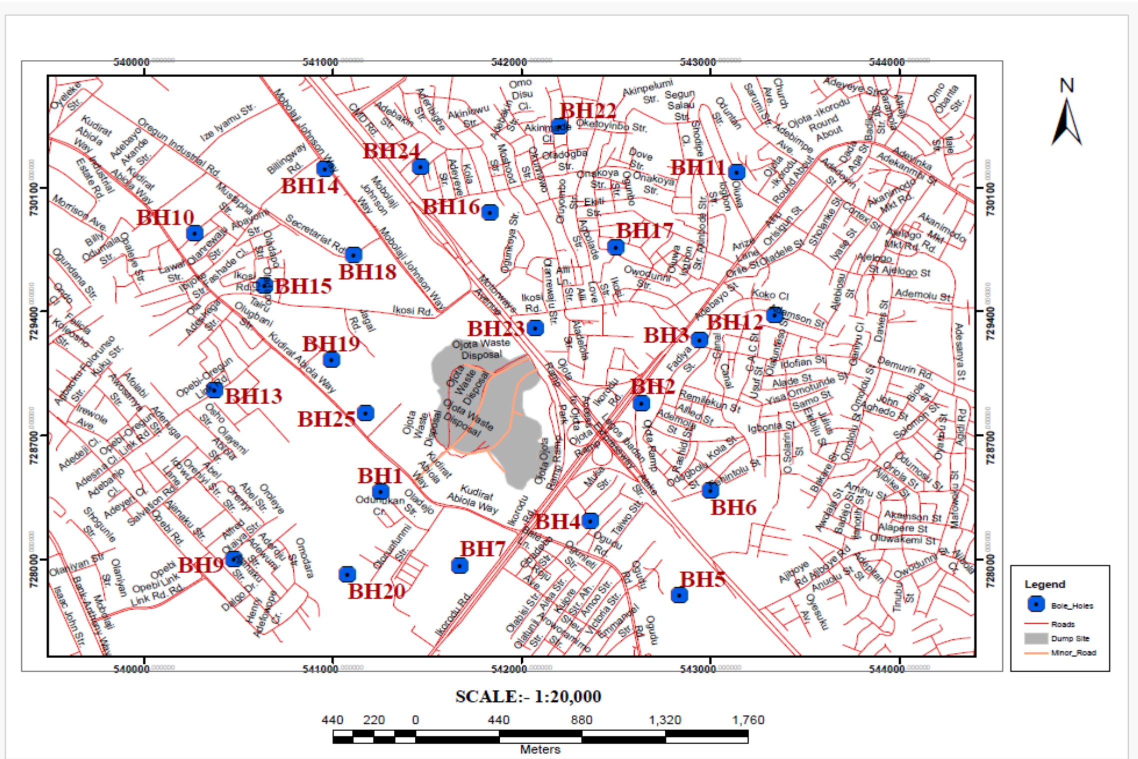

Figure 2 Spatial distribution of boreholes around the Olusosun landfill

3.0 RESULTS AND DISCUSSION

This section is divided into two parts. The first part presents the pollutant levels found in borehole water and compares them to the established thresholds set by the Nigeria Standard for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO) standards. Moreover, it focuses on geospatial analysis, exploring the relationships between pollution levels and the various parameters measured. The second part focuses on the discussion of the results obtained.

3.1. Results

The parameters that were compared for each of the boreholes collected included electrical conductivity (EC), temperature of the water, total dissolved solids (TDS), and water colour, respectively. WHO (2011) has a standard value of 1000 µS/cm as the maximum permitted level for electrical conductivity, while on the other hand, Nigeria's Standard for Drinking Water Quality has 1000 µS/cm. The standard for Total Dissolved Solids for both WHO (2011) and NSDWQ (2015) is 500mg/l, respectively. The temperature allowed for by WHO (2011) is given as 25°C, while that of NSDWQ (2015) is considered as ambient. The parameters measured from the laboratory result are compared to both the World Health Organisation (2011) and Nigerian Standard for Drinking Water Quality (SON) 2015 standards, as shown in Table 2 below. In this study, the physical properties examined are Electrical Conductivity (EC), Total Dissolved Solid (TDS), temperature, and colour, as seen in Table 2. The water analysed from all the boreholes is clear, a first indication for an average individual to assume that the water is suitable for consumption. The temperatures of all the water samples are, however, higher than the WHO standard. If compared to the NSDWQ ambient standard, the results may lead to another assumption that the water is of good quality. EC and TDS are, however, higher in boreholes closer to the landfill, with some exceeding recommended limits. This suggests that dissolved materials, potentially from landfill leachate, may be seeping into the groundwater.

Table 2 Physical Properties of Groundwater Around Olusosun Landfill

BOREHOLE	Distance from Landfill (m)	Elevation (m)	EC (⌠S/cm)	Temp. (^{o}C)	TDS (mg/l)	Colour
NSDWQ (2015)	---	---	**1000**	**Ambient**	**500**	**--**
WHO (2011)	---	---	**1000**	**25**	**500**	**--**
BH1	80	30	1213	28.1	599	Clear
BH2	300	30	998	28.7	576	Clear
BH3	900	30	715	28.1	420	Clear
BH4	450	30	1112	28.5	581	Clear
BH5	1050	20	587	28.5	344	Clear
BH6	900	20	678	28.4	386	Clear
BH7	600	20	985	29.5	550	Clear
BH8	1200	30	412	28.2	278	Clear
BH9	1150	20	387	28.6	256	Clear
BH10	1200	32	492	29.0	312	Clear
BH11	1350	22	362	28.5	197	Clear
BH12	1200	25	315	28.0	162	Clear
BH13	900	30	796	28.4	469	Clear
BH14	900	28	757	28.7	432	Clear
BH15	750	25	869	29.1	528	Clear
BH16	600	32	977	28.3	539	Clear
BH17	750	30	844	28.0	511	Clear
BH18	450	29	1118	28.5	587	Clear
BH19	300	22	1225	28.7	608	Clear
BH20	900	20	800	28.1	488	Clear
BH21	1150	30	309	29.2	149	Clear
BH22	1050	25	463	28.5	300	Clear
BH23	150	24	1256	28.4	634	Clear
BH24	750	31	853	28.6	521	Clear
BH25	150	26	1242	29.0	613	Clear

The results of the physicochemical parameters are presented in Table 3. The result in Table 3 shows that the iron and lead levels near landfills exceed safety standards. Testing water quality is crucial, especially for drinking. This study found high levels of iron and lead in boreholes close to a landfill. These levels surpass the recommended limits set by WHO in 2011 and NSDWQ in 2015, making the water unsafe for consumption. Iron exceeding these limits can make water unpleasant to drink and cause stomach issues. Lead poisoning and blood poisoning are potential risks from lead contamination.

Table 4 presents the summary of results of physicochemical properties of water samples based on the percentages of water samples that meet WHO and NSDWQ standards. According to the results, 48% of water samples have TDS values that are outside of WHO and NSDWQ standards. As for pH and electrical conductivity, the percentages of water samples outside of the prescribed standards are 52% and 24%, respectively. The NSDWQ standard for total hardness of water is not available; however, 12% are outside of the WHO standard. All the water samples meet the NSDWQ iron standard, but 28% fall out of the WHO standard. Results for zinc and lead show that 52% and 100% of water samples are outside of the WHO and NSDWQ standards.

Table 3 Result of Physico-Chemical Parameters

BOREHOLE	PH (H+) Values	Total Hardness of Water	Copper ion (mg/L)	Zinc ion (mg/L)	Iron (Fe) (mg/L)	Lead (Pb) (mg/L)
NSDWQ (2015)	6.5-8.5		1	3	0.3	0.01
WHO (2011)	6.5-8.5	50.00	2	3	0.1	0.01
BH1	6.3	55.00	1.59	4.35	0.19	9.35
BH2	6.41	50.00	1.46	4.08	0.11	8.75
BH3	6.93	20.00	1.16	1.96	0.06	6.76
BH4	6.37	52.00	1.48	4.19	0.13	8.23
BH5	7.54	15.00	0.96	1.66	0.06	5.50
BH6	7.22	25.00	1.09	1.73	0.07	6.88
BH7	6.52	40.00	1.42	4.00	0.09	7.80
BH8	8.86	8.00	0.77	0.83	0.04	4.93
BH9	8.95	6.00	0.72	0.66	0.05	5.00
BH10	7.73	14.00	0.91	1.42	0.03	4.42
BH11	9.00	5.00	0.65	0.59	0.02	3.59
BH12	9.63	4.00	0.59	0.43	0.01	3.43
BH13	6.87	28.00	1.21	2.81	0.08	6.81
BH14	6.90	23.00	1.19	2.33	0.07	6.33
BH15	6.68	38.00	1.35	3.83	0.06	6.98
BH16	6.63	40.00	1.39	3.91	0.07	7.91
BH17	6.81	32.00	1.29	3.20	0.05	7.00
BH18	6.33	43.00	1.53	4.23	0.15	8.23
BH19	6.23	45.00	1.68	4.48	0.21	9.85
BH20	6.83	32.00	1.26	3.11	0.03	6.11
BH21	10.0	4.00	0.48	0.38	0.01	3.38
BH22	8.83	10.00	0.86	0.94	0.02	3.94
BH23	5.62	47.00	1.83	4.64	0.23	11.2
BH24	6.75	38.00	1.33	3.75	0.06	7.24
BH25	5.48	45.00	1.75	4.73	0.24	10.7

Table 4: Summary of the Physicochemical Results as Compared with WHO and NSDWQ Standards

	Total Dissolved Solid (%)	pH (%)	Electrical Conductivity (%)	Total Hardness (%)	Cupper (%)	Zinc (%)	Iron (%)	Lead (%)
Out of Standard	48	52	24	12	68	52	28	100
Remarks				NSDWQ (NA)	WHO (OK)		NSDWQ (OK)	

Note: NA = Standards are not available, OK = water samples meet required standard)

Geospatial analysis was carried out in the Geographic Information Systems (GIS) environment to analyse the physicochemical properties of the collected water samples. pH measures the concentration of hydrogen ions (H). It is an indispensable parameter in the description of chemical processes that are possible in a water sample. pH values range from acidic (0) to basic (14). WHO and NSDWQ, however, state that standard water pH values range between 6.5 and 8.5. Results from this study suggest that as a result of the dumpsite coupled with the natural decomposition of wastes and sedimentation, the pH of borehole water samples close to that dumpsite is acidic (</=5-6) when compared to boreholes further away from the dumpsite (Figure 3).

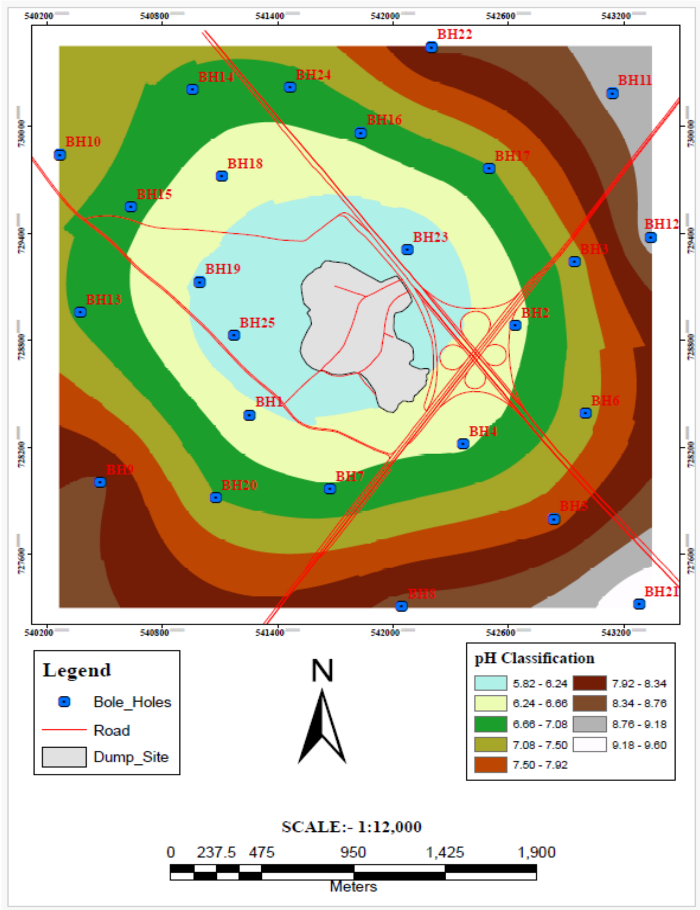

Figure 3: Spatial distribution of the pH of groundwater around Olusosun dumpsite, Lagos

Results from this study indicate that the concentration of TDS of samples closer to the dumpsite shows considerably high values as against water samples quite remote from the dumpsite (Figure 4). High Total Dissolved Solid (TDS) values could also be an indication of possible leachate flow into the groundwater. Figure 4 shows the spatial distribution of total dissolved solids in the twenty-five boreholes and the impact of the landfill on the total dissolved solids of the water. The map shows that the closer the boreholes are to the landfill, the greater the total dissolved solids of the water. Inorganic salts (mostly calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates) and trace amounts of organic materials dissolved in water make up total dissolved solids. Natural sources, sewage, urban runoff, and industrial wastewater are the sources of TDS in drinking water. In certain nations, salts used for road melting may also raise the TDS level of drinking water. Concentrations of TDS in water vary considerably in different geological regions owing to the differences in the solubility of minerals. Results of this study indicate that the concentration of TDS of samples closer to the dumpsite shows considerably high values as against water samples quite remote from the dumpsite.

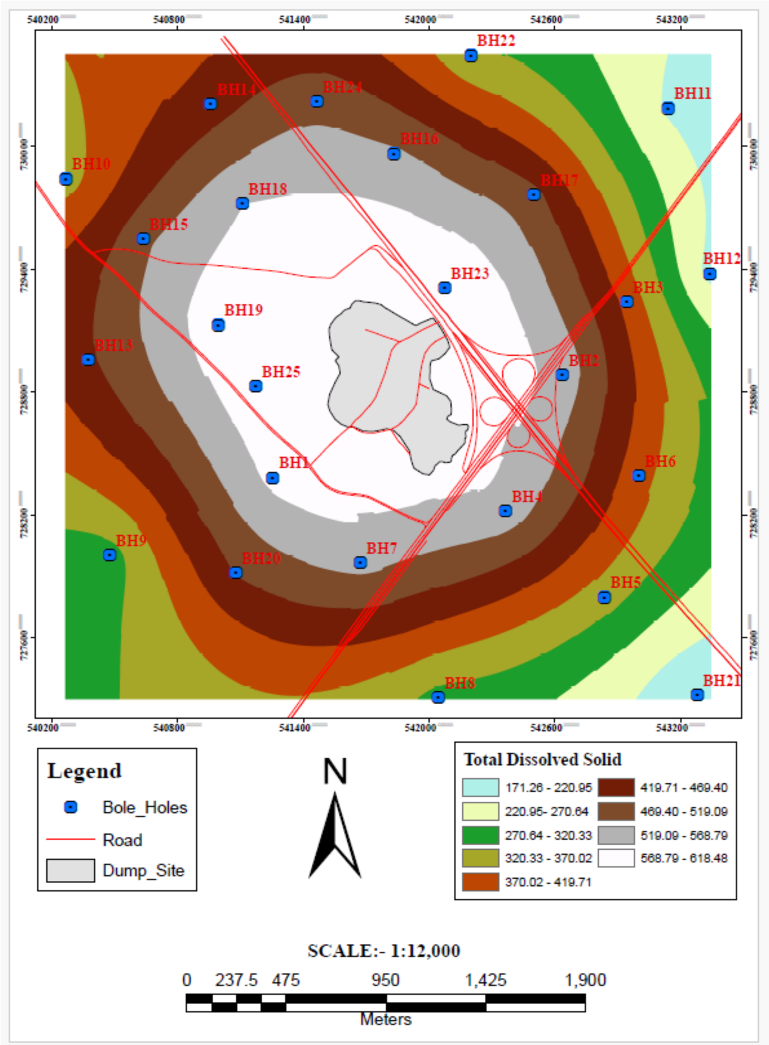

Figure 4: Spatial distribution of the TDS of groundwater around Olusosun Dumpsite, Lagos

The amount of dissolved salts in water, measured by electrical conductivity (EC), affects its taste, usability, and even safety. This is especially important for private wells and boreholes. High EC levels can lead to an unpleasant taste in drinking water, difficulty washing clothes, the feeling of thirst even after drinking (reduced taste quenching), and the potential for diarrhea. EC is also beneficial in identifying areas where freshwater and saltwater mix. The geospatial results of EC levels in water samples around the Olusosun landfill are presented in Figure 5. Results indicate that electrical conductivity is higher as distance to landfill reduces. Iron is a common metal found naturally in rocks and soil. In freshwater sources, iron levels typically range from 0.5 to 50 milligrammes per litre (mg/L). However, iron can also enter drinking water through water treatment (iron coagulants) or from old pipes. The results of the analysis of sampled water in this study revealed elevated iron concentrations beyond both NSDWQ and WHO standards in borehole samples collected near the dump site (Figure 6). This raises concerns about the water's suitability for drinking.

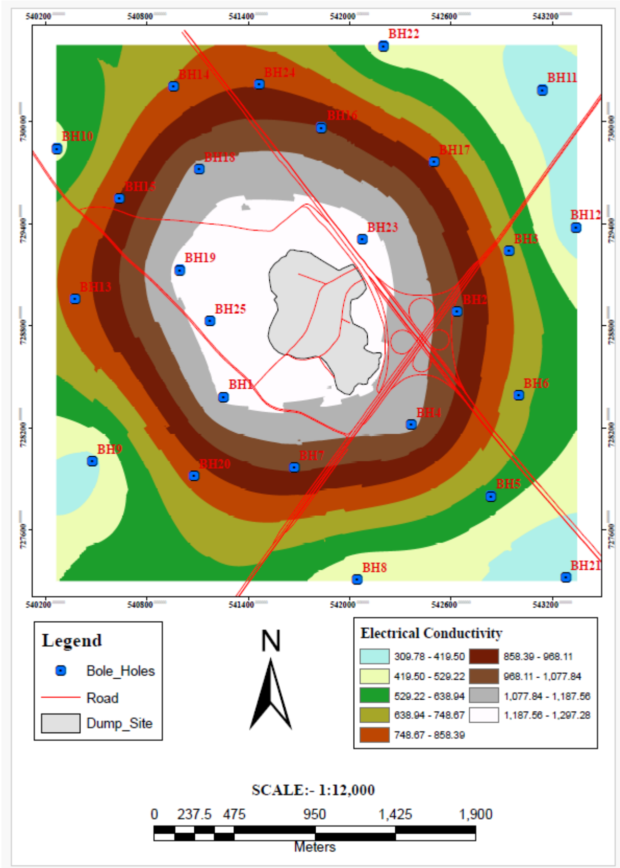

Figure 5: Spatial distribution in the EC of groundwater around Olusosun Dumpsite, Lagos

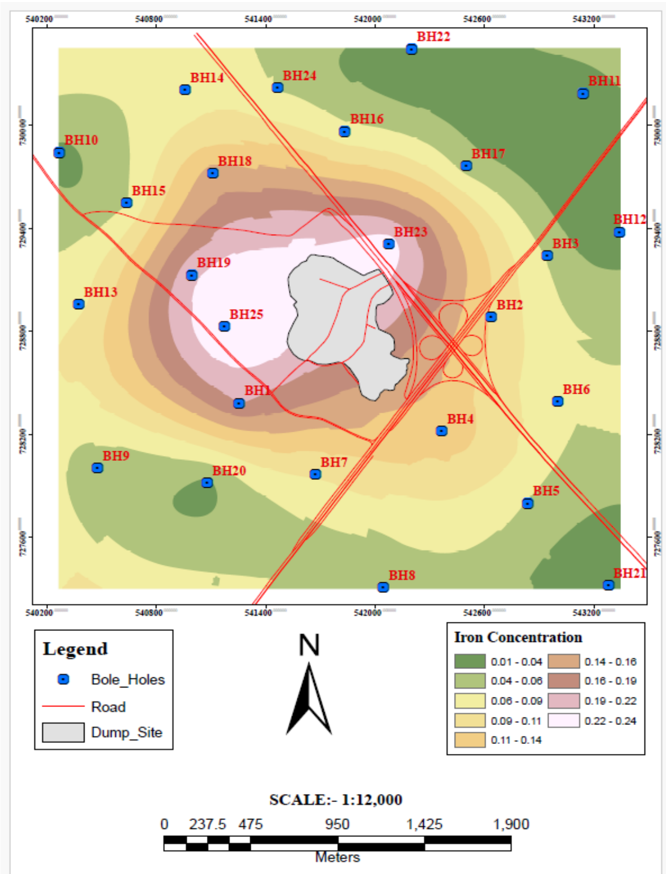

Figure 6: Spatial distribution of Iron (Fe) groundwater around Olusosun Dumpsite, Lagos

The testing also examined lead (Pb), zinc (Zn), and copper (Cu) levels in the water samples. Similar to iron, lead concentrations in boreholes closer to the dumpsite were found to be above the safe limits set by the WHO and NSDWQ standards (Figure 7). This condition makes the water unsafe for drinking. Zinc levels, while elevated in some samples, particularly those near the dumpsite, remained within the permissible range (e.g., 4.69 and 4.73 mg/L) (Figure 8). Copper concentrations showed a clear trend, with higher levels closer to the dumpsite and lower levels further away (Figure 9). This suggests a potential link between the dumpsite and copper contamination.

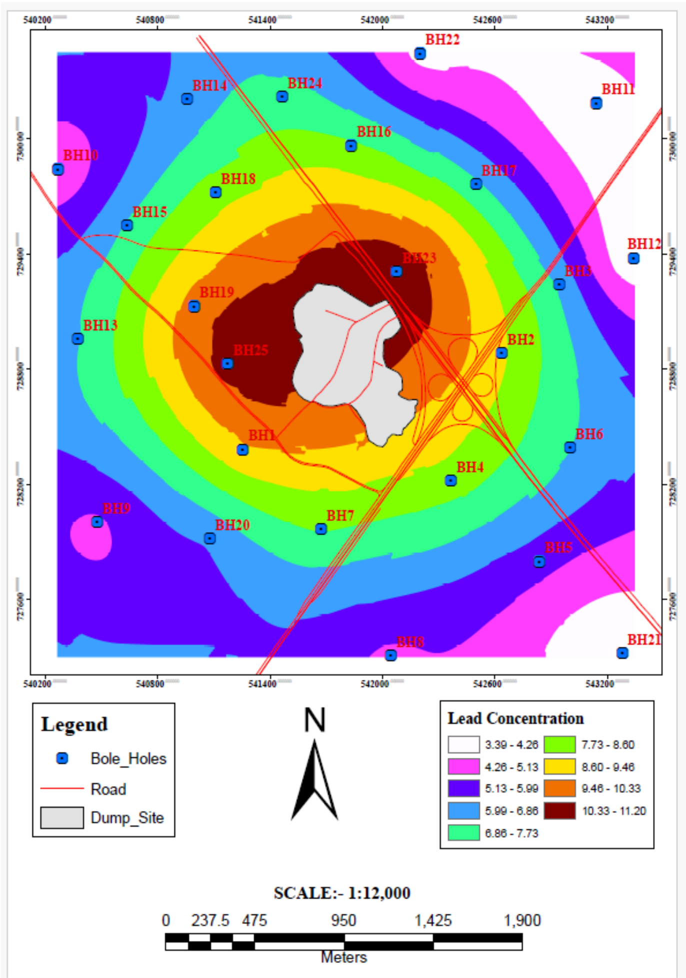

Figure 7: Spatial distribution of Lead (Pb2+) groundwater around Olusosun dumpsite, Lagos

Zinc is one of the trace elements required in the human body for tissue repair and cell replacement [8]. From the results of this study, it can be seen that the level of zinc concentration in some of the samples, especially water samples that are closer to the dumpsite, exhibit high traces of the element when compared to samples farther away (Figure 8). Careful study of the result analysis indicates that there is a significant difference in the level of copper concentration as we move away from the dumpsite. Samples closer to the dumpsite have greater values, while samples that are farther exhibit lower concentration values, and this could be as a result of the change in distance from the dumpsite (Figure 9).

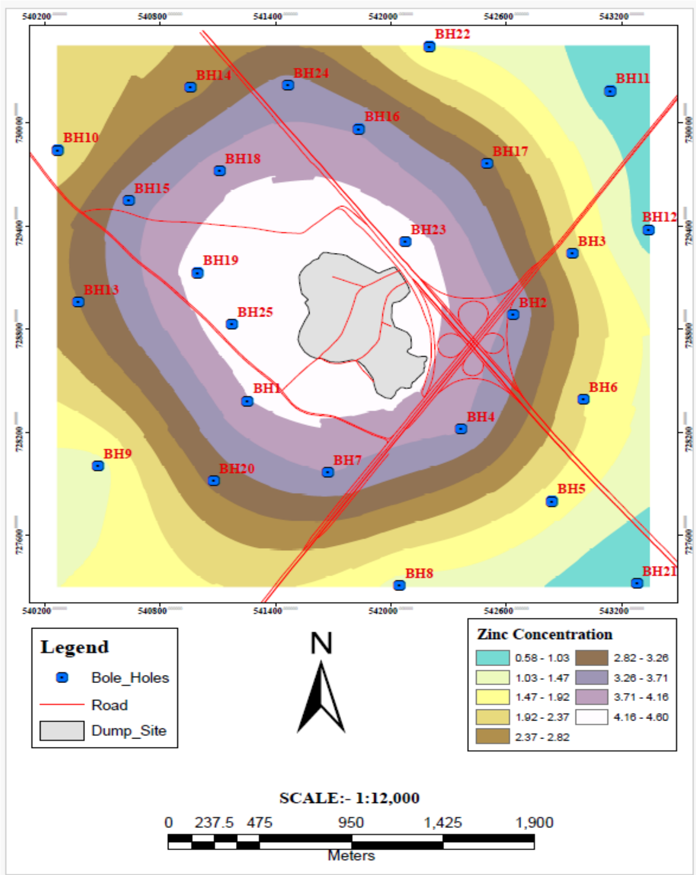

Figure 8: Spatial distribution of Zinc (Zn2+) groundwater around Olusosun dumpsite, Lagos

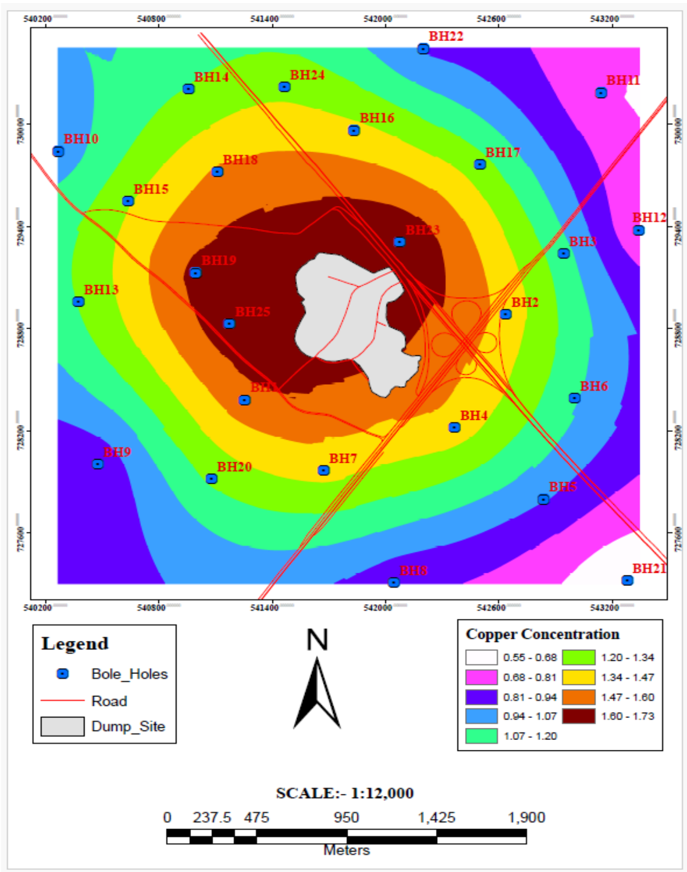

Figure 9: Spatial distribution of Copper (Cu2+) groundwater around Olusosun Dumpsite, Lagos

The results of the 2-tailed correlation analysis between the measured parameters and distance to landfill are presented in Table 5.

Table 5: Results of Correlation Statistics Between Measured Parameters and Distance to Landfill

Parameters	Correlation (r)	P value
Electrical Conductivity (EC)	-0.96	0.00
Temperature	-0.07	0.76
Total Dissolved Solid (TDS)	-0.91	0.00
pH	0.85	0.00
Total Hardness of Water	-0.94	0.00
Copper	-0.94	0.00
Zinc	-0.92	0.00
Iron	-0.90	0.00
Lead	-0.96	0.00

The results of correlation statistics between distance to landfill and the measured parameters show that there is a strong negative correlation between distance to landfill and Electrical Conductivity (EC). The result of the *p*-value ($p<0.05$) is a strong indication that this correlation statistic is significant. Similar results of strong negative correlation can be observed between distance to landfill and Total Dissolved Solid (TDS), total hardness of water, copper, zinc, iron and lead. There is also a strong but positive correlation between distance to landfill and pH value. This data is an indication that as distance to landfill increases, pH value increases significantly. There is, however, no significant correlation between distance to landfill and temperature.

3.2. Discussion

Based on the results presented in Table 2, the distance of water sample points from the landfill ranges from 80 metres (BH1) to 1.35 km (BH11). The sample points were on elevations that range from 20 to 30 metres. The temperature for all water samples ranges between 28°C and 29°C. The fact that Nigeria is located in the tropical region combined with the fact that water samples were obtained during the hot dry season (February) may be responsible for water sample temperatures higher than 25°C. While temperature results are higher than the WHO-recommended temperature (25°C), it may be acceptable with NSDWQ, where the recommended water temperature is ambient. Agudelo-Vera [15] and Senthold et al. [16] had previously stated that ambient water temperature is normal in the tropical region even if it is higher than the WHO-recommended value. Secondly, all the water samples were coloured. These two physical properties may be deceptive, leading to an assumption that these water samples are suitable for consumption. Other physical and chemical properties are, however, required to arrive at this conclusion. Based on results presented in Table 2, EC results of 5 water samples were outside of WHO and NSDWQ recommendations. The five water sample points were less than 500 metres from the landfill. Generally, the electrical conductivity (EC) of water samples decreases as the distance from the landfill increases. This may suggest that being close to a landfill contributes to high electrical conductivity (EC) in water samples. Amano et al. [17] and Przydatek et al. [18] had previously reported that EC of groundwater reduces as the distance of sample points increases from landfill. TDS is another property tested in the water samples. Results in this study show that TDS were higher than 500mg/l with water samples at a distance less than 800 metres. This analysis shows that 12 water samples at distances more than 800 metres away from the landfill have TDS values acceptable by WHO and NSDWQ. It may also be suspected that proximity to a landfill affects TDS water samples in the study area. Zeng et al. [19] had also reported that proximity to landfill can contribute to higher TDS in groundwater, which corroborates the results of this study.

According to the results presented in Table 3, the data indicate that water samples are acidic due to their proximity to the landfill. According to Usman et al. [20], landfill contributes to acidic water and therefore corroborates the findings of this study. Results of total hardness of water show that water samples at points B1 and B4 were outside of WHO recommendations. These points were closer to the landfill, and points farther from the landfill, such as B11 and B12, had far less than the recommended value of 50. Results may also suggest that landfill contributes to the total hardness of water samples in the area. The Cupper content in all the water samples was within the WHO recommended value; however, a larger proportion of the water samples were outside of the NSDWQ recommendation. Spatial results of cupper content show that cupper content increases with proximity to landfill. Ogbaran & Uguru [21] based on the outcome of their study on the effect of landfill on groundwater, reported that groundwater proximity to landfill increases cupper content in groundwater samples. More than half of the water samples that were analysed indicated a zinc content that was higher than the recommended value. Spatial distribution of zinc content in water samples also shows that zinc content reduces with farther distance from landfill. Lead content in all the water samples was outside of the recommended values. Spatial distribution of lead content in water samples increases with proximity to landfill. Results from this study suggest that landfill contributes to high copper, zinc and lead content in water samples analysed. The results agree with the study conducted by [22] and [23], where the authors reported that landfill increases copper, zinc and lead content of groundwater samples. High lead content in all the water samples might suggest that groundwater in the entire study area is not good for consumption. Overall, the study highlights the risks associated with using groundwater near the Ojota landfill and emphasises the need for alternative water sources or proper treatment of water from existing wells before consumption.

Correlation analysis of the leachate parameters and the distance to landfill revealed that the concentration of leachate is a function of the distance of groundwater to landfill. All the parameters analysed, except temperature, have higher concentrations of leachate as the distance to the landfill decreases. The observed temperature of groundwater could be the actual ambient temperature since the recorded temperature ranges are within the temperature ranges in Lagos [24]. This suggests that landfill leachate might not have any effect on groundwater temperature in the study area. While this study is not particularly focused on water quality around Olusosun landfill, observed physicochemical parameters of groundwater in the study area suggest that the water might not be safe for consumption.

4.0 CONCLUSION

Analysis of groundwater near the Ojota landfill in Lagos, Nigeria, revealed contamination issues. Over half (52%) of the samples from boreholes have properties that exceed the specified WHO and NSDWQ standards. Based on this reason and coupled with the observed elevated levels of copper, lead, and total dissolved solids (TDS), it may be inferred that water within this category might not be safe for drinking. Geospatial analysis suggests a strong correlation between the dumpsites and underground water contamination. Interestingly, physicochemical properties from sizeable water samples fell within the WHO's acceptable limits. Zinc, iron, and copper were only elevated in some samples; lead concentrations consistently exceeded WHO standards throughout the study area, particularly near the dumpsites. This makes the water unsafe for consumption. Copper levels were also consistently high throughout the area. Overall, the study brings to the fore the risk associated with using groundwater near the Ojota landfill and the need for alternative water sources or proper treatment of water from existing wells before consumption. The analysis of groundwater near the Olusosun dumpsite highlights the urgency of safeguarding water resources around this landfill. It may be necessary for government and stakeholders to engage in public awareness so as to educate residents around Olusosun landfill about the health risks associated with consuming borehole water in the area. Although results based on this study suggest that water contamination may have been due to leachate, adequate infrastructure such as proper well and borehole casing may also prevent surface water runoff as well as other contaminants from gaining access to groundwater [25]. Government can also provide adequate and accessible waste disposal facilities in residential areas. Intensive further studies are required on waste recycling so as to limit the amount of pollution to groundwater due to landfill leachate. Results from this study will form a basis for multi-criteria selection of the best sanitary landfill site not only in Lagos but also in Nigeria.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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