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Physicochemical and toxicological characteristics of leachates and water quality around dumpsites in Lagos Nigeria

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ABSTRACT

Improper waste management leading to contamination of groundwater resources is a global environmental issue. This study examined the physicochemical and toxicological characteristics of leachates and their effect on water quality around the dumpsite in Alimosho Lagos, Nigeria. Samples of water and leachates were collected from boreholes around the dumpsite. Physiochemical and toxicological characterization of water around the dumpsite was based on American Public Health Association standards. Seventeen physiochemical and heavy metals of leachate and borehole water samples were analysed. The result of the study shows that the temperature, odour, appearance and turbidity of the water in the study area were within the limits set by WHO. However, the pH was below the WHO limits indicative of the acidity of the groundwater. The presence of Pb, Cr, and Cd confirmed leachate pollution. The contemporary effects confirmed the insignificant effect of the dumpsite operations at the groundwater source. Without a properly designed leachate series system, uncontrolled accumulation of leachates at the bottom of the dumpsite poses capacity infection dangers to groundwater resources. It is recommended that proper disposal of waste, in addition to implementing a higher sustainable environmental sanitation practice, is needed to ensure the safety of groundwater within the locality.

1. BACKGROUND TO THE STUDY

One of the pressing global challenges of the 21st century is waste management. Waste is defined as unwanted or unsuitable material discarded due to its inability to fulfil its primary function or meet its owner's needs (Agunwamba, 1998). However, substances deemed waste in one context can become valuable components in another illustrating the cyclical nature of waste management. For instance, human inhale oxygen and exhale carbon dioxide while plants utilize carbon dioxide during photosynthesis and release oxygen (Ikpe et al., 2019).

Nigeria has a total population of well over 230 million people and generates a significant amount of waste annually. The amount of waste generated by people in Nigeria amounts to 0.43kg/head per day, with 60-80% being organic (Onyelowe, 2017). This amounts to over 42 million tons annually. Poor waste management practices, including indiscriminate disposal in public and private spaces, pose substantial environmental and health risks to the people (Ik et al., 2018). Dumpsites can contaminate groundwater resources through precipitation or waste infiltration, while leachates from solid waste can alter the physical and chemical characteristics of nearby wells (Al-Yaqout & Hamoda, 2003; Taylor & Allen, 2006; Nta & Odiong, 2017).

The migration of waste into natural environments results in biogas and leachate pollution. Biogas is produced through organic matter fermentation, while leachates are contaminated water that seeps through waste posing risks to soil and groundwater (Ahn et al., 2002). Nigeria's inadequate waste management stems from limited knowledge about processed waste's economic benefits and the availability of processing machinery (Afangide et al., 2018).

The R3 (Reduce, Reuse, Recycle) system is an effective waste management approach, but its adoption in Nigeria is limited (Awopetu et al., 2012). Instead, open dumping and indiscriminate disposal near water sources prevail (Joseph et al., 2012). Proper management of municipal solid (MSW) waste is critical to mitigating environmental and health risks, particularly in developing regions where open dumpsites are common (Jayawardhana et al., 2019). Groundwater is a reliable water supply source is highly vulnerable to contamination from untreated leachate (Guppy et al., 2018).

The rapid generation of MSW poses significant environmental and health risks if not properly managed. Open dumpsites, the predominant disposal method in developing regions, produce leachate through percolation of intrinsic waste fluids and extrinsic waste sources, including precipitation (Jayawardhana et al., 2019). This untreated leachate frequently contaminates adjacent groundwater. Groundwater as defined by the International Ground-water Resources Assessment Centre, refers to subsurface water occupying rock and soil pore spaces and fractures (Guppy et al., 2018). More importantly, groundwater serves as a reliable water supply source due to its relatively limited pollutant mobility within the soil profile.

Although natural contaminants contribute a lot to water pollution, anthropogenic activities are primary groundwater pollutants. Such anthropogenic activities that pollute water include sewage and wastewater treatment effluent, storage tank leakage, oil well operations, dumpsite leachate, agricultural leaching and septic tank discharge (Olufemi 2010). The unregulated disposal of MSW leachate into groundwater bodies usually leads to waterborne disease transmission, ecosystem disruption, soil degradation and increased human health risks. To effectively manage waste, landfill facilities must be constructed, leachate prior to discharge, monitor groundwater quality regularly. It is important to enforce waste management policies and regulations.

Rainfall plays a significant role in leachate generation (Martin et al., 2019). Leachate generation at non-engineered dumpsites such as those found in Alimosho Local Government Area of Lagos State, is primarily driven by rainfall infiltration. As precipitation percolates through the waste, it usually undergoes physical and chemical reactions, assimilating diffused and suspended components from the ecological waste (Martin et al., 2019). This uncontrolled waste disposal method poses significant environmental and health risks, including respiratory tract infections, dysentery, cholera and typhoid fever resulting from exposure to contaminated air and waste sources. Soluos dumpsites in Lagos, Nigeria, are characterized by massive waste heaps receiving substantial waste influx from surrounding areas, exacerbating the pollution of local ecosystems.

Inappropriate management of dumpsites, particularly in the Soluos area of Lagos, poses profound environmental and health risk challenges to human due to insufficient policy frameworks and ineffective stakeholder interventions. Lack of oversight by local council authorities has led to rampant unauthorized waste disposal resulting in egregious environmental degradation and health hazards. Uncontrolled dumping outside or near the site generates noxious odours, air pollution and surface and groundwater contamination, imperiling community health and wellbeing. This precarious situation jeopardizes sustainability, exacerbating the vulnerability of communities where waste collection and treatment infrastructure is deficient or nonexistent.

Moreover, there is increasing generation of MSW in Lagos, Nigeria, due to rapid urbanization and population growth. Nigeria's urban population growth stood at 3.7% leading to increased generation. Also, inadequate waste management practices lead to environmental and health concerns. Nigeria's environmental regulations are often poorly enforced exacerbating pollution and health risks. Moreover, Nigeria alone has over 1,000 dumpsites nationwide with many lacking proper controls. Nigeria's waste management market is projected to reach about $10 billion by 2050. Lagos is the economic hub of Nigeria, which generates significant waste volumes daily. There are limited studies on physicochemical and toxicological characteristics of leachates from dumpsites in Lagos.

Therefore, this study aims to address the critical knowledge gaps, inform evidence-based policies, contribute to sustainable waste management practices and protect public health and environmental sustainability. investigates the physicochemical and toxicological characteristics of leachates and their effect on water quality around the Lagos dumpsite. It analyzes water and leachate samples collected from boreholes around the dumpsite to determine their heavy metal content and physiochemical characteristics. It assesses the extent of groundwater contamination caused by leachate pollution from the dumpsite. The study also evaluates the contemporary effects of dumpsite operations on the groundwater source and recommends proper waste disposal methods and sustainable environmental sanitation practices to ensure the safety of groundwater within the locality.

2. MATERIALS AND METHODS

The study used a mixed method to investigate physicochemical and toxicological characteristics of leachates and water quality around Soluos dumpsites situated in Alimosho Local Government Area of Lagos State, Nigeria. The dumpsite which has been in operation since 1996 covers 10.8 hectares and receives approximately 2,250 m^2 of waste daily. Soil stratigraphy consists of intercalated lateritic clay protecting the underlying confined aquifer from leachate contamination (Longe & Balogun, 2010). The top layer comprises lateritic clay, underlain by fine-grained sand (Balogun & Adegun 2013).

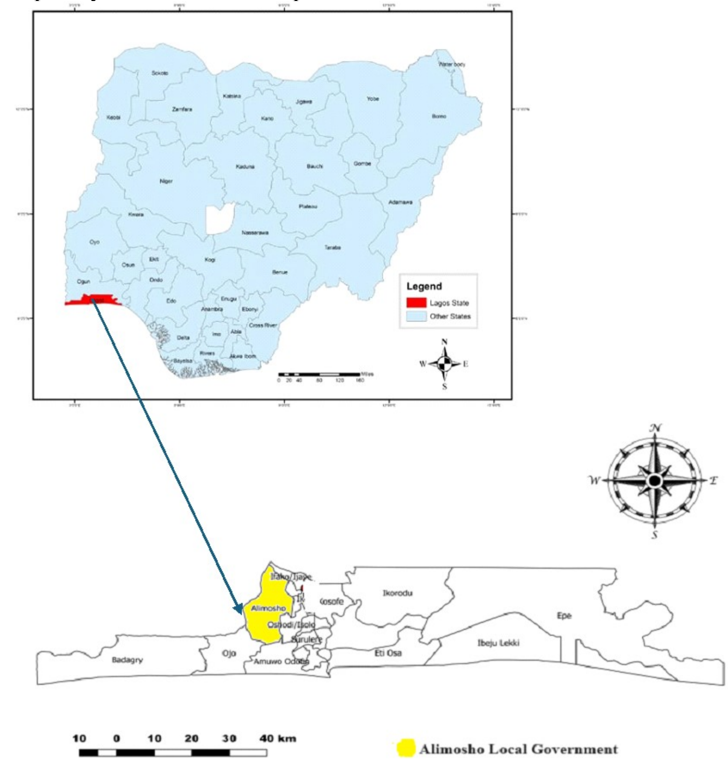

Figure 1. Map Showing sample location for Leachate and borehole water

(Source: Oziegbe et al., 2021)

Data collection employed primary and secondary sources. The primary data collection method includes reconnaissance surveys, field observations, leachate analysis in a standard laboratory. Secondary data was sourced from urban planning documents, journals, seminar papers, textbooks and online resources. A purposive sampling technique was used for data collection. Sampling occurred in November and December 2022, during the dry season. Underground water samples were collected twice as recommended (Lee & Jones, 1983). Leachate and borehole water samples were collected from four locations (Figure 1). Samples were stored in sterilized polyethylene bottles for laboratory analysis. Physicochemical characteristics and heavy metals (HMs) in water and leachate samples were analyzed. Four replicate samples each of leachate (L1- L4) and borehole water (WS1-WS4) were collected from plains sands aquifer surrounding the dumpsite. Samples were immediat4ely transported to the laboratory for physicochemical analyses.

Physicochemical parameters, including pH, temperature, conductivity, and HMs were analysed using standard methods. The study aimed to determine the impact of leachate on groundwater quality and identify potential environmental and health risks associated with the Soluos dumpsite.

The study investigated the physical and chemical parameters of leachate and groundwater samples, including pH, conductivity, total dissolved solids (TDS), salinity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and alkalinity. Heavy metal analysis was conducted using Atomic Absorption Spectrophotometry (AAS) on a Shimadzu AA650 model. The targeted HMs were nickel (Ni), iron, (Fe), copper (Cu), magnesium (Mn), cadmium (Cd), lead (Pb), zinc (Zn), and cobalt (Co). These parameters were selected due to their prevalence as pollutants in groundwater surrounding dumpsites. The analytical methods employed followed the American Public Health Association's (APHA) standard recommendations. All samples underwent analysis for pH, conductivity, TDS, salinity, sulphate, DO, BOD, COD, turbidity, alkalinity, and HMs (Fe, Zn, Pb, Cu, Cr, Cd and Ni)

Samples (100 ml each) were digested with 5 ml of nitric acid (HNO_3) to liberate organic molecules, then heated at 45-65°C. Chemical parameters were determined through titration, while heavy metal content was analyzed using AAS. The AAS procedure involved filtering the water sample to obtain a clear filtrate. A hollow cathode lamp specific to the element of interest was aligned with the spectrometer. The monochromator was adjusted for the appropriate wavelength and slit width. With optimized fuel and oxidant settings, the burner was positioned for maximum absorption and stability. All analyses were conducted in triplicate to ensure accuracy and precision. The Central Laboratory University of Lagos, provided the necessary facilities and expertise for the analysis, ensuring the reliability and validity of the results. The sample was aspirated by the machine through the aspirator and the absorbance was noted. Data were analyzed using both descriptive (means) and inferential statistical tools (correlation and regression analyses).

3. RESULTS

Table 1 shows the physiochemical analysis of borehole water and leachate from Igando dumpsite in Lagos State, Nigeria.

The pH values range between 5.40 -6.34 for groundwater, while the pH value for Leachate ranged from 7.69 - 8.05 (Table 1). The conductivity of groundwater in the study locations was from 38.20-52.85, while the leachate conductivity ranged from 1293.0 - 11,700.00 (Table 1). The total dissolved Solid value in the groundwater was from 19.10 -26.15 while that of leachate was from 3,010.00-6,450.00 (Table 1). The salinity of the groundwater ranges between 15.01 mg/L to 17.52 mg/L while the salinity of the leachate ranges between 1700.00 mg/L to 3253.00 mg/L. The Sulphate level in the groundwater (10.10 mg/L – 20.04 mg/L) was lower when compared to the sulphate level (38.62 mg/L – 180.08 mg/L) in the leachate.

The level of Dissolved Oxygen ranged between 4.00 mg/L - 4.50 in groundwater. A higher level of dissolved oxygen was recorded in leachate 14.00 mg/L -22.00. The highest level of COD (1430 mg/L) was also recorded in leachate while the range of value for COD in groundwater was between 40.0 mg/L-70.0 mg/L. The range value of BOD5 in groundwater was between 0.30 mg/L - 1.80 mg/L while in leachate the value ranged from 14.00 mg/L - 22.00 mg/L. The Turbidity was not detected in groundwater while the range value for turbidity in leachate was 65.0 mg/L - 95.0 mg/L. The level of Alkalinity, ranged between 10 mg/L - 15.0 mg/L in groundwater while in leachate it ranged between 5000 mg/L and 7,500 mg/L.

The lowest level of Fe (<0.001) was recorded in groundwater while the highest level (2.88). was recorded in the leachate. However, for Zn, the highest level of Zn (0.78) was recorded in groundwater. The same trend was observed for Cu where the highest level (0.17) was recorded in groundwater. The level of Pb, Cd and Cr in all the samples at the locations was below 0.001 (Table 1). The highest level of Ni (0.19) recorded was observed in the leachate.

Table 1. Physiochemical analysis of borehole water and leachate from Igando dumpsite in Lagos State

Test Performed	Groundwater Sample								Leachate							
	WS 1	**WS 2**	**WS 3**	**WS 4**	**Mean**	**Min**	**Max**	**S.D**	**L1**	**L2**	**L3**	**L4**	**Mean**	**Min**	**Max**	**S.D**
pH	5.6	6.0	5.4	6.3	5.8	5.4	6.3	0.4	8.05	8	7.89	7.69	7.9	7.69	8.05	0.17
Conductivity	52.5	38.2	52.9	41.3	46.2	38.2	52.9	7.6	1293	6570	11,700	7,480	6761	1293	11700	4276
Total Dissolved Solid	26.2	19.1	26.2	20.5	23	19.1	26.2	3.7	6,450	3,290	3,950	3,010	4175	3010	6450	1567
Salinity, mg/L	15.2	17.5	15.0	15.1	15.7	15.0	17.5	1.2	3,253	2,252	2,550	1,700	2439	1700	3253	647
Sulphate, mg/L	15.2	8.1	20.0	10.1	13.3	8.1	20.0	5.4	10	38.6	180.1	78.00	100	38.6	180.1	59.7
DO, mg/L	4.2	4.5	4.3	4.10	4.3	4.1	4.5	0.2	4.30	4.0	3.90	3.89	4.02	3.9	4.3	0.19
BOD5, mg/L	0.3	1.4	0.5	1.80	1.0	0.3	1.8	0.7	18	14.0	20.1	22.00	18.5	14	22	3.4
COD, mg/L	40.0	60.0	45.0	70.0	53.8	40	70	13.8	1,120	560.0	1,430	800	978	560	1430	379
Turbidity, NTU	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	88.0	80.0	95.0	65.0	82	65	95	12.9
Alkalinity, mg/L	10	10	15.0	12.0	11.8	10	15	2.4	7,500	5,000	6,800	4,300	5900	4300	7500	1499
Fe, mg/L	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	0.1	0.1	NTKDD	2.9	0.6	3.1	3.2	2.44	0.6	3.2	1.2
Zn, mg/L	0.8	0.6	0.6	0.5	0.6	0.5	0.8	0.1	0.6	0.5	0.6	0.6	0.59	0.5	0.6	0.1
Pb, mg/L	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	<0.01	ND	NTKDD	NTKDD
Cu, mg/L	0.2	0.1	NTKDD	0.1	0.1	0.1	0.2	0.1	0.2	0.1	NTKDD	NTKDD	0.05	0.1	0.2	0.1
Cr, mg/L	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	<0.01	NTKDD	NTKDD	NTKDD
Cd, mg/L	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	NTKDD	<0.01	NTKDD	NTKDD	NTKDD
Ni, mg/L	NTKDD	NTKDD	NTKDD	0.1	0.1	NTKDD	0.1	0.1	0.2	0.2	0.1	0.1	0.15	0.1	0.2	0.1

(WS: Water sample, L: Leachate; Ntkdd = Not detected)

The correlation between WS3 vs L3 and WS4 vs L4 indicates a strong association between them. While WS1 vs L1 and WS2 vs L2 have a weak positive correlation.

Table 2. Correlation table of samples using the Pearson correlation method

S/N	Parameter	Correlation Value	Interpretation
1	WS1 vs L1	0.35	Weak positive correlation
2	WS2 vs L2	0.49	Weak positive correlation
3	WS3 vs L3	0.75	Strong positive correlation
4	WS4 vs L4	0.51	Strong positive correlation

(WS: Water sample, and L: Leachate)

4. DISCUSSION

The management of garbage disposal at Solous dumpsite has continued to be a major contributor to negative environmental impacts such as pollution of air, soil and water despite the efforts of the Lagos state waste management authority to curtail the impact. Mishra et al. (2018) submitted that post-closure care of uncontrolled dumpsites is essential for risk assessment over a long period which is based on the threat to human and environmental receptors. Leachate generation at Solous has contributed to the underground water pollution with HMs. Its effects are seen across all analysed parameters in this study, as it has affected the groundwater quality and altered the constituents. Physiochemical analysis of inorganic, organic and HMs pollutant characteristics of both the dumpsite leachate and surrounding borehole water revealed that the analysed parameters have values, some within the acceptable range and others above the acceptable standards set by the World Health Organization (WHO). However, the level of heavy metal in the underground water and leachate in this study was higher than most of the previous studies at the location.

pH values of the leachate samples of Solous dumpsite show that it is basic and, according to Mishra et al. (2018) and Singh et al. (2016), alkaline nature of leachate indicates the old age of the dumpsite. Kostova (2006) concluded that concentration (mg/L) of leachate constituents are in phases, namely transition (0-5 years), acid-formation (5-10 years), methane fermentation (10-20 years) and final maturity (>20 years). The basicity of leachate samples from the Solous dumpsite shows that it is in its final maturity phase. The electrical conductivity value was high for all leachate samples collected. This is in agreement with the findings of Fatta et al. (1999) and Mishra et al. (2018) who submitted that a higher value of conductivity in leachate samples signifies a higher content of dissolved inorganics such as chloride, nitrate, and phosphate as anions and sodium, magnesium, calcium and iron as cations.

The presence of HMs in leachate from the findings of this research attests to the pollution of leachate and later possible accumulation in underground water in the environment as observed by Siva and Prasada (2016) who submitted that leachate has a high concentration of HMs which can alter the properties and fertility of the soil, thereby compromising the integrity of the underground water. The non-detection of most of the heavy metals, as observed in the underground water in the study area, may be due to the nature of the soil in the area. Nwaka et al. (2018) observed, and this study agrees that the high concentrations of these HMs being non-residual fractions in the soil can leach into the soil profile and be further transported to the surroundings, particularly ground and surface water. The pollution of the environment is a potential threat to human health and animals. As observed in this study, residents have had to rely on commercial portable water for drinking and cooking. According to Binion and Gutberlet (2012), there is a high prevalence of infectious diseases among scavengers and nearby residents due to their exposure to hazardous materials. Residents and scavengers at Solous Dumpsites face many environmental and occupational risks. Sometimes the risks faced are based on leachate quality and quantity, dumpsite gas production, system integrity, and groundwater quality (Gibbons et al., 2014).

The inevitable generation of waste from human activities is exacerbated by indiscriminate disposal and inadequate management practices, posing significant threats to environmental sustainability, public health and economic risks to the people as observed in this investigation. Notably, the study's findings further revealed that leachate generated through organic matter decomposition in dumpsites undergoes harmful interactions with water and toxic inorganic waste, culminating in significant water quality degradation in the study area, highlighting the imperative for enhanced waste management intervention. This study has shown that uncontrolled and untreated solid waste can result in environmental pollution and severe health risks; this is corroborated by the findings of Ikpe et al. (2019) who submitted that proper control and treatment of waste can prevent pollution and severe health risks. The risk level of contamination of underground water by leachate in the study area is very low. However, uncontrolled accumulation of heavy metal in leachate and underground water in the study area over time will make the water in the area unreliable for drinking and other domestic purposes. Therefore, proper waste treatment and pollution control in the study area are of utmost concern.

5. CONCLUSION AND RECOMMENDATIONS

Improper waste management and the age of the dumpsite were identified as major contributors to the elevated levels of HMs in the leachate within the study area. The results of this investigation further identified suboptimal waste management practices and dumpsite longevity as critical factors influencing the elevated concentrations of HMs in leachate samples. Conversely, the non-detection of HMs in groundwater samples at the dumpsite can be attributed to the site's pedological characteristics, specifically the lateritic clay soil composition and the substantial depth of the borehole which likely precluded leachate infiltration. Notwithstanding the compliance of HMs and select conventional contaminant concentrations with WHO guidelines in certain groundwater samples, the unchecked accumulation of leachate over time presents a profound threat to groundwater quality. These findings highlight the imperative for implementing robust waste management interventions to mitigate long-term environmental degradation and potential human health risks associated with leachate contamination. The findings further indicated that the groundwater in the study area is unsafe for drinking. Therefore, it is crucial to improve waste management practices and construct properly engineered sanitary landfill sites to prevent further groundwater contamination.

It is recommended that:

– Leachate collection and storage systems should be installed at the dumpsite to prevent contamination of surrounding areas.

– The Lagos State government should reconsider the siting of dumpsites, ensuring they are located away from residential areas.

– The Ministry of Environment should advise households near the Solous dumpsite to use pH+ treatments to neutralize their water, as the study revealed acidic water in the sampled area.

– Shredding MSW is recommended to enhance the rate of biological degradation.

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