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ASSESSMENT OF THE IMPACT OF LANDFILL LEACHATE ON GROUNDWATER QUALITY IN OWERRI WEST LOCAL GOVERNMENT AREA, IMO STATE, NIGERIA

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ABSTRACT

Groundwater contamination resulting from landfill leachate has become a major environmental concern in many developing countries due to indiscriminate solid waste disposal practices. This study assessed the impact of landfill leachate on groundwater quality around the Umuchima landfill site in Ihiagwa, Owerri West Local Government Area, Imo State, Nigeria. Four leachate samples and four groundwater samples from boreholes located within 12–30 m of the dumpsite were collected and analyzed alongside two control groundwater samples located away from the landfill. Standard analytical procedures involving spectrophotometric and titrimetric methods were employed to determine selected physicochemical parameters including pH, temperature, turbidity, total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity, nitrate, sulphate, chloride, total hardness, bicarbonate, carbonate, sodium, calcium, magnesium, iron, and copper. The results showed that leachate contained elevated concentrations of dissolved solids, suspended solids, conductivity, chloride, hardness, bicarbonate, and other dissolved constituents. Groundwater samples collected near the landfill exhibited considerably higher values of turbidity, TDS, TSS, electrical conductivity, chloride, nitrate, sulphate, and total hardness than the control samples, indicating the influence of leachate migration into the surrounding aquifer. These findings agree with previous studies that identified landfill leachate as a major source of groundwater pollution. Although heavy metal concentrations remained relatively low, the elevated physicochemical parameters demonstrate deterioration in groundwater quality associated with landfill activities. The study concludes that landfill leachate has adversely affected groundwater quality in the study area and recommends continuous groundwater monitoring, improved landfill engineering with leachate collection systems, and regular environmental assessment to safeguard public health and groundwater resources.

Keywords: landfill, contamination, Leachate, physicochemical, groundwater.

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1.0 Introduction

Due to the exponential growth of population, industrialization and urbanization, many types of byproducts have been generated daily (Athar et al., 2024). Leachate is a complex chemical mixture that contains dissolved organic matter, inorganic salts, organic trace impurities, and heavy metals. Each of these substances is found in varying concentrations as a result of the physical, chemical, and microbiological processes occurring in the deposited waste (Aziz et al., 2010). Composition of leachate is affected by the type of trash deposited, usage of the landfill, availability of oxygen, prevailing hydro-geological conditions, and the age of the landfill (Przydatek and Kanownik, 2019). In the same vein, Li et al., (2017) noted that Leachate can cause serious pollution to ground water aquifer as well as adjacent surface waters as it migrates away from landfill. The contamination of ground water caused by landfill leachate is regarded as the biggest threat to the environment and public health associated with garbage disposal (Przydatek and Kanownik, 2019). As discussed by Yu et al. (2025) municipal solid waste landfills are the chief source of environmental pollution. Even though countries around the globe have established strict regulations on the entire life of landfills, reports of groundwater environmental pollution caused failure due to improper operation or natural disasters which are common (Feng et al., 2019; Wdowczyk et al., 2024; Yang et al., 2024).

Municipal Solid Waste (MSW) disposal is a global concern (Aderemi et al., 2011), especially in many developing countries including Nigeria, landfills have been largely unsuccessful because the landfill sites have a very limited time frame of usage (Abd El-Salam and Abu-Zuid, 2014). Furthermore, waste disposal is commonly carried out through uncontrolled open dumping without engineered liners or leachate collection systems. Consequently, contaminants migrate into surrounding soils and groundwater, thereby posing serious environmental and public health risks. Communities located near dumpsites frequently depend on shallow wells and boreholes for domestic water supply, increasing the likelihood of exposure to contaminated groundwater. According to Abu-Rukah and Al-Kofahi, (2001), ground-water contamination can occur by infiltration recharge from surface water, direct migration and inter-aquifer exchange. They noted that the first and second mechanisms primarily affect surface aquifers and the third and fourth may affect both surface and deep aquifers. As a precondition for groundwater remediation or control, the rapid and precise identification of pollution and a comprehensive understanding of the migration as well as the transformation of various pollutants have become vital (Yu et al., 2025; Lang et al., 2024; Zhang et al., 2025). Groundwater contamination resulting from landfill leachate has become an environmental concern because pollutants often persist for long periods and remediation is technically difficult and economically expensive. Heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), zinc (Zn), and nickel (Ni), together with high concentrations of nitrate, chloride, sulphate and dissolved organic carbon, have been widely reported in groundwater near landfill sites. The continuous expansion of urban populations and increasing rates of waste generation in Owerri have intensified pressure on existing waste disposal facilities. Many dumpsites lack adequate environmental protection measures, thereby increasing the potential for groundwater contamination through leachate migration. Therefore, evaluating groundwater quality around landfill sites is essential for sustainable water resources management and protection of public health. In addition, rapid urbanization, increasing population growth and poor municipal solid waste management practices have resulted in the proliferation of open dumpsites across many Nigerian cities. These dumpsites generate leachate that infiltrates into surrounding soils and groundwater systems, thereby threatening the quality of groundwater used for drinking and domestic purposes. Although groundwater remains the principal source of potable water in many communities, limited information exists regarding the extent of leachate contamination around many dumpsites in Owerri. The impact of Landfill leachate on the surface and groundwater has given rise to numerous studies recently (Saarela, 2003; Abu-Rukah and Al-Kofahi, 2001; Looser et al., 1999; De Rosa et al., 1996; Md et al., 2014). Consequently, there is a need for systematic assessment of groundwater quality to determine the degree of contamination and associated health risks. Hence, the objective to assess the impact of landfill leachate on groundwater quality around selected dumpsites in Owerri, Imo State, Nigeria becomes very crucial.

2.0 Materials and Method

2.1 Study Area

The landfill used for this study is located at Umuchima Village in Ihiagwa Town, Owerri West Local Government Area of Imo State Nigeria. The landfill sites are along foot paths leading to different student's residential lodges. It is geographically located on (5.8282°N, 7.0552°E). The site receives waste from the entire students living in the residential lodges as well as shops and mini markets located within Umuchima Village and is accessible by footpaths. It is surrounded by residential and commercial set-ups and the dumpsite is made up of domestic, market, commercial and institutional origins. The wastes are of different types, ranging from organic to inorganic. Sorting of metal and plastic containers is carried out by private individuals and metal scrap dealers for recycling. The site is characterized by landfill fires mostly due to spontaneous combustion which are prevalent in the dry season. The study area is humid tropical, has an annual rainfall of about 2500 mm and annual temperature range of 27-29°C. There is usually a long-wet season that last from March to September which creates an annual relative humidity of 75% reaching 90% at percent of the world's soil and 40 percent of the soils in Africa are already degraded, a special focus on the restoration of degraded soils and maintenance of soil health is required (Balogun et al., 2020; FAO, 2011)

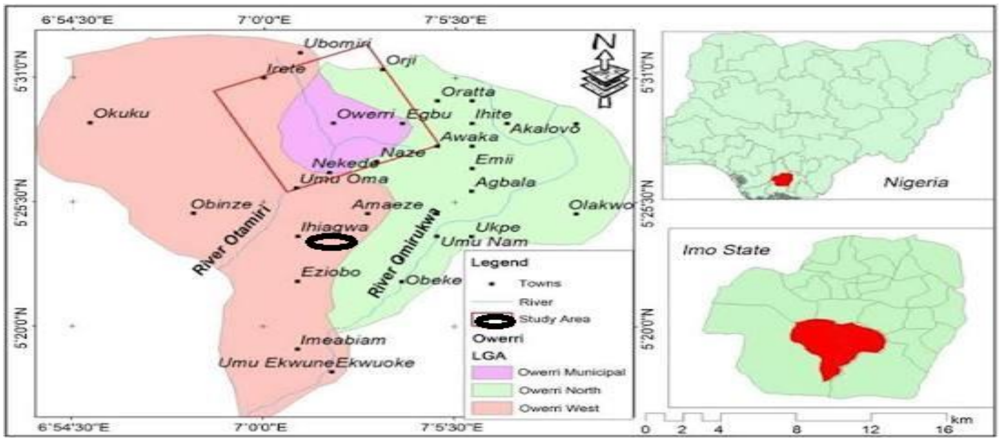

Figure 1: Map of Owerri West, Imo State Showing the study area.

Location of Specimen Sites

A specimen can be regarded as a refuse dump with a borehole situated not more than 50 meters away. For the purpose of research, four (4) specimen sites were located at Umuchima Village in Ihiagwa town, Owerri West LGA of Imo State. Collection of leachate was done using a specimen landfill (leachate collector). It was constructed using a cylindrical plastic container of uniform texture and properties incapable of inhibiting or aging its own chemical content to the leachate. This set up was exposed to the atmosphere for one week in each specimen site. During this period, natural precipitations drench and percolate through the solid waste. The leachate was collected through the valve and kept in a plastic bottle labelled according to the specimen site and the analysis was performed two days afterward.

Laboratory Analysis

Ground water samples were collected from boreholes, which are situated near leachate site. These water samples were kept in plastic bottles, which are labelled according to specimen site. They were taken for analysis immediately. Two (2) control sites were utilized during the study, these were to enable us ascertain the extent of pollution on the ground water present in leachate site. Physicochemical analysis was conducted at the Michael Okpara University of Agriculture Umudike Laboratory using standard analytical methods. A HACH DREL/5 spectrophotometer (wavelength range 400–810 nm) was used to measure color, turbidity, conductivity, TDS, TSS, total iron, phosphorus, copper, sulphate, and nitrate. Prepared samples were treated with pre-measured reagents and allowed distinct reaction windows for color development. Titrimetric methods were utilized for hardness, bicarbonate, and carbonate parameters.

Table 1: Sources of Collection of Samples for Specimen sites and Control sites

S/no	Location of specimen sites	Distance from refuse dump(m)	Specimen number
1	eagles wings lodge	12	Ls 01, Bh 01
2	Koko Mansion lodge	25	Ls 02, Bh 02
3	Siesta water factory	30	Ls 03, Bh03
4	Psalms 23 lodge	20	Ls 04, Bh04
S/n	Control site		
1	Hostel A FUTO, Owerri		Bh 05
2	SEET Complex Owerri		Bh 06

Ls= leachate sample, Bh = Borehole sample

3.1 Method of Analysis

The spectrophotometric method and the titrimetric methods were employed in the analysis of the water samples. The instrument used in the spectrophotometric method is the HACHDREL/5 spectrophotometer, which operates within the wavelength region 400-7000m, with an extension to 810mm range. The parameters determined by this method include; colour, turbidity, conductivity, total dissolved salts, total suspended solids, total iron, phosphorus, copper, sulphate, and nitrate. The spectrophotometer compares the intensity of radiation of different colours in the visible region of the E.M spectrum, after appropriate treatment sample. The photocell converts this radiation (energy) into usable signals, which is processed by a signal processor and displayed in an analogue readout. The intensity of the developed odour is linearly related to the concentration of sought elements. The sample preparation is achieved by adding the contents of a pre measured reagent to 25ml of the sample and allowing time for reaction which is indicated by colour development. There is a specific waiting period for every element being sought. All parameters were measured using analytical methods based on standard methods.

3.0 Results and Discussions

Table 2: Physicochemical Properties of Landfill Leachate

Parameter	Ls 01	Ls 02	Ls 03	Ls 04
Temperature (^{O}C)	27.1	28.4	28.7	28.8
pH	7.2	6.76	6.84	6.98
Turbidity (TNU)	59.7	40.8	81.3	41.2
TDS (Mg/l)	147.7	222.8	267	282
TSS (Mg/l)	247.8	358.3	268	69.4
Conductivity (Ns/cm)	1308	1349	1075	1128
NO_3^- (Mg/l)	1.83	0.72	1.04	2.29
SO4 (Mg/l)	24.6	2.75	0.46	3.09
Cl^- (Mg/l)	120	50	174	28.4
Total Hardness (Mg/l)	239.6	188	184.8	217.6
CO_3^{2-} (Mg/l)	2.12	6.4	12.3	20.2
HCO_3^- (Mg/l)	193.2	108.6	176.5	252.8
Na^{2+} (Mg/l)	7.6	24.6	22.6	22.9
Ca^{2+} (Mg/l)	16.8	18.05	25.1	27.9
Mg^{2+} (Mg/l)	3.65	13.37	7.29	20.6
Fe^{2+} (Mg/l)	0.24	0.24	0.27	0.21
CU^{2+} (Mg/l)	0.01	0.22	0.06	0.02

The near-neutral pH stability (6.76–7.20) signals that the Umuchima landfill has reached a mature, methanogenic stage of anaerobic organic waste decomposition, matching trends seen by Aziz et al. (2010). Electrical conductivity values far exceeding 1000 µS/cm confirm high structural concentrations of dissolved ionic products. High chloride, TDS, TSS, and bicarbonate values reveal active organic degradation, highlighting the high potential for pollutant migration via rainfall percolation (Li et al., 2017; Przydatek and Kanownik, 2019).

3.2 Groundwater impact Assessment

Comparing proximal boreholes (Bh 01–Bh 04) with control boreholes (Bh 11–Bh 12) highlights clear leachate-induced deterioration (Table 3).

Table 3: Groundwater Quality Analysis Near vs Away from Dumpsite

Parameter	Bh 01	Bh 02	Bh 03	Bh 04	Bh 11	Bh 12
Temperature (^{O}C)	27.1	28.4	28.7	28.8	27.5	28.00
pH	7.2	6.76	6.84	6.98	6.0	6.40
Turbidity (TNU)	59.7	40.8	81.3	41.2	12.69	18.00
TDS (Mg/l)	147.7	222.8	267	282	30.0	12.00
TSS (Mg/l)	247.8	358.3	268	69.4	1.60	3.40
Conductivity (Ns/cm)	1308	1349	1075	1128	12.0	19.20
NO_3^- (Mg/l)	1.83	0.72	1.04	2.29	0.22	0.13
SO4 (Mg/l)	24.6	2.75	0.46	3.09	2.00	2.10
Cl^- (Mg/l)	120	50	174	28.4	6.50	8.20
Total Hardness (Mg/l)	239.6	188	184.8	217.6	80.00	64.00
CO_3^{2-} (Mg/l)	2.12	6.4	12.3	20.2	44.00	34.50
HCO_3^- (Mg/l)	193.2	108.6	176.5	252.8	14.00	18.00
Na^{2+} (Mg/l)	7.6	24.6	22.6	22.9	24.40	79.00
Ca^{2+} (Mg/l)	16.8	18.05	25.1	27.9	17.60	3.70
Mg^{2+} (Mg/l)	3.65	13.37	7.29	20.6	21.50	4.90
Fe^{2+} (Mg/l)	0.24	0.24	0.27	0.21	0.40	0.70
CU^{2+} (Mg/l)	0.01	0.22	0.06	0.02	0.10	0.10

Boreholes closest to the dumpsite (12–30 m) displayed elevated levels of turbidity, conductivity, TDS, TSS, chloride, and total hardness. These sharp variations prove that waste contaminants migrate downward into the shallow water table (Abu-Rukah and Al-Kofahi, 2001).
Electrical conductivity serves as a highly sensitive metric for leachate pollution due to its rapid response to inorganic ion enrichment (Li et al., 2017). Similarly, chloride acts as a conservative indicator because it remains stable and highly soluble during groundwater movement; its elevated presence confirms leachate intrusion (Przydatek and Kanownik, 2019).
Although nitrate concentrations remained beneath official World Health Organization boundaries, values near the landfill systematically outpaced control targets. Unchecked long-term infiltration could spark dangerous nitrate build-up, creating severe health risks for infants and sensitive populations (WHO, 2022). Heavy metal trace indicators (iron and copper) stayed relatively low for now. However, continuous indiscriminate dumping will likely increases trace metal accumulation over time due to changing geochemical and subsurface conditions (Aziz et al., 2010).
The lack of engineered barriers allows unchecked leachate to alter underlying aquifers. Given that a large portion of the Umuchima community depends on these private boreholes for domestic usage, this ongoing contamination presents immediate public health concerns (Abd El-Salam and Abu-Zuid, 2014).

4.0 Discussion

The physicochemical characteristics of the landfill leachate indicate that the dumpsite generates highly mineralized wastewater capable of degrading surrounding groundwater quality. The near-neutral pH values (6.76–7.20) observed in the leachate suggests that the landfill is in a relatively mature stage of waste decomposition where methanogenic activities predominate. Similar observations have been reported in municipal landfill studies conducted by Aziz et al. (2010). Electrical conductivity values exceeding 1000 µS/cm across all leachate samples indicate high concentrations of dissolved ionic substances resulting from the decomposition of municipal solid waste. Likewise, the elevated total dissolved solids and total suspended solids demonstrate the abundance of soluble and particulate contaminants capable of migrating into the subsurface through infiltration, particularly during periods of intense rainfall (Li et al., 2017). High chloride and bicarbonate concentrations further support the occurrence of intensive organic matter decomposition within the landfill environment (Przydatek and Kanownik, 2019).
Comparison between groundwater samples located close to the dumpsite and the control boreholes clearly indicates evidence of groundwater deterioration. Boreholes situated within 12–30 m of the landfill exhibited substantially higher turbidity, conductivity, TDS, TSS, chloride, nitrate, sulphate, and total hardness than groundwater collected farther away. These differences strongly suggest that contaminants generated within the landfill have migrated through the soil profile into the groundwater system. Similar findings were reported by Abu-Rukah and Al-Kofahi (2001), who observed that landfill leachate can infiltrate surface and subsurface aquifers through percolation processes.
The elevated turbidity and suspended solids observed in nearby boreholes may result from infiltration of fine particulate matter transported by landfill leachate. Increased electrical conductivity similarly reflects enrichment of groundwater with dissolved inorganic ions originating from decomposing wastes. According to Li et al. (2017), electrical conductivity is one of the most sensitive indicators of groundwater contamination by landfill leachate because it responds rapidly to changes in dissolved ion concentrations.
Chloride serves as one of the most reliable indicators of landfill contamination because it is highly soluble and relatively conservative in groundwater systems. The higher chloride concentrations observed in boreholes near the dumpsite therefore provide strong evidence of leachate intrusion. Similar observations have been reported in groundwater quality studies around landfill sites in both developed and developing countries (Przydatek and Kanownik, 2019).
Nitrate concentrations in groundwater remained relatively low compared with World Health Organization standards; however, boreholes near the landfill consistently recorded higher concentrations than the control sites. Continuous waste decomposition and prolonged infiltration could increase nitrate accumulation over time, thereby posing health risks, particularly to infants and vulnerable populations (WHO, 2022).
Heavy metals such as iron and copper occurred at relatively low concentrations in both leachate and groundwater samples. Although these concentrations do not presently indicate severe heavy metal pollution, continued indiscriminate waste disposal may gradually increase metal accumulation in groundwater due to prolonged leaching and changing geochemical conditions (Aziz et al., 2010).
Overall, the findings demonstrate that groundwater quality decreases with proximity to the landfill. The absence of engineered liners and leachate collection systems allows contaminants generated within the refuse dump to infiltrate surrounding soils and eventually reach shallow aquifers. This observation agrees with the findings of Abd El-Salam and Abu-Zuid (2014), who reported that uncontrolled dumpsites constitute significant sources of groundwater contamination in developing countries. Considering that many households around Umuchima depend on borehole water for domestic purposes, continuous exposure to contaminated groundwater may

present significant environmental and public health concerns. The findings therefore emphasize the need for improved landfill management practices, periodic groundwater quality monitoring, and the establishment of appropriate buffer distances between waste disposal sites and potable water sources.

5.0 Conclusion

This study evaluated the influence of landfill leachate on groundwater quality around the Umuchima dumpsite in Owerri West, Imo State, Nigeria. The physicochemical analysis revealed that landfill leachate contains elevated concentrations of dissolved and suspended materials capable of contaminating surrounding groundwater (Aziz et al., 2010). Borehole water samples collected near the landfill consistently exhibited higher values of turbidity, electrical conductivity, total dissolved solids, total suspended solids, chloride, nitrate, sulphate, and total hardness than the control locations, confirming the migration of leachate-derived contaminants into the groundwater system. These findings corroborate earlier reports by Li et al. (2006) and Abu-Rukah and Al-Kofahi (2001), who identified landfill leachate as a significant source of groundwater pollution.

Although the concentrations of iron and copper remained relatively low, the observed deterioration in several important water quality parameters indicates that the landfill has negatively influenced groundwater quality. The continued use of unengineered open dumpsites therefore presents a significant environmental and public health risk, particularly in communities that depend on groundwater for drinking and domestic purposes (Abd El-Salam and Abu-Zuid, 2014).

The study recommends the construction of properly engineered sanitary landfills equipped with impermeable liners and efficient leachate collection systems, routine groundwater quality monitoring around waste disposal sites, enforcement of environmental regulations governing municipal solid waste management, and increased public awareness regarding the risks associated with sitting boreholes close to refuse dumps. Implementing these measures will contribute significantly to protecting groundwater resources and ensuring sustainable environmental management in Owerri and similar urban environments (Przydatek and Kanownik, 2019).

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