

Investigating the impact of solid waste dumpsites on groundwater quality: A case study of the Mkpuka Obosi Landfill

Obiabunmo Obiora and Obiekezie Theresa*

Department of Physics and Industrial Physics, Faculty of Physical Sciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

*Corresponding author. Email: tn.obiekezie@unizik.edu.ng; Co-author. Email: obiora22@yahoo.com

Copyright © 2024 Majolagbe et al. This article remains permanently open access under the terms of the [Creative Commons Attribution License 4.0](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Received 13th March 2024; Accepted 13th April 2024

ABSTRACT: Leachate, which refers to the contaminated fluid that results from water percolating through a landfill or waste disposal site, is a significant concern in sub-Saharan Africa. The uncontrolled release of leachate, particularly from dumpsites, is a primary contributor to groundwater pollution in the region. This research aimed to assess the impact of solid waste dumpsites on groundwater quality, specifically focusing on the landfill at Mkpuka Obosi. The study area was divided into eight concentric cells (C1-C8), each containing water and soil samples for analysis. The parameters examined include Temperature ($^{\circ}\text{C}$), pH, Iron (Fe^{2+}), Lead (Pb^{2+}), Copper (Cu), Zinc (Zn^{2+}), Calcium (Ca), Sodium (Na), Magnesium (Mg^{2+}), Sulphate (SO_4^{2-}), Chloride (Cl^-), Nitrate (NO_3^-), Bicarbonate (HCO_3^-), Total Dissolved Solid (TDS), Biological Oxygen Demand (BOD), Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Total Hardness (TH), Electrical conductivity (EC), for the water analyses, while for soil analyses, pH values, Total organic carbon, Iron, Zinc, Temperature, Sand, Silt, Clay, Electric conductivity and copper were analyzed. The results were compared with relevant standards set by organizations like the World Health Organization (WHO). The findings indicated that parameters such as chemical oxygen demand, total suspended solids, chloride, nitrate, sodium, calcium, copper, lead, iron, and electrical conductivity exceeded the recommended standards. This suggests that water contamination from the dumpsite has adversely affected groundwater quality. Analysis of the graphs and tables revealed that the contamination spread decreased proportionally with distance from the dumpsite. As a result, water within approximately 500 m of the centre of the landfill was deemed unsuitable for consumption due to health risks and hazards. The water quality index ranged from 13 to 513, indicating that wells and boreholes located around 500 m from the dumpsite require significant treatment before being considered safe for consumption. The excess presence of sandy soil in the area, attributed to the geological formation, was found to contribute to the rapid flow of contaminants from the dumpsite. Coarse textured soils, being more permeable, have lower sorption potentials, while fine textured soils have slower permeability and higher sorption potentials. Consequently, the high proportion of coarse sandy soil surrounding the landfill favours the accelerated movement of contaminants.

Keywords: Groundwater quality, Mkpuka Obosi Landfill, physical and chemical factors, solid waste dumpsites.

INTRODUCTION

Landfilling is a waste disposal method that involves in filling of the land's depression, such as excavation sites, valleys or erosion-affected areas mainly with waste (Orhorhoro and Oghenekevwe, 2023). Waste here is described as materials from activities or processes that

have no immediate economic values or demand. During raining season, waste placed in landfills in this context open dumpsites are subjected to precipitation infiltration and as the water percolates through the waste, it picks up varieties of highly contaminated inorganic and organic

compounds that flow to the bottom of the landfill passing through the cells and pores of the soil to the aquifer (Alao, 2023; Orhorhoro and Oghenekevwe, 2023). The resulting contaminated compounds, which are mainly fluids, are known as leachate.

Leachate composition and migration depends mainly on the age of landfill, types of waste found on the landfill and degree of waste stabilization. According to Pohland and Harper (1986), there are five sequential or distinct stages and the rate of progress through these stages is dependent on the physical, chemical and microbiological conditions developed within the landfill in time (Keenan *et al.*, 1993; Olafisoye *et al.*, 2013b; Pohland *et al.*, 1987).

The degree of waste stabilization has shown that landfilling by waste can be considered as one of the major threats to groundwater (Pohland *et al.*, 1987; USEPA, 2021). The scale of these threats depends on the concentration and toxicity of contaminant in leachate, permeability of geological strata, depth of water table and the direction of groundwater flow (Keenan *et al.*, 1993). In most developed countries, landfills come with liners at the bottom to trap leachate (Lone *et al.*, 2012; Olafisoye *et al.*, 2013a). However in many developing countries, most landfill are not regulated by the necessary authorities hence they lack the leachate trapping liners.

Open dumpsites pose significant environmental impacts and public health risks (Dixit *et al.*, 2024). These include subsoil contamination, groundwater pollution, generation of volatile organic compounds (VOCs), and the creation of greenhouse gas emissions (Alao, 2023). Studies have highlighted the environmental consequences of open dumpsites. Several research studies conducted in Ghana and Nigeria have focused on the environmental impact of open dumpsites and non-sanitary landfills on groundwater and surface water quality. Dapaah-Siakwan and Gyau-Boakye (2000), Gyabaah *et al.* (2023) and Osei *et al.* (2011) conducted research in Ghana, analyzing the geophysical and physicochemical properties of groundwater, surface water, and soils in areas affected by dumpsites. The objective of these studies was to identify contaminants and evaluate their environmental impact, providing insights for intervention measures and identifying priority areas. The findings of these studies indicate that leachate from dumpsites and non-sanitary landfills has infiltrated the aquifer, affecting the quality of drinking water sources within specific radii from the dumpsites and landfills. This contamination poses a threat to human health and emphasizes the need for regular monitoring of water quality to prevent further degradation.

In Nigeria, studies conducted at the Obosi landfill site by Akanwa (2013) and (Osuagwu *et al.*, 2023) revealed the presence of contaminated substances in the analysis of portable water. These studies emphasized the importance of continuous monitoring of water quantity to mitigate potential risks to human health. Subsequent research conducted in the same area by Anagboso *et al.* (2016),

Emereibeole *et al.* (2021), Okolo *et al.* (2017) and Ugbor *et al.* (2021), demonstrated a continued degradation of groundwater quantity. Further investigations by Akakuru *et al.* (2023) revealed the presence of trace metal in groundwater collected from 42 groundwater sample in and around to the dumpsite, with concentrations exceeding the permissible limits set by the World Health Organization (WHO). These studies collectively highlight the detrimental impact of dumpsites and non-sanitary landfills on groundwater quality in Ghana and Nigeria. The contamination of aquifers and portable water sources underscores the urgent need for effective waste management practices, including the closure of open dumpsites and the implementation of sanitary landfills. Regular monitoring of water quality is essential to safeguard public health and prevent further pollution.

Naturally, water is never a pure liquid in a chemical sense. It contains impurities of various kinds such as (H_2S , CO_2 , NH_3 , H_2), dissolved minerals (Ca, Mg, Na, Salt), suspended matter (Clay, Silt, Sand) and microscopic plants and animal (Ameloko and Ayolabi, 2018), which are natural impurities derived from the atmosphere, catchment areas and soil. They are very small and naturally do not pollute water but classical unlined landfills, like those in developing countries, are known to release large amount of hazardous and otherwise deleterious chemicals (leachate) into nearby groundwater thereby increasing the amount and number of chemical found in the water (Chibuogwu and Ugwu, 2023b, Ikhifa *et al.*, 2019; Joseph Omeiza *et al.*, 2023; Mohammadi *et al.*, 2023).

The quantitative information of these contaminants have not been fully recorded and only by carrying out a physico-chemical analysis on the groundwater can the level of hazardous chemical be measured (Chibuogwu *et al.*, 2023; Heiß *et al.*, 2020; Hussain *et al.*, 2024; Khan *et al.*, 2022; Uyo *et al.*, 2021). A geophysical technique can also determine the extend at which the leachate has traveled in the subsurface (Chibuogwu and Ugwu, 2023a; Obiri-Nyarko *et al.*, 2023; Osuagwu *et al.*, 2023).

For this study a physico-chemical measurement of the groundwater parameters were conducted at Mpuka Obosi landfill with the aim of investigating, and accessing the migration path of the leachate contamination.

METHODOLOGY

Study area

The study was conducted in Mgbuka Obosi, a location situated in Idemili North Local Government Area of Anambra State. The area is characterized by plains with elevations between 50-200 m above sea level and experiences annual rainfall ranging from around 2500 to 4000 mm, with the highest precipitation occurring in April and October. The average relative humidity hovers around

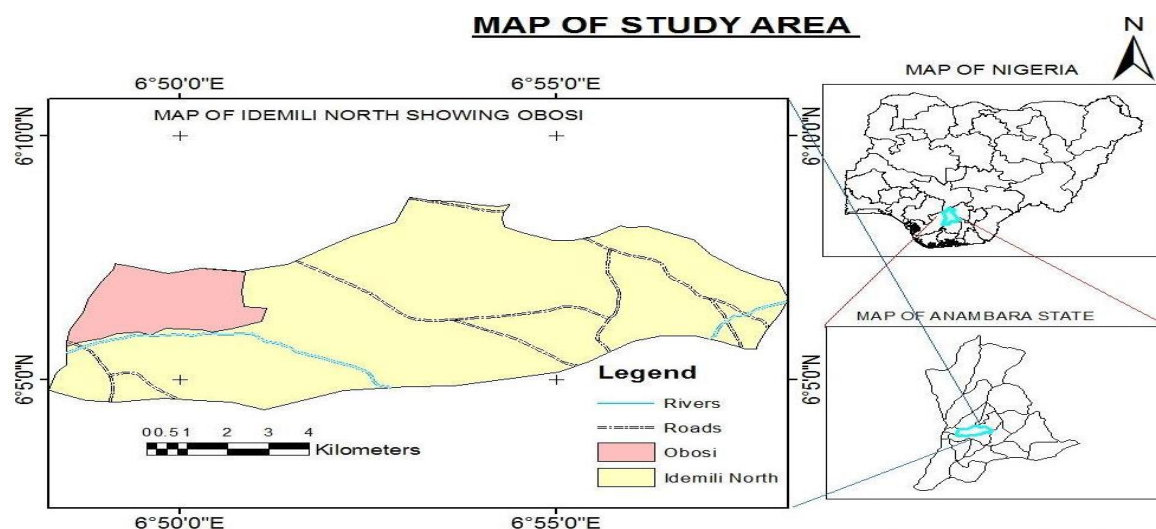


Figure 1. Map of Idemili North showing Obosi. (Source: Cartography Department of National Population Commission Anambra State, 2006).



Figure 2. Obosi dumpsite.

80%, while it goes up to 90% during the wet season. Figure 1 displays a map of the Idemili North region, highlighting the location of Obosi.

The Obosi dumpsite

The Obosi landfill site is situated between longitude $06^{\circ} 47' 59.2''$ E and latitude $06^{\circ} 06' 07.8''$ N, surrounded by residential structures over an area of approximately four hectares. It has been in operation in the study area for more than 50 years, and the dump comprises of several categories of solid waste such as food waste, plastics, textiles, paper, e-waste, scrap metal, batteries, used tires, and used oil. Figure 2 shows a section of the Obosi dumpsite with a proliferation of different categories of solid wastes.

Geology and lithostratigraphic of study area

The study area is situated within the Anambra Sediment Basin, located in southeast Nigeria, which spans an estimated area of $40,000 \text{ km}^2$ (Ocheli *et al.*, 2021), depicted in Figure 3. Its southern boundary coincides with the deltaic swamps of the Niger Delta basin, and it extends northwards beyond the Bende-Ameki Formation. Geologists believe that the basin originated simultaneously with the Abakaliki-Benue mountainous region, which underwent folding and uplifts during the Santonian era (Adeigbe and Salufu, 2009; Ocheli *et al.*, 2021; Kelechi, 2017). The Anambra Basin is recognized as a significant depocentre of elastic sediments and deltaic sequences formed from the second phase of tectonic activity in the lower Benue Trough (Ocheli *et al.*, 2021). The geological map of the southern region of Anambra is

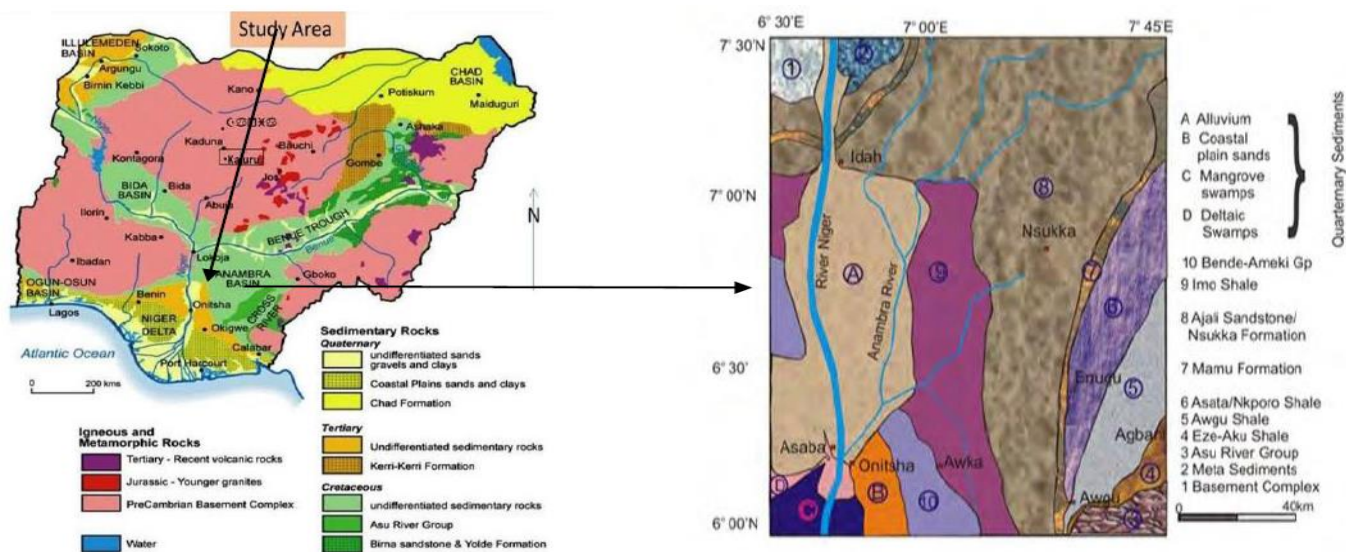


Figure 3. Geological Map of Nigeria and the Southern Anambra Basin (Ocheli *et al.*, 2021).

available in Figure 3.

The groundwater reservoirs present in the soils of Anambra State exacerbate ecological challenges in the area. These soils are predominantly coastal plain sands, highly vulnerable to erosion, and contribute to severe ecological damage in the region. The geologic rocks and material beneath the unstable and poorly consolidated lateritic and acidic soils are also highly susceptible to erosion (Kelechi, 2017). Within the sandy components of these geologic units, enormous groundwater reservoirs known as aquifers exist that pose a threat when subjected to uncompromising loads from superimposed structures, leading to pore water pressures (Chibuogwu and Ugwu, 2023c; Ocheli *et al.*, 2021; Kelechi, 2017). Furthermore, the easily erodible lateritic and sandy soils are susceptible to damage by stormwater runoff.

Experimental design

The data was collected from the water and soil that are in and around the largest landfill in Anambra, situated in Mgbuka Obosi within Idemili North Local Government Area of Anambra State. The study area was divided into 8 concentric cells labeled C1 to C8. Each cell contained at least three water sample and one soil sample, an average or the most suitable water sample will then be considered. Each cell will be approximately 200 m apart from the preceding cell except for the control cell which is 2 km from the northern end of the dumpsite. Water samples were then designated as W₁, W₂, BH₃... BH₈ and was taken immediately to the Anambra State Ministry of Utility for chemical, physical and heavy metals analyses. All the analyses were carried out by Anambra State Ministry of

Utility officials with author in attendance and results were obtained for interpretation. Soil textural/grain size analysis was carried out at the Anambra State Ministry of Work.

Parameters examined

For the water analysis

The study examined Nineteen (19) parameters for physical and chemical (including heavy metals) analyses, namely; Temperature (O°C), pH, Iron (Fe²⁺), Lead (Pb²⁺), Copper (Cu), Zinc (Zn²⁺), Calcium (Ca), Sodium (Na), Magnesium (Mg²⁺), Suphate (SO²⁻⁴), Chloride (Cl⁻), Nitrate (NO³⁻), Biocarbonate (HCO), Total Dissolved Solid (TDS), Biological Oxygen Demand (BOD), Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Total Hardness (TH), Electrical conductivity (EC).

For the soil analysis

The study will examine ten (10) parameters namely; pH values, Organic carbon, Iron, Zinc, Temperature, Sand, Silt, Clay, Electric conductivity and Copper. The criteria behind the selection of these parameters are based on the parameters which are the common pollutant elements in groundwater around the dumpsites.

Analytical techniques and laboratory analysis

The adopted methods of analyses for the examination of all parameters in potable and waste water was in accordance with (American Public Health Association

Table 1a. Method employed and WHO standard for the year 2004.

Parameters	Method employed	WHO Standard
Distance from dumpsite (m)		Nil
Colour		Colourless
Odour		Unobjectionable to customer
Taste		Unobjectionable to customer
pH		6.5 – 8.5
Temp (°C)		24.5 -39.5
Fe ²⁺ (mg/l)	Atomic absorption spectrophotometry (APHA 3120 - B)	1
Pb ²⁺ (mg/l)	Atomic absorption spectrophotometry (APHA 3120 - B)	1.05
Cu ²⁺ (mg/l)	Atomic absorption spectrophotometry (APHA 3120 - B)	1.5
Zn ²⁺ (mg/l)	Atomic absorption spectrophotometry (APHA 3120 - B)	4
Ca(mg/l)	Atomic absorption spectrophotometry (APHA 3120 - KB)	15
Na ⁺ (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - MgB)	200
Mg ²⁺ (mg/l)	Atomic absorption spectrophotometry (APHA 3120 - NaB)	150
Cl ⁻ (mg/l)	Titrimetry (APHA 4500 - B)	600
SO ₄ ²⁺ (mg/l)	Spectrophotometry (APHA 4500 SO4B)	400
NO ₃ ⁻ (mg/l)	Spectrophotometry (APHA 4500 P)	250
HCO ₃ ⁻ (mg/l)	Atomic absorption spectrophotometry (APHA 3120 - B)	50
TDS (mg/l)	Gravimetry (APHA 2540 - B)	1000
BOD (mg/l)	Titrimetry (APHA 5210 - B)	10
COD (mg/l)	Titrimetry (APHA 5210 - B)	40
Total (mg/l) Hardness	Titrimetry (APHA 2340 - B)	500
Conductivity (µS)	Conducting meter (APHA 2510 - B)	1500
Suspended Solid	Spectrophotometry (APHA 2540 - D)	5

(APHA, 2005) standard recommendation (Table 1a). All samples were analyzed for selected physical, chemical and heavy metals parameters.

Data analysis

Results from the water analysis was compared with those obtained by Chiedozie *et al.* (2022), Umoh and Etim (2013), Uyo *et al.* (2021) and with the (World Health Organization, 2004) and a simple bar chart is used to graphically interpret the data.

Calculation of water quality index

The following procedures (Brown *et al.*, 1972) were follow to determine the quality of fresh drinking water within and around the dumpsite (Table 1b).

Step 1: calculate the unit weight (W_n) factor for each parameter by using equation 3.7 and 3.8.

$$W_n = \frac{K}{S_n} \quad (3.7)$$

$$\text{Where: } K = \frac{1}{\frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3} \dots \frac{1}{S_t}} \quad (3.8)$$

Table 1b. Water quality status (Brown, et al., 1972).

Water quality	Water quality status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unfit for consumption

S_n = standard desirable value of the n^{th} parameter

Step 2: calculate the sub-index (Q_n) value by using equation 3.9.

$$Q_n = \frac{[(V_n - V_t)]}{[(S_n - V_t)]} \times 100$$

Where: V_n = Mean concentration of the n^{th} parameter, and V_t = Actual Value of the parameter in pure water

Step 3: Calculate the Overall Water Quality Index (WQI)

$$WQI = \frac{\text{sum } Q_n}{\text{sum } V_n}$$

The status of WQI is developed by Brown *et al.* (1972) and it is given in Table 1.

RESULTS

Water analysis

Figure 4a and Table 2 Show the variation of pH values at different sampling stations. pH is the measure of how acidic/basic a water can be. High pH means high alkalinity and it is caused by excess carbon dioxide. The pH values fall within the range of 6.3 to 7.2 the slight decrease of B2 to B6 and the increase in pH of W1 and W2 may be due to their distance from the centre of the dumpsite. All the pH samples in the study area are within the standard WHO limit (except those of the leachate Table 1).

Figure 4b and Table 2 show the variation of iron at different sampling stations. Excess iron combines with bacteria to cause bacteria slimes that give fresh water a metallic taste. It can be observed from the graph that the value of iron ranges from 0.07 to 11.2 mg/l (excluding the value of the leachate sample). The value tends to decrease as the distance from the center of the dumpsite is increased. All but sample B5 and B6 are outside the permissible WHO limit (Table 1). The reason for the increase in the value of iron can be attributed to the high value of iron from the leachate sample, which may have possibly affected the groundwater within the dumpsite due to migration of leachate in the subsurface.

Figure 4c and Table 2 show the variation of lead at the different sampling stations. The value of lead ranges from 0.01 to 4.3 Mg/l. The trend from sample W1 to sample B6 indicates a decrease in the amount of lead. All but sample B4 to sample B6 value of lead are outside the permissible limit of WHO (Table 1). The high increase in lead in sample W1 and W2 may be as a result of the closeness of the wells to the dumpsite.

Figure 4d and Table 2 show the variation of copper at the different sampling stations. The value of copper ranges from 0.03 to 3.2 Mg/l (excluding the value of the leachate sample). The trend in the value of copper shows a slight decrease from sample W1 to B6, however the overall value copper is very low which may be due to the fact that the leachate in the dumpsite is mainly composed of domestic waste and not industrial waste. All of the samples except those of the leachate are within the standard value of WHO and hence in good quality.

Figure 4e and Table 2 show the variation of calcium at the different sampling stations. Calcium in water is mainly as a result of the geological composition of the surrounding rocks. It can be observed that the value of calcium ranges from 5.5 to 18.1 mg/l (excluding the value of the leachate sample). The value tends to decrease as the distance from the center of the dumpsite is increased. All but sample B4, B5 and B6 are outside the permissible WHO limit. The reason for the increase in the value of calcium can be attributed to high value of calcium salt in the leachate sample (composing mainly of domestic waste) and the type of geological formation in the area.

Figure 4f and Table 2 show the variation of zinc at the different sampling stations. The value of zinc ranges from 1.5 to 3.7 Mg/l. There is a slight decrease in the trend of zinc from sample W1 to B6, however, the overall value of zinc is very low which may be due to the fact that the leachate in the dumpsite is mainly composed of domestic waste and not industrial waste. All of the samples except those of the leachate are within the standard value of WHO.

Figure 4g and Table 2 show the variation of sodium with the water samples. High level of sodium in water an index for polluted water and it is caused by decomposed sewage and fertilizer. The value of sodium ranges from 216.2 to 1.7 mg/l (excluding the value of the leachate sample). The value tends to decrease as the distance from the center of the dumpsite is increased. All but sample W1 are within the permissible WHO limit.

Figure 4h and Table 2 show the variation of magnesium at the different sampling stations. Magnesium is often associated with calcium in water. It is essential for chlorophyll growth and acts as a limiting factor for the growth of phytoplankton. The value of magnesium ranges from 1.1 to 6.2 Mg/l (excluding the value of the leachate sample). The trend of magnesium from sample W1 to sample B6 indicates a decrease in the amount of magnesium as the distance from the dumpsite increases. All but samples W1 shows a very low value of magnesium which is within the permissible limit of WHO. These low values of magnesium may be attributed to the geological formation of the area which may have hinder to migration of leachate filled magnesium to flow farther away from the dumpsite.

Figure 4i and Table 2 show the variation of sulphate at the different sampling stations. Sulphate is the leading cause of diarrhea and can only be removed in water by carrying out a distillation or reverse osmosis separation techniques. The value of sulphate ranges from 17.2 to 108 mg/l (excluding the value of the leachate sample). The value tends to decrease as the distance from the center of the dumpsite is increased. However, all the samples are within the permissible WHO limit.

Figure 4j and Table 2 Show the variation of chlorine at the different sampling stations. Excess chlorine in inland water is taken as index of pollution. The salt of sodium, potassium and calcium contributes to chlorine in water. The value of chlorine ranges from 180.3 to 910.2 mg/l (excluding those of the leachate samples). The trend of the value of chlorine decreases from sample W1 to B6. The high value of chlorine may be due to the type of waste that constitute the leachate that is migrating in the subsurface as can be seen from the amount of chlorine in the leachate sample. Samples B4, B5 and B6 falls within the standard value of WHO while the others are outside the standard value.

Figure 4k and Table 2 show the variation of nitrate at the different sampling stations. Nitrate concentration depends

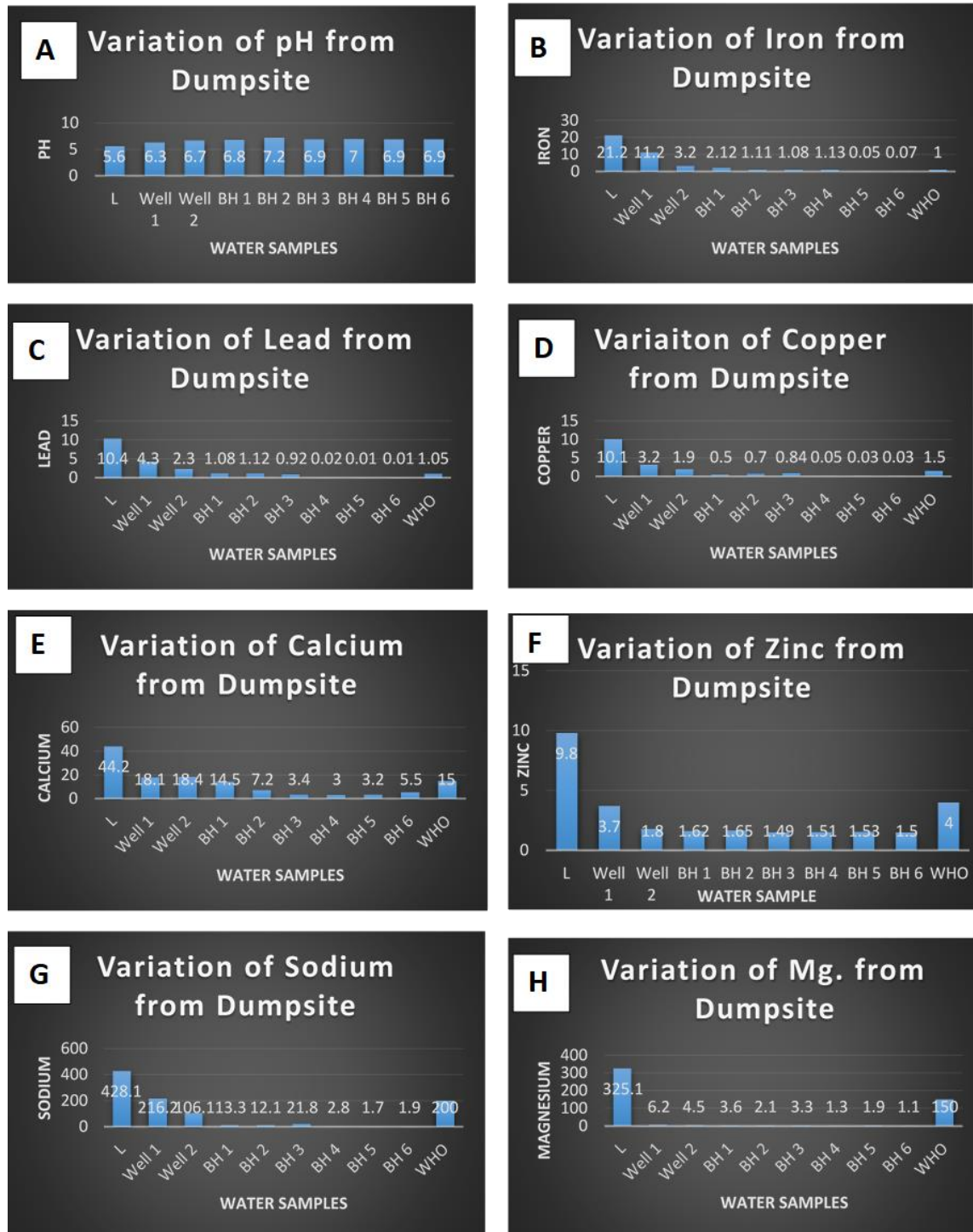


Figure 4 (A-H). water sampling analyses.

on the activities of nitrifying bacteria which in turn get influenced by the presence of dissolved oxygen. The value of nitrate ranges from 98 to 650.4 mg/l (excluding those of the leachate samples). The trend of nitrate is in

no particular order. High value of nitrate may be due to the composition of the leachate and the geological formation of the surrounding area. Sample W1 to B3 fell outside the standard range of WHO.

Table 2. Summary of result from water sampling analyses.

Parameters	L	Well 1	Well 2	BH 1	BH 2	BH 3	BH 4	BH 5	BH 6
Distance from dumpsite (m)	0	20	214	360	480	620	1100	1500	2200
Colour	Dark brown	Light brown	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Odour	Undesirable Odour	Undesirable Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Taste	ND	ND	Salty	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
pH	5.6	6.3	6.7	6.8	7.2	6.9	7.0	6.9	6.9
Temp (°C)	29.5	28.2	26.8	26.5	26.5	26.4	26.3	26.3	26.5
Fe ²⁺ (mg/l)	21.2	11.2	3.2	2.12	1.11	1.08	1.13	0.05	0.07
Pb ²⁺ (mg/l)	10.4	4.2	2.3	1.08	1.12	0.02	0.02	0.01	0.01
Cu	10.0	3.2	1.9	0.5	0.7	0.8	0.05	0.03	0.03
Zn ²⁺ (mg/l)	9.8	3.7	1.8	1.62	1.65	1.49	1.51	1.53	1.5
Ca(mg/l)	44.2	18.1	18.4	14.5	7.2	3.4	3	3.2	5.5
Na(mg/l)	428.1	216.2	106.1	13.3	12.1	2.8	2.8	1.7	1.9
Mg ²⁺ (mg/l)	325.1	6.2	4.5	3.6	2.1	3.3	1.3	1.9	1.1
SO ₄ ²⁺ (mg/l)	150	108	94	28.1	18.5	19	17.2	16.9	17.5
Cl ⁻ (mg/l)	1830.6	910.2	705.5	602.2	311.3	411.3	181.1	211.3	180.3
NO ₃ ⁻ (mg/l)	950	650.4	540.2	293.2	375.1	184.3	110.2	98.8	209
HCO ₃ ⁻ (mg/l)	10.6	15.3	12.3	28.8	23.9	29.4	20	35.5	35.9
TDS	3000	900	740	301	230	150	151	200	156
BOD	30.2	9.7	5	4.8	4.5	5.4	4	4.2	4.2
TSS	110	15	9	7	7	3	4	4	3
COD	57	15.3	9.5	8.1	5.1	2.5	1.1	1.1	1.1
Total Hardness	1200.2	680.5	450.2	240.5	136.6	75.2	38.1	35	35.1
Conductivity	4920	1450	503	300	243	242	171	150	201

Figure 4l and Table 2 show the variation of bicarbonate at the different sampling stations. Bicarbonate is a natural component of all mineral water, it plays a vital role in buffering acids and ensures that the mineral water taste clean and refreshing. The value of bicarbonate ranges from 12.3 to 35.9 mg/l. The values of the bicarbonate increase from the centre of the dumpsite. All of the samples except those of the leachate are within the

standard value of WHO and hence in good quality.

Figure 4m and Table 2 show variation of total dissolved solid at different sampling stations. Total dissolved solid is a parameter that indicates the amount of dissolved solid in a water. There is a decreasing trend of 156 to 900 Mg/l (excluding the value of leachate sample), indicating that the water samples close to the dumpsite have higher values of TDS from the samples far from the dumpsite. All

the samples are within the permissible limit of WHO (Table 1).

Figure 4n and Table 2 show the variation of the biological oxygen at different sampling stations. BOD is an indicator of the amount of oxygen needed by the microorganism and it was obtained after it has been cultured for five (5) days. It also indicates the presence of microorganism in the water. The BOD in the water samples ranges from

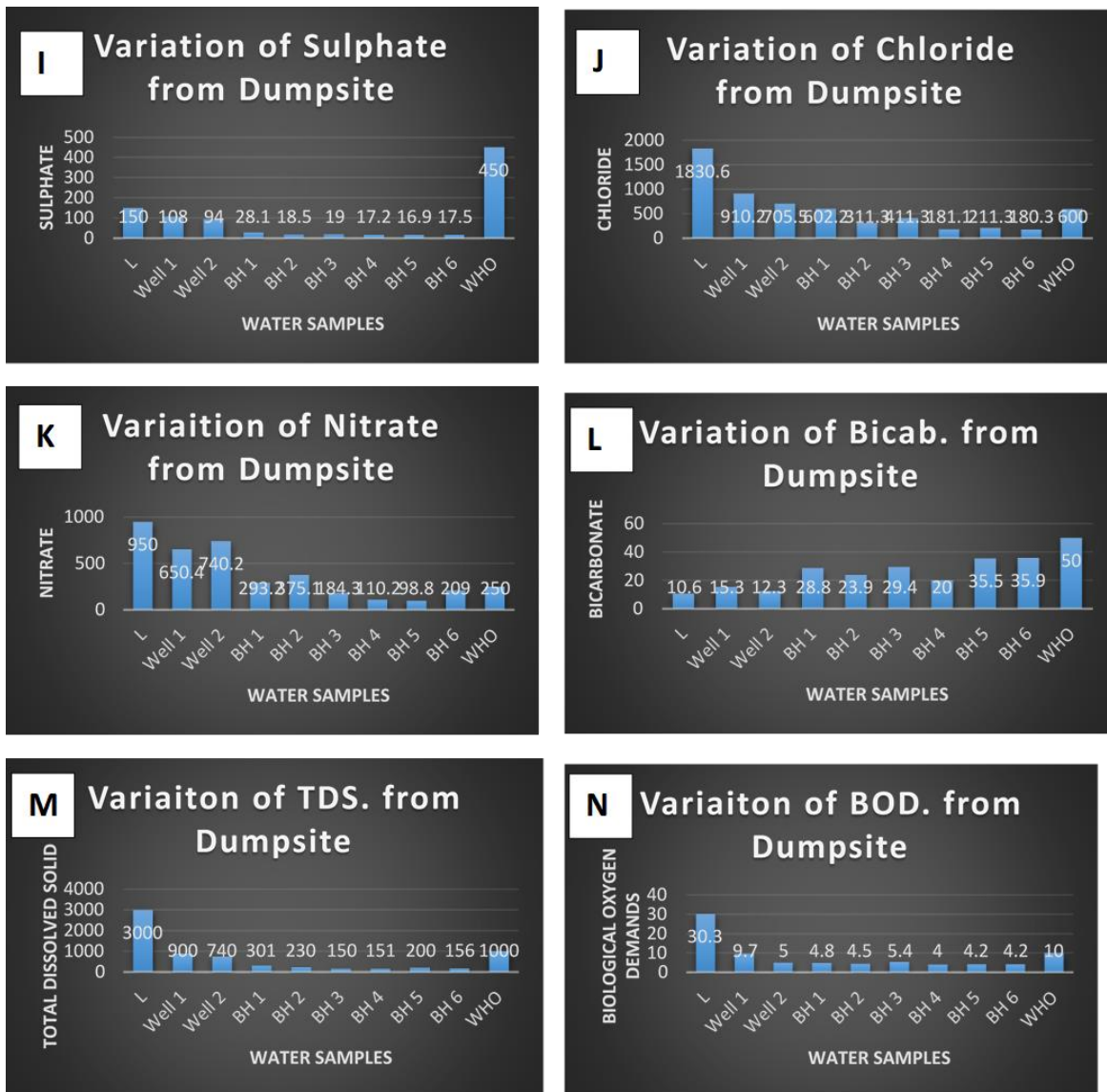


Figure 4 (I-N). water sampling analyses.

4 to 9.7 Mg/l (excluding those from the dumpsite), indicating that water samples close to the dumpsite have higher values of BOD than samples far from the dumpsite. All but sample W1 are within the permissible limit of WHO (Table 1).

Figure 4o and Table 2 show variation of total suspended solid at different sampling stations. TSS is the portion of fine particulate matter that remains in suspension in water. From the table TSS ranges from 3 to 15 Mg/l (excluding those of the leachate sample) indicating that water samples close to the dumpsite have more suspended particles than samples far from the dumpsite. Samples Well 1 to BH 3 fall below the permissible limit of WHO.

Figure 4p and Table 2 show variation of chemical

oxygen demands at different sampling stations. COD is the measure of wastewater in domestic water. From the table COD ranges from 1.1 to 15.3 mg/l (excluding those of the leachate sample) indicating that water samples close to the dumpsite have more wastewater content than samples far from the dumpsite. Samples Well 1 and Well 2 fall below the permissible limit of WHO.

Figure 4q and Table 2 show variation of total Hardness at different sampling stations. TH is the sum of the calcium and magnesium concentration both express as calcium carbonate. From the table TH ranges from 35 to 680.5 Mg/l (excluding those of the leachate sample) indicating that water samples close to the dumpsite have more suspended particles than samples far from the dumpsite.

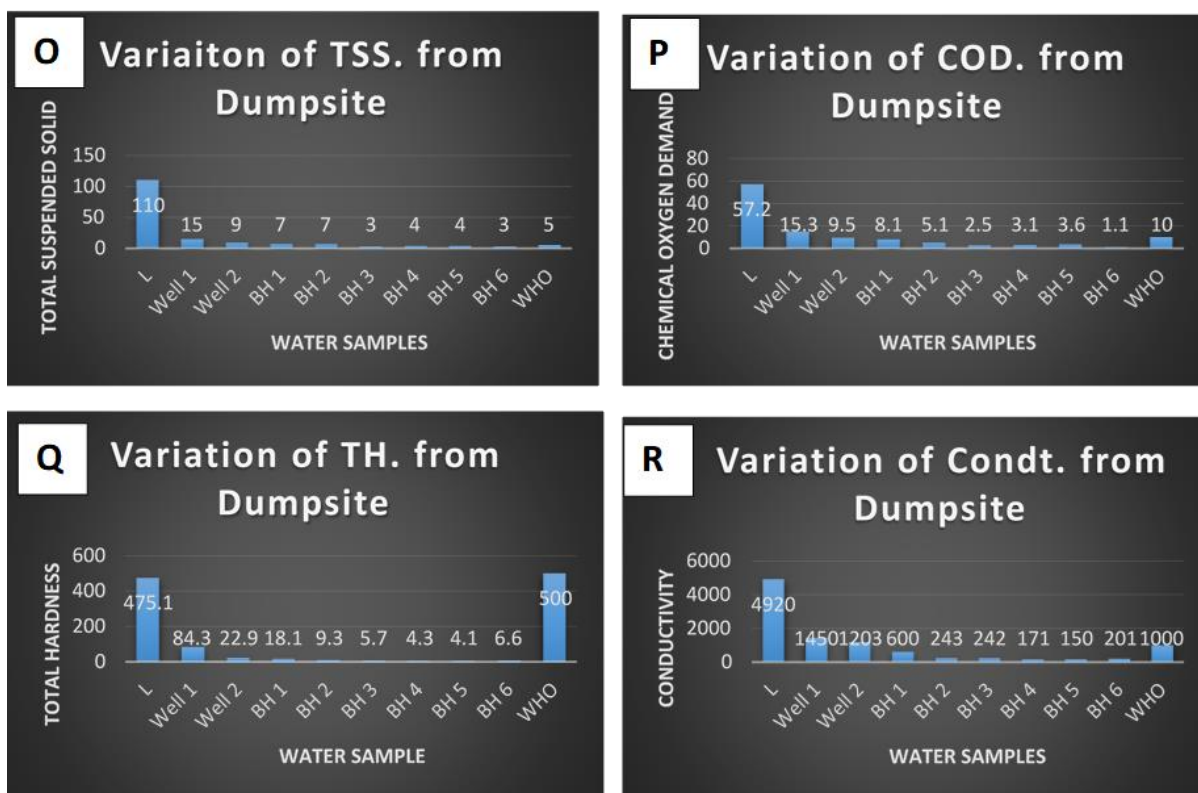


Figure 4 (O-R). water sampling analyses.

Table 3. Water quality index and status.

Water samples	Water quality index	Water quality status
W1	512.53	Unfit for Consumption
W2	199.69	Unfit for Consumption
B1	113.25	Unfit for Consumption
B2	86.75	Very poor
B3	61.52	Poor
B4	45.32	Good
B5	13.32	Excellent
B6	13.59	Excellent

All the water samples fall below the permissible limit of WHO.

The conductivities of the water samples are presented in Figure 4r and Table 2. The conductivity indicates the amount of concentrated (ionized) solute in a solvent, from the values of conductivity in the water samples it shows that there is a trend from Well 1 to BH 6 indicating a decrease in conductivity which could be due to the leachate from the dumpsite, which was richer in metal ions as can be seen in the value of the leachate sample. The value of samples Well 1 and Well 2 are the only water samples below the permissible limit of WHO.

Water quality index analyses

The water quality analysis was conducted on various sampling stations, and the obtained results (Table 3) were analyzed based on multiple parameters. The parameters considered include pH, iron, lead, copper, zinc, potassium, sodium, magnesium, sulphate, chlorine, nitrate, bio-carbonate, total dissolved solvent, biological oxygen demand, total suspended solid, chemical oxygen demand, total hardness, and conductivity.

The overall WQI ranges from 13.52 to 513, with station W1 having the highest WQI of 512. The water content at

Table 4. Summary of analysis from the soil sample.

S/N	Parameters	Units	Standard methods	Sample 1	Sample 2	Control
1	pH	µs/cm	ASIMD 12933-90	7.25	7.09	6.1
2	Electric conductivity	mg/l	ASIMD 1125-95	82	62	26
3	Iron	mg/l	ASTMD 1068-96	79.77	87.21	43.9
4	Zinc	mg/l	ASTMD 1691-95	23.5	39.1	19.4
5	Copper	mg/l	ASTMD 1188-95	3.05	3.77	1.06
6	Temp	0C	EPA 1979	27.5	26.4	28
7	Total organic carbon	%	ASTMD 2974	3.1	1.12	0.36
8	Sand	%	HYDROMETER	65.42	63.33	66.18
9	Silt	%	HYDROMETER	3.46	4.45	3.3
10	Clay	%	HYDROMETER	36.12	35.22	34.52

station W1 was found to be unfit for consumption. Similar to station W1, stations W2 and B2 also had high WQI values of 119.69 and 113.25, respectively, indicating that their water content is also unfit for consumption.

Samples B2 and B3 were designated as very poor and poor, respectively, with WQI values of 86.75 and 61.52. On the other hand, samples B4, B5, and B6 were designated as good and excellent, with WQI values of 45.23, 13.32, and 13.59, indicating that their water content is fit for consumption and free from contamination.

The results in Table 2 show that the physiochemical parameters of the water samples, located approximately 500 m from the dumpsite, are below the permissible limit set by the World Health Organization (WHO). However, total hardness and sulphate levels were within the WHO standards.

Soil analysis

Table 4 presents the soil samples collected at the dumpsite and the control site. It is evident that the soil samples collected from the dumpsite exhibit higher values compared to those from the control site. This increase in values within the dumpsite can be attributed to the influence of leachate from the dumpsite.

The composition of sand within the dumpsite ranges from 63 to 65%, while the composition of silt ranges from 3 to 4%. Additionally, the composition of clay ranges from 34 to 35%. The excess sand in relation to clay and silt can be attributed to the geological formation of the area. Coarse-textured soils typically exhibit moderate to high sensitivities due to their higher permeability and lower sorption potentials. Conversely, fine-textured soils have slower permeability and higher sorption potentials.

DISCUSSION

The presence of contaminated samples as observed in the above section may be attributed to leachate migration that has come into contact with the aquifer. This finding is

consistent with previous works conducted by Aderemi *et al.* (2011) and Olafisoye *et al.* (2013b) in the western region of the country.

Physico-chemical analysis of the water samples found in areas closed to landfill area supported the above claim by revealing elevated levels of parameters such as COD, TSS, Cl, Nitrate, Na, Ca, Cu, Pb, Fe, and electrical conductivity, exceeding the standards set by reputable organizations such as the World Health Organization (WHO, 2004). These findings strongly indicate that water contamination from the dumpsite has significantly affected the groundwater quality in the vicinity.

However, based on the graphical representation and table of samples, most of the heavy metal samples were found to be within the permissible limit set by the WHO. This may be due to the composition of the dumpsite, which mainly consists of domestic waste rather than industrial waste. This finding is supported by the works of Chiedozi *et al.* (2022) in Nnewi and Uyo *et al.* (2021) in Obosi.

The graphical and tabular representations of the data also suggest that the rate of contamination from the dumpsite is inversely proportional to the distance from the source. This implies that the further away from the dumpsite, the lower the level of contamination. Consequently, water within and around a radius of approximately 500 meters from the dumpsite is deemed unsuitable for drinking, as it poses potential health risks and hazards. This observation is consistent with the findings of Chiedozi *et al.* (2022) in Nnewi and Uyo *et al.* (2021) in Obosi, but it disagrees with the works of Umoh and Etim (2013) in Akwaibom.

The water quality index, ranging from 13 to 513, further confirms that the well and borehole located approximately 500 meters from the dumpsite are not safe for consumption and require extensive treatment before use, a similar survey by Chiedozi *et al.* (2022) in Nnew found the WQI to range 90 to 118.4 in areas close to the dumpsite surveyed.

The prevalence of excess sand in relation to clay and silt can be attributed to the geological composition of the area. Coarse-textured soils, characterized by higher permea-

bility and lower sorption potentials, generally exhibit moderate to high sensitivities. Conversely, fine-textured soils have slower permeability and higher sorption potentials. The presence of a significant amount of coarse sandy soil in and around the landfill facilitates the rapid flow of contaminants from the dumpsite, as can be seen in the geophysical analysis of leachate migration by Obiabanmo and Obiekezie (2023) in Obosi.

While the average concentration of clay may impede the free migration of leachate, the excess sand allows pollutants to freely move along with the groundwater. Consequently, the proximity of wells and boreholes to the dumpsite may not be the sole determinant of groundwater pollution. The clay content found within the soil samples explains the gradual movement of contaminants from the dumpsite to more distant wells and boreholes through leaching. Similar results were obtained by Aderemi *et al.* (2011), Chiedozie *et al.* (2022), Olafisoye *et al.* (2013a) and Uyo *et al.* (2021).

Conclusion

The findings from the hydro-physicochemical analysis, coupled with the utilization of the Water Quality Index (WQI), provide compelling evidence that the water samples collected from locations in close proximity to the dumpsite, within 500 m radius from the dumpsite, have been significantly impacted by the leachate flowing through the subsurface. The presence of traces of sampled parameters exceeding the recommended standards set by the World Health Organization (WHO) underscores the urgent need for remedial actions to address the contamination issue and safeguard the health and well-being of the affected communities.

Addressing this issue requires immediate action, including the implementation of remedial measures, collaboration among stakeholders, and advocacy for policy changes. By taking these steps, relevant work towards restoring the quality of the water and ensuring the well-being of the affected communities can be achieved.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCE

- Adeigbe, O., & Salufu, E. (2009). Geology and depositional environment of Campano-Maastrichtian sediments in the Anambra Basin, Southeastern Nigeria: Evidence from field relationship and sedimentological study. *Earth Sciences Research Journal*, 13, 148-165.
- Aderemi, A. O., Oriaku, A. V., Adewumi, G. A., & Otitoloju, A. A. (2011). Assessment of groundwater contamination by leachate near a municipal solid waste landfill. *African Journal of Environmental Science and Technology*, 5(11), 933-940.
- Akakuru, O. C., Akaolisa, C. C. Z., Aigbadon, G. O., Eyankware, M. O., Opara, A. I., Obasi, P. N., Ofoh, I. J., Njoku, A. O., & Akudinobi, B. E. B. (2023). Integrating machine learning and multi-linear regression modeling approaches in groundwater quality assessment around Obosi, SE Nigeria. *Environment, Development and Sustainability*, 25(12), 14567-14606.
- Akanwa, A. O. (2013). *Health implications of open waste dumping on groundwater resources at Onitsha South and Idemili North Local Government Areas in Anambra State*. Digital Library for Online resource sharing among the University communities. Retrieved from <https://naudigitalibrary.wordpress.com/2013/02/21/health-implications-of-open-waste-dumping-on-groundwater-resources-at-onitsha-south-and-idemili-north-local-government-areas-in-anambra-state/>.
- Alao, J. O. (2023). Impacts of open dumpsite leachates on soil and groundwater quality. *Groundwater for Sustainable Development*, 20, 100877.
- Ameloko, A. A., & Ayolabi, E. A. (2018). Geophysical assessment for vertical leachate migration profile and physicochemical study of groundwater around the Olusosun dumpsite Lagos, south-west Nigeria. *Applied Water Science*, 8(5), 142.
- American Public Health Association (APHA) (2005). *Standard methods for the examination of water and wastewater. 21st Edition, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC*.
- Anagboso, M. O., Orji, M. U., Nwankwegu, A. S., & Azi, F. (2016). Phytotoxicity, Bioload and Heavy Metal Evaluation of a Selected Municipal Dumpsite in Obosi, Anambra State, Nigeria. *Advances in Research*, 8(4), Article 4.
- Brown, R. M., McClelland, N. I., Deininger, R. A., & O'Connor, M. F. (1972). A water quality index—crashing the psychological barrier. In: *Indicators of Environmental Quality: Proceedings of a symposium held during the AAAS meeting in Philadelphia, Pennsylvania, December 26–31, 1971* (pp. 173-182). Springer US.
- Chibuogwu I. U., Ugwu G. Z., & Egwuonwu G. N. (2023). Conducting a comprehensive physical investigation on uncontrolled internal soil erosion leading to sinkholes in Anambra State, Nigeria. *Asian Journal of Geographical Research*, 6(3), 104-122.
- Chibuogwu, I. U., & Ugwu, G. Z. (2023a). Investigation into the chemical characteristics of soils near sinkholes situated in Anambra State, Nigeria. *Saudi Journal of Civil Engineering*, 7(09), 211-225.
- Chibuogwu, I. U., & Ugwu, G. Z. (2023b). Recruiting the very low frequency electromagnetic geophysical technique for the characterisation of two eroded soil pipes in Awka, Anambra State, Nigeria. *Asian Journal of Geological Research*, 6(2), 84–92.
- Chibuogwu, I. U., & Ugwu, G. Z. (2023c). Investigating the susceptibility of tunnel erosion in Southern Nigeria using Integrated Geophysical Methods. *African Journal of Environment and Natural Science Research*, 6(3), 67-87.
- Chiedozie, A., Okoye, P.-A., Abugu, H., & Eze, V. (2022). Discover Water Pollution and water quality index of boreholes within unlined waste dumpsite in Nnewi, Nigeria. *Discover Water*, 2, Article number 14.
- Dapaah-Siakwan, S., & Gyau-Boakye, P. (2000). Hydrogeologic framework and borehole yields in Ghana. *Hydrogeology Journal*, 8(4), 405-416.
- Dixit, A., Singh, D., & Shukla, S. K. (2024). Assessment of human health risk due to leachate contaminated soil at solid waste

- dumpsite, Kanpur (India). *International Journal of Environmental Science and Technology*, 21(1), 909-924.
- Emereibeole E. I., Dike M. U., Mgbearuiké L. U., Edo F.A., & Uyo C. N. (2021). A Modflow assisted simulation of leachate plume pathway from the Idemili North Municipal dumpsite, Anambra State Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 15(16), 27–35.
- Gyabaah, D., Awuah, E., Antwi-Agyei, P., & Kuffour, R. A. (2023). Characterization of dumpsite waste of different ages in Ghana. *Heliyon*, 9(5), e15827. <https://doi.org/10.1016/j.heliyon.2023.e15827>
- Heiß, L., Bouchaou, L., Tadoumant, S., & Reichert, B. (2020). Index-based groundwater vulnerability and water quality assessment in the arid region of Tata city (Morocco). *Groundwater for Sustainable Development*, 10, 100344.
- Hussain, A., Deshwal, A., Priyadarshi, M., Pathak, S., Sambandam, G., Chand, S., & Shukla, A. K. (2024). Landfill leachate analysis from selected landfill sites and its impact on groundwater quality, New Delhi, India. *Environment, Development and Sustainability*. Pp. 1-26.
- Ikhiba, I., Obiekezie, T., & Iyoha, A. (2019). Geophysical contribution of using 3D view in landfill site. *To Physics Journal*, 2, 1-6.
- Keenan, P. J., Iza, J., & Switzenbaum, M. S. (1993). Inorganic Solids development in a pilot-scale anaerobic reactor treating municipal solid waste landfill leachate. *Water Environment Research*, 65(2), 181-188.
- Kelechi, O. F. (2017). The southern benue trough and Anambra basin, southeastern Nigeria: a stratigraphic review. *Journal of Geography Environment and Earth Science International*, 12, 1-16.
- Khan, S., Naushad, Mu., Govarthanam, M., Iqbal, J., & Alfadul, S. M. (2022). Emerging contaminants of high concern for the environment: Current trends and future research. *Environmental Research*, 207, 112609.
- Lone, I. H., Kumar, A., Khan, F., Saxena, S., Dar, A. I. (2012). Evaluating the effect of landfill leachate on groundwater quality in relation to physicochemical and bacteriological characteristics. *Journal of Chemical and Pharmaceutical Research*, 4(12), 5202-5214.
- Mohammadi, A., Malakootian, M., Dobaradaran, S., Hashemi, M., Jaafarzadeh, N., & Parniani, N. (2023). Determination and seasonal analysis of physicochemical characterization and metal (oids) of landfill leachate in Bushehr port along the Persian Gulf. *Toxin Reviews*, 42(1), 161-175.
- Obiabanmo, O. C., & Obiekezie, T. N. (2023). The geophysical investigation of leachate formation in Mgbuka Obosi, Idemili North Local Government Area of Anambra State, Nigeria. *Asian Journal of Geographical Research*, 6(4), 44-57.
- Obiri-Nyarko, F., Duah, A. Appiah., Karikari, A. Y., & Tagoe, R. (2023). Characterization of leachate, groundwater quality analysis, and evaluation of hydrogeochemical processes at the Kpone engineered landfill site, Ghana. *Sustainable Water Resources Management*, 9, Article number 15.
- Ocheli, A., Ogbe, O. B., & Aigbadon, G. O. (2021). Geology and geotechnical investigations of part of the Anambra Basin, Southeastern Nigeria: Implication for gully erosion hazards. *Environmental Systems Research*, 10, Article number 23
- Okolo, C. M., Akudinobi, B. E. B., Obiadi, I. I., & Okoyeh, E. I. (2017). Assessment of pollution status of lower Niger drainage area, south-Eastern Nigeria using heavy metals. *Journal of Basic Physical Research*, 3(2), 59-67.
- Olafisoye, E. R., Sunmonu, L. A., Adagunodo, T. A., & Oladejo, O. P. (2013a). Groundwater contaminant's investigation at aarada waste disposal site using geophysical and hydro-physicochemical approach. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 2(4), 1-10.
- Olafisoye, E. R., Sunmonu, L. A., Adagunodo, T. A., & Oladejo, O. P. (2013b). Impact assessment of solid waste on groundwater: a case study of aarada Dumpsite, Nigeria. *ARPN Journal of Earth Sciences*, 2(2), 45-53.
- Omeiza, A. J., Adeniyi, L. H., & Shettima, N. M. Investigation of groundwater vulnerability to open dumpsites and its potential risk using electrical resistivity and water analysis, *Heliyon*, 9(2), e13265.
- Orhorhoro, K., & Oghoghorie, O. (2023). The assessment of physicochemical properties of municipal solid waste leachate from dumpsites in Ovia North-East Local Government Area, Nigeria: Physicochemical properties of municipal solid waste leachate from dumpsites. *Journal of Energy Technology and Environment*, 5(4), 9-18.
- Osei, J., Osae, S. K., Fianko, J. R., Adomako, D., Laar, C., Anim, A. K., Ganyaglo, S. Y., Nyarko, M., & Nyarko, E. S. (2011). The impact of Oblogo landfill site in Accra-Ghana on the surrounding environment. *Research Journal of Environmental and Earth Sciences*, 3(6), 633-636.
- Osuagwu, E. C., Uwaga, A. M., & Inemeawaji, H. P. (2023). Effects of leachate from Osisioma Open Dumpsite in Aba, Abia State, Nigeria on surrounding borehole water quality. In: Sherif, M., Singh, V. P., Sefelnasr, A., & Abrar, M. (eds.), *Water Resources Management and Sustainability* (Vol. 121, pp. 319–333). Springer Nature Switzerland.
- Pohland, F. G., & Harper, S. R. (1986). *Critical review and summary of leachate and gas production from landfills*. USEPA, Atlanta, U.S.A.
- Pohland, F. G., Ravi, S., Schaffer, T. R., & Cross, W. H. (1987). *The fate of selected organic pollutants during landfill disposal operations: Vol. AD-A180 117*. USEPA, Atlanta, U.S.A.
- Ugbor, C. C., Ikwuagwu, I. E., & Ogboko, O. J. (2021). 2D inversion of electrical resistivity investigation of contaminant plume around a dumpsite near Onitsha expressway in southeastern Nigeria. *Scientific Reports*, 11, Article number 11854.
- Umoh, S. D., & Etim, E. E. (2013). Determination of heavy metal contents from dumpsites within Ikot Ekpene, Akwa Ibom State, Nigeria using atomic absorption spectrophotometer. *The International Journal of Engineering and Science*, 2(2), 123-129.
- USEPA (2021). *USEPA Document*. U.S Environmental Protection Agency.
- Uyo, C., Emereibeole, E., Mgbearuiké, L., Irene, E., Edo, F., Nmecha, M., & Acholonu, C. (2021). Groundwater contamination from a municipal solid waste dumpsite: Case study of Obosi, Southeastern Nigeria. *Nature and Science*, 12(2), 15-22.
- World Health Organization (WHO) (2004). *Guidelines for drinking-water quality, 4th edition, incorporating the 1st addendum*. Retrieved from <https://www.who.int/publications-detail-redirect/9789241549950>.