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IMPACTS OF DUMPSITE LEACHATE ON GROUNDWATER QUALITY IN AWKA, ANAMBRA STATE, NIGERIA AND ENVIRONS: A PHYSICOCHEMICAL AND HEAVY METAL ANALYSIS

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ABSTRACT

Groundwater contamination from improper solid waste disposal is a critical environmental issue in urban areas like Awka South Local Government Area (LGA), Anambra State, Nigeria, where rapid population growth and inadequate waste management exacerbate leachate infiltration into aquifers. This study evaluates the impact of dumpsite leachate on groundwater quality by analyzing physicochemical parameters (hardness, alkalinity, chloride, nitrate, sulphate, potential of hydrogen (pH), Total dissolved sold (TDS), and turbidity) and heavy metals (lead, mercury, chromium, and arsenic) in groundwater and leachate samples from six locations: Amawbia, Agu-Awka, Ifite Awka, Okpuno, Amaenyi, and Amansea. Samples were collected from boreholes, wells, and dumpsite runoff, analyzed using standard methods (APHA, 2017), and compared against World Health Organization (WHO) drinking water guidelines and Food and Agriculture Organization (FAO) irrigation standards. Results indicate that groundwater physicochemical parameters largely comply with WHO limits, with minor exceedances in pH (e.g., Ifite Awka 6.33) and turbidity (up to 2.114 NTU). Leachates exhibit greater deviations, including acidic pH (6.14–6.52), high turbidity (up to 5.891 NTU), and elevated nitrates (up to 47.807 mg/l), suggesting landfill influence. Heavy metal concentrations frequently exceed WHO health-based limits, with lead (up to 0.267 mg/l), mercury (up to 1.352 mg/l), chromium (up to 2.706 mg/l/), and arsenic (up to 0.231 mg/l) posing toxicity and carcinogenic risks for drinking. For irrigation, most parameters meet FAO guidelines, except some chromium and arsenic in leachates. The study highlights significant groundwater contamination risks from leachate, particularly heavy metals, necessitating remediation, improved waste management, and geospatial monitoring to protect public health and agricultural sustainability in Awka South LGA.

Keywords: Groundwater Contamination, Leachate, Heavy Metals, Physicochemical Parameters, Dumpsite, Awka South LGA

1.0 INTRODUCTION

Groundwater is a vital resource that serves as the primary source of drinking water for millions of people globally, especially in regions where surface water is either scarce or unreliable, it also plays an integral role in agricultural irrigation and industrial use. Groundwater is often regarded as a relatively clean and safe source of water compared to surface water bodies, which are more exposed to contamination from external sources (Zhang *et al.*, 2014; WHO, 2017). However, the quality of groundwater is increasingly under threat from various human activities, particularly the improper disposal of solid waste. Solid waste disposal, if not properly managed, has the potential to degrade water quality and introduce harmful contaminants into the groundwater, posing serious public health and environmental risks (Kumar and Singh, 2015; UNEP, 2015). Groundwater remains poorly monitored and vulnerable to overexploitation and contamination. Rapid urban growth, population increase, and the declining reliability of surface water sources have intensified groundwater dependence—especially in developing regions like sub-Saharan Africa. In urban centers such as Ibadan, Nigeria, residents increasingly rely on boreholes and shallow wells, which are often exposed to contamination due to poor sanitation, unregulated land use, and inadequate waste disposal (Barbieri *et al.*, 2023; Renou *et al.*, 2008; Kjeldsen *et al.*, 2002). Solid waste management is a pressing environmental challenge in developing countries, where rapid urbanization and population growth outpace infrastructure development, leading to the proliferation of uncontrolled dumpsites. These nations, spanning Africa, Asia, and Latin America, generate billions of tons of municipal solid waste (MSW) annually, with inadequate systems exacerbating pollution and health risks (Ferronato and Torretta, 2019; Hoornweg and Bhada-Tata, 2012). Limited funding, outdated technology, and weak regulations foster open dumping, allowing harmful leachate to contaminate soil and water. Heavy rainfall, common in tropical regions, accelerates leachate production and migration, amplifying environmental risks. Globally, poor waste management contributes to greenhouse gas emissions, soil degradation, and biodiversity loss, necessitating sustainable practices aligned with United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 6 (Clean Water and Sanitation) (Vinti and Vaccari, 2022; United Nations, 2015).

In Nigeria, the most populous African nation, municipal solid waste generation exceeds 32 million tons annually, with much of it disposed of in open dumpsites lacking proper lining or leachate collection systems (Ibrahim, 2023). Urban centers like Lagos, Abuja, and regional hubs generate 0.5-0.7 kg of waste per capita daily, overwhelming infrastructure (Ogwueleka, 2009). Informal dumpsites cause air pollution from open burning and water contamination from runoff. The National Environmental Standards and Regulations Enforcement Agency (NESREA) promotes engineered landfills, but corruption, resource scarcity, and low public awareness hinder progress. Over 80% of Nigeria’s waste is organic, yet recycling rates are below 10%, increasing decomposition and leachate production during the rainy season (Ezeudu *et al.*, 2024; Oloruntade *et al.*, 2013). Environmental pollution arising from improper waste disposal and the consequent contamination of groundwater resources has emerged as a critical concern in both developed and developing countries. In urban regions such as Awka and its environs in Awka South LGA, Anambra State, Nigeria, the exponential increase in population and the expansion of businesses, public and private organizations have led to increased waste generation. A substantial portion of this waste, particularly solid waste, is disposed of in open dumpsites or poorly engineered landfills, which in turn become significant sources of leachate (Bhattacharya *et al.*, 2012).

Leachate, a highly contaminated liquid formed by rainwater percolating through decomposing waste, contains organic compounds, inorganic ions, heavy metals, and pathogens. Young leachate from newer dumpsites is acidic with high biochemical oxygen demand (BOD), while mature leachate becomes alkaline with persistent heavy metals. When this leachate infiltrates into the subsurface, it may eventually reach and contaminate the groundwater, thereby posing environmental and health hazards (Alam and Ahmaruzzaman, 2021; Chiedozie *et al.*, 2021). The physicochemical properties of leachate, including pH, electrical conductivity (EC), BOD, chemical oxygen demand (COD), total dissolved solids (TDS), and heavy metals like lead (Pb), chromium (Cr), cadmium (Cd), and arsenic (As), determine its impact on soil and water chemistry

(Budianto *et al.*, 2024). The improper disposal of waste on land has raised substantial concerns regarding its impacts on both surface water and groundwater resources, thereby prompting substantial research dedicated to assessing the effects of leachate infiltration into the groundwater within the confines of the study area. Leachate migration threatens groundwater, especially in regions with permeable soils and high rainfall, where it infiltrates aquifers and degrades water quality (Umobi *et al.*, 2025; Okafor *et al.*, 2024; Okoye *et al.*, 2020). In southeastern Nigeria's sandy or fractured geology, leachate plumes can travel hundreds of meters, altering groundwater pH, increasing TDS, and introducing pathogens (Mor *et. al.*, 2006). Groundwater is a primary drinking water source for Nigeria's rural and peri-urban communities, making contamination a public health concern linked to gastrointestinal illnesses, neurological disorders, and carcinogenic effects from toxic elements (Afolabi *et al.*, 2019). Heavy metals like As and Cd are carcinogenic, while Pb impairs child development (WHO, 2019). Over 60% of Nigerians rely on untreated groundwater, and outbreaks of cholera and dysentery have been linked to polluted wells near dumpsites (Adelekan, 2010). Economic impacts include healthcare costs and lost productivity, costing billions of naira annually. Studies show elevated toxic elements in groundwater near dumpsites, with seasonal variations—wet seasons (May-October) increase leachate volume and mobility, while dry seasons concentrate pollutants (Wisniewski *et al.*, 2024).

In Anambra State, southeastern Nigeria, dense populations and inadequate waste management exacerbate the issue (Nwachukwu *et al.*, 2022). With over 6 million residents, the state generates 500,000 tons of waste yearly, managed by the Anambra State Waste Management Agency (ASWAMA), but enforcement is weak. Urban areas like Awka and Onitsha host informal dumpsites with minimal waste segregation and frequent open burning. The region's lateritic soils and high rainfall (>2,000 mm annually) facilitate leachate percolation (Egboka *et al.*, 1989). Awka South Local Government Area (LGA), including the state capital Awka and areas like Agu-Awka, faces significant waste accumulation from residential, commercial, and industrial activities. Uncontrolled dumpsites generate leachate that infiltrates aquifers, degrading groundwater quality through changes in physicochemical parameters (Okafor *et al.*, 2024). The local geology, dominated by Imo Shale and Ameki Formations, includes permeable sandstones that aid contaminant transport. Studies in nearby areas report sulphate and heavy metal concentrations exceeding World Health Organization (WHO) guidelines, highlighting the need for site-specific assessments (Aralu and Okoye, 2020; Budianto *et al.*, 2024). For instance, Pb levels in Awka's soil and plants near dumpsites reach 0.5 mg/l, far above WHO 0.01 mg/l, water limit (WHO, 2019). Yet, few studies explore the direct link between leachate properties and groundwater impacts in Awka South LGA, leaving gaps in understanding hydrogeochemical dynamics and mitigation strategies. Existing research often ignores spatial factors, like distance from dumpsites, or temporal variations, such as pre- and post-monsoon sampling. This gap hinders effective interventions, as pollutant pathways and risks require detailed analysis. Contaminated groundwater also threatens agriculture, as irrigation spreads pollutants into crops, causing bioaccumulation in food chains (Bhattacharya *et al.*, 2012). Policy solutions could adopt circular economy principles, like enhanced recycling and composting, to reduce waste volumes. Investments in lined landfills, leachate treatment (e.g., membrane filtration or constructed wetlands), and community education are critical (Vinti and Vaccari, 2022). Geospatial monitoring could track plume migration (Han *et al.*, 2014). This study aims to evaluate the impact of dumpsite leachate's physicochemical properties on groundwater quality in Awka South LGA, Anambra State. By analyzing leachate and groundwater samples for key parameters and assessing spatial and temporal variations, the research seeks to quantify contamination levels, identify dominant pollutants, and propose sustainable waste management and groundwater protection strategies.

2.0 METHODOLOGY

2.1 Study Area

This study was conducted in Awka South Local Government Area (LGA) in Anambra State, Nigeria. Leachate samples were collected from selected towns within the Awka South LGA, including Amawbia, Agu-Awka, Ifite, Okpuno, Amaenyi, and Amansea. This region has a tropical climate, sandy-loam soils, and shallow aquifers that are susceptible to contamination from surface waste disposal, the geology features Imo Shale and Ameki Formations with permeable sandstones, facilitating leachate migration, exacerbated by high rainfall (>2,000 mm annually) (Egboka *et al.*, 1989). Additionally, the proximity of open dumpsites to residential areas heightens the risk of leachate infiltrating into the groundwater.

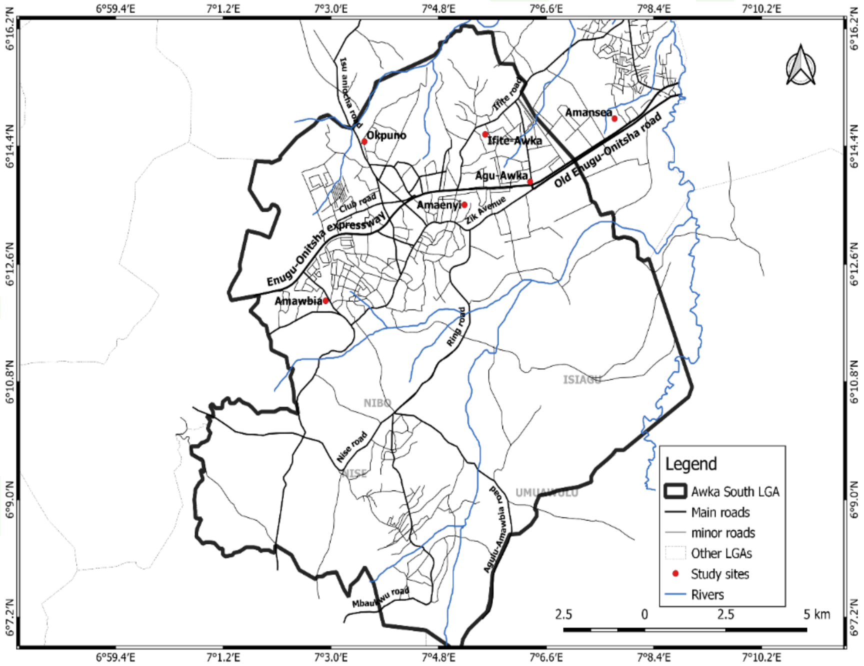

Figure 1: Map Showing the Study Area. *Source ArcGIS 10.2*

2.2 Sample Collection and Sampling Technique

Groundwater and leachate samples were collected from six locations (Amawbia, Agu-Awka, Ifite, Okpuno, Amaenyi, and Amansea) in Awka South LGA. Physicochemical parameters (hardness, alkalinity, chloride, nitrate, sulphate, pH, TDS, turbidity) and heavy metals (Cr, Mn, Cd, Ni, Pb) were analyzed using standard methods (APHA, 2017). Groundwater was sampled from boreholes and wells, while leachate was obtained from dumpsite runoff. Parameters were measured in mg/l, (except pH and turbidity in NTU), with heavy metals determined via Atomic Absorption Spectrophotometry (AAS). Results were compared against WHO drinking water guidelines (WHO, 2017).

2.2.1 Determination of pH

Procedure:

i. The electrodes were rinsed with distilled water and blot dry.
ii. The pH electrodes was then rinsed in a small beaker with a portion of the sample.
iii. Sufficient amount of the sample was poured into a small beaker to allow the tips of the electrodes to be immersed to a depth of about 2cm. The electrode was at least 1cm away from the sides and bottom of the beaker.
iv. The temperature adjustment dial was adjusted accordingly.
v. The pH meter was turned on and the pH of sample recorded

2.2.2 Determination of Turbidity

i. The turbidity curvette was rinsed with distilled water and the instrument adjusted to zero.
ii. The water sample was poured into the curvette and the instrument adjusted to read result.

The obtained result is measured in NTU unit.

2.2.3 Determination of Total Hardness

Procedure: 50cm^3 of the water sample was introduced into a beaker and 1cm^3 buffer solution of NH_3 added. Three drops of solocrome Black T indicator was also added and the solution swirled properly. The mixture was titratated with 0.01EDTA solution until the colour changed from wine red to pure blue with no bluish tinge remaining. The total hardness of the water sample was calculated.

$$\text{Total hardness (mg/CaCO}_3) = \frac{\text{Volume of Titrate x 100}}{\text{Volume of Samples (cm}^3)} \text{ ……………….. eqn. 1}$$

2.2.4 Nitrate Determination

Procedure: 50ml of the sample was measured into a porcelain dish and evaporated to dryness on a hot water bath. 2ml of phenol disulphonic acid was added to dissolve the residue by constant stirring with a glass rod. Concentrated solution of sodium hydroxide and distilled water was added with stirring to make it alkaline. This was filtered into a Nessler's tube and made up to 50ml with distilled water. The absorbance was read at 410nm using a spectrophotometer after the development of color.

$$\text{Concentration of sample} = \frac{\text{Absorpance of Sample x Concentration}}{\text{Absorpance of Standard}} \text{ ……………….. eqn. 2}$$

2.2.5 Chloride Determination

Procedure: 100ml of the sample was measured into an Erlenmeyer flask and the pH adjusted to 7-10 with either H_2S0_4 or NaOH solution. Then 1ml of K_2CrO_4 indicator solution was added and titrated with standard solution of 0.01M silver nitrate to reddish brown coloration.

Chloride concentration = Titre value x 10 (mg/l) ……………….. eqn. 3

2.2.6 Determination of Total Dissolved Solids

Procedure: 50ml of the water samples was measured with the aid of measuring cylinder into a pre-weighed dish and evaporated to dryness at 100^{o}C on electric hot plate. The evaporated sample was dried in an oven for about an hour at 105^{o}C, cooled in a desiccator and recorded for constant weight.

$$\text{TDS} = \frac{\text{Weight Loss x 1000}}{\text{Volume of Sample Used}} \text{ ……………….. eqn. 4}$$

2.2.7 Alkalinity

i. 50ml burette was rinsed with with 0.02N HCL.
ii. The burette was filled with the HCL solution wth no bubbles
iii. 100ml of the water sample to be analyzed was measured into a 250ml Erlenmeyer flask.
iv. This was titrated to a bromcresol green (pH = 4.5) end point.

$$\text{Alkalinity} = \frac{\text{(ml HCL titrant) x (normality of HCL)x (50,000)}}{\text{(Volume of sample used)}} \text{ ……………….. eqn. 5}$$

2.2.8 Sulphate Determination

Procedure: 50ml of the water sample was evaporated to dryness on a dish. The residue was moisten with a few drop of conc. HCl and 30ml distilled water was added. This was boiled and then filtered. The dish was rinsed and the filter paper washed with several portions of distilled water and both filtrate and washings added together. This was heated to boiling and then 10ml of 10% $BaCl_2$ solution was added, drop by drop with constant stirring. The mixture was digested for about 30minutes, filtered and the filter paper washed with warm distilled water. It was then ignited, cooled and weighed in an already weighed crucible.

Sulphate concentration = weight loss x 411.5 (mg/l) ……………….. eqn. 6

2.2.9 Preparation of Water Sample for Heavy Metals

Procedure: 100ml of the water sample was measured into a beaker containing 1ml of nitric acid and allowed to stand on electric hot plate at temperature of 100^{0}C until it boils. This was allowed to cool in a desiccator and filtered with the aid of whatman filter paper, the filtrate was stored in a reagent bottle for heavy metal analysis with Atomic Adsorption Spectrophotometer (AAS).

2.2.9.1 Methods for the Heavy Metal Analysis

Heavy metal analysis were conducted using Varian AA240 Atomic Absorption Spectrophometer according to the method of APHA 2015 (American Public Health Association).

Working principle: Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

3.0 RESULTS AND DISCUSSION

Groundwater and leachate samples were collected from six locations (Amawbia, Agu-Awka, Ifite-Awka, Okpuno, Amaenyi, and Amansea towns) were analyzed for physiochemical parameters and heavy metals quality to evaluate the effect of solid waste leachate on groundwater quality. The parameters are divided into two categories: physicochemical (hardness, alkalinity, chloride, nitrate, sulphate, pH, total dissolved solids [TDS], and turbidity) and heavy metals (lead, mercury, chromium, and arsenic). All concentrations are in mg/l unless otherwise specified.

3.1 Physicochemical and Heavy Metals Properties Analysis

Table 1: physiochemical Properties Concentrations in Groundwater and Leachate Samples

Samples	Hardness	Alkalinity	Chloride	Nitrate	Sulphate	pH	TDS	Turbidity(NTU)
WHO Guideline	100-200	20-200	≤250	≤50	≤250	6.5-8.5	≤600	≤5 (ideal <1)
Amawbia water	70mg/l	22mg/l	41mg/l	29.385mg/l	96.291mg/l	6.86	12.64mg/l	1.300
Leachate	78mg/l	20mg/l	40mg/l	26.315mg/l	103.286mg/l	6.52	10.56mg/l	5.034
Agu awka water	66mg/l	30mg/l	37mg/l	26.973mg/l	74.482mg/l	6.63	4.92mg/l	2.110
Leachate	70mg/l	28mg/l	33mg/l	25.657mg/l	139.087mg/l	6.50	14.24mg/l	4.893
Ifite awka water	96mg/l	28mg/l	41mg/l	18.201mg/l	73.659mg/l	6.33	6.740mg/l	2.013
Leachate	70mg/l	26mg/l	52mg/l	47.807mg/l	122.627mg/l	6.26	14.28mg/l	5.891
Okpuno water	68mg/l	28mg/l	31mg/l	33.556mg/l	75.305mg/l	6.50	10.62mg/l	2.009
Leachate	76mg/l	22mg/l	49mg/l	31.798mg/l	131.680mg/l	6.45	14.30mg/l	5.482
Amaenyi water	64mg/l	20mg/l	52mg/l	37.280mg/l	99.172mg/l	6.80	2.60mg/l	1.672
Leachate	78mg/l	24mg/l	48mg/l	39.692mg/l	102.464mg/l	6.43	6.78mg/l	1.905
Amansea water	48mg/l	26mg/l	38mg/l	19.736mg/l	87.649mg/l	6.38	6.68mg/l	2.114
Leachate	90mg/l	24mg/l	43mg/l	26.973mg/l	139.910mg/l	6.14	8.48mg/l	5.411

Table 2: Heavy Metals Concentrations in Groundwater and Leachate Samples

Samples	Lead (mg/l)	Mercury (mg/l)	Chromium (mg/l)	Arsenic (mg/l)
Amawbia water	0.115	0.945	2.037	0.011
Leachate	0.076	0.636	0.000	0.231
Agu awka water	0.000	1.352	1.123	0.012
Leachate	0.209	1.613	0.147	0.034
Ifite awka water	0.267	0.219	1.367	0.004
Leachate	0.123	0.000	0.011	0.018
Okpuno water	0.190	0.192	0.000	0.010
Leachate	0.000	0.000	1.822	0.004
Amaenyi 1	0.137	0.000	2.706	0.011

Amaenyi 2	0.096	0.000	2.051	0.020
Amansea water	0.057	0.000	2.050	0.013
Leachate	0.000	0.052	0.402	0.025

The water quality data from groundwater and leachate samples across six Awka locations—Amawbia, Agu Awka, Ifite Awka, Okpuno, Amaenyi, and Amansea—are compared to World Health Organization (WHO) drinking water guidelines, which prioritize human health and acceptability, and Food and Agriculture Organization (FAO) irrigation water guidelines, focusing on crop production, soil health, and sustainability (World Health Organization, 2022; Ayers and Westcot, 1985). WHO sets health-based limits for nitrate (≤50 mg/l to prevent methemoglobinemia), arsenic (0.01 mg/l), lead (0.01 mg/l), mercury (0.006 mg/l), and chromium (0.05 mg/l), with acceptability thresholds for chloride (≤250 mg/l for taste), sulphate (≤250 mg/l for taste and laxative effects), pH (6.5-8.5 for corrosion and taste), TDS (≤600 mg/l for taste), and turbidity (≤5 NTU, ideally <1 for disinfection) (World Health Organization, 2022; Wikipedia contributors, 2024). FAO classifies restrictions as none, slight to moderate, or severe based on salinity or toxicity, with TDS (<450 mg/l none, 450-2000 slight to moderate, >2000 severe), chloride for surface irrigation (<142 mg/l none, 142-355 slight to moderate, >355 severe), nitrate (<22 mg/l none, 22-133 slight to moderate, >133 severe, converted from NO_3-N), pH (normal 6.5-8.4), and heavy metal limits like arsenic (0.1 mg/l), chromium (0.1 mg/l), lead (5.0 mg/l), with mercury typically low (~0.002 mg/l in extensions) (Ayers and Westcot, 1985; Wikipedia contributors, 2024). Hardness and alkalinity lack strict WHO health limits but are typically 100-200 mg/l and 20-200 mg/l for acceptability, while FAO notes high hardness may affect soil structure and alkalinity relates to bicarbonate (0-610 mg/l, no restrictions). The data's low TDS values suggest possible unit errors or ultra-pure conditions but are analyzed as provided. Hardness (48-96 mg/l in groundwater, 70-90 mg/l in leachates) indicates soft water, compliant but potentially corrosive for drinking, with no irrigation issues. Alkalinity (20-30 mg/l groundwater, 20-28 mg/l leachates) meets drinking standards and avoids soil irrigation issues. Chloride (31-52 mg/l groundwater, 33-52 mg/l leachates) is well below 250 mg/l for drinking and in FAO's "none" category (<142 mg/l), safe for crops. Nitrate (18.201-37.280 mg/l groundwater, 25.657-47.807 mg/l leachates) is under 50 mg/l for drinking, with irrigation mostly "none" to "slight to moderate" (NO_3-N ≈4-10.8 mg/l), though Ifite Awka leachate nears the drinking limit, suggesting contamination. Sulphate (73.659-99.172 mg/l groundwater, 102.464-139.910 mg/l leachates) is far below 250 mg/l and poses no irrigation risk. pH (6.33-6.86 groundwater, 6.14-6.52 leachates) is mostly within 6.5-8.5 for groundwater but slightly low in Ifite Awka (6.33) and Amansea (6.38), and all leachates are acidic, suitable for irrigation but potentially mobilizing soil metals and needing adjustment for drinking. TDS (2.60-12.64 mg/l groundwater, 6.78-14.30 mg/l leachates) is extremely low, compliant for drinking and "none" for irrigation. Turbidity (1.300-2.114 NTU groundwater, 1.905-5.891 NTU leachates) is below 5 NTU in groundwater but often above ideal <1 NTU, while some leachates exceed 5 NTU (e.g., Ifite Awka 5.891), unsuitable for drinking without treatment and potentially clogging irrigation systems. For heavy metals, lead (0.000-0.267 mg/l groundwater, 0.000-0.209 mg/l leachates) exceeds WHO 0.01 mg/l in most samples but is below FAO's 5.0 mg/l for irrigation. Mercury (0.000-1.352 mg/l groundwater, 0.000-1.613 mg/l leachates) exceeds WHO 0.006 mg/l in many cases, posing neurotoxicity risks for drinking, with irrigation caution advised due to possible soil accumulation. Chromium (0.000-2.706 mg/l groundwater, 0.000-1.822 mg/l leachates) exceeds WHO 0.05 mg/l and FAO 0.1 mg/l in many samples, indicating contamination risks. Arsenic (0.004-0.020 mg/l groundwater, 0.004-0.231 mg/l leachates) exceeds WHO's 0.01 mg/l in some cases, with Amawbia leachate (0.231 mg/l) also over FAO's 0.1 mg/l, posing carcinogenic risks for drinking but mostly safe for irrigation. Overall, groundwater physicochemical parameters largely meet WHO standards, with minor pH and turbidity issues, while leachates show more deviations (acidity, high turbidity, and elevated nitrates), indicating landfill impacts. Heavy metals render most samples unsuitable for untreated drinking due to toxicity, but irrigation is generally safe per FAO except for some chromium and arsenic in leachates, with long-term soil monitoring and remediation recommended.

4.0 CONCLUSION

The analysis of groundwater and leachate samples from Awka South LGA reveals that while physicochemical parameters generally meet WHO drinking water standards, minor pH and turbidity issues persist, and leachates show greater deviations, indicating landfill impacts. Heavy metal contamination, particularly lead, mercury, chromium, and arsenic, exceeds WHO health-based limits in most samples, rendering groundwater unsuitable for untreated consumption due to toxicity and carcinogenic risks. For irrigation, FAO guidelines are largely met, except for elevated chromium and arsenic in some leachates, requiring long-term soil monitoring. These findings underscore the urgent need for improved waste management, including lined landfills and leachate treatment systems, to mitigate aquifer contamination. Community education and stricter regulations could enhance sustainable practices, aligning with SDG 6 and 11 objectives.

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