# Physicochemical Quality of Groundwater Around Municipal Solid Waste Dumpsite in Obio Akpor Local Government Area, Rivers State

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DOI: 10.56201/ijgem.vol.11.no11.2025.pg13.24

***Abstract***
*This study was conducted to assess the physicochemical quality of groundwater around municipal solid waste dumpsites in Obio-Akpor Local Government Area. Four objectives guided the research: to assess the physicochemical quality of leachates from municipal solid waste dumpsites, to assess the physicochemical quality of groundwater around municipal solid waste dumpsites, and to assess the concentration of heavy metals (Lead, Arsenic, Cadmium) in groundwater around municipal solid waste dumpsites in Obio Akpor Local Government Area. Groundwater samples were collected from twelve boreholes around two dumpsites at distances of less than 50 meters and 51-300 meters from the dumpsites. Six leachate samples were collected from the drains of both dumpsites. The samples were analyzed for physicochemical parameters, including pH, Electrical Conductivity (EC), Temperature, Turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Chloride, Fluoride, Nitrate, Salinity, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Arsenic, Lead, and Cadmium. The physicochemical analysis revealed that all samples had acidic pH levels below the WHO and NSDWQ permissible limit. Parameters such as Temperature, Electrical Conductivity, Turbidity, Nitrate, Fluoride, Chloride, Total Dissolved Solids, and Total Suspended Solids were within WHO guidelines. However, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Salinity, Fluoride, Dissolved Oxygen (DO), Arsenic, Lead, and Cadmium exceeded the WHO permissible limits, indicating groundwater contamination. Statistical analysis using one-way ANOVA showed significant differences ($p < 0.05$) in the contamination levels of most parameters across the distances.*

***Keywords***: *Leachate, Municipal, Dumpsites, Physicochemical, Groundwater, Contamination.*

## Introduction

Groundwater, a vital natural resource for domestic use, is degrading rapidly due to human activities (Yadav *et al.,* 2023). Rapid population growth and industrialization have led to a significant increase in solid waste generation. Despite guidelines for the collection, segregation, storage, transportation, processing, and disposal of municipal solid waste, the problem of improper waste disposal persists (Ding *et al.,* 2021). Open dumpsites are often the preferred method of waste disposal in many developing countries; however, this practice poses serious environmental threats. Uncontrolled open dumping without protective liners allows leachate to percolate into the aquifer system, seeping into the surrounding soil and ultimately reaching the groundwater table, causing contamination. In numerous cities, the emission of landfill gases and the release of leachate are major health concerns for residents living near dumpsites (Dixit *et al.,* 2024). This contradicts the sixth Sustainable Development Goal, which aims to ensure access to clean water and sanitation, fundamental needs for human health and well-being.

In Rivers State, open dumping is the most common method for solid waste disposal because it is inexpensive and easy to implement. However, due to the negative effects of open dumpsites on human health and the environment, there is a need to stop illegal waste disposal in the state, as the problem has become critical (Afolabi *et al.,* 2022). The main environmental hazards reported include odor problems, pests, breeding of disease vectors, and damage to the visual scenery (Parvin and Tareq, 2021). Additionally, studies have shown that groundwater contamination from leachates can lead to waterborne diseases, including typhoid, cholera, and dysentery. Over time, it can also cause neurological disorders, cancers, kidney diseases, and other health issues (Akpan and Olukanni, 2020).

Physicochemical parameters such as pH, electrical conductivity, turbidity, total dissolved solids, total suspended solids, dissolved oxygen, and salinity serve as indicators of groundwater quality. They play a vital role in assessing water quality, detecting pollutants, and monitoring ecological changes. Heavy metals can be harmful even in trace concentrations and tend to accumulate in specific tissues because living systems are unable to metabolize them. The metals and their compounds disrupt the functions of various organs and systems, including the central nervous system (CNS), the liver, and the kidneys (Mulware, 2020). Long-term exposure to these metals through contaminated groundwater can cause serious health issues, such as neurological disorders, organ damage, cancer, and developmental issues, particularly in children (Dahiya, 2022).

Physicochemical and heavy metal analysis of groundwater helps identify potential health hazards associated with groundwater contamination, allowing authorities to take appropriate measures to protect public health, such as implementing water treatment or alternative water supply measures. Monitoring these parameters helps ensure that water is safe for consumption and minimizes health risks associated with waterborne diseases.

## Methods

### Study Setting

This study was conducted in Obio-Akpor Local Government Area, at dumpsites located in Rumuagholu and Rukpokwu communities.

### Study Design

An Analytical study design was used to assess groundwater quality around two municipal solid waste dumpsites.

### Sample Collection and Procedures

Groundwater samples were collected from twelve boreholes around dumpsites located in Rumuagholu and Rukpokwu Communities, at distances of less than 50 meters and 51-300 meters from the dumpsites. The collection of the samples from these points was done linearly and influenced by the availability of boreholes in the study areas. Six Leachate samples were also collected from the drains of both dumpsites.

The samples were collected in 1-liter plastic containers; the containers were thoroughly washed with distilled water and then rinsed three times with the site sample water before collection. Each bottle was labeled according to the sampling location, and the samples were stored in an ice-packed cooler and transported to the laboratory for analysis. The physical and chemical parameters analyzed include salinity, turbidity, temperature, pH, electrical conductivity, total dissolved solids (TDS), total suspended solids (TSS), Chemical oxygen demand (COD), Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), nitrates ($NO_3^-$), fluorides ($F^-$), and chlorides ($Cl^-$), Lead, chromium, and Arsenic. PH, electrical conductivity, and temperature were measured on-site using the portable HANNA pH meter (Model HI 28129), conductivity meter (Model DDS-307), and mercury-in-glass thermometer, respectively, using APHA 2005 guidelines. Turbidity was determined with a turbidity meter, gravimetric method (Standard Method 2540C; APHA 2005) was used to determine the total dissolved solids. Dissolved oxygen was determined through Wrinkler's method by azide modification of the iodometric method, and Chloride concentration was determined argentometrically by titration using silver nitrate (Standard Method 2350-B; APHA 2005). The standard method determined the total suspended solids and biological oxygen demand. Nitrate was determined by the spectrophotometric method. Fluoride and Heavy metals analysis were done by atomic absorption spectrophotoscopy (AES-FP910 series, model-PG 990) after digestion with nitric acid (Standard Method 3030-E; APHA 2005), with direct air-acetylene flame hollow cathode lamps (Standard Method 3111-B; APHA 2005). To ensure the quality of analytical procedures, appropriate calibration of devices was performed. The results of the physical and chemical parameters were compared with the WHO standards and Nigerian Standard for Drinking Water Quality (NSDWQ) to evaluate the suitability of the groundwater for human consumption.

**Statistical Analysis**

The result of the laboratory investigation was analyzed using SPSS version 27. Descriptive statistics (mean and standard deviation) were used to summarize data for tabulation, and one-way analysis of variance (ANOVA) was used to test for significant differences between means of the various parameters from both dumpsites at $P \leq 0.05$.

## Results

### Physicochemical Quality of Groundwater and Leachate Samples

The concentrations of physicochemical parameters in leachate and groundwater samples from the Rumuagholu dumpsite, along with the WHO standard and Nigerian standard for drinking water quality, are presented in Table 1.

The mean pH of groundwater samples ranged from 5.38- 5.72, while the leachate sample was 5.0. The mean temperature of groundwater samples ranged from 24.96°C - 25.93°C, while the leachate sample was 26.8°C. The mean Electrical conductivity (EC) ranged from 245.17 µS/cm to 448.06 µS/cm in groundwater samples and 1960.35µS/cm in the leachate sample. Mean turbidity value of groundwater samples ranged from 1.40 NTU to 1.52 NTU, while the leachate sample was 200 NTU. Mean Salinity level of groundwater ranged from 108.92mg/L to 207.01mg/L, while the leachate sample was 600mg/L. The mean Total dissolved solids (TDS) in groundwater samples ranged from 98.02 mg/L to 179.87 mg/L, while the leachate sample was 660mg/L. The mean total suspended solids (TSS) in groundwater samples ranged from 1.78mg/L to 2.01mg/L, while the leachate sample was 3.08mg/L. Mean Nitrate values in groundwater samples ranged from 0.25mg/L to 0.33 mg/L, while the leachate sample was 4.5mg/L. Mean chloride value in groundwater samples ranged from 24.64 mg/L to 25.88mg/L, while the leachate sample was 600mg/L. The mean Fluoride values in groundwater ranged from 0.29mg/L to 0.33mg/L, while the leachate sample was 3.5mg/L. The mean Dissolved oxygen (DO) values in groundwater samples ranged from 2.64mg/L to 3.09mg/L, while the leachate sample was 0.76mg/L. The mean Chemical oxygen demand (COD) in groundwater samples ranged between 129.35mg/L and 200.07mg/L, while the leachate sample was 272.56mg/L. The mean biological oxygen demand (BOD) values in groundwater samples ranged from 5.53mg/L to 6.04mg/L, while the leachate sample was 6.87mg/L.

Statistical analysis using one-way analysis of variance showed that there was a significant difference ($p<0.05$) in the values of most parameters studied except Temperature, Nitrate, Fluoride, and Chemical Oxygen Demand.

**Table 1: Concentration of physicochemical parameters in Leachate and Groundwater Samples around Rumuagholu Dumpsite with the WHO Standard and Nigerian Standard for Drinking Water Quality.**

| Parameters | 0 mtrs (Leachate) Mean±SD | ≤ 50 mtrs (Near) Mean±SD | 51-300 mtrs (Far) Mean±SD | p-value | WHO Standard Permissible Values for Water Quality | Nigerian Standard for Drinking Water Quality |
|---|---|---|---|---|---|---|
| **pH** | 5.0±0.10 | 5.34±0.18 | 5.72±0.22 | 0.0034* | 6.5-8.5 | 6.5-8.5 |
| **Temperature(°C)** | 26.8±0.10 | 24.96±0.56 | 25.93±0.02 | 0.0014* | 22-29 | Ambient |
| **EC (µS/cm)** | 1960±0.01 | 448.06±75.67 | 245.17±60.44 | <0.0001* | 1000 | 1000 |
| **Turbidity (NTU)** | 200±1.00 | 1.40±0.07 | 1.52±0.03 | <0.0001* | 5.0 | 5.0 |
| **Salinity(mg/l)** | 600±1.0 | 207.01±50.21 | 108.92±16.51 | <0.0001* | 200 | - |
| **TDS (mg/l)** | 680±1.0 | 179.87±28.58 | 98.02±15.15 | <0.0001* | 500-1000 | 500 |
| **TSS (mg/l)** | 3.08±0.01 | 2.01±0.84 | 1.78±0.07 | 0.0384* | 75 | - |
| **Nitrate(mg/l)** | 4.5±0.10 | 0.33+0.16 | 0.25±0.02 | <0.0001* | 50 | 50 |
| **Chloride(mg/l)** | 600±1.0 | 24.64±1.64 | 25.88±3.50 | <0.0001* | 250 | 250 |
| **Fluoride(mg/l)** | 3.5±0.10 | 0.29±0.01 | 0.33±0.03 | <0.0001* | 1.0-1.5 | 1.0 |
| **DO (mg/l)** | 0.76±0.02 | 2.64±0.81 | 3.09±1.03 | 0.0085* | 4-7.5 | 5 |
| **COD (mg/l)** | 272.6±0.02 | 200.07±9.02 | 129.35±46.45 | 0.0021* | 10 | - |
| **BOD (mg/l)** | 6.87±0.02 | 5.53±0.83 | 6.04±0.51 | 0.0895 | 6 | 5 |

***Significant at p<0.05**

The concentrations of physicochemical parameters in leachate and groundwater samples at Rukpokwu dumpsite, with the WHO and Nigerian standards for drinking water quality is presented in Table 2.
The mean pH of groundwater samples ranged from 5.39 to 5.92, while the pH of the leachate sample was 5.02. The mean temperature of groundwater samples ranged from 25.42°C to 25.71°C, while the leachate sample was 26.30°C. The mean electrical conductivity (EC) ranged from 508.80 µS/cm to 227.91 µS/cm in groundwater samples and 1942.10µS/cm in the leachate sample. The mean turbidity value of groundwater samples ranged from 0.36 NTU to 0.54 NTU, while the leachate sample was 180 NTU. The mean Salinity level of groundwater ranged from 236.74mg/L to 145.78mg/L, while the leachate sample was 580mg/L. The mean Total dissolved solids (TDS) in groundwater samples ranged from 216.04mg/L to 98.46mg/L, while the leachate sample was 653.33mg/L. The mean total suspended solids (TSS) in groundwater samples ranged from 1.90mg/L to 1.55mg/L, while the leachate sample was 4.22mg/L. The mean Nitrate values in groundwater samples ranged from 0.16mg/L to 0.22 mg/L, while the leachate sample was 3.40mg/L. The mean chloride values in groundwater samples ranged from 35.57mg/L to 32.58mg/L, while the leachate sample was 550mg/L. The mean Fluoride values in groundwater ranged from 0.57mg/L to 0.47mg/L, while the leachate sample was 3.20mg/L. The mean Dissolved oxygen (DO) values in groundwater samples ranged from 1.8mg/L to 2.77mg/L, while the leachate sample was 0.02mg/L. The mean Chemical oxygen demand (COD) in groundwater samples ranged between 182.43mg/L and 64.99mg/L, while the leachate sample was 278.02mg/L. The mean biological oxygen demand (BOD) values in groundwater samples ranged from 5.69mg/L to 5.87mg/L, while the leachate sample was 7.03mg/L.
Statistical analysis using one-way analysis of variance showed that there was a significant difference ($p<0.05$) in the values of most parameters studied except Temperature, Nitrate, Fluoride, and Chemical Oxygen Demand.

**Table 2: Concentration of Physicochemical Parameters in Leachate and Groundwater Samples around Rukpokwu Dumpsite with the WHO Standard and Nigerian Standard for Drinking Water Quality.**

| **Parameters** | **0 mtrs (Leachate) Mean±SD** | **≤ 50 mtrs (Near) Mean±SD** | **51-300mtrs (Far) Mean±SD** | **p-value** | **WHO Standard Permissible Values for Water Quality** | **Nigerian Standard for Drinking Water Quality** |
|---|---|---|---|---|---|---|
| **pH** | 5.02±0.01 | 5.39±0.18 | 5.92±0.25 | 0.0047* | 6.5-8.5 | 6.5-8.5 |
| **Temperature(°C)** | 26.30±0.02 | 25.42±0.39 | 25.71±0.39 | 0.0537 | 22-29 | Ambient |
| **EC (µS/cm)** | 1942±0.10 | 508.80±68.77 | 227.91±20.07 | <0.0001* | 1000 | 1000 |
| **Turbidity (NTU)** | 180±2.0 | 0.36±0.15 | 0.54±0.13 | <0.0001* | 5.0 | 5.0 |
| **Salinity(mg/l)** | 580±20.0 | 236.74±43.35 | 145.78±60.19 | <0.0001* | 200 | - |
| **TDS (mg/l)** | 653.33±1.0 | 216.04±35.49 | 98.46±6.75 | <0.0001* | 500-1000 | 500 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **TSS (mg/l)** | 4.22±0.22 | 1.90±0.26 | 1.55±0.15 | <0.0001* | 75 | - |
| **Nitrate(mg/l)** | 3.40±0.01 | 0.16+0.03 | 0.22±0.01 | <0.0001* | 50 | 50 |
| **Chloride(mg/l)** | 550±20.0 | 35.57±1.37 | 32.58±1.58 | <0.0001* | 250 | 250 |
| **Fluoride(mg/l)** | 3.20±0.10 | 0.57±0.16 | 0.47±0.02 | <0.0001* | 1.0-1.5 | 1.0 |
| **DO (mg/l)** | 0.02±0.01 | 1.8±0.48 | 2.77±1.01 | 0.0057* | 4-7.5 | 5 |
| **COD (mg/l)** | 278.02±1.0 | 182.43±13.32 | 64.99±44.10 | 0.0003* | 10 | - |
| **BOD (mg/l)** | 7.03±0.01 | 5.69±0.42 | 5.87±0.83 | 0.0326* | 6 | 5 |

***Significant at p<0.05**

**Heavy Metal Concentration of Groundwater and Leachate Samples**

The concentration of heavy metals in groundwater and leachate samples around Rumuagholu dumpsite is presented in Table 3.

The concentration of Arsenic in groundwater samples ranged from 0.61 mg/L to 0.25 mg/L, while the leachate sample is 4.56mg/L. The concentration of Lead in groundwater samples ranged from 0.05 mg/L to 0.38 mg/L, while the leachate sample is 3.038mg/L. The concentration of Cadmium in groundwater samples ranged from 1.521mg/L to 0.58mg/L, while the leachate sample is 3.43mg/L.

**Table 3: Concentration of Heavy Metals in Leachate and Groundwater Samples around Rumuagaholu Dumpsite with the WHO Standard and Nigeria Standard for Drinking Water Quality.**

| HEAVY METALS (HM) | 0 mtrs (Leachate) Mean±SD | ≤ 50 mtrs (Near) Mean±SD | 51-300 mtrs (Far) Mean±SD | p-value | WHO Standard Permissible Values for Water Quality | Nigeria Standard for Drinking Water Quality |
|---|---|---|---|---|---|---|
| **As (mg/l)** | 4.56±0.01 | 0.61±0.25 | 0.25±0.11 | <0.0001* | 0.01 | **0.01** |
| **Pb (mg/l)** | 3.04±0.001 | 1.05±0.16 | 0.38±0.13 | <0.0001* | 0.01 | 0.01 |
| **Cd (mg/l)** | 3.43±0.001 | 1.521±0.51 | 0.58+0.01 | 0.0005* | 0.003 | 0.003 |

*Significant at p<0.05

The concentration of heavy metals in groundwater and leachate samples around Rukpokwu dumpsite is presented in Table 4.
The concentration of Arsenic in groundwater samples ranged from 0.38 mg/L to 0.36 mg/L, while the leachate sample is 4.92mg/L. The concentration of Lead in groundwater samples ranged from 0.96 mg/L to 0.66 mg/L, while the leachate sample is 3.42mg/L. The concentration of Cadmium in groundwater samples ranged from 1.69mg/L to 0.54mg/L, while the leachate sample is 3.04mg/L.

**Table 4: Concentration of Heavy Metals in Leachate and Groundwater Samples around Rukpokwu Dumpsite with the WHO Standard and Nigeria Standard for Drinking Water Quality.**

| HEAVY METALS (HM) | 0 mtrs (Leachate) Mean±SD | ≤ 50 mtrs (Near) Mean±SD | 51-300 mtrs (Far) Mean±SD | p-value | WHO Standard Permissible Values for Water Quality | Nigeria Standard for Drinking Water Quality |
|---|---|---|---|---|---|---|
| **As (mg/l)** | 4.92± | 0.38±0.07 | 0.36±0.09 | <0.0001* | 0.01 | **0.01** |
| **Pb (mg/l)** | 3.42± | 0.96±0.86 | 0.66±0.12 | 0.0036* | 0.01 | 0.01 |
| **Cd (mg/l)** | 3.04± | 1.69±0.69 | 0.54+0.16 | 0.0034* | 0.003 | 0.003 |

*Significant at p<0.05
Heavy Metals: Arsenic (As), Lead (Pb), Cadmium (Cd)

**Discussion**

**Physicochemical Analysis of Groundwater Samples**

The hydrogen ion concentration (pH) is a measure of the acidic or alkaline nature of a solution (Saalidong *et al.,* 2022). The mean pH value of all samples ranged from The pH value of all samples ranged from 5.34 - 5.72 at Rumuagholu dumpsite and 5.39 to 5.92 at Rukpokwu dumpsite, below the WHO and NSDWQ recommended limit of 6.5 to 8.5, indicating that groundwater samples are slightly acidic, similar to the work of Ferreira *et al.* (2023) who reported low pH values, and is also in agreement with the findings of Lawal *et al.* (2025) who also reported values lower than the WHO permissible values. Acidic water corrodes metal pipes, and at low pH, the solubility of metals tends to be high and becomes more toxic (Hussein Farh *et al.,* 2023).
Temperature ranged from 24.96°C to 25.93°C at Rumuagholu dumpsite and 25.42°C to 25.71°C at Rukpokwu dumpsite, which falls within the WHO permissible limit, similar to the work of (Lawal *et al.,* 2025).
Electrical Conductivity value of groundwater samples ranged from 245.17 µS/cm to 448.06 µS/cm at the Rumuagholu dumpsite and 227.91µS/cm to 508.80µS/cm at Rukpokwu dumpsite, which is

within the WHO and NSDWQ permissible limit of 1000 μS/cm, and in line with the work of Barambu *et al.* (2020).

Turbidity values of groundwater samples ranged from 1.40 to 1.52 NTU at Rumuagholu dumpsite and 0.36 to 0.54 NTU at Rukpokwu dumpsite, within the WHO and NSDWQ permissible limit of 5 NTU, indicating that water samples are free from suspended particles. Groundwater normally has very low turbidity because of the natural filtration that occurs as the water penetrates through the soil (Omer, 2019). This study's finding contrasts with the work of Sabiu (2021), who recorded higher turbidity values. High levels of turbidity could harbor pathogenic organisms (Omer, 2019).

Salinity value of groundwater samples ranged from 108.92 mg/L to 207.01 mg/L at Rumuagholu dumpsite and 145.78 mg/L to 236.74 mg/L at Rukpokwu dumpsite, with samples closer to the dumpsite recording values above the WHO permissible limit of 200 mg/L, suggesting an impact from dumpsite leachate, in line with the work of Barambu *et al.* (2020). Salinity is the dissolved salt content in a body of water. Elevated salinity in drinking water may increase the risk of adverse health effects, particularly in individuals with certain health conditions such as hypertension or kidney disease.

The total dissolved solids (TDS) measure the quantity of dissolved solids in water (Omer, 2019). The value of TDS recorded in groundwater samples ranged from 98.02mg/L to 179.87 mg/L at Rumuagholu dumpsite and 98.46 mg/L to 216.04mg/L at Rukpokwu dumpsite, within the WHO and NSDWQ permissible limit of 500-1000 mg/L. The TDS values obtained in this study were in contrast to the work of Sabiu (2021) where high TDS values were recorded, this may be due to the purification of the water by non-porous aquifers, such as clay, by simple filtration (adsorption and absorption), dilution, and in some cases, chemical reactions and biological activity as water percolates down the earth's structure from the dumpsites.

Total suspended solids (TSS) measure the mass of fine inorganic particles suspended in water. The TSS value in groundwater samples ranged from 1.78 mg/L to 2.01 mg/L at Rumuagholu dumpsite and 1.55 mg/L to 1.90 mg/L at Rukpokwu dumpsite, within the WHO standard of 75 mg/L, similar to the values recorded by Sam-Uroupa and Ogbeibu (2020).

Nitrate concentration in groundwater samples ranged from 0.25 mg/L to 0.33 mg/L at Rumuagholu dumpsite and 0.16 mg/L to 0.22 mg/L at Rukpokwu dumpsite, which is within the WHO and NSDWQ permissible limit of 50 mg/L, in line with the work by Bukunmi and Achi (2021) In Ibadan, and similar to the work by Hurra and Bhawsar (2021).

Chloride values recorded in the groundwater samples ranged from 24.64 mg/L to 25.88 mg/L at Rumuagholu dumpsite and 32.58 mg/L to 35.57 mg/L at Rukpokwu dumpsite, within the WHO and NSDWQ permissible limit of 250 mg/L. The chloride content in groundwater samples decreased with increasing distance, similar to the study by Lawal *et al.* (2025).

Fluoride values in groundwater ranged from 0.29 mg/L to 0.33 mg/L at Rumuagholu dumpsite and 0.57 mg/L to 0.47 mg/L at Rukpokwu dumpsite, below the WHO and NSDWQ permissible limit of 1.0-1.5 mg/L. Fluoride in drinking water, either below or above the established permissible range, can adversely affect oral health, leading to tooth decay and dental fluorosis (WHO, 2022). Fluoride levels below the minimum WHO and NDSWQ standard of 1.0mg/L can lead to tooth decay if the water is consumed without any supplementary fluoride intake.

Dissolved oxygen (DO) value in groundwater ranged from 2.64 mg/L to 3.09 mg/L at Rumuagholu dumpsite and 1.80 mg/L to 2.77 mg/L at Rukpokwu dumpsite, with distances closer to the dumpsites having lower values. All DO values are below the WHO and NSDWQ limit of 4 to 7.5 mg/l, indicating oxygen depletion, suggesting the presence of organic matter in water, making it unsuitable for consumption (Kulkarni, 2016). These findings agree with the results of Sam-

Uroupa and Ogbeibu (2020) in Benin City, where low dissolved oxygen levels were also recorded. Low DO levels may result in anaerobic conditions that can cause a bad odor in water caused by decomposing organic matter, dissolved gases, industrial waste, mineral waste, and landfill leachate (Kulkarni, 2016).

Chemical oxygen demand measures the amount of oxygen required to chemically oxidize organic and inorganic matter, indicating the potential for oxygen depletion and contamination of a water body. The mean Chemical Oxygen Demand (COD) values ranged from 129.35 mg/L to 200.07 mg/L at Rumuagholu dumpsite and 64.99 mg/L to 182.43 mg/L at Rukpokwu dumpsite, above the WHO permissible limit of 10 mg/L, with the highest value recorded at distances closer to the dumpsites. This is in line with the study conducted by Lawal *et al.* (2025), where high COD values were also recorded. High COD levels in groundwater indicate the presence of organic pollutants, which can lead to reduced dissolved oxygen, harming aquatic life, and potentially contaminating drinking water sources (Grinberga *et al.,* 2022).

The biological oxygen demand (BOD) test is useful for determining the degree of oxygen demand by biological organisms. It is often indicative of organically polluted water. The mean BOD values recorded in groundwater samples ranged from 5.53 mg/L to 6.04 mg/L at Rumuagholu dumpsite and 5.69 mg/L to 6.04 mg/L at Rukpokwu dumpsite, a little lower than the WHO standard of 6 mg/l and in contrast to the values obtained by Sam-Uroupa and Ogbeibu (2020) in Benin City.

**Heavy Metal Concentration of Groundwater Samples**

The concentration of Arsenic in groundwater samples ranged from 0.25 mg/L to 0.61 mg/L at Rumuagholu dumpsite and 0.36 mg/L to 0.38 mg/L at Rukpokwu dumpsite, exceeding the WHO and NSDWQ permissible limit of 0.01 mg/L. This is similar to the work of Ullah *et al.*(2022), where high levels of arsenic were also recorded in groundwater, suggesting possible contamination of groundwater. The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans and also stated that arsenic in drinking water is carcinogenic to humans. The first symptoms of long-term exposure to high levels of inorganic arsenic through drinking water are usually observed in the skin through pigmentation changes, skin lesions, and hard patches on the palms and soles of the feet (hyperkeratosis). This occurs after a minimum of approximately five years and can be a precursor to skin cancer (Dahiya, 2022). In addition to skin cancer, long-term exposure to arsenic may also cause cancers of the bladder and lungs. Other adverse health effects that may be associated with long-term ingestion of inorganic arsenic include developmental effects, diabetes, pulmonary disease, and cardiovascular disease.

The concentration of Lead in groundwater samples ranged from 0.38 mg/L and 1.05 mg/L at Rumuagholu dumpsite and 0.96 mg/L to 0.66 mg/L at Rukpokwu dumpsite, above the WHO and NSDWQ permissible limit, in agreement with the work of Omorogieva *et al.* (2022), where high lead concentration was also recorded in groundwater samples. Higher lead levels were recorded at distances closer to the dumpsite, indicating that lead concentrations decrease with increasing distance from the dumpsite. This might be due to dilution effects, where toxins spread and become increasingly diluted in groundwater as it flows away from the dumpsite (Lawal *et al.,* 2025). The presence of lead, even in low quantities, is hazardous, and chronic exposure to lead may cause significant health problems, particularly in sensitive groups such as children and pregnant women (Dave and Yang, 2022). Exposure to very high levels of Lead can severely damage the brain and central nervous system, causing convulsions, coma, and even death. Children who survive severe lead poisoning may be left with permanent intellectual disability and behavioral disorders (Dave and Yang, 2022).

The concentration of Cadmium ranged from 0.58 mg/L to 1.521 mg/L at Rumuagholu dumpsite and 0.54 mg/L to 1.69 mg/L at Rukpokwu dumpsite, above the WHO and NSDWQ limit of 0.003mg/L, indicating possible contamination of groundwater. This is in contrast with the work of Barambu *et al.* (2020) in Bauchi, where lower cadmium levels were recorded. Exposure to cadmium produces acute and chronic effects in humans. Cadmium accumulates in the human body, especially in the kidneys, resulting in kidney damage (renal tubular damage). Other effects of cadmium exposure are disturbances in calcium metabolism, hypercalciuria, and the formation of kidney stones. It may play a role in the development of diseases related to the central nervous system (CNS).

## Conclusion

This study was carried out to determine the physicochemical quality of groundwater around the municipal solid waste dumpsite in Obio-Akpor Local Government Area, Rivers State. The study revealed that some of the physical and chemical parameters influencing groundwater quality, including pH, Salinity, Fluoride, Chloride, and COD, were not within the WHO and NSDWQ permissible limits. The average concentration of heavy metals analyzed exceeded the recommended WHO and NSDWQ limits for drinking water, suggesting that the nearby dumpsite may have contaminated the groundwater in the study locations. Low pH values suggest acidification from leachates, and high DO, COD, lead, arsenic, and cadmium values further confirm groundwater contamination. The findings of this study established that leachates from dumpsites contaminate groundwater

## Recommendations

i. The construction of engineered landfills with adequate liners for waste disposal is highly recommended. There are no lined landfills in Rivers State for proper waste disposal, leading to contamination of the surrounding soil and groundwater.
ii. Better waste management practices should be adopted. Waste Management agencies should implement a Circular Economy, a waste management strategy that aims for zero waste and promotes sustainable development.
iii. Waste management agencies should launch public awareness campaigns and educational programs to teach citizens about proper waste disposal techniques for reducing waste. Information on how to recycle waste should be easily accessible to the public. Biodegradable waste can be processed and turned into compost suitable for use as fertilizer in home gardens, while non-biodegradable waste can be recycled into other products.
iv. The government should prioritize building water treatment plants to supply safe and drinkable water.

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