



e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE



Assessment of physicochemical parameters and heavy metals concentration of leachates from dumpsite around Idemili River, Obosi Nigeria

N.A. Dibua¹ , E.C.S. Okoye^{1*} , N.A. Egudu² , C.B. Chibueze¹, C.P. Azuka¹, I.K. Ojeh³ and O.K. Nwosu⁴ 

¹Department of Microbiology, Faculty of Natural Sciences, Chukwuemeka Odumegwu Ojukwu Univeristy, Uli, Anambra State, Nigeria

²Department of Agricultural Technology and Microbiology, School of Agriculture, Enugu State Polytechnic, Iwollo Enugu State, Nigeria

³Department of Microbiology, Faculty of Science, University of Delta, Agbor, Delta State, Nigeria

⁴National Biosafety Management Agency, Federal Capital Territory, Abuja, Nigeria

*Corresponding Author's E-mail: ec.okoye@coou.edu.ng

ARTICLE HISTORY

Received: 07 April 2025

Revised received: 11 June 2025

Accepted: 19 June 2025

Keywords

Correlation
Dumping sites
Heavy metals
Idemili River
Leachate

ABSTRACT

Leachates originating from solid waste dumpsites pollute water bodies, especially in Nigerian urban areas. This study aimed to assess the concentrations of heavy metals and physicochemical parameters in leachates from dumpsite around the Idemili River in Obosi, Nigeria. Physicochemical parameters (pH, temperature, EC, TDS, DO, BOD, turbidity, chloride, nitrate, phosphate, sulphate), heavy metals (Zn, Pb, Cd, Cu, Fe, As) and bacteriological parameters (total and faecal coliforms) were analyzed in leachate and Idemili River water. ANOVA, Tukey's post-hoc and Pearson correlation were applied to find spatial variations and relationships between physicochemical properties and heavy metals concentration in leachate and water samples. Results revealed significant ($p < 0.05$) contamination, with EC, sulphate, phosphate, nitrate, Fe, Cd and Pb in leachate samples exceeding WHO/NSDWQ limits. Leachate contained significantly higher levels of Fe (4.430 ± 3.231 mg/L), As (4.455 ± 3.1465 mg/L) and Cd (2.8783 ± 2.794 mg/L), suggesting potential leachate infiltration, thereby influencing water quality. Also the leachate and water samples had elevated levels of total and faecal coliforms, exceeding the WHO standards of 10 cfu/mL and 0 cfu/mL, respectively. Results also revealed significant spatial variations in the physicochemical, heavy metals, and bacteriological parameters across various sampling points in leachate and water samples. Therefore, water samples from Idemili River are unsafe for human consumption, and aquatic ecosystems, due to leachates infiltration. It is recommended that governments should adopt inclusive approaches to reducing amount of wastes reaching dumpsites.

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Citation of this article: Dibua, N. A., Okoye, E. C. S., Egudu, N. A., Chibueze, C. B., Azuka, C. P., Ojeh, I. K., & Nwosu, O. K. (2025). Assessment of physicochemical parameters and heavy metals concentration of leachates from dumpsite around Idemili River, Obosi Nigeria. *Archives of Agriculture and Environmental Science*, 10(2), 364-373, <https://dx.doi.org/10.26832/24566632.2025.1002025>

INTRODUCTION

The generation of solid wastes has become an increasing environmental and public health concern worldwide. The rapid expansion of urban, industrial and agricultural activities, coupled with rapid population growth and the change in consumer habits have contributed tremendously to generation of solid wastes (UNEP, 2024). Every year, an estimated 1.2 billion tonnes of solid wastes is collected worldwide and decay of the organic

proportion of solid waste is contributing about 5% of global greenhouse gas emissions. It is estimated that between 2030 and 2050 municipal solid waste generation per year is projected to grow from 2.1 billion tonnes to 3.8 billion tonnes, a 56% increase within a generation or less (Figure 1). Open dumps are the oldest and commonest form of disposing solid wastes. In recent years, thousands of refuse dumps have been closed, particularly in developed countries, while many are still being used. In most developing countries like Nigeria, refuse dumps are

located wherever land is available, without regard to health hazard, safety and aesthetic degradation (Salami et al., 2024b). In this form, the waste is often piled as high as equipment allows. In some instances, the refuse is ignited and allowed to burn, especially during the dry season (Olagbemiro et al., 2025). The most commonly reported danger to human health from landfills is from the use of groundwater that has been contaminated by leachate (Ekeu-Wei et al., 2018; Ugbaja et al., 2021; Salami et al., 2024a).

Leachate is produced when moisture enters the refuse in a landfill, extracts contaminants into the liquid phase, and produces moisture content sufficiently high to initiate liquid flow (Bassey et al., 2019). It is generated in a landfill as a consequence of the contact of water with solid waste. Leachate from a solid waste disposal site is generally found to contain major elements like calcium, magnesium, potassium and ammonia; trace metals like iron, copper, manganese, chromium, lead, nickel, and organic compounds like phenols, polyaromatic hydrocarbons, acetone, benzene, chloroform, toluene, etc. (Ashraf et al., 2011; Bassey et al., 2015). The concentration of these substances in leachate and water depends on the composition of wastes. The rate and characteristics of leachate produced depends on many factors such as solid waste composition, particle size, degree of compaction, hydrology of site, age of landfill, moisture and temperature conditions, and available oxygen (Okoye et al., 2023). Leachate migration from waste sites or landfills and the release of pollutants from sediment (under certain conditions) pose a high risk to groundwater resources, if not adequately managed (Bassey et al., 2018). Their impact on groundwater continues to raise concern, and have become the subject of recent and past investigations. Empirical investigations as well as modeling techniques have been used to assess pollution of groundwater by leachate from a landfill. The discharge of untreated leachates, either directly or indirectly through runoffs, into water bodies may result in high BOD and low DO level, which are indications that the water may not sufficiently support aquatic life (Bassey et al., 2019). Presence of heavy metals as contaminants in water is an indication of global industrialization, attributed to inappropriate disposal of large scale of untreated wastewater containing heavy metals from anthropogenic sources (Azourgarh et al., 2019; UNEP, 2024). Heavy metals can bio-accumulate over a

period of time, and the concentrations become apparent and measurable. Through food chains and trophic levels, heavy metals can reach target organs or tissue of organisms through bio-accumulation process, which can ultimately threaten human health (Ekeu-Wei et al., 2018). Heavy metals naturally enter humans through ingestion, inhalation and absorption in minute quantities as trace elements. Trace elements are essential to maintaining the metabolism of human body. However, trace amount of heavy metal is dangerous because they tend to bio-accumulate and bio-magnify (Adewunyi & Opasina, 2010; Okoye et al., 2022). Bio-accumulation and bio-magnification increase the concentration of heavy metal in a biological organism or targeted organ overtime, until they become hazardous to health. This can lead to deficiencies in certain nutrients, and also result in Parkinson's disease, cancer, skin disorders, respiratory abnormalities, abdominal and intestinal problems, central nervous system damage, blood disorders and reproductive failure (USEPA, 2013; Olayiwola et al., 2017). Acute exposure to high concentrations of heavy metal can cause nausea, anorexia, vomiting, gastrointestinal abnormalities and dermatitis (Nwachi et al., 2024). Therefore, it is important to constantly monitor the concentration of heavy metal, and physicochemical parameters of leachate and nearby water bodies. This study is, therefore, aimed at evaluating the physicochemical parameters and assessing the heavy metals concentration of leachates from dumpsites around Idemili River, Obosi in Anambra State, Nigeria.

MATERIALS AND METHODS

Study area

The study was carried out in Obosi, Idemili North Local Government Area of Anambra State, Nigeria, with geographical coordinates of Latitude 6°6'0" N and Longitude 6°49'0" E. As reported by the National Population Commission of Nigeria (NPC), Obosi as of 2011, had a population of 1,748,300 with population density projected to be 70.6 p km⁻² and a growth rate of +3.05 % per year. Children below 14 years of age make up 42.5 % of the population while 53.5 % and 4 % of the residents are between the ages 15–64 and above 64 years, respectively (NPC, 2011). Obosi is located in the south-eastern region of Nigeria with the rainy and dry months from April to October, and November to March, respectively. The dry season follows immediately in November up until March. Its climate has an average annual rainfall of 1,400 mm, with tropical rainforest vegetation and run-off estimated to reach 90 %. Relative humidity is usually above 85 % in wet season but decreases to 45 % in dry season. It records a yearly average temperature of 26.5 °C and hottest month temperature of 31.5 °C in the month of March.

Description of study site and collection of water and leachate samples

The dumpsite is an open dumpsite, around Idemili River (a tributary to River Niger) and receives wastes on daily basis. The disposed wastes are mainly from domestic, industrial and

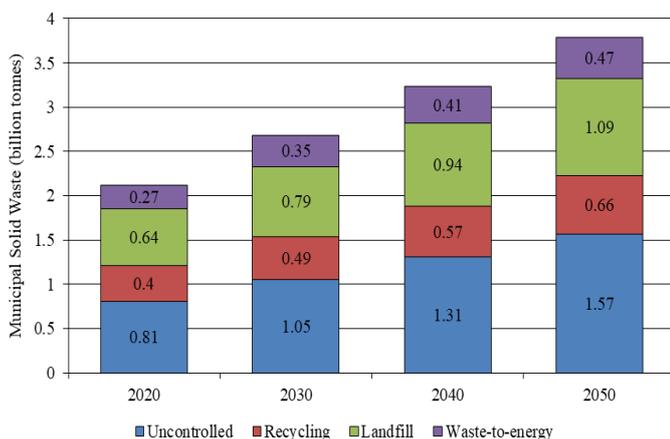


Figure 1. Projected global municipal solid waste destination in 2030, 2040 and 2050 compared with 2020 (Source: UNEP, 2024).

electronic wastes. At the time of sampling, the waste dumpsite covered an area of about 1,850 m² and is less than 1m from Idemili River. Idemili River serves as domestic and irrigation water sources for many households and vegetable growers within the study site, and gin distillery industries around it discharge their wastewater into it. The river empties into the Great River Niger. Collection of samples was carried out between July to December, 2020 and sampling covered parts of wet and dry seasons for that year. Water samples were collected at the water surface using 250-mL HDPE (high density polyethylene) bottles at four designated stations (L1, L2, L3 and L4) with various distances of 5 m, 10 m, 20 m and 40 m respectively along the Idemili River (Figure 2). Water sampling bottles were thoroughly washed with detergents, rinsed with tap water, and at the site, they were rinsed twice with the water before sampling was done at each site. The samples inside sterile bottles were tightly capped, maintained in vertical position, kept in cooler filled with ice blocks and were transported to the Microbiology Laboratory for coliform detection and isolation of microorganisms. Leachate samples were collected using the method described by Bassey et al. (2019). PVC pipes were cut into four (4) parts, each of 1 m in length, separated from one another by some distances. The base end of each pipe was permanently sealed with a pipe cover and an adhesive, while the top ends were just fitted with pipe covers. The pipes were perforated evenly at considerable distances from their base ends to allow for leachate percolation and collection. The whole pipe lengths were then buried into an already dug ground in each sampling point with small allowances at the top for easy access to the top ends. The buried pipes at different depth were left for a period of four (4) weeks before sampling for the percolated leachates. Sterile Enema pumps were used for leachate collection into sterile bottles and labeled properly as L1 (5 m away from Idemili River), L2 (10 m), L3 (20 m) and L4 (40 m; which serves as control). The samples were then transported immediately to the laboratory for physicochemical and microbiological analyses.

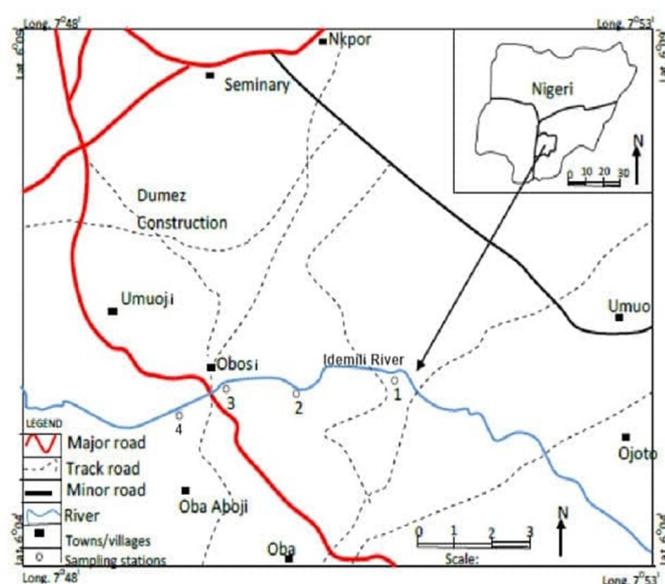


Figure 2. Map showing the sampling stations in Idemili River, in Obosi, Idemili North LGA, Anambra State, Nigeria (Source: Ayadiuno et al., 2020), Cartographic Unit, University of Nigeria, Nsukka Nigeria).

Physicochemical analysis of water and leachate samples

Physical parameters (pH, turbidity, total dissolved solids (TDS), electrical conductivity (EC), and dissolved oxygen (DO)) were determined on site for water and leachate samples using *in-situ* probe model (PC60 Premium multi parameter). For BOD₅, samples were incubated at 20 °C for 5 days. Dissolved oxygen (DO) was measured initially and after incubation. BOD₅ was computed from the difference in DO (APHA, 2012). For Nitrate (NO₃⁻), 10 mL of the sample was mixed with Nitra Ver. 5 Reagent (prepared sample). A blank sample was used for zeroing the DR 5000 UV Spectrophotometer (Spec), and nitrate (mg/L NO₃⁻-N) was recorded. For sulphate (SO₄²⁻), 25 mL of the sample was mixed with barium chloride reagent, stirred, and left for 5 minutes. The prepared sample was analyzed using the DR 5000 UV Spec, with a detection limit of 0.10 mg/L. For Phosphate (PO₄³⁻), 10 mL of the sample was mixed with phosphate reagent and allowed to react. A blank sample was used for zeroing the DR 5000 UV Spec, and phosphate concentration (mg/L) was recorded following APHA (2012).

Determination of heavy metals in water and leachate samples

Heavy metals zinc (Zn), copper (Cu), lead (Pb), iron (Fe), arsenic (As) and cadmium (Cd) in water and leachate were analyzed following APHA (2012). A 100 mL sample was transferred to a 150 mL volumetric flask, and 5 mL of 1:1 HCl and distilled water was added. The sample was heated via steam until reduced to 20 mL, then filtered to remove insoluble materials. The pH was adjusted to 4 using 5.0 N NaOH, and de-ionized water was added to restore to 100 mL volume. Heavy metal concentrations were determined using Atomic absorption spectrophotometer (ASTM D3557) with AAS Model 210 VGP (Buck Scientific, detection limit: 0.001 mg/L). Calibration was done with known standards, and dissolved metals were analyzed by directly aspirating a filtered sample into the AAS. Results were recorded (Förstner & Wittman, 1981).

Isolation of microorganisms in leachate and water samples

Isolation of microorganisms in leachate and water samples was performed according to the method described by Antai et al. (2016) with slight modification. Ten milliliter (10 mL) of the leachate samples was introduced into 90 mLs of sterile distilled water in a 100 mL-conical flask. The samples were vortexed to homogenize and allowed to stand for 10 minutes. From this initial dilution, 10-fold serial dilutions were carried out in clean sterile test tubes containing 9 mLs of sterile distilled water. One millilitre of aliquots from tubes 4 and 5 were plated on solidified plate count agar, and incubated at 37 °C for 24 h. Multiple tubes technique was used for detection of coliform in water samples. Lactose broth was prepared to industrial standard specifications with phenol red as indicator. The lactose broth (10 mL) was dispensed into test tubes as single strength while double concentration of the broth was used as double strength for lactose fermentation. The media used were Plate Count Agar (PCA), Nutrient Agar (NA), Eosin Methylene Blue (EMB) Agar (HiMedia Laboratories Ltd, India) and Triple Sugar Iron (TSI) agar (Lab M

Ltd, UK). All the media were prepared according to the manufacturer's instructions. The water sample (1 mL) was inoculated into PCA medium using pour plating technique, and then incubated at 37 °C for 24 hr. This method quantified colony-forming units per 100 mL (cfu/100 mL) of water (Cheesbrough, 2006).

Statistical analysis

One-way analysis of variance (ANOVA) was done to test for spatial difference ($p < 0.05$) among the parameters measured, then Tukey-Kramer HSD post-hoc was done to separate means. Correlation between the physicochemical properties of leachate and water quality was carried out. The analysis was carried out using SPSS 25 and Microsoft Excel 2020.

RESULTS AND DISCUSSION

Physicochemical characteristics in water and leachate samples

The mean values with standard deviation of physicochemical parameters in water and leachate samples are presented in Table 1 and Figure 3. From the stations sampled (data not presented), the pH values in water samples ranged from 7.0 to 9.2, while those in leachate samples ranged from 8.0 to 8.85. The pH values of the water samples (7.0 to 9.2) do not corroborate the findings of Olukanni et al. (2017), where pH values in groundwater near dumpsites in Ota, Nigeria, ranged from 6.5 to 8.5. This could be attributed to the composition of the wastes at dumpsites near Idemili River, which composed mainly of domestic and electronic wastes. Similarly, Oluyori & Oluyori (2020) reported that the pH values in a stream around a waste dumpsite in the FCT, Nigeria ranged from 6.78 to 8.60. However, the pH values (8.0 to 8.85) in leachate samples corroborate the findings of Salami et al. (2024a), who recorded similar results (8.1–9.0) and (8.0–8.85) around electronic wastes dumpsites in Oluku, Edo State and Ekehuan (Asoro) dumpsites, Benin City,

both in Nigeria, respectively. Water temperature ranged from 28.1 °C to 29.2 °C, while those of leachate ranged from 27.8 to 28.5 °C. EC values in water samples ranged from 480.0 to 595.4 $\mu\text{S}/\text{cm}$, while those in leachate ranged from 395.8 to 525 $\mu\text{S}/\text{cm}$. Saheed et al. (2020) reported lower values of EC (225–586 $\mu\text{S}/\text{cm}$) in their study than the EC values (584–3,610 $\mu\text{S}/\text{cm}$) obtained in this study.

EC is an indirect measurement of TDS in solutions. Higher EC values in the water imply high concentrations of anions and cations in the water, which might have leached from dumpsite's leachates through percolation. Olagbemiro et al. (2025) noted that higher EC levels in water can significantly exacerbate the aesthetic properties such as taste, odour, colour, turbidity, salinity, hardness, softness, and temperature of water. Turbidity levels in water samples had almost same values (73.5 to 75 NTU), except at L4 which had 56.5 NTU, while those in leachate ranged from 34.15 to 55.65 NTU. Turbidity and EC levels obtained in this study (34.5 to 55.0 NTU) were above the WHO acceptable limits, and this is a reflective of high values of TDS. Salami et al. (2024b) also reported elevated levels of turbidity in leachate from Ewu-Elepe dumpsite, Ikorodu, Lagos Nigeria. DO and BOD values in water samples ranged from 3.8 to 4.8 mg/L and 0.65 to 1.01 mg/L, while those in leachate ranged from 1.52 to 2.2 mg/L and 0.98 to 1.58 mg/L, respectively. The DO and BOD levels obtained in this study were within the WHO acceptable limits, and also corroborate the results by Ugbaja et al. (2021), who reported that DO and BOD in leachate samples from Ikot Effanga dumpsite, Calabar, Nigeria, ranged from 1.2 to 2.0 mg/L and 0.77 to 1.42 mg/L, respectively. Similarly, Ferreira et al. (2023), observed that DO and BOD levels in the groundwater sources near a dumpsite in Lagos metropolis were within the WHO permissible limits, and ranged from 3.05 to 4.91 mg/L and 1.61 to 3.25 mg/L, respectively.

TDS values in water samples ranged from 350 to 770.3 mg/L,

Table 1. Physicochemical parameters in river and leachate samples near dumpsites.

Parameters	River samples	Leachate samples	WHO, 2017	NSDWQ, 2017
pH	8.4625±.99111	8.4775±.35827	6.5 – 8.5	6.5 – 8.5
Temp. (°C)	28.7750±.47871	28.1750±.29861	27 – 28.5	27 – 28
EC ($\mu\text{S}/\text{cm}$)	562.3750±55.11384	477.3250±56.75464	1000	1000
Turbidity (NTU)	69.7500±8.85532	43.9800±9.89441	5	5
TDS (mg/L)	652.7000±202.18241	314.6750±35.56153	500	500
DO (mg/L)	4.2500±.47958	1.8700±.28367	5	5
BOD (mg/L)	0.8075±.15370	1.3150±.25305	5	5
Hardness (mg/L)	164.1275±68.49296	63.8250±20.64193	250	250
Chloride (mg/L)	38.5900±7.71053	62.7625±19.65873	100	100
Nitrate (mg/L)	4.2100±.75776	5.3225±1.57305	50	50
Phosphate (mg/L)	32.6275±7.19479	22.8000±6.74735	100	250
Sulphate (mg/L)	104.0875±16.23106	37.8450±9.70723	100	100

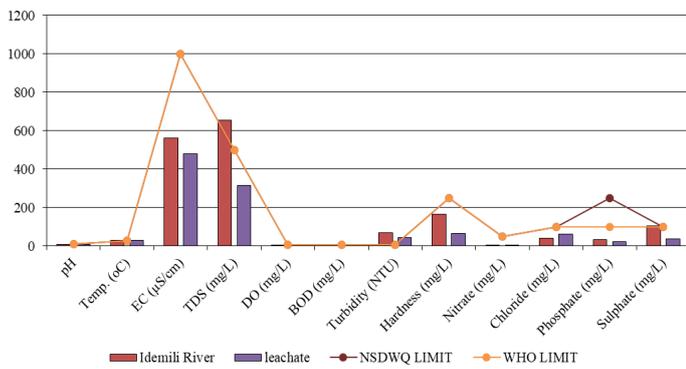


Figure 3. Spatial distribution of physicochemical parameters in Idemili River and leachate samples.

while those in leachate ranged from 281.5 to 360.2 mg/L. The TDS levels in water samples were above the WHO and NSDWQ permissible limits, except at L4, which had 350 mg/L, while its levels in leachate were within limits. Egbon *et al.* (2024), reported that the TDS values in leachate from Ikhueniro open solid wastes dumpsites were within the WHO limit, and ranged from 115 to 185.8 mg/L. The elevated levels of TDS in this study (281.5 – 360.2 mg/L) could be attributed to the composition of wastes being dumped near Idemili River, which composed mainly of industrial and electronic wastes. The dumpsite has close proximity to the electrical and motor spare parts, and vegetable markets in Obosi, Anambra State, Nigeria. Lower TDS values implied less impact on river contamination by leachate migration from dumpsites, through groundwater aquifers.

Total hardness in water and leachate samples ranged from 75.61 to 225.2 mg/L and 56.7 to 82.5 mg/L, respectively. Sulphate levels in water and leachate samples ranged from 83.05 to 121.3 mg/L and 24.07 to 46.2 mg/L, respectively. Phosphate levels in water and leachate samples ranged from 22.50 to 38.01 mg/L and 12.8 to 27.6 mg/L, respectively. Chloride levels in water and leachate samples ranged from 28.52 to 46.71 mg/L and 35.5 to 80.6 mg/L, respectively. Nitrate levels in water and leachate samples ranged from 3.10 to 4.75 mg/L and 3.35 to 7.20 mg/L, respectively. These results were all within the WHO and NSDWQ acceptable limits, except sulphate levels (83.05 to 121.2 mg/L). These findings corroborate the reports of various researchers (Azourgarh *et al.*, 2019; Ikpe *et al.*, 2019; Golden & Inichinbia, 2020; Ezemonye *et al.*, 2022; Ferreira *et al.*, 2023). The results indicate spatial variation in leachate characteristics across the various points. However, statistically significant differences ($p < 0.05$) were observed between the points for DO, BOD, EC, sulphate, phosphate, and nitrate values. This implies that the overall differences between the points are substantial. Despite the variations between the points, statistically significant differences ($p \geq 0.05$) were not observed between the various points for pH, TDS and turbidity values. The EC, DO, BOD, sulphate, phosphate, and nitrate levels in river water samples were within the WHO (2017) and NSDWQ (2017) permissible limits for drinking water. Egbon *et al.* (2024) also reported that most physicochemical parameters examined in water samples near Ikhueniro dumpsites in Benin City, Nigeria were within the WHO permissible limits, except for pH, TDS and turbidity. The

leachate samples recorded high values of physicochemical parameters than the river sample, except for TDS, DO, BOD and sulphate. Descriptive statistics and independent t-tests indicated that several parameters such as TDS, DO, turbidity, hardness, and sulphate in river samples were higher than those in leachate samples, as seen in Table 2. Notably, TDS and turbidity in both sources exceeded WHO and NSDWQ limits, posing risks to aquatic life and potential water users. However, the independent samples t-test showed no statistically significant difference ($p = 0.197$) between the two sites in overall physicochemical composition, suggesting variability within each source.

Heavy metals parameters in water and leachate samples

From the points sampled around the dumpsite (data not presented), heavy metals had higher values than the WHO permissible limits. The concentrations of heavy metals in water and leachate samples are presented in Table 2. Fe levels in water and leachate ranged from 0.01 to 0.68 mg/L and 0.95 to 7.55 mg/L, which were greater than WHO permissible limit (0.01 mg/L). Salami *et al.* (2024a) observed that Fe values in groundwater and leachate samples around Ekehuan dumpsite in Benin City, Nigeria were 0.87 ± 0.12 mg/L and 7.74 ± 16.3 , respectively. Similarly, Okiongbo *et al.* (2020) reported that Fe concentrations in groundwater samples of the Niger Delta around dumpsites were more than acceptable limit (>0.03 mg/L). Zn levels in this study ranged from <0.01 to 0.35 mg/L and 0.50 to 4.21 mg/L for water and leachate samples, respectively. As levels in water and leachate samples ranged from 0.001 to 0.014 mg/L and 1.06 to 7.91 mg/L, indicating high pollution in leachate samples. The values were above the WHO and NSDWQ permissible limits. Fe and As levels in leachate samples recorded the highest HM levels (0.95 to 7.55 mg/L) and (1.06 to 7.91 mg/L), respectively. These results align with Ikpe *et al.* (2019), which reported that Fe and As in leachate from open dumpsites in Benin City, Nigeria had high concentrations of HMs, above WHO permissible limits. Zn levels in leachate were greater than WHO standard limits. Pb levels in water and leachate samples ranged from 0.17 to 1.05 mg/L and 0.027 to 0.23, respectively, exceeding WHO limits for drinking water. Khatiebi *et al.* (2018) also reported elevated levels of Pb (0.20–1.15 mg/L) in Lake Victoria Basin near a dumpsite in Eldoret, Kenya, and were above the permissible limit of 0.01 mg/L. The results of Pb levels align with Akinrinlola *et al.* (2024), which showed similar variability in lead concentrations across dumpsites in Osogbo metropolis. Cu levels in water samples had almost same value (0.01 mg/L), and were within the permissible limit (0.03 mg/L), unlike those in leachate sample which ranged from 3.05 to 5.76 mg/L. Ugbaja *et al.* (2021), observed that Cu levels (0.001–0.011) in groundwater samples near Ikot Effanga dumpsite in Calabar, Nigeria were within the acceptable limit, but leachate had elevated Cu levels (1.27 to 3.44 mg/L). Cd levels in water and leachate samples ranged from 0.01 to 0.29 mg/L and 0.035 to 6.28 mg/L, respectively. It was observed that Cd levels in water samples were within the WHO permissible limits, corroborating the findings of Onwukeme & Eze (2021), where Cd values in groundwater

sources around active dumpsites in Southeastern Nigeria were within the acceptable limit. Ekeu-Wei et al. (2018) proposed using remote sensing to track chemical contaminants, especially heavy metals in the environment. The flow of leachate into the Idemili River resulted in elevated levels of heavy metals as observed in this study. The concentrations of heavy metals in this study decreased with increasing distance downstream from the leachate entry point through dilution (Figure 2). This could be attributed to distance from the percolation of leachate into surrounding areas. Ugbaja et al. (2021), also reported that heavy metals concentrations at hundred meters after the entry point of leachate were 0.012, 0.546, 0.007 and <0.002 mg/L for arsenic, lead, mercury and cadmium, as compared to levels at ten meters (0.85, 1.25, 1.92 and 0.065 mg/L) respectively. Okeh et al. (2024) also reported that sample H, which had the closest distance to dumpsites in Karu-Abuja and Keffi, Nasarawa State, Nigeria, had the highest heavy metal pollution index (HPI) of 300.3. Khatiebi et al. (2018) reported elevated levels of heavy metals (Pb, Cu, Cr, Cd, Hg, Zn) from leachate near dumpsites at Eldoret, Kenya in the Lake Victoria basin. Similarly, findings from Azourgarh et al. (2019), Akinrinlola et al. (2024), Salami et al. (2024a) and Olagbemiro et al. (2025) revealed elevated levels of Pb, Cd, Cr, Cu, Fe, Mn, Hg, etc. from leachate in and around dumpsites. The means indicated that heavy metal concentrations were generally higher in leachate than in river samples. For instance, Zn and Cu were present in significantly elevated amounts in leachate. The independent t-test revealed a statistically significant difference ($p < 0.001$), indicating that the heavy metal load in leachate is markedly greater than that in river water. Importantly, concentrations of Pb, As, and Cd in both sources exceeded WHO permissible limits, indicating significant public health concerns. Heavy metals in water samples do not necessarily cause serious threats to human health, except in very high levels. Titilawo et al. (2018) opined that constant monitoring of heavy metals in water systems is crucial to maintaining the quality and beauty of the

water. Azourgarh et al. (2019) recommended eliminating heavy metals contained in leachates by percolation-infiltration technology, before discharge into the water body.

Coliform and bacterial counts in water and leachate samples

Municipal solid waste dumpsites often produce high volume of leachate, loaded with diverse microbial species that are highly pathogenic. The water samples collected from nearby distances (below 20 m from source of leachate) were found to be highly polluted by leachate infiltration. Results of the bacteriological analysis of water and leachate samples from Idemili River and dumpsite are presented in Table 3 and Figure 4. Water samples revealed total coliforms ranged from 24 cfu/100mL to TNTC (Too Numerous to Count), while leachate samples 34 cfu/100mL to TNTC, indicating a high pollution. All water and leachate samples tested positive for *E. coli* and faecal *Streptococcus* and *Pseudomonas* sp. except for water samples from L4. The bacteriological analysis revealed that all water samples from Idemili River had germ colonies above the WHO guidelines. Only water samples from L4 (40 m away from dumpsite) had zero faecal *Streptococci* and *Pseudomonas* sp. This suggests that water samples near solid wastes dumpsites exhibited higher levels of contamination, compared to those collected from residential areas with no dumpsites around (Okeh et al., 2024). Findings from this study also corroborate the result of Ocheoibo & Atuanya (2024), on the evaluation of microbial loads in water samples near electronic-wastes dumpsites in Oluku and Osasogie in Edo State, and Alaba in Lagos State. Similarly, Okeh et al. (2024) reported that all the water sources near dumpsites in Karu-Abuja and Keffi, Nasarawa State, Nigeria had coliform counts (12 cfu/100mL to TNTC) above the WHO guidelines (10 cfu/100mL). These results also corroborate the findings of Olagbemiro et al. (2025), whereby microbial loads in groundwater samples near solid waste dumpsites and leachate in Onne, Rivers State, Nigeria were all above the WHO

Table 2. Heavy metal concentrations in Idemili River and leachate samples.

Parameter	$\bar{X} \pm \text{std}$		WHO 2017
	Idemili River	Leachate	
Zn (mg/L)	0.09525±.169838	3.0275±1.72589	0.003
Pb (mg/L)	0.57000±.382361	0.109±5.08608	0.01
Cu (mg/L)	0.00863±.002750	4.6500±1.14213	2.0
Fe (mg/L)	0.41000±.292005	4.4300±3.23148	0.01
As (mg/L)	0.00728±.006726	4.4350±3.14652	0.001
Cd (mg/L)	0.08050±.139670	2.8763±2.79490	0.05

Table 3. Microbiological characteristics of water and leachate samples.

Parameters	Water	Leachate	WHO 2017
Coliforms (cfu/100mL)	110.5000±128.44843	122.2500±120.46127	10
<i>E. coli</i> (cfu/100mL)	6.0000±1.63299	9.0000±2.58199	0
Faecal <i>Strept.</i> (cfu/100mL)	2.0000±1.63299	7.2500±2.21736	0
<i>Pseudomonas</i> sp. (cfu/100mL)	4.500±3.41565	1.5000±1.91485	0

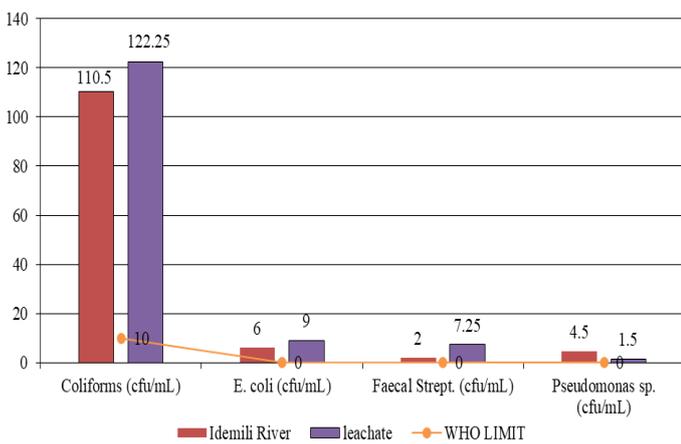


Figure 4. Spatial distribution of bacterial loads in Idemili River and leachate samples.

maximum permissible limits for drinking water. *E. coli* 6 to 12 cfu/100mL; faecal *Streptococcus* 5 to 10 cfu/100mL and *Pseudomonas* sp. from 0 to 4 cfu/100mL. *Pseudomonas* sp. was not isolated from L3 and L4, indicating only total and faecal coliforms were found in the leachate samples. A study by Gold & Inichinbia (2020) in Obio/Akpor, Rivers State, Nigeria observed similar trends in total coliform values from various sampling points near a dumpsite, with no significant differences among points. They highlighted the importance of considering other factors such as waste composition and hydrogeological conditions, as that could contribute to the overall leachate characteristics. These values on coliform and bacterial counts were above the WHO permissible limits for drinking water. These results revealed potential public health risks of using water samples from Idemili River, either for domestic or irrigation purposes. Descriptive statistics showed higher counts of total and faecal coliforms and other bacterial loads in the leachate, with particularly elevated levels of *E. coli* and faecal *Streptococci*. These findings suggest the presence of faecal contamination and potential health risks in the leachate and water samples. Agbozu *et al.* (2015) also reported presence of faecal contamination in leachates from Warri waste dumpsites, Southern Nigeria. The independent samples t-test, however, indicated no statistically significant difference in microbial load ($p = 0.873$) between the river water and leachate samples. The lack of statistical difference may be due to high within-group variability. Pearson correlation analysis (Table 4a, b) revealed various relationships between physicochemical parameters and heavy metals. Notably, strong positive correlations were observed between parameters such as TDS and turbidity ($r = 0.916, p < 0.01$); hardness and phosphate ($r = 0.916, p < 0.01$); sulphate and DO ($r = 0.975, p < 0.01$); lead and hardness ($r = 0.953, p < 0.01$); Cd and As ($r = 0.981, p < 0.01$). These associations indicate that elevated levels of certain physicochemical parameters may be linked with increased concentrations of heavy metals, further emphasizing the need for holistic water quality management.

Table 4a. Correlations between physicochemical characteristics and heavy metals concentrations.

Parameters	pH	Temp	EC	TDS	DO	BOD	Turbidity	Hardness	NO ₃	Cl ⁻	PO ₄	SO ₄	Zn	Pb	Cu	Fe	As	Cd	
pH	1																		
Temp	0.488 Sig. (2-tailed)	1																	
EC	0.415 Sig. (2-tailed)	0.896 1	1																
TDS	0.557 PC	0.855 Sig. (2-tailed)	0.783 0.022	1															
DO	0.153 Sig. (2-tailed)	0.675 0.084	0.645 0.007	0.854 1	1														
BOD	-0.142 PC	-0.869	-	-0.752 1	0.765	1													
Turbidity	0.738 Sig. (2-tailed)	0.005	0.009	0.027	0.031	-0.726 1	1												
Hardness	0.3 Sig. (2-tailed)	0.037	0.097	0.001	0.006	-0.721 0.89	0.042 1	1											
NO ₃	0.14 Sig. (2-tailed)	0.048	0.034	0.001	0.023	0.044 0.48	0.003 -0.03	-0.012 1	1										
	0.628 PC	-0.158	-	0.162	0.107	0.229	0.944	0.977											
	0.095 Sig. (2-tailed)	0.708	0.702	0.8	0.419	0.229	0.944	0.977											

Table 4b. Correlations between physicochemical characteristics and heavy metals concentrations.

Parameters	pH	Temp	EC	TDS	DO	BOD	Turbidity	Hardness	NO ₃	Cl ⁻	PO ₄	SO ₄	Zn	Pb	Cu	Fe	As	Cd	
Cl ⁻	0.449	-0.495	-0.48	-0.364	-0.582	0.74	-0.293	-0.221	0.906	1									
Sig. (2-tailed)	0.265	0.212	0.228	0.375	0.13	0.036	0.481	0.6	0.002										
PO ₄	0.657	0.527	0.573	0.851	0.729	-0.433	0.82	0.916	0.24	0.046	1								
Sig. (2-tailed)	0.076	0.18	0.137	0.007	0.04	0.284	0.013	0.001	0.567	0.914									
SO ₄	0.257	0.744	0.728	0.914	0.975	-0.746	0.891	0.824	-0.25	-0.52	0.786	1							
Sig. (2-tailed)	0.538	0.034	0.041	0.001	0	0.034	0.003	0.012	0.551	0.187	0.021								
Zn	0.127	-0.702	-0.594	-0.657	-0.728	0.9	-0.624	-0.545	0.754	0.89	-0.253	-0.686	1						
Sig. (2-tailed)	0.764	0.052	0.12	0.077	0.041	0.002	0.098	0.162	0.031	0.003	0.545	0.06							
Pb	0.466	0.652	0.706	0.832	0.644	-0.731	0.827	0.953	-0.079	-0.232	0.792	0.699	-0.569	1					
Sig. (2-tailed)	0.245	0.08	0.05	0.01	0.085	0.04	0.011	0	0.852	0.581	0.019	0.054	0.141						
Cu	0.108	-0.684	-0.667	-0.75	-0.895	0.878	-0.734	-0.667	0.667	0.846	-0.466	-0.866	0.933	-0.638	1				
Sig. (2-tailed)	0.799	0.062	0.071	0.032	0.003	0.004	0.038	0.071	0.071	0.008	0.245	0.005	0.001	0.089					
Fe	0.277	-0.572	-0.683	-0.473	-0.62	0.783	-0.323	-0.386	0.81	0.934	-0.141	-0.599	0.826	-0.387	0.849	1			
Sig. (2-tailed)	0.507	0.139	0.062	0.236	0.101	0.022	0.435	0.344	0.015	0.001	0.739	0.116	0.011	0.344	0.008				
As	0.22	-0.603	-0.687	-0.551	-0.677	0.794	-0.393	-0.451	0.809	0.929	-0.219	-0.661	0.858	-0.438	0.886	0.992	1		
Sig. (2-tailed)	0.601	0.113	0.06	0.157	0.065	0.018	0.336	0.262	0.015	0.001	0.602	0.074	0.006	0.277	0.003	0			
Cd	0.218	-0.533	-0.624	-0.472	-0.566	0.705	-0.257	-0.363	0.833	0.9	-0.139	-0.553	0.798	-0.352	0.798	0.972	0.981	1	
Sig. (2-tailed)	0.605	0.173	0.099	0.237	0.144	0.051	0.539	0.377	0.01	0.002	0.743	0.155	0.018	0.392	0.018	0	0		

Conclusion

The present study underscores the potential impact of leachate from dumpsites on surface water quality. Several physicochemical parameters such as TDS, DO, turbidity, hardness and sulphate in water samples were higher than those in leachates. Notably, TDS and turbidity in both sources exceeded WHO and NSDWQ limits, posing risks to aquatic life and potential water users. All leachate and water samples were heavily polluted with elevated levels of heavy metals, except for Cu in water samples which had values (0.01 to 0.045 mg/L) within permissible limits. The observed variations in leachate characteristics emphasize the importance of site-specific assessments for effective pollution management. Correlation analyses reveal potential links between river water quality and leachate contaminants, particularly pH, temperature, TDS and sulphates. Microbial analyses also revealed that both water and leachate samples were highly polluted, with values exceeding the WHO permissible limits. The water samples from Idemili River are not safe for human consumption based on the results of this study. There is, therefore, an urgent need for improved landfill management practices, including leachate collection and treatment systems, to protect water sources. Governments can adopt inclusive approaches to reducing waste and making waste management affordable. Regular monitoring is recommended to assess the effectiveness of any mitigation measure and safeguard public health. Further studies on effect of leachates from dumpsites around Idemili River or any water body should incorporate evaluation of Water Quality Index (WQI) and Heavy Metal Pollution Index (HPI).

ACKNOWLEDGMENTS

We are thankful to the laboratory staff at Springboard Research Laboratories, Udoka Housing State, Awka, and Microbiology Laboratory, Chukwuemeka Odumegwu Ojukwu University, Uli both in Nigeria for providing lab spaces for this work.

DECLARATIONS

Author contribution statement: Conceptualization: D.N.A., C.B.C. and A.C.P.; Methodology: A.C.P., E.C.S.O. and D.N.A.; Software and validation: E.C.S.O. and E.N.A.; Formal analysis and investigation: C.B.C. and A.C.P.; Resources: O.I.K., C.B.C., A.C.P. and D.N.A.; Data curation: E.C.S.O.; Writing—original draft preparation: C.B.C. and A.C.P.; Writing—review and editing: E.C.S.O.; Visualization: D.N.A. and E.C.S.O.; Supervision: D.N.A.; Project administration: N.O.K., E.N.A. and E.C.S.O.; Funding acquisition: C.B.C., A.C.P. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethics approval: This study did not involve any animal or human

participant and thus ethical approval was not applicable.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Supplementary data: No supplementary data is available for the paper.

Funding statement: No external funding is available for this study.

Additional information: No additional information is available for this paper.

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