Research Article

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Electrochemical and microbiological effects of dumpsite leachates on soil and air quality

https://doi.org/10.1515/chem-2025-0158
received March 11, 2025; accepted April 24, 2025

Abstract: This study investigated the environmental impact and health challenges of poorly managed solid waste materials. During this study, soil specimens were sampled at five spatial points (within a radius of 250 m) from the active and passive unlined dumpsites. Thereafter, the electrical properties and microbiology levels of the heavy metals, cadmium (Cd), lead (Pb), nickel (Ni), and arsenic (As) sampled specimens were evaluated in accordance with approved International standards. Also, the environmental air quality was measured using a portable gas detector. The results obtained revealed that the dumpsite activities substantially increased the soil's heavy metal concentration, while the total bacterial count in the contaminated soils ranged from 7.54×10^6 to 128.30×10^6 cfu/g. Likewise, the soil's electrical conductivity and electrical resistivity varied from 21.31 to 76.02 mS/m and 7.61 to 17.23 Ω m, respectively. Exceptionally, the SO_2, NO*x*, and NH_3 levels around the active dumpsite vicinity were greater than the level approved by the World Health Organization. Furthermore, the contamination factor and pollution load index results indicated that the dumpsite neighborhood soils were contaminated with toxic metals. The findings of this study have highlighted the necessity of proper waste management approaches to avoid toxic metal toxicity, epidemic diseases, and disruption of telecommunication services.

Keywords: environmental pollution, heavy metals, microbiology, public health, telecommunication sector

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1 Introduction

Environmental public health has emerged as a significant yet intricate and multi-faceted issue on the public policy agendas of states and international organizations. In most developing nations, there is a waste management (WM) crisis, leading to poorly managed solid waste dumpsites [1,2]. Poor municipal solid WM has unprecedented ecological and human-related consequences. Due to inadequate urban and rural regional planning, waste materials are dumped indiscriminately in lowland and undeveloped areas, which pose significant environmental risks [3]. These anthropogenic issues profoundly contaminate the landform and groundwater with harmful substances and are becoming a major global challenge [4,5]. Effluent discharge from poorly managed solid wastes has lethal consequences on the

ecosystems. This creates an alteration of the vegetation, soil, and sediment qualities; thereby, leading to a reduction in crop productivity and widespread diseases [6–8].

High concentration of potentially toxic metals (PTMs) is a major contributor to ecological pollution, leading to serious public health issues. Primarily, this can be linked to the doggedness and toxicity nature of these potentially toxic elements (metals), which result in their substantial accumulation in the environment [9,10]. These PTMs, chromium (Cr), cadmium (Cd), nickel (Ni), lead (Pb), mercury (Hg), arsenic (As), and cobalt (Co), are not required for the human body performance, even in trace quantity; hence their prevalence in the food chain becomes lethal to humanity [7,11,12]. Impressively, previous studies [13,14] stated in their observations that metallic toxicity is associated with the activities of active or passive dumpsites, and this action is exacerbated by erosion, weathering, and leaching processes.

Poor WM approaches considerably influence soil's electrical properties. Leachate from solid and liquid waste contains significant amount of heavy metals and other ionic compounds, which tends to alter the soil's electrical and electromagnetic properties [15,16]. These effluents primarily alter the soil's moisture content and ionic concentration; thus, they have detrimental consequences on the soil electrical attributes and engineering applications. Leachate from waste materials is rich in both biological and inorganic impurities, and their accumulation in the soil leads to changes to the soil's electrical conductivity (EC) and dielectric properties. Soil's dielectric properties, which are essential parameters used to evaluate the soil's capability to retain and conduct electromagnetic energy, are severely impacted by effluents from solid waste [17–19]. Basic components found in waste product leachate include volatile organic compounds (VOCs), chlorides, heavy metals, sulfates, phosphates, ammonia, and nitrates [20]. These contaminants have the capability of elevating the soil's EC levels and, consequently, decreasing the soil's electrical resistivity [19]. It has been recorded that high soil EC and lower resistivity facilitate rapid corrosion processes of metallic electric and electronic devices and, hence, compromise the integrity and durability of these engineering components [21–23].

Numerous scientific investigations have been carried out to appraise the negative consequences of improper WM procedures on the ecosystems, engineering infrastructure, and the atmosphere [18,24–27]. Strikingly, another group of researchers [5,28] verified that inadequate WM systems lead to the accumulation of deadly gases, virulent compounds, and zoonotic diseases in the environment. Although the abovementioned studies have investigated numerous potential harmful consequences, associated with poor WM, their observations were mainly based on either single or dual factors (areas of concentration). Therefore, there is still lack of information on the impact of dumpsite emissions on multiple factors, such as electrochemical, air quality, and microbiological parameters; hence, it has become foremost to scientifically investigate the effect of mismanaged unlined dumpsites on the environmental and engineering structures. Hence, the aim of this research is to evaluate the effect of improper WM on the air quality and soil's pathogenic microbial performance, toxic metals levels, and electrical properties, with a special focus on southern Nigeria. The outcomes of this study will enhance proper management of both active and passive dumpsites, elude heavy metal poisoning, maintain reliable telecommunications, and prevent prevalence of illness caused by pathogens.

2 Materials and methods

2.1 Description of the study area

The study was conducted within the Anambra, Delta, and Bayelsa states of Nigeria, as displayed in Figure 1. Delta and Bayelsa states are located in the Niger Delta wetlands of south-southern Nigeria [29]. Similarly, Anambra state is a major commercial hub in Nigeria, which is situated in the south-eastern region of Nigeria, with weakly consolidated subsoils prone to gully erosion [30]. The studied region's climate can be categorized into wet "rainy" and dry seasons. According to the estimates of the National Population Commission, Anambra, Delta, and Bayelsa states have populations of about 5.7 million, 6.1 million, and 2.4 million, respectively [29,31]. Table 1 presents the prevailing climatic and environmental conditions of the dumpsites locations.

Additionally, there are few government-monitored solid waste disposal and management structures (dumpsites) in the region. These dumpsites receive their municipal/domestic

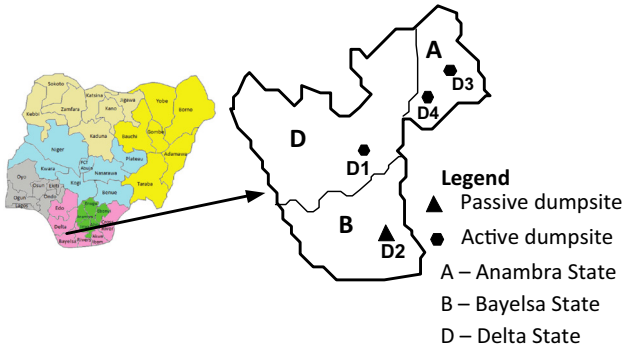

Figure 1: The map of the study area showing the respective dumpsites (D1 – dumpsite 1, D2 – dumpsite 2, D3 – dumpsite 3, D4 – dumpsite 4).

waste materials, mainly through private sector partnerships, that facilitate the collection of these wastes from the individuals/parastatals and convey them in trucks to the dumping point. These dumpsites are poorly managed, leading to the acute emission of offensive odor, poisonous gases, and pathogenic microorganisms into the environment [33]. Remarkably, dumpsites are predisposed to wildfires, particularly during dry seasons, releasing large volume of toxic substances into the atmosphere [25,26].

2.2 Sample collection and preparation

Subsoil (0.4 m depth) samples were carefully sampled from five spatial locations within the vicinity of an unlined dumpsite for the four unlined dumpsites evaluated in this current research. Four spatial points were situated approximately 250 m north, south, east, and west from the epicenter of the dumpsite, while the fifth point was located at the center of each dumpsite. The four unlined dumpsites used to achieve the aim of this study include three active sites and one passive site. Active sites are those dumpsites that are still receiving waste materials, while passive sites are those dumpsites that are nonfunctioning (not receiving waste materials again). Typically, government tends to shut down (reallocate) active dumpsites, primarily due to rapid urban expansion and ecological issues. These passive dumpsites rely heavily on natural remediation to clear the environment [33]. This has resulted in toxic compounds and pathogens persistence, within the proximity of passive dumpsites. Remarkably, the passive site chosen in this research was closed down approximately 2 years ago by the government.

Furthermore, the Delta state site (dumpsite) received approximately 150,000 tons of waste weekly, while each of the Anambra state sites received roughly 200,000 tons of municipal solid waste weekly. The larger volume of waste generated at Anambra state can be attributed to the high daily influx of people into the state due to its high socio-commercial activities [31]. Specifically, the active dumpsites were more than 15 years old, and each covers an area of 30,000 m^2. The wastes received by these sites consist mostly of domestic, medical, industrial, and electronic wastes [33]. These dumpsites lack proper waste sorting and recycling structures; hence, their dumpsites and landfills are littered with organic and inorganic materials.

In order to define the pollution level and pollution index of the dumpsite on the environment, a reference point (control) 3 km upland from the dumpsite was selected. The control location (reference point) had no documented records of the presence of a waste yard for the past decade. The soil samples were located from the designated points by using a soil auger, poured into sterilized containers, labeled accordingly, and transported to the laboratory.

2.3 Laboratory analyses

Table 2 shows the recap of the specimens, factors tested, and the testing techniques adopted to accomplish the research goals.

2.4 Air quality determination

The air quality at the various dumpsites was measured by using a portable gas detector (model GC310, Henan Chicheng Electric Co., Ltd, China) at a height of 2 m above the ground level, and sampling duration of 1 h per sampling time.

Table 1: Climatic and environmental characterization of the dumpsite subregions [29–33]

Parameter	D1	D2	D3	D4
Rainfall (mm per annual)	2,200	2,800	1,800	1,800
Temperature (°C)	23–38	21–35	21–33	22–37
Wind direction	SW	SW	SW	SW
Wind speed (m/s)	1.96	1.74	2.18	2.25
Prevailing soil texture	Sandy clay, loam, alluvial soil	Alluvial soil, silty clay	Sandy loam	Sandy loam
Groundwater level	Moderate	High	Low	Low
Soil drainage	Moderate	Poor	Well-drained	Well-drained
Terrain	Gentle	Gentle and flood basins	Rough	Rough
Soil infiltration rate	Moderate	Low	High	High

SW – southwest.

Table 2: Summary of the testing procedures

	Sample nature	Sampling tool	Sample quantity	Parameters tested	Testing standard
1	Soil	Soil auger	24	PTM (Pb, Cd, Ni, As)	ASTM methods using AAS (atomic absorption spectrophotometry).
2	Soil	Soil auger	24	Dielectric constant, EC, and electrical resistivity	Dielectric constant – ASTM D150 approach, EC – conductivity meter according to ASTM D1125 approach, and electrical resistivity – ASTM method
3	Soil	Soil auger	24	Microbial load	APHA 9215 standard
4	Air	Gas detector	6	Toxic gases (CO, CH_4, NH_3 NO*x*, VOCs, and SO_2)	National Institute for Occupational Safety and Health methods by using a gas monitor

Sampling was done at three defined periods of 7–8 a.m., 12–1 p.m., and 6–7 p.m. for all locations. CO (carbon (ii) oxide), CH_4 (methane), NH_3 (ammonia), NO*x* (nitrogen oxide), VOCs, and SO_2 (sulfur dioxide) were measured in ppm and converted to $\mu g/m^3$, with a conversion factor of 1,000 [26].

2.5 Heavy metal analysis

The specimens were air-dried in the research laboratory, crumpled, and sifted using a 1 mm sieve. Two grams of the sifted dried soil were digested in 10 mL of concentrated acids (trioxonitrate(v) acid, hydrochloric acid, and tetraoxosulfate(vi) acid) in a mixture ratio of 4:1:1, at a temperature of 90°C to achieve a transparent solution. The digested product was strained using a standard filter paper (Grade 42) into a volumetric bottle and diluted to 100 mL using deionized water. Thereafter, the As, Pb, Ni and Cd levels in the solution were measured by atomic adsorption spectrometry, and the results are presented in mg/kg (ppm) [11].

3 Electrical property analysis

3.1 Dielectric constant and EC

The dielectric constant (ε') of each soil specimen was determined in agreement with ASTM D150 approved guidelines at a constant frequency of 10.0 GHz. Additionally, the soil EC level, which is the measure of the amount of salt ions in the soil, was determined following standard guidelines [34–36].

3.2 Electrical resistivity

The electrical resistivity level of the soil was measured in harmony with the standard procedures explained in previous studies [36,37], as shown in Figure 2. Thereafter, the soil resistance (R) and resistivity (ρ) were computed using equations (1) and (2), respectively:

$$R = \frac{V}{I}, \tag{1}$$

$$\rho = \frac{RA}{L}, \tag{2}$$

where A is the soil column area and L is the soil column length.

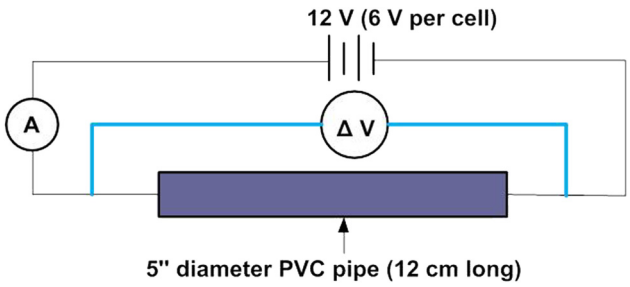

Figure 2: Structural diagram of the testing unit [36].

3.3 Microbial analysis of the soil

The plate count method was used to measure the total bacterial count (TBC) of each sample by plating serial dilutions of 5 g of the soil specimen, in agreement with the processes explained by Frączek et al. [38]. TBC was then quantified as colony-forming units per gram (cfu/g). Thereafter, the population of *Staphylococcus aureus, Escherichia coli, Pseudomonas* spp., *Bacillus* spp., *Arthrobacter* spp., and *Streptococcus* spp. in the soil samples was determined by using the culture-based methods. *S. aureus* was evaluated using the mannitol salt agar, *E. coli* was determined using the eosin methylene blue agar, *Pseudomonas* spp. was evaluated using the Cetrimide agar, *Bacillus* spp. was measured using the nutrient agar (spore-forming), *Arthrobacter* spp. was evaluated using the *Actinomycetes* isolation agar, and *Streptococcus* spp. was determined using the blood agar [7,38].

3.4 Evaluation of pollution indices

The pollution level of HMs was determined using the contamination factor and pollution load index (PLI).

3.5 Contamination factor (CF)

This pollution evaluation index was calculated using equation (3).

$$\text{Contamination factor} = \frac{X_1}{X_2}, \tag{3}$$

where X_1 and X_2 are the concentrations of HMs at the dumpsite and control point, respectively.

Soil CF is classified as follows: low – Cf < 1, moderate – Cf > 1 < 3, considerable – Cf > 3 < 6, and very high – Cf ≥ 6 [33].

3.6 PLI

The PLI was computed using equation (4):

$$\text{PLI} = \sqrt[n]{\text{CF1} \times \text{CF2} \times \text{CF3} \times \text{CF4} \ldots \times \text{CF}n}. \tag{4}$$

PLI is classified as follows: PLI > 1 indicates a polluted condition, and PLI < 1 specifies nonpolluted situation [33].

3.7 Health hazard assessment

3.7.1 Daily intake dose (EDI)

The EDI values of toxic metals are computed using equation (5):

$$\text{BDI} = \frac{\text{C} \times \text{IR}}{\text{BW}} \times \text{CF}, \tag{5}$$

where *C* is the metal concentration, IR is the ingestion rate (~200 mg/person/day for children and 100 mg/person/day for adults), BW is the individual body weight (~30 kg for children and 75 kg for adults), and CF is the conversion factor (~ $\times 10^6$) [4,7].

3.7.2 Non-carcinogenic health hazards

The hazard quotient (HQ) and hazard index (HI) values of toxic metals are calculated using equations (6) and (7):

$$\text{HQ} = \frac{\text{EDI}}{\text{RfD}}, \tag{6}$$

$$\text{HI} = \sum \text{HQ}, \tag{7}$$

where RfD is the reference dose. Cd, Pb, Ni, and As have standard approved RfD values of 0.001, 0.0014, 0.02, and 0.0003 mg kg^{-1} day^{-1}, respectively [4,26].

3.7.3 Carcinogenic hazards

The carcinogenic risk values are calculated using equations (8) and (9) [7]:

$$\text{CR} = \text{EDI} \times \text{CSF}, \tag{8}$$

$$\text{TCR} = \sum \text{CR}, \tag{9}$$

where CSF is the cancer slope factor. Cd, Pb, Ni, and As have verified CSF values of 0.38, 0.0085, 0.84, and 1.5, respectively [4].

3.8 Statistical analysis

The relationship between the parameters investigated and sampling locations was evaluated using the SPSS software (version 20.0, Chicago, IL, USA). The analysis of variance was used to evaluate the significant effects on the dumpsite activities, soil PTMs, and microbial and electrical properties status (levels). The average values were separated by Duncan's multiple range test (DMRT) at a 95% confidence level. Additionally, apart from the air quality measurement, most of the tests were repeated three times, and the average documented.

4 Results and discussion

4.1 Air quality assessment

The results of the air quality of the dumpsites regions in comparison to the reference points are presented in Table 3. In the three active dumpsites (D1, D3, and D4) investigated, tt was highlighted that the average SO_2, NO*x*, NH_3, VOC, CO, and CH_4 concentrations ranged from 99.50 to 242.20 μg/m^3, 60.60 to 85.60 μg/m^3, 1376.80 to 1812.20 μg/m^3, 10663.30 to 18097.90 μg/m^3, 32.40 to 73.00 μg/m^3, and 3365.40 to 3823.30 μg/m^3, respectively. Remarkably, the results revealed that the volume and concentration of gaseous emission around the dumpsite locality were considerably greater than the results verified at the reference points. This confirmed previous findings that emissions from decomposing organic and inorganic materials are loaded with hazardous compounds [25]. According to Uguru et al. [26], substances released from ineffectively managed dumpsites contain large percentages of CO, methane, ammonia, and VOCs. Interestingly, the results indicated that the high concentrations of SO_3 and NO*x* recorded around the active dumpsites (1, 3, and 4) exceeded the maximum allowable limits approved by World Health Organization (WHO, 2024) for residential areas.

Furthermore, the elevated concentrations of VOCs, CH_4, and NH_3 detected around D1, D3, and D4 vicinity can be primarily attributed to emissions from degrading (decomposing or burning) organic materials, paints, tyres, petroleum-based materials, and pesticides [26]. These findings aligned with the previous observations made by researchers in previous studies [25,39,40], where activities correlated with dumpsites released significant amount of toxic compounds and greenhouses gases into the ecosystems. Distinctively, considerable SO_2, NO*x*, NH_4 and CH_4 levels, documented at the reference point, can be linked to the emissions from other anthropogenic activities with the control point's locality. High SO_2, NH_3, and NO*x* concentrations are highly lethal, posing significant health challenges to human survival. Some health challenges linked to higher levels of SO_2, NO*x*, NH_3, CO, CH_4, and VOCs in the atmosphere include respiratory issues and cardiovascular diseases [26,39].

4.2 Heavy metal parameters

The results of the effect of the dumpsite leachate on the subsoil heavy metal content are shown in Table 4. Table 4 shows that D1–D4 actions had significant effect ($p \leq 0.05$) on the Ni, Pb, Cd, and As concentrations in the subsoil. This indicates negative implications of solid waste effluents on public health and human safety. At dumpsite 1, it was observed that the subsoil specimens had mean Cd, Pb, Ni, and As concentrations that ranged from 0.66 to 1.86 mg/kg, 35.30 to 72.53 mg/kg, 8.65 to 20.13 mg/kg, and 1.33 to 7.67 μg/kg, respectively. In dumpsite 2, the samples recorded average Cd, Pb, Ni, and As concentrations that varied from 0.04 to 0.1 mg/kg, 31.87 to 76.73 mg/kg, 3.91 to 7.12 mg/kg, and BDL to 6.33 μg/kg,

Table 3: Air quality level within the dumpsites and control regions (μg/m^3)

	Region	SO_2	NO*x*	NH_3	CO	CH_4	VOCs
D1	Vicinity	99.50^a ± 47.71	60.60^a ± 35.92	1376.80^a ± 402.79	73.00^b ± 30.78	3823.30^a ± 1244.34	10663.30^a ± 3180.73
	Control	8.20 ± 5.07	10.80 ± 5.87	86.20 ± 45.80	23.50 ± 10.67	650.80 ± 138.11	1242.00 ± 377.63
D3	Vicinity	125.60^a ± 107.87	73.60^b ± 38.54	1424.70^a ± 596.69	32.40^a ± 12.06	3365.40^a ± 1250.46	13394.30^a ± 4321.83
	Control	5.10 ± 3.07	20.60 ± 8.09	24.50 ± 19.78	25.30 ± 9.04	672.50 ± 190.47	1045.40 ± 306.37
D4	Vicinity	242.20^b ± 55.23	85.60^c ± 26.51	1812.20^a ± 702.42	39.30^a ± 9.91	3544.80^a ± 757.08	18097.90^b ± 4497.01
	Control	8.80 ± 4.57	23.40 ± 8.16	69.80 ± 12.93	10.90 ± 3.57	626.10 ± 192.15	1686.10 ± 417.32
WHO*		40	25	25	4000		

Mean ± standard deviation; D1 – dumpsite 1; D4 – dumpsite 3; D4 –~ dumpsite 4; *WHO [41]; $n = 10$; within the vicinity of each dumpsite, rows with the same common letter (superscript) indicate that they are not significantly different at $p \leq 0.05$ using DMRT.

respectively. Then, at dumpsite 3, it was noted that the subsoil had mean Cd, Pb, Ni and As contents that ranged from 0.46 to 1.70 mg/kg, 26.56 to 66.08 mg/kg, 0.74 to 5.24 mg/kg, and BDL to 6.67 µg/kg, respectively. Additionally, at dumpsite 4, the average Cd, Pb, Ni, and As concentrations ranged from 0.24 to 2.75 mg/kg, 17.01 to 75.48 mg/kg, 15.51 to 34.26 mg/kg, and 3.33 to 233.33 µg/kg, respectively. The wide HM concentration difference observed among D1–D4 can be attributed to several factors, such as the soil's geotechnical properties, the region's topography, and the soil's hydraulic conductivity [7,42].

Furthermore, the results indicated that the PTM – cadmium, nickel, lead and arsenic – levels in the dumpsite locality soils were significantly greater than those in the control location. Notably, the PTM concentrations verified at the passive dumpsite (D2) were considerably lower than those recorded in the active dumpsites (Dumpsites 1, 3, and 4). This buttressed earlier reports, which stated that solid waste effluent tends to contribute immensely to heavy metal pollution and its associated health issues [43,44]. Hosseini Beinabaj et al. [14] gave a concise view that there is strong correlation between PTM level, dumpsite age, and dumpsite volume. Additionally, bioremediation activities occurring in D2 greatly help in weakening the PTM concentration, consequently, leading to overall lower metal concentrations [45].

The elevated concentrations of the PTMs recorded at the dumpsite center could be attributed to the significant amount and concentration of leachate, emitted from the metallic and non-metallic wastes deposited in the localities [7,33]. When metallic objects corrode, they emit harmful minerals, including toxic metals, into the environment leading to ecological contamination; this further elevates the PTM toxicity of the ecosystems [10]. Peculiarly, Cd and Ni levels in this study were lower than those recorded by Abd-Elhalim et al. [44] for soils located around waste yard vicinities; on the contrary, the Pb and Cd levels in this study were greater than those found in previous studies [42,44]. Correspondingly, the Cd levels documented in this research were less than that (2.31 mg/kg) obtained for other region's dumpsites' soils [46]. The mean Ni concentrations found here were greater than those of Magaji et al. [47] but aligned with observations made by Uguru et al. [7]. Notably, the Cd concentrations in the D2 and D3 subregions were substantially lower than those in previous studies [48,49].

Table 4: PTM concentration in soils

Location	Spatial point	Cd (mg/kg)	Pb (mg/kg)	Ni (mg/kg)	As (µg/kg)
Dumpsite 1	Central	1.86^{c} ± 0.08	72.53^{a} ± 6.00	20.13^{b} ± 1.68	7.67^{a} ± 3.51
	1	1.01^{c} ± 0.39	35.79^{a} ± 11.03	12.05^{b} ± 2.23	2.00^{a} ± 2.00
	2	1.56^{c} ± 0.41	35.30^{a} ± 14.52	12.46^{b} ± 1.63	1.67^{a} ± 2.89
	3	0.69^{c} ± 0.28	37.29^{a} ± 6.17	8.65^{b} ± 2.13	1.33^{a} ± 1.53
	4	0.66^{c} ± 0.35	38.54^{a} ± 6.85	11.95^{b} ± 2.47	2.33^{a} ± 2.08
	Control	0.22 ± 0.17	19.71 ± 2.16	7.95 ± 1.72	0.33 ± 0.58
Dumpsite 2	Central	0.10^{a} ± 0.04	76.63^{b} ± 7.03	7.12^{a} ± 0.37	6.33^{a} ± 2.08
	1	0.04^{a} ± 0.04	63.99^{b} ± 10.27	5.35a ± 1.11	1.67^{a} ± 2.08
	2	0.06^{a} ± 0.03	51.23^{b} ± 3.83	5.75a ± 1.67	BDL
	3	0.10^{a} ± 0.04	75.23^{b} ± 4.70	4.21a ± 1.18	3.33^{a} ± 2.08
	4	0.04^{a} ± 0.03	31.87^{b} ± 3.00	3.91a ± 1.27	1.33^{a} ± 2.31
	Control	0.04 ± 0.07	29.80 ± 9.02	1.96 ± 0.97	0.67 ± 0.58
Dumpsite 3	Central	1.70^{b} ± 0.31	32.80^{a} ± 0.95	5.24^{a} ± 2.47	6.67^{a} ± 3.79
	1	0.91^{b} ± 0.16	26.56^{a} ± 3.65	0.74^{a} ± 0.76	1.67^{a} ± 2.89
	2	0.58^{b} ± 0.13	46.97^{a} ± 2.72	4.76^{a} ± 1.08	2.00^{a} ± 1.73
	3	0.79^{b} ± 0.29	66.08^{a} ± 3.54	2.62^{a} ± 0.79	1.00^{a} ± 1.73
	4	0.46^{b} ± 0.15	52.59^{a} ± 7.31	2.08^{a} ± 0.23	BDL
	Control	0.02 ± 0.03	21.16 ± 7.10	0.32 ± 0.52	1.00 ± 1.73
Dumpsite 4	Central	2.75^{c} ± 0.57	75.48^{a} ± 7.24	34.26^{c} ± 7.84	233.33^{b} ± 92.92
	1	1.13^{c} ± 0.18	54.92^{a} ± 8.67	22.88^{c} ± 5.82	33.33^{b} ± 30.55
	2	0.57^{c} ± 0.35	45.06^{a} ± 7.37	20.89^{c} ± 2.57	3.33^{b} ± 5.77
	3	1.37^{c} ± 0.42	54.15^{a} ± 13.07	16.99^{c} ± 4.71	50.00^{b} ± 43.59
	4	0.24^{c} ± 0.14	17.01^{a} ± 4.85	15.51^{c} ± 12.02	76.67^{b} ± 30.55
	Control	0.02 ± 0.03	20.89 ± 9.21	0.48 ± 0.75	3.33 ± 5.77
WHO/FAO		0.8	70.00	100.00	20.0

Mean ± standard deviation; BDL = below detection level; $n = 3$; within the vicinity of each dumpsite, rows with the same common letter (superscript) indicate that they are not significantly different at $p \leq 0.05$ using DMRT.

However, the Cd and Pb values found here were confirmed to be greater than those reported by Omo-Irabor et al. [43] for an unlined landfill.

It is interesting to note that the PTM levels around the dumpsite neighborhood soils were below the maximum acceptable concentrations values, approved by WHO and European Union for human safety. However, their elevated concentrations present considerable risks to food safety and electrical installations. Toxic metal pollutants have the ability of causing numerous diseases in humans by their accumulation in the food chain and food web [14,43]. Food poisoning resulting from PTM toxicity is a leading cause of human mortality, as it poses a severe hazard to humanity [44]. PTMs have the potential of accumulating in the soil, vegetation, and human bodies, resulting in chronic health issues such as system failures, memory loss, nervous disorders, and cancer diseases [7,50]. Cadmium primarily enters in the environment through leachates from electroplated materials and electronic components [7]; while leachate from battery circuit boards and semiconductors are significant contributors to nickel pollution in the soil [14]. Anthropogenic sources such as leachate from paint materials, pesticides, batteries, and tires are the major contributors of Pb contamination in the environment [51]; while industrial chemicals, electronic waste, batteries, and photovoltaic cells are the major sources of arsenic in the soil [7].

Based on the impact of these dumpsite actions on engineering infrastructures, the high PTM concentrations in the soil can significantly impact the functionality of telecommunication facilities [53]. According to ref. [21], metallic ions facilitate corrosion, thereby diminishing the material proficiency in numerous electrical and electronic components. PTMs (mostly Pb and Cd) have the ability of increasing the soil moisture's salinity level, leading to corrosion of metallic circuits and connectors, which in turn undermines the electrical integrity of the system [52]. Corrosion is enhanced by high soil EC, resulting in interference with signals and energy transmission. This subsequently leads to telecommunication and grounding system interruptions and failures [53,54]. These conditions are associated with signal degradation, leading to deprived connectivity and service consistency.

Table 5: Microbial concentrations at the dumpsites (n = 3)

Loc.	SP	TBC ($\times10^6$ cfu/g)	Staph ($\times10^3$ cfu/g)	*E. coli* ($\times10^3$ cfu/g)	Pseu ($\times10^3$ cfu/g)	Strep ($\times10^3$ cfu/g)	Bac ($\times10^3$ cfu/g)	Arth ($\times10^3$ cfu/g)
D1	Ce	$72.62^{a} \pm 3.47$	$6.83^{a} \pm 0.24$	$26.32^{c} \pm 1.01$	20.61b ± 1.10	$4.90^{a} \pm 0.04$	59.03b ± 1.94	22.32c ± 0.72
	1	$19.07^{a} \pm 0.47$	$4.51^{a} \pm 0.46$	$19.09^{c} \pm 1.47$	11.43b ± 0.79	$3.21^{a} \pm 0.07$	35.96b ± 5.15	12.52c ± 1.91
	2	$26.52^{a} \pm 0.62$	$2.80^{a} \pm 0.24$	$10.02^{c} \pm 1.11$	12.88b ± 1.71	$3.01^{a} \pm 0.03$	25.89b ± 0.50	8.21c ± 0.82
	3	$9.50^{a} \pm 0.85$	$3.46^{a} \pm 0.51$	$9.83^{c} \pm 0.99$	7.02b ± 1.19	$3.43^{a} \pm 0.36$	22.93b ± 2.13	10.41c ± 1.60
	4	$15.29^{a} \pm 1.24$	$3.26^{a} \pm 0.34$	$15.51^{c} \pm 1.03$	10.29b ± 0.77	$1.59^{a} \pm 0.23$	29.66b ± 3.55	11.38c ± 0.71
	Co	12.22 ± 0.54	0.79 ± 0.18	2.40 ± 0.48	1.51 ± 0.37	0.58 ± 0.10	8.29 ± 1.60	3.12 ± 0.73
D2	Ce	$53.08^{a} \pm 1.93$	$5.14^{a} \pm 0.81$	20.63a ± 1.09	15.14a ± 1.30	8.02b ± 0.60	$91.02^{c} \pm 6.03$	28.12b ± 2.42
	1	$27.52^{a} \pm 3.11$	$3.51^{a} \pm 0.28$	6.26a ± 0.80	8.95a ± 0.24	2.38b ± 0.19	$33.49^{c} \pm 2.18$	10.48b ± 1.06
	2	$7.54^{a} \pm 1.01$	$2.46^{a} \pm 0.35$	8.88a ± 0.83	5.65a ± 0.29	3.87b ± 0.31	$53.4^{c} \pm 2.84$	4.57b ± 0.60
	3	$29.32^{a} \pm 1.37$	$1.76^{a} \pm 0.29$	14.34a ± 1.20	5.55a ± 0.60	2.66b ± 0.10	$28.13^{c} \pm 3.22$	3.66b ± 0.17
	4	$12.95^{a} \pm 0.51$	$3.99^{a} \pm 0.37$	10.71a ± 1.25	16.79a ± 0.77	3.19b ± 0.25	$30.64^{c} \pm 0.73$	7.47b ± 1.91
	Co	9.73 ± 1.23	0.63 ± 0.20	2.35 ± 0.46	1.94a ± 0.10	1.17 ± 0.09	5.91 ± 0.22	0.62b ± 0.21
D3	Ce	$65.78^{b} \pm 2.06$	$10.42^{b} \pm 0.55$	$26.53^{b} \pm 1.13$	$19.60^{b} \pm 1.15$	$8.77^{c} \pm 0.39$	20.71a ± 2.21	15.39a ± 0.48
	1	$6.78^{b} \pm 0.94$	$7.60^{b} \pm 0.68$	$7.25^{b} \pm 0.53$	$8.65^{b} \pm 0.28$	$5.79^{c} \pm 0.35$	6.91a ± 0.36	8.35a ± 0.56
	2	$35.23^{b} \pm 3.75$	$3.72^{b} \pm 0.60$	$12.03^{b} \pm 1.46$	$9.31^{b} \pm 1.07$	$2.79^{c} \pm 0.24$	15.94a ± 1.10	8.08a ± 0.44
	3	$11.93^{b} \pm 1.34$	$6.57^{b} \pm 0.35$	$8.53^{b} \pm 0.54$	$11.20^{b} \pm 0.65$	$4.62^{c} \pm 0.48$	11.35a ± 0.83	7.94a ± 0.22
	4	$40.49^{b} \pm 0.87$	$5.80^{b} \pm 0.35$	$12.35^{b} \pm 1.81$	$8.65^{b} \pm 0.96$	$3.18^{c} \pm 0.11$	9.43a ± 0.37	3.27a ± 0.32
	Co	12.23 ± 1.64	1.57 ± 0.42	4.11 ± 0.23	3.08 ± 0.12	0.87 ± 0.14	1.35 ± 0.29	0.92 ± 0.20
D4	Ce	$128.30^{c} \pm 13.7$	$15.26^{b} \pm 4.73$	33.92c ± 2.71	$45.74^{c} \pm 3.33$	$6.15^{b} \pm 0.98$	82.82d ± 8.07	$19.99^{d} \pm 3.80$
	1	$40.12^{c} \pm 2.45$	$9.04^{b} \pm 0.46$	20.78 ± 2.09	$6.01^{c} \pm 1.95$	$2.92^{b} \pm 0.25$	49.34d ± 7.52	$10.30^{d} \pm 3.01$
	2	$76.59^{c} \pm 3.13$	$4.24^{b} \pm 0.09$	6.37 ± 0.65	$3.78^{c} \pm 0.25$	$5.43^{b} \pm 0.57$	40.01d ± 2.05	$13.42^{d} \pm 2.40$
	3	$25.59^{c} \pm 7.20$	$2.73^{b} \pm 0.28$	3.68 ± 0.53	$23.74^{c} \pm 2.82$	$4.54^{b} \pm 0.44$	13.67d ± 5.14	$7.39^{d} \pm 1.01$
	4	$36.21^{c} \pm 3.83$	$5.71^{b} \pm 0.81$	19.88 ± 2.52	$19.85^{c} \pm 2.61$	$2.13^{b} \pm 0.05$	68.29d ± 6.64	$22.51^{d} \pm 0.51$
	Co	11.57 ± 3.07	0.68 ± 0.24	1.24 ± 0.47	1.96 ± 0.19	0.79 ± 0.15	8.74 ± 1.17	1.39 ± 0.47

Loc – location; D – dumpsite; SP - spatial point; Ce – central; Co – control; TBC - total bacterial count; Staph – *Staphylococcus*, Pseu – *Pseudomonas* spp.; Strep – *Streptococcus*; Arth - *Arthrobacter* spp.; Bac - *Bacillus* spp.; within the vicinity of each dumpsite, rows with the same common letter (superscript) indicate that they are not significantly different at $p \leq 0.05$ using DMRT.

4.3 Microbial analysis

Table 5 presents the microbiological analysis of the dumpsite and its environmental soil samples. The average TBC in the dumpsites regions varied between 7.54×10^6 and 128.30×10^6 cfu/g, while the load of *S. aureus* ranged from 1.76×10^3 to 15.26×10^3 cfu/g. The population of *E. coli* was between 7.25×10^3 and 33.92×10^3 cfu/g. whereas the count of *Pseudomonas* spp. fluctuated from 5.55×10^3 to 45.74×10^3 cfu/g. Likewise, the mean *Bacillus* spp. load was between 6.91×10^3 and 91.02×10^3 cfu/g, while the *Arthrobacter* spp. population varied from 3.66×10^3 to 28.12×10^3 cfu/g. Finally, the mean population of *Streptococcus* spp. ranged from 1.59×10^3 to 8.77×10^3 cfu/g. The results revealed that the bacteria population at the central area and in the vicinity of the dumpsites were significantly highly than the results obtained from the reference points. This is an indication that leachates from the waste materials immensely lead to microbial infestation of the environment.

Remarkably, out of the six bacteria isolated from the dumpsite soil samples, *Bacillus s*pp., *Pseudomonas* spp., and *E. coli* have the highest prevalence, regardless of the sampling location and dumpsite. At D3, *Streptococcus* recorded the highest frequency of isolation, while *Bacillus* spp. was dominant in dumpsite 2. The *Pseudomonas* spp. population at D4 was significantly greatest compared to the populations observed at Dumpsites 1–3, while *Arthrobacter* spp. and *E. coli* had the highest isolation frequency at dumpsites 4 and 1, respectively. The high bacteria prevalence in the dumpsite soils portrayed the harmful impact of inappropriate WM practices on the ecosystems. These findings are consistent with the observations previously made in Refs [55,56], where it was noted that the organic material effluent has extremely large population of *Streptococcus* spp., *Bacillus* spp., *E. coli,* and *Pseudomonas* spp., subsequently causing massive environmental pollution. Uguru et al. [26] critically observed during their investigation into public health that a strong correlation existed between emissions from organic waste and microbial contamination of the environment.

The findings in this study highlighted that the non-active dumpsite typically had the lowest bacteria population. This could be linked to the favorable bacteria habitat conditions created by decomposition solid waste residues. *Pseudomonas* spp., *Bacillus* spp., and *Arthrobacter* spp. are heavy metal-resistant pathogens, while *Staphylococcus* and *Pseudomonas* spp. are biofilm-forming bacteria. Therefore, these microorganisms can thrive successfully in contaminated environmental conditions [33,57,58]. Additionally, the variation observed in microbial loads both within and among dumpsite neighborhoods can be correlated with the composition of the waste materials. Waste type (organic, inorganic, or toxic), environmental conditions (temperature, moisture, pH, and oxygen levels), as well as the remediation processes, tend to influence microbial reproduction and survival in the soil [56,59]. The outflow from organic materials tends to enhance the survival and performance of microorganisms [26,60]. On the contrary, seepages from synthetic or hazardous sources tend to hinder microbial growth and favorability [26,60].

Despite the pathogenic nature of *Bacillus* spp. and *Pseudomonas* spp., these bacteria can play bioremediation roles, mainly due to their resilience to degrading toxic compounds [58,61]. *E. coli*, *Bacillus* spp., and *Pseudomonas* spp. dominance in the polluted soils depicts colossal microbial diversity alteration. This context can be correlated with potential response to environmental stressors, which is caused by the waste materials' seepage into the landscape [62]. The significant bacteria population recorded at the control points could be attributed to activities associated with anthropogenic actions, such as agricultural production and domestic activities [26].

4.4 Electrical property parameters

The results of the electrical properties of the soil samples are presented in Table 6. The results highlighted that the subsoil's EC values at dumpsites 1, 2, 3, and 4 varied from 26.06 to 70.15 mS/m, 22.93 to 46.57 mS/m, to 21.31 to 65.06 mS/m, and 32.57 to 76.02 mS/m, respectively; while their ρ varied between 7.61 and 12.04 Ω m, 12.25 and 17.23 Ω m, 9.08 and 15.26, 8.64 Ω m and 15.31 Ω m, respectively. Likewise, their ε' values at dumpsites 1, 2, 3, and 4 ranged from 2.46 to 3.54, 2.64 to 3.23, 2.75 to 3.64, and 2.58 to 3.32, respectively. Generally, the results revealed that the soils around the dumpsites had higher EC values, along with decreased ε' and resistivity values compared to the soil samples at the reference points. This is an indication that leachate actions successfully initiate an increment in the soil's ability to conduct electrons and electrical charges throughout the soil mass. This action can be linked to the presence of large amount of HMs in the soil, performing the function of electron transporters, thereby facilitating the electron mobility and increasing EC of the soil in the process [17].

Furthermore, the results show that anthropogenic activities – leachate from the waste products – interfere with the soil's ρ values, which is similar to the findings of ref. [19]. High metallic concentrations of the soil tends to improve electrons' conductive routes, hence reducing the soil's electrical resistivity [62]. These findings highlighted that the dumpsite discharge reduces the soil's insulating capability, thereby creating conductive bridges within the soil mass. Depreciation of the soil ρ, particularly around the dumpsite surroundings, will adversely

affect the electrical earthing performance of electrical installations constructed in these areas. These conditions result in a higher occurrence of electrical faults and electrical accessories/systems malfunctions [37].

The smaller ε' values documented at the dumpsite neighborhood, compared to the reference point, can be attributed to the higher PTM levels recorded within the dumpsite area. Heavy metal pollution has the potential to cause significant alteration in the soil structure and moisture retention ability. Consequently, this will lead to an increase in the soil's ion concentration, causing substantial reduction in the ε' rates [64,65]. Notably, the high EC levels detected in the soils around the waste yards could foster corrosive conditions, which accelerate rapid deterioration of electrical and mechanical installations.

4.5 Heavy metal health hazards

4.5.1 Non-carcinogenic and carcinogenic risks

The results of the non-carcinogenic risks (EDI, HQ, and HI) and carcinogenic risks (CR and TCR) of the PTMs are presented in Table 7 and Figures 3 and 4. It was observed that the EDI values for Cd, Pb, Ni, and As were found as follows: $8.51 \times 10^{-7} - 1.07 \times 10^{-5}$ mg/kg/day, $1.26 \times 10^{-6} - 1.11 \times 10^{-4}$ mg/kg/day, $8.28 \times 10^{-6} - 7.22 \times 10^{-5}$ mg/kg/day, and $2.90 \times 10^{-8} - 7.33 \times 10^{-7}$ mg/kg/day, respectively. Basically, the EDI values obtained at the center of the dumpsites were greater than those found around the vicinity of the dumpsites. This reflects the emissions from the waste materials dumped at these waste yards; this builds on previous investigation of ref, [7], which identified the detrimental impact of emissions from waste materials on the environment. According to the results, the HQs of the Cd, Pb, Ni, and As varied from 8.51×10^{-4} to 1.07×10^{-2}, 3.60×10^{-3} to 3.17×10^{-2}, 4.14×10^{-4} to 3.61×10^{-3}, and 9.67×10^{-5} to 4.90×10^{-4}, respectively. Likewise, the HI values for the PTMs revealed varied levels of risk, depending on the age group and contamination point. At the dumpsite center, the HI values were 4.85×10^{-2} for children and 9.72×10^{-3} for adults; within the dumpsites' neighborhood soils, the documented HI values were 2.48×10^{-2} and 4.96×10^{-3} for the children and adult age categories, respectively (Figure 3). These results show that though the HI values were considerably high, they did not exceed the threshold (HI ≥ 1), which is associated with non-carcinogenic health risks linked to

Table 6: Electrical properties of the dumpsite soils

Location	Spatial point	EC (mS/m)	ρ (Ω m)	Dielectric constant
Dumpsite 1	Central	70.15^{a} ± 2.70	8.95^{a} ± 1.97	2.46^{b} ± 0.16
	1	26.95^{a} ± 1.74	12.04^{a} ± 1.65	3.54^{b} ± 0.32
	2	32.48^{a} ± 0.57	8.99^{a} ± 1.19	3.46^{b} ± 0.39
	3	26.06^{a} ± 0.64	7.6^{1a} ± 2.05	3.15^{b} ± 0.15
	4	30.01^{a} ± 1.14	10.54^{a} ± 2.14	3.06^{b} ± 0.25
	Control	9.66 ± 1.56	22.02 ± 1.29	3.89 ± 0.12
Dumpsite 2	Central	46.57^{a} ± 3.81	12.25^{b} ± 5.06	2.64^{a} ± 0.11
	1	33.49^{a} ± 2.11	17.23^{b} ± 2.68	3.12^{a} ± 0.13
	2	22.93^{a} ± 2.41	10.96^{b} ± 3.69	2.73^{a} ± 0.14
	3	27.68^{a} ± 2.61	11.85^{b} ± 4.49	3.08^{a} ± 0.11
	4	41.31^{a} ± 2.94	12.70^{b} ± 3.42	3.23^{a} ± 0.19
	Control	14.12 ± 3.22	27.45 ± 1.76	3.85 ± 0.08
Dumpsite 3	Central	65.06^{a} ± 8.64	9.08^{b} ± 3.43	2.75^{ab} ± 0.13
	1	21.31^{a} ± 2.21	13.14^{b} ± 0.97	3.00^{ab} ± 0.20
	2	39.11^{a} ± 3.84	13.06^{b} ± 3.46	3.64^{ab} ± 0.25
	3	37.48^{a} ± 10.33	15.26^{b} ± 1.11	3.08^{ab} ± 0.23
	4	26.75^{a} ± 2.12	13.09b ± 3.11	3.04^{ab} ± 0.21
	Control	14.34 ± 1.57	20.76 ± 6.80	3.88 ± 0.10
Dumpsite 4	Central	76.02^{b} ± 7.59	8.64^{ab} ± 1.67	2.58^{a} ± 0.18
	1	50.59^{b} ± 5.94	12.74^{ab} ± 1.87	2.66^{a} ± 0.29
	2	32.57^{b} ± 2.69	11.03^{ab} ± 1.49	3.32^{a} ± 0.43
	3	48.87b ± 3.58	12.96^{ab} ± 3.40	3.08^{a} ± 0.09
	4	41.16^{b} ± 7.05	15.31^{ab} ± 1.22	3.16^{a} ± 0.20
	Control	41.14 ± 7.31	21.17 ± 3.46	3.83 ± 0.20

EC = electrical resistivity; ρ = electrical resistivity; mean ± standard deviation; $n = 3$; rows with the same common letter at the dumpsite vicinity indicate that they are not significantly different at $p \leq 0.05$ using DMRT.

Table 7: Non-carcinogenic and carcinogenic risks of PTMs

PTM	Location	EDI (mg/kg/day)		HQ		CR	
		Children	Adults	Children	Adults	Children	Adults
Cd	Central	1.07×10^{-5}	2.14×10^{-6}	1.07×10^{-2}	2.14×10^{-3}	4.07×10^{-6}	8.13×10^{-7}
	Locality	4.25×10^{-6}	8.51×10^{-7}	4.25×10^{-3}	8.51×10^{-4}	1.62×10^{-6}	3.23×10^{-7}
Pb	Central	1.11×10^{-4}	2.23×10^{-5}	3.17×10^{-2}	6.37×10^{-3}	9.44×10^{-7}	1.90×10^{-7}
	Locality	6.29×10^{-5}	1.26×10^{-5}	1.80×10^{-2}	3.60×10^{-3}	5.35×10^{-7}	1.07×10^{-7}
Ni	Central	7.22×10^{-5}	1.44×10^{-5}	3.61×10^{-3}	7.20×10^{-4}	6.06×10^{-5}	1.21×10^{-5}
	Locality	4.14×10^{-5}	8.28×10^{-6}	2.07×10^{-3}	4.14×10^{-4}	3.48×10^{-5}	6.96×10^{-6}
As	Central	7.33×10^{-7}	1.47×10^{-7}	2.44×10^{-3}	4.90×10^{-4}	1.10×10^{-6}	2.21×10^{-7}
	Locality	1.45×10^{-7}	2.90×10^{-8}	4.83×10^{-4}	9.67×10^{-5}	2.18×10^{-7}	4.35×10^{-8}

prolong exposure to heavy metal assimilation. Typically, an HI value less than 1 is an indication that prolonged exposure to these harmful PTMs will not pose any significant non-carcinogenic health risk to humans [7].

Furthermore, the carcinogenic risks results for Cd, Pb, Ni, and As were observed to be within the following ranges: 3.23×10^{-7} to 4.07×10^{-6}, 1.07×10^{-7} to 9.44×10^{-7}, 6.96×10^{-6} to 6.06×10^{-5}, and 4.35×10^{-8} to 1.10×10^{-6}, respectively. The results further highlighted that children and the center of the dumpsites had higher CR values compared to the adults and soils sampled from the vicinity of the dumpsites. This finding is in conformity with previous observations reported by Hu et al. [69] and Uguru et al, [7]. Additionally, the TCR results (Figure 4) show that at the dumpsite center, the TCR values for children and adult were 6.67×10^{-5} and 1.33×10^{-5}, respectively, while within the dumpsite locality, the TCR values were 3.72×10^{-5} and 7.43×10^{-6} for children and adults, respectively. Based on the health safety standard, the TCR values obtained in this study, regardless of the sampling point and age category, do not exceed the minimum allowable limit of 1×10^{-4}, as stipulated by the USEPA for metropolitan areas [66]. Interestingly, the TCR results portrayed that there are no carcinogenic health hazards, which can be linked to prolong exposure to the pollutants (PTMs) emitted in the form of leachate from both the active and passive dumpsites studied. This depicted a relatively lower environmental and health concern, related to PTM lethality from poorly managed dumpsites.

4.6 Evaluation of the pollution rate

4.6.1 Contamination factor and PLI

The CF and PLI values of the soil samples are presented in Table 8. It is observed that the cadmium CF values ranged from 0.75 (low level) to 60.60 (very high pollution degree). With regard to the Pb contamination, the soil had moderate degree of contamination across all the dumpsite localities. In terms of Ni and As pollution, the contaminant factor values ranged from 1.64 to 46.05 for Ni and 2.4 to 25.8 for As. These outcomes depicted that the dumpsite regions

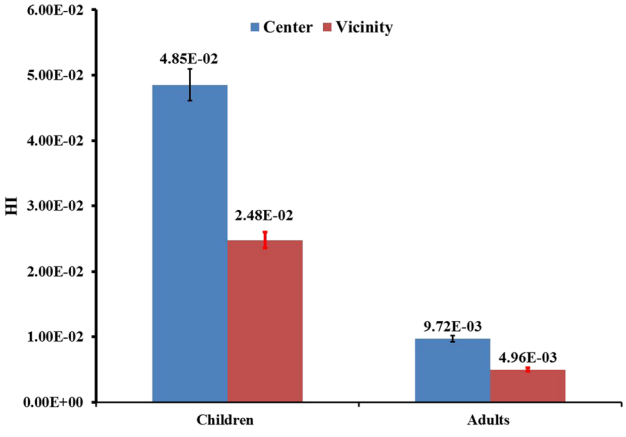

Figure 3: The HI values of PTMs.

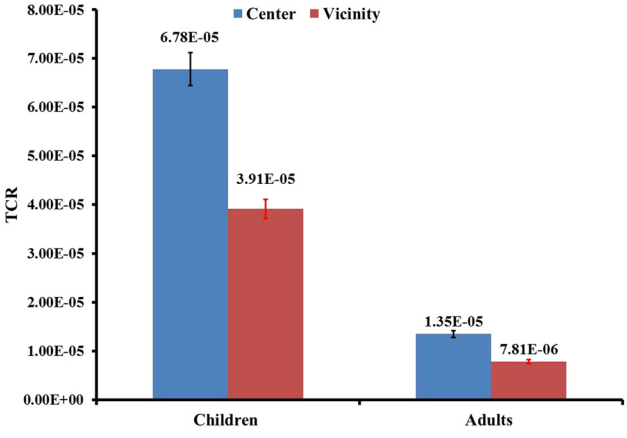

Figure 4: The TCR values of PTMs.

Table 8: Pollution indices of the dumpsite soils

Location	CR				PLI
	Cd	Pb	Ni	As	
Dumpsite 1	5.78	2.29	1.64	10	3.86
Dumpsite 2	0.75	2.01	2.83	3.43	1.96
Dumpsite 3	44.40	2.13	9.65	2.4	6.84
Dumpsite 4	60.60	2.36	46.05	25.8	20.30

have high contamination levels of cadmium and arsenic. These findings buttressed the previous observations made in ref. [7], which stated that dumpsite activities have hazardous impact on the ecosystems. The high contamination factor observed in this research indicates that anthropogenic sources, likely the waste yard, were responsible for the contamination of the environment [50]. According to the experimental findings of Ogbaran and Uguru [33], in a scenario where the CF value is lower than 1.5, there are high possibilities that the PTM contamination mainly resulted from natural sources. However when the CF levels are higher than 1.5, their strong correlation that the pollution result from primarily anthropogenic sources.

Besides, the PLI of the soil samples indicates that the PLI values ranged from 1.96 to 20.30, indicating that dumpsites and their neighborhoods were polluted (PLI > 1). As shown in Table 6, the pollution rates fluctuated among the dumpsites, with dumpsite 4 having a highest PLI value of 20.30, and point 2 having the lowest PLI value (1.96). High accumulation of toxic elements in the body can lead to nervous system disorders [67]. The Agency for Toxic Substances and Disease Registry (ATSDR) stated that persistent contact to Cd and Pb can result in carcinogenic hazards, neurological disorder, and cardiovascular and kidney diseases [67]. The high environmental pollution rates noted in this study, which are similar to the findings in previous studies [14,38], could be attributed to the unlined nature of these dumpsites investigated. This facilitates rapid percolation of the toxic waste effluents into the adjacent soils. Liners, which are typically made of water-resistant materials, are designed to provide an impermeable barrier at the bottom of landfills and dumpsites; consequently, retarding seepage of effluent produced by the decomposing waste materials into the surrounding soil and atmosphere [68].

5 Conclusion

Environmental pollution resulting from poor solid WM has become a major public concern. This is basically due to the neurotoxic, mutagenic, and carcinogenic effects, linked to poorly managed waste. This research was carried out to evaluate the effect of the gaseous emissions and leachate from solid waste on the air quality as well as the soil's heavy metal content, dielectric parameters, and microbial population. Soil sampled from active and passive dumpsites were subjected to laboratory analyses using approved ASTM International techniques. The results obtained show that the dumpsite effluent had significant effect on the environment ($P \leq 0.05$). The soil's arsenic, lead, nickel, and cadmium concentrations recorded within the dumpsite's vicinity were considerably greater than those documented at the reference points. Likewise, the dumpsite activities caused significant increment in the soil EC, but a decline in the soil's dielectric constant and electrical resistivity. It was noted that regardless of the dumpsite status, the dumpsite anthropogenic action enhanced the reproduction and survival of microorganisms. Furthermore, the outdoor air around the active dumpsites was of lower air quality, containing considerable amount of toxic compounds. This study's outcomes depicted that even after discontinuation of the dumpsite usage (passive dumpsite), the region still remains pathogenic microorganisms hotspot, which can pose latent health and ecological risks. The findings of this research and pollution indices highlighted the importance of environmental protection agencies to engage in proper solid WM approaches to prevent the occurrence of pathogenic-borne diseases, reduce heavy metals toxicity, and maintain telecommunication integrity.

Acknowledgments: The authors extend their appreciation to Taif University, Saudi Arabia, for supporting this work (project number TU-DSPP-2024-10).

Funding information: This research was funded by Taif University, Saudi Arabia (Project No. TU-DSPP-2024-10).

Author contributions: S.A. and B.E.I. designed the experiment; H.U. and S.H. analyzed the results; D.N.A. and O.I.A. wrote the first draft; R.S. and R.H.K. edited the manuscript and helped in sample collection; A.M.A. facilitated data curation, writing – review and editing, M.H. and O.A. helped in supervision and project administration. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

Ethical approval: The conducted research is not related to either human or animal use.

Data availability statement: All data analyzed during this study are included in this published article.

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