KADUNA JOURNAL OF GEOGRAPHY
2025, VOL. 7, No. 1, 165-174
https://doi.org/10.47514/kjg.2025.07.01.019

SPECIAL ISSUE: CELEBRATING 20 YEARS OF GEOGRAPHY IN KADUNA STATE UNIVERSITY - ADVANCES AND FRONTIERS IN GEOGRAPHY

Soil Quality Assessment Near a Solid Waste Dumpsite in Awka, Southeastern, Nigeria

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ABSTRACT

Solid waste dumpsite, as seen in many urban centers like Awka, southeastern Nigeria constitute a major risk factor to soils in its vicinity, which could result from leachate infiltration that contains heavy metals and altered physiochemical properties. This study assessed the impact of solid waste dumps on soil quality in Awka, Anambra State, Nigeria. Soil samples were collected at 3(three) different points denoted as (SP A, SP B, SP C). Samples were analyzed for heavy metals (Lead, Copper, Zinc, Mercury, Chromium) and other parameters using an AA Atomic Absorption Spectrophotometer. Data generated from the study were subjected to statistical analysis, such as mean, range, standard deviation, and correlation analysis. Results revealed that pH level ranged from 7 to 7.85 in the topsoil and 6-7 in the subsoil. Nitrite and Nitrate were below the permissible limits. However, heavy metals (chromium, zinc, copper, and lead) showed a moderate concentration, although they were still below permissible limits, with sample point B showing a higher concentration. On the other hand, sulphate (300-1000mg/kg) and phosphate (2466-9888mg/kg) were extremely higher than the other heavy metals. Results also indicated that most heavy metals showed a pollution index below 1. However, an increase was noticed in zinc for sample point B and sulphate for sample point A, which were above the permissible limit of 1. The most significant finding was the exceedingly high value of phosphate, which was (49-118), indicating serious contamination. Although the analyzed soil sampling points exhibited non-carcinogenic risk as nitrate, nitrite, Zinc, copper, chromium showed HQ< 1, except lead with HI >1in Sulphate and phosphate, which were also with HI>1indicating that unsafe potential non-cancer adverse effects could happen, resulting in serious environmental challenges. The study therefore recommends that regular monitoring of sulphate and phosphate levels, particularly at SP B and SP A, and the recycling and composting of waste, be undertaken to ensure environmental sustainability.

ARTICLE HISTORY
Submitted 24 October 2025
Accepted 24 December 2025
Published 25 December 2025

GUEST EDITOR
A. M. Ahmed

KEYWORDS
Solid Waste Dumps; Heavy Metal Contamination; Soil Quality; Awka; Anambra State

1 Introduction

Solid waste management (SWM) remains a significant socio-economic and governance concern, particularly in urban regions experiencing rapid population increase and waste generation (Abubakar et al., 2022). This is further exacerbated by the development in economic activity and population, which has led to an extraordinary rise in solid waste production in most metropolitan areas (Acholonu et al., 2023). This is because waste generation is closely related to the population of an area (Okorondu et al., 2024). As a result, the proper disposal of waste, as well as its treatment, is of great concern to the quality of our environment and the well-being of humans. The generation of Municipal solid waste (MSW) is increasing rapidly and is becoming more challenging, especially in developing nations like Nigeria. Improper municipal solid waste disposal can lead to unhygienic circumstances, which can deteriorate the environment and aid the breeding of rodents and insects, which can directly or indirectly spread diseases.

As the world's population grows to 8 billion by 2025 and 9.3 billion by 2050, cities around the world will face significant challenges in SWM due to economic growth, improved lifestyles, and consumerism, as about 70% of the population will live in urban areas (FAOSTAT, 2013; OECD, 2003). Hence, the tendency for solid waste generation to surpass human population growth by 2050 (Okorondu et al., 2024).

In developing countries, household garbage is often disposed of in landfills or dumpsites, which are expected to hit capacity within a decade. Dumping or burning waste in open spaces, especially near impoverished areas, or pouring garbage into bodies of water were once considered acceptable garbage disposal methods (Abubakar et al., 2022) and are still operational in most areas surrounded by water bodies (Diagi et al., 2025). This system of dumping solid waste in landfills that are not controlled or regulated brings about severe pollution by toxic materials containing carcinogenic elements like heavy metals (Agbeshie et al., 2020; Benhamdoun et al., 2023; El Fadili et al., 2022).

Many cities around the world continue to depend on obsolete or poorly maintained facilities, as well as unregulated dumping or open-air waste burning. Disposal procedures frequently have a negative impact on underprivileged communities nearby (Abul, 2010), as this technique has various sustainability issues, including

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resource depletion, pollution, and the spread of contagious diseases (Abubakar et al., 2022).

The Indiscriminate handling of municipal waste can cause technical environmental problems like air pollution, water pollution, soil pollution, etc. They can also cause lots of new economic, administrative, and social issues, like increased energy cost, which can be caused by the build-up of waste, disruption of the aquatic ecosystem, and many more that need to be addressed (Ashbolt, 2004). Inadequate MSWM has led to unexpected consequences such as contamination of oceans and drains, floods, and infection transmission through vector breeding (Hoang & Fogarassy, 2020; Liu & Hung, 2023).

This condition endangers not just the environment but also all living organisms (Liu & Hung, 2023), such as air, water, and local soil. Many states in Nigeria are commonly faced with the dumping of solid waste in open dumps, which has been practiced for decades, and it is still mostly in use today. These open methods of solid waste dumping are unsustainable as there is no consideration for safety of the well-being of the population. Most locations with these methods of waste dumping are faced with several health challenges and infestation of rodents, amongst others. These solid waste dumps also deface most of the environment and, as such, lose their aesthetic value as shown in Plate 1 of the study area. This is particularly the case in most poor and developing nations as compared to rich and developed nations, which have advanced in methods of waste management (Okorondu et al., 2024). This has been documented in a World Bank report in 2022, affirming this statement that developed nations have advanced techniques in the management of waste.

These unsustainable practices of solid waste dumping have far-reaching effects, as their impact on the environment by affecting the soil and groundwater quality contributes to climate change with the release of methane gas, and is a source of concern to the health of the population. Solid waste can affect soil and soil bacteria in several ways, which can be through the discharge of degenerative elements of solid waste that can affect the pH of soil (Yakubu & Udochukwu, 2022), as waste can mix with soil systems, thereby interfering with its physicochemical properties (Sam-Uroupa & Ogbeibu, 2020). Soils are vital elements of the physical environment that are essential for agriculture, human settlement, recreational activities, etc. (Diagi, 2023). Therefore, elevated concentrations of this heavy metal in soil can be harmful to soil health, crops, and the well-being of humans. This study, therefore, seeks to evaluate the extent of soil contamination resulting from the open dumping of solid waste in Awka and its environment.

Plate 1: Dumpsite located in the study area showing accumulation of solid waste

2 Materials and Methods

2.1 Study Area

Awka serves as the capital of Anambra State, situated in the southeastern region of Nigeria, approximately between Latitude 6°06'N to 6°16'N; Longitude 7°01'E to 7°10'E (Figure 1). Historically, the city has been recognized for its craftsmanship, particularly in blacksmithing, which has significantly influenced the economic and cultural dynamics of the Igbo community, which has resulted to more urbanization and consequently increased generation of municipal solid waste. The population of Awka has grown over the years. According to the national population commission in 2006, it was about 301,657.

The population of Awka has increased over time due to commercial activities that have resulted in an influx of people. Okonkwo and Okeke (2019) in their study noted that there was an increase in waste generation in Awka, which has resulted in pressure on the available waste infrastructure, which is also a consequence of increased population, hence the need for adaptive methods in coping with waste generation. Awka capital territory covers a land mass of 400 square kilometres and consists of six local government areas, namely Anaocha. Awka North, Awka South, Dunukofia, Njikoka, and Orumba North, in part or in full (UN-HABITAT, 2009).

Awka falls under the rainforest vegetation zone and experiences two distinct climatic conditions, which are the rainy season and dry season (Ezeigwe, 2015). The rainy season occurs around April and October, and it has wet, humid, and sometimes cold weather conditions. However, the dry season is between November and March with an annual rainfall range of 1,750 to 2,500mm, and a temperature range of 28°C to 34°C (Orji & Obasi, 2012). In terms of geology, Awka lies within the Anambra Basin, which is characterized by sedimentary rocks that consist of Nkporo Shale, Mamu formation, Ajali sandstone, and Nsukka formations, and its soil is marked by very deep, well-drained soil that is mostly found in coastal plain sand. The soil type is sandy loamy soil, which is good for agriculture.

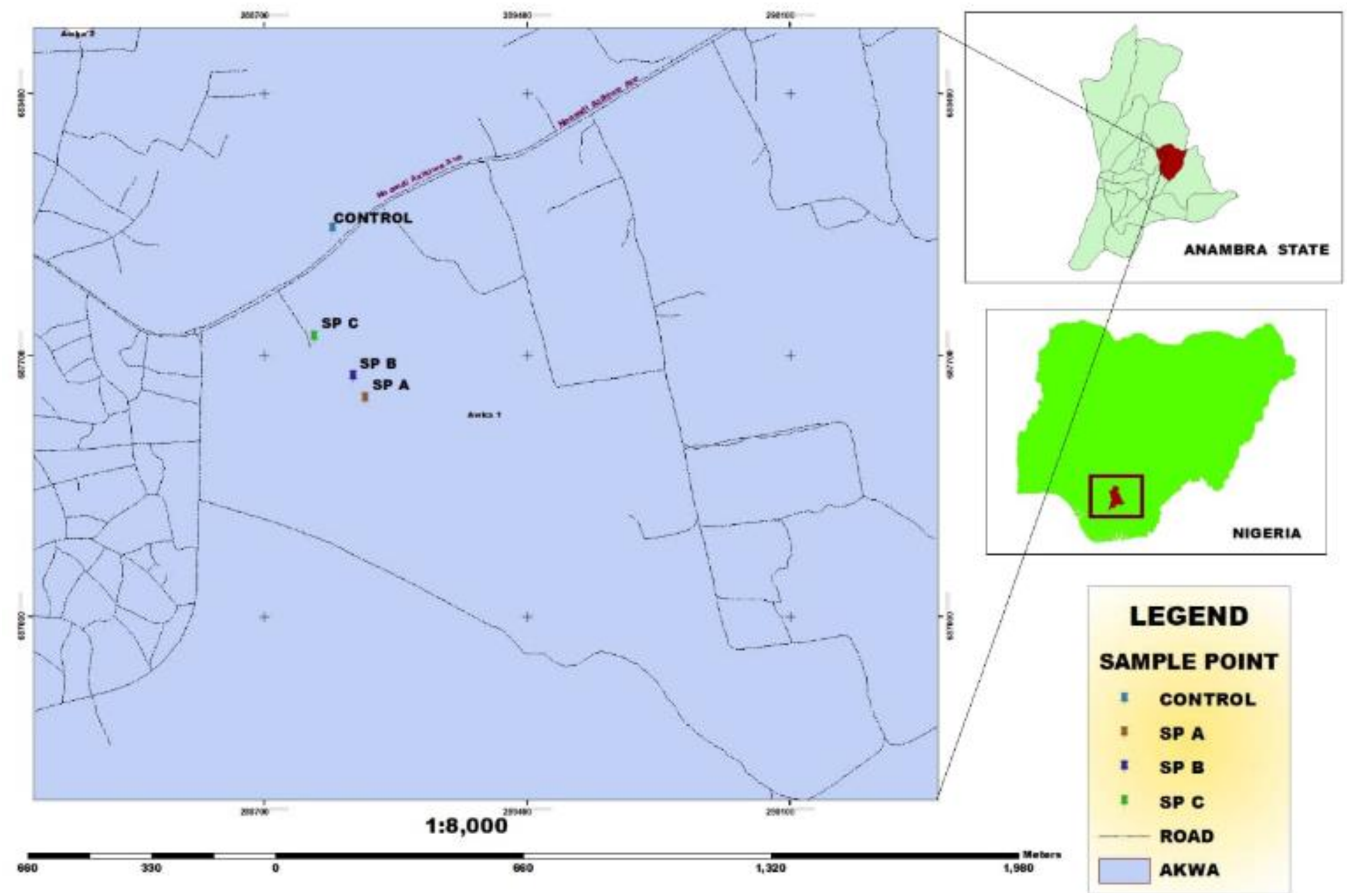

Figure 1: Study Area showing sampling points

2.2 Data Collection

This research utilized a combination of field sampling and laboratory analyses. Soil samples were collected at 3 different points of the dumpsite and a control point. Sampling points were labelled A, B, and C and were carefully planned out within the solid waste dump site. Samples were collected from three (2) different soil depths in each of the stations: 0–15 cm and 15–30 cm, separately, utilizing a handheld soil auger. The handheld soil auger was washed with clean water, rinsed with distilled water, and dried after sampling to avoid contamination with subsequent sampling. Soil samples collected were clearly labelled in a polyethylene bag and transported to the laboratory for pre-treatment and analysis of various parameters.

Soil samples collected were air-dried and smashed utilizing a mortar and pestle. Concentrated Nitric acid of ten millilitres was added to one gram of sieved soil in a round-bottom flask, washed with acid before heating the mixture on a hot plate for between 15 and 20 minutes. When it was cool, it was then filtered into a flask of 50ml. Soil samples were collected during the dry season, although seasonal variation is not a consideration for this study. The concentrations of heavy metals were ascertained with the use of AAS. The sampled locations are shown in Table 1.

Table 1: Sampling locations

Sampling Points	Latitude	Longitude	Name
SPA	6.219634	7.088971	Behind Botech Industry LTD, Zik Ave, Awka
SP B	6.217769	7.090705	Behind Emegawave ventures Zik Ave, Awka
SP C	6.219261	7.091548	Behind Carsul Nig. Ltd, Zik Ave Road, Awka
CONTROL POINT	6.212669	7.093138	Farmland

(SPA: Sampling point A, SPB: sampling point B, and SPC: sampling point C)

2.3 Statistical Analysis

Mean, standard deviation, and range were applied to soil samples collected. They were applied to show differences in the samples collected in the three different collection sites. Presentation of results was done using tables. Comparison was done using mean values with the limits in soil using World Health Organization standards. Data analysis was carried out using SPSS statistical software.

3 Results and Discussion

Soil samples collected showing heavy metals and other pollutants concentration at the waste dump site are presented in Table 2, and descriptive Statistical Analysis of heavy metals and other pollutants is shown in Table 3.

Table 2: Soil Sample of The Study Location

Parameter	SP A (Topsoil) 0-15cm	SP A (Subsoil) 15-30cm	SP B (Topsoil) 0-15cm	SP B (Subsoil) 15-30cm	SP C (Topsoil) 0-15cm	SP C (Subsoil) 15-30cm	Control (Topsoil) 0-15cm	Control (Subsoil) 15-30cm	FAO/WHO Limit
pH	7.85	7.00	7.80	6.80	6.70	6.00	6.50	6.50	6.50 – 8.50
Sulphate	600	1000	300	500	300	500	300	500	NA
Phosphate	2466.7	4111.1	5666.7	9444.5	5200	8666.7	5933.3	9888.9	NA
Nitrate	24.00	40.00	20.00	33.30	24.00	40.00	16.00	26.70	50 mg/kg
Nitrite	0.42	0.7	0.001	0.001	0.001	0.001	0.001	0.001	-
Chromium	11.49	19.2	11.2	18.7	9.48	15.8	8.25	13.8	200 mg/kg
Zinc	91.34	152.2	125.6	209.3	30.3	50.5	27.67	46.1	300 mg/kg
Copper	16.76	27.9	26.5	44.2	3.96	6.6	5.03	8.4	100 mg/kg
Lead	19.88	33.1	25.29	42.2	6.33	10.6	6.68	11.1	85 mg/kg
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	0.3–1.0 mg/kg
Carbonate	ND	ND	ND	ND	ND	ND	ND	ND	-

ND = Not detected, NA= Not available

Table 2 shows the concentration values of the different parameters analyzed. Result revealed that pH values ranged from 6 to 7.85. The pH values are all within the permissible limit of W.H.O/ FAO, except for SPA, which was a bit higher than the other sample points.

Sulfate and phosphate levels in Table 2 from the study's dumpsite (300–1000 mg/kg sulfate; 2466.7–9888.9 mg/kg phosphate) exceed typical agricultural baselines and conform with increased contamination patterns observed in similar studies from Nigerian dumpsites. For instance, Olaniyan et al. (2024) carried out a study in Lagos state and reported the following: Phosphate 9.31–14.39 mg/kg, sulfate 36.71–39.49 mg/kg, which is far less than the values from the present study, signifying serious phosphorus deficiency in the soil. Similarly, Adedinni et al. (2023) also conducted a study at Oke-Tage dumpsite, where the value of phosphate was up to 2.142mg/kg; the soil was not suitable for agricultural activity. Others include the study by Ogunlana et al. (2025), where the values of Phosphate 5.10–15.10 mg/kg, sulfate variable (17.8–301.6 mg/kg), confirming that dumpsites typically show 10–100x agricultural norms (e.g., 0.67–3.98 mg/kg P).

Although phosphate has both positive and negative effects on plants, high levels of it can lead to soil acidity, and if it leaches into water can increase eutrophication, which can encourage algae blooms. Table 2 also showed the concentration level of nitrite for both topsoil and subsoil. Nitrate concentration for both topsoil and subsoil was well below the permissible limit of WHO/FAO, which suggests that the soil was not impacted. Similarly, nitrate concentration for both topsoil and subsoil was relatively low, even though no limit was provided by WHO/FAO. For chromium, all sampled points were relatively low when compared with the permissible limit of regulatory bodies.

Table 2 similarly showed the different concentration levels for the sampled points. Values for chromium range from 8.2mg/kg to 19.2mg/kg. Zinc values for the three sampled points range from 30.3mg/kg to 152.2mg/kg for both topsoil and subsoil. While the concentration values for copper were also lower than the permissible limit for all the sampled points. The values range from 3.96mg/kg to 27.9mg/kg. This study is in contrast with the study conducted by Andaloussi et al. (2025), whose study showed a higher concentration of copper in the vicinity of the dumpsite studied in Targuist Dumpsite, North Morocco. The concentration of Lead was also relatively low for both topsoil and subsoil, with values ranging from 6.33mg/kg to 42.2mg/kg. Mercury and Carbonate were not detected in all the sample points.

Table 3: Descriptive Statistical Analysis of heavy metals and other pollutants

Parameters	Mean	Range	Std dev.	Mean	Range	Std dev.	FAO/WHO Limit
	Topsoil			Subsoil			
pH	7.45	1.15	**0.531**	6.6	**0.8**	**0.432**	6.5 – 8.5
Sulphate	400	300	**1412.7**	666.7	**500**	**235.7**	NA
Phosphate	4444.5	2733.3	**1412.7**	7407.4	**5333.4**	**2292.36**	NA
Nitrate	22.7	4	**1.89**	37.8	**6.7**	**3.16**	50 mg/kg
Nitrite	0.14	0.419	0.1975	0.234	0.699	0.330	-
Chromium	10.7	2.01	**0.887**	17.9	**3.4**	**1.5**	200 mg/kg
Zinc	82.41	95.3	**39.45**	137.3	**158.8**	**57.56**	300 mg/kg
Copper	15.74	22.54	**9.25**	26.2	**37.6**	**15.4**	100 mg/kg
Lead	51.5	18.96	**7.98**	28.6	**31.6**	**13.3**	85 mg/kg
Mercury	ND	ND	**ND**	ND	**ND**	**ND**	0.3 – 1.0 mg/kg
Carbonate	ND	ND	**ND**	ND	**ND**	**ND**	-

ND = Not detected

The results under consideration in Table 3 encompass several parameters, including pH, sulphate, phosphate, nitrate, nitrite, chromium, zinc, copper, and lead. Calculation of mean was done as follows: (SP A topsoil + SP B topsoil + SP C topsoil)/3, (SP A subsoil + SP B subsoil +SP C subsoil)/3. These were repeated for all samples. Mean pH readings for topsoil and subsoil are within the permitted range (6.5-8.5).

The topsoil has a slightly higher pH (7.45), but it is still considered neutral. These pH levels are compatible with the World Health Organization's drinking water guidelines, which suggest a pH range of 6.5 to 8.5. The pH range in the topsoil is greater (1.15), indicating that it varies more than in the subsoil (0.8). This shows that environmental factors such as irrigation, rainfall, and agricultural methods may have a greater impact on topsoil pH than subsoil pH.

The mean value of sulphate ranges between 400mg/L for topsoil and 666.7mg/L for subsoil, with a standard deviation of 1412.7mg/kg for topsoil and 235.7mg/kg for subsoil. For phosphate, the mean value ranges between 4444.5mg for topsoil and 7407.4mg/kg for subsoil, with a standard deviation of 1412.7mg/kg for subsoil and 2292.36mg/kg for subsoil.

Table 4 also revealed a mean concentration value of nitrate as22.7mg/kg for topsoil and 37.8mg/kg for subsoil with a standard deviation of 1.89mg/kg and 3.16mg/kg, respectively. Mean concentration for nitrite was 0.14mg/kg for topsoil and subsoil, 0.234mg/kg with a standard deviation of 0.1975mg/kg, and 0.330 mg/kg. For chromium, the mean value of 10.7mg/kg for topsoil and 17.9mg/kg for subsoil also showed that the concentration was higher in subsoil than in topsoil. While the range from topsoil to chromium for topsoil was 2.01mg/kg, as compared to subsoil with a range of 3.4mg/kg. The standard deviation for topsoil was 0.887mg/kg, and subsoil was 1.5mg/kg, showing a wider variation in the concentration of chromium.

Mean concentration of Zinc was 82.41mg/kg for topsoil and 137.3mg/kg for subsoil. While the concentration of zinc ranged from 95.3mg/kg to 158.8mg/kg, indicating a higher concentration in the subsoil, with a Standard deviation of 39.45mg/kg/kg for topsoil and 57.56mg/kg for subsoil. Mean for copper was 15.74mg/kg for topsoil and 26.2mg/kg for subsoil.

Copper ranged from 22.54mg/kg with a standard deviation of 9.25mg/kg for topsoil, and 37.6mg/kg with a standard deviation of 15.4mg/kg. Lead has a mean of 51.5mg/kg, a range of 18.96mg/kg, and a standard deviation of 7.98mg/kg for topsoil and a mean of 28.6mg/kg for subsoil, a range of 31.6mg/kg, and a standard deviation of 13.3 for subsoil. Generally, concentration was more at the subsoil than in the topsoil for all the parameters assessed. Carbonate and mercury were not detected in either topsoil or subsoil.

Table 4: Correlation Analysis of The Two Soil Sample Depths

	pH	Sulphate	Phosphate	Nitrate	Nitrite	Chromium	Zinc	Copper	Lead
Ph	1								
Sulphate	0.73	1							
Phosphate	-0.03	-0.24	1						
Nitrate	0.57	0.71	0.26	1					
Nitrite	0.59	0.89	-0.65	0.40	1				
Chromium	0.82	0.74	0.34	0.89	0.41	1			
Zinc	0.90	0.45	0.04	0.40	0.34	0.72	1		
Copper	0.86	0.36	0.07	0.31	0.26	0.66	0.99	1	
Lead	0.92	0.50	0.02	0.42	0.39	0.73	0.99	0.99	1

The correlation analysis detailed in Table 4 examines the interrelationships among various chemical parameters, including pH, anions, and heavy metals, in soil samples obtained from different depths at a dumpsite.

Dumpsites are frequently characterized by intricate interactions between organic and inorganic pollutants, which are shaped by factors such as waste decomposition, leachate movement, and environmental variables like pH and moisture content. The pH level of soil at dumpsites plays a pivotal role in determining the solubility, mobility, and bioavailability of heavy metals and anions. Notably, pH exhibits a strong correlation with Lead (0.923), Zinc (0.901), Copper (0.864), and Chromium (0.825) (Table 4).

Correlation analysis of heavy metals helps to show the similarity of the sources of origin. Conversely, heavy metals with high coefficients show that they have a similar origin or sources, and heavy metals that have a low correlation coefficient, or a negative correlation shows that they have different sources.

The correlation analysis shown in Table 4 shows that pH has a strong positive correlation with Lead (0.923), Zinc (0.901), copper (0.864), and chromium (0.825). Sulphate (0.728) and Nitrite (0.574) exhibit a moderate positive correlation. Strong correlation is observed in the relationship between sulphate and nitrite (0.891) and Nitrate (0.714). Similarly, phosphate exhibited a negative correlation with various parameters, such as sulphate (-0.244) and nitrite (-0.653).

Other forms of correlation are observed between nitrate and chromium (0.892) and between nitrite and sulphate. On the other hand, Lead correlated strongly with pH (0.923). Chromium also showed a strong correlation with pH (0.825) and nitrate (0.892). In dumpsite soils, Chromium typically exists in the forms of Cr (III) or Cr (VI), with Cr (VI) being more mobile and toxic under oxidizing conditions.

Furthermore, the exceptionally strong intercorrelations among Zinc, Copper, and Lead (Zinc-Copper: 0.994, Zinc-Lead: 0.998, Copper-Lead: 0.987) suggest that these metals likely originate from similar waste sources, such as electronic components, paints, and plastics. The positive correlations with pH indicate that variations in acidity due to leachate can enhance the mobility of these metals, thereby increasing their bioavailability and the potential for leaching into groundwater. The strong correlation of Lead with pH (0.923) is particularly alarming, as Lead is highly toxic and can easily contaminate adjacent ecosystems if mobilized.

3.1 Health Risk Assessment

The dumpsite evaluated for this study is in Akwa, Anambra state, located in proximity to agricultural areas and communities. Therefore, it presents a threat to the people living in that environment. This dumpsite is visited by scavengers who are mostly teenagers and children who go there in search of plastics and other commended materials that could contain heavy metals such as Chromium, Lead, copper, amongst others. Additionally, farming activities are going on around the dumpsite, which can, in the long run, affect the food chain. It is assumed that some soil could be ingested mistakenly by these scavengers, so many exposure pathways and associated risks should be considered (Vinti et al., 2023; Nuripuoh et al., 2022). This is similar to the approach adopted by Dutta et al. (2022) and Ihedioha et al. (2017) in their study, where chromium and other pollutants were considered. The exposure pathway to heavy metals is potentially through ingestion, inhalation, and dermal contact in this study.

Table 5. Soil calculations on CDI INGESTION, CDI DERMAL, HQ Ingestion, HQ Dermal, and HI

Heavy Metal	Location	CONC.	Matrix	CDI ingestion	CDI_dermal	HQ Ingestion	HQ Dermal	HI
Nitrate	SP A	24	Soil	0.2938776	0.000594351	0.183673	0.000135	0.183809
	SP B	20	Soil	0.244898	0.000495292	0.153061	0.000113	0.153174
	SP C	24	Soil	0.2938776	0.000594351	0.183673	0.000135	0.183809
	Control	16	Soil	0.1959184	0.000396234	0.122449	9.01E-05	0.122539
Nitrite	SP A	0.42	Soil	0.0051429	1.04011E-05	0.051429	5.2E-05	0.051481
	SP B	0.0001	Soil	1.224E-06	2.47646E-09	1.22E-05	1.24E-08	1.23E-05
	SP C	0.0001	Soil	1.224E-06	2.47646E-09	1.22E-05	1.24E-08	1.23E-05
	Control	0.0001	Soil	1.224E-06	2.47646E-09	1.22E-05	1.24E-08	1.23E-05
Chromium	SP A	11.49	SOIL	0.1406939	0.000284545	46.89796	0.010539	46.9085
	SP B	11.2	SOIL	0.1371429	0.000277364	45.71429	0.010273	45.72456
	SP C	9.48	SOIL	0.1160816	0.000234769	38.69388	0.008695	38.70257
	control	8.25	SOIL	0.1010204	0.000204308	33.67347	0.007567	33.68104
Zinc	SP A	91.34	SOIL	1.118449	0.002262	3.728163	0.0377	3.765863
	SP B	125.6	SOIL	1.5379592	0.003110436	5.126531	0.051841	5.178371
	SP C	30.3	SOIL	0.3710204	0.000750368	1.236735	0.012506	1.249241
	control	27.67	SOIL	0.3388163	0.000685237	1.129388	0.011421	1.140808
Copper	SP A	16.76	SOIL	0.2052245	0.000415055	5.130612	0.010376	5.140989
	SP B	26.5	SOIL	0.3244898	0.000656262	8.112245	0.016407	8.128651
	SP C	3.96	SOIL	0.0484898	9.80679E-05	1.212245	0.002452	1.214697
	control	5.03	SOIL	0.0615918	0.000124566	1.539796	0.003114	1.54291
Lead	SP A	19.88	SOIL	0.2434286	0.000492321	173.8776	0.351658	174.2292
	SP B	25.29	SOIL	0.3096735	0.000626297	221.1953	0.447355	221.6427
	SP C	6.33	SOIL	0.0775102	0.00015676	55.36443	0.111971	55.4764
	control	6.68	SOIL	0.0817959	0.000165428	58.42566	0.118163	58.54382
Sulphate	SP A	600	SOIL	7.3469388	0.014858771	7.346939	0.007429	7.354368
	SP B	300	SOIL	3.6734694	0.007429386	3.673469	0.003715	3.677184
	SP C	300	SOIL	3.6734694	0.007429386	3.673469	0.003715	3.677184
	control	300	SOIL	3.6734694	0.007429386	3.673469	0.003715	3.677184
Phosphate	SP A	2466.67	SOIL	30.204122	0.061086141	302.0412	0.169684	302.2109
	SP B	5666.67	SOIL	69.387796	0.14033292	693.878	0.389814	694.2678
	SP C	5200	SOIL	63.673469	0.128776016	636.7347	0.357711	637.0924
	control	5933.33	SOIL	72.65302	0.146936653	726.5302	0.408157	726.9384

Table 5 shows soil samples measured at the three different locations (SP A, SP B, and SP C), showing the concentration of heavy metals, as well as the control site, all of which showed significant variation from one point to another. Chromium, zinc, copper, sulphate, phosphate, and lead revealed increased concentration. Furthermore, Table 5 illustrates that Chronic Daily Intake (CDI) quantifies daily exposure to contaminants via ingestion or dermal absorption. The pathways of exposure were considered, and the ingestion pathway is the most vital source of exposure to substances that are hazardous in nature from sediments.

3.2 Nitrate and Nitrite

The hazard quotients (HQ) range from0.15-0.18 (nitrate) (HQ≤ 1), and HI ranges between 0.15 and 0.18. These values for HQ and HI indicate that the health risk associated with nitrate is minimal. While the hazard quotient for Nitrite ranges from 0.0001 to 0.42, the HQ and HI values are also considerably low, indicating a low risk association.

The hazard quotients (HQ) for Chromium range from 38.69 SPC to 46.90 SPA (HQ ≥1) HI (33.68104-46.9085) < 1, (the non-cancer health guideline is exceeded. Zinc ranges from 1.25 SP C to 5.18 SP B HI <1, indicating no potential non-carcinogenic effects. The HI values are greater than 1, with the highest seen at sample point B.

Copper HQ values range from 1.21 SPC to 8.11 SPB HQ<1 in all sample points, HI >1. HI values for copper exceeded 1; the highest risk is seen at sample point B.

Lead ranges from 55.36 SP C to 221.20 SP B, HI 55.48 SP C to 221.64 SPB HQ<1, HI>1. The HQ (ingestion) values are exceptionally high at all the sites and are above the threshold for safety. The highest risk is seen at sample point B.

Sulphate ranges from 3.67 SP B and C to 7.35 SP A

HQ<1, HI 3.68 SP B, C to 7.35 SP A HI> 1, indicating unsafe potential non-cancer adverse effects could happen. For phosphate, in all sampled points, it ranges from HQ (SP A 302.0412) (SPB693.878) (SPC 636.7347) HQ <1, indicating a non-cancerogenic risk. HI values are extremely high.

Narayan et al. (2021) reported non-carcinogenic risks associated with Cr exposure through the dermal pathway in agricultural soils. Also, Rudzi et al. (2018) showed a lack of significant health risk of Cr to farmers in Malaysia. However, except for nitrite and nitrate, all examined samples showed Hi values exceedingly above 1, indicating a high likelihood of non-carcinogenic adverse effects on the population living within the dumpsite. This result is in line with the study conducted by Ben Ali et al. (2023), showing that the concentration of metal examined was higher than the reference point.

Consequently, the analyzed soil sampling points show that the soil in the vicinity of the dumpsite used for this study is not suitable for human prolonged exposure, especially for children or the elderly, who are very vulnerable. Hence the need for urgent soil remediation measures to be put in place. Restrictions should also be put in place on the land use around the dumpsite, especially for agricultural purposes, to prevent bioaccumulation of toxins.

3.3 Pollution Index for Soil

The pollution index, usually referred to as PI, is a standard metric used to evaluate the quality of soil. A pollution index greater than 1 means significant contamination levels.

Table 6: Pollution Index for Soil

Heavy Metal	Location	CONCENT.	Matrix	Pollution Index
Nitrate(NO_3^-)	SP A	24	SOIL	0.24
	SP B	20	SOIL	0.2
	SP C	24	SOIL	0.24
	CONTROL	16	SOIL	0.16
Nitrite(NO_2^-)	SP A	0.42	SOIL	0.014
	SP B	0.0001	SOIL	3.33E-06
	SP C	0.0001	SOIL	3.33E-06
	CONTROL	0.0001	SOIL	3.33E-06
Chromium(Cr)	SP A	11.49	SOIL	0.1149
	SP B	11.2	SOIL	0.112
	SP C	9.48	SOIL	0.0948
	CONTROL	8.25	SOIL	0.0825
Zinc(Zn)	SP A	91.34	SOIL	0.742602
	SP B	125.6	SOIL	1.021138
	SP C	30.3	SOIL	0.246341
	CONTROL	27.67	SOIL	0.224959
Copper(Cu)	SP A	16.76	SOIL	0.3352
	SP B	26.5	SOIL	0.53
	SP C	3.96	SOIL	0.0792
	CONTROL	5.03	SOIL	0.1006
Lead(Pb)	SP A	19.88	SOIL	0.132533
	SP B	25.29	SOIL	0.1686
	SP C	6.33	SOIL	0.0422
	CONTROL	6.68	SOIL	0.044533
Sulphate(SO_4^{2-})	SP A	600	SOIL	1.2
	SP B	300	SOIL	0.6
	SP C	300	SOIL	0.6
	CONTROL	300	SOIL	0.6
Phosphate(PO_4^{3-})	SP A	2466.67	SOIL	49.3334
	SP B	5666.67	SOIL	113.3334
	SP C	5200	SOIL	104
	CONTROL	5933.33	SOIL	118.6666

3.4 Heavy metal pollution index and reference value

The results in Table 6 provide an analysis of the concentrations of various heavy metals and anions in water samples collected from two locations, designated as Sampling Point A (SP A) and Sampling Point B (SP B), along with their respective pollution indices (PIs). PI < 1 → Low contamination, generally safe.

Table 6 shows the pollution load index of Nitrite and Nitrate to be below 1, indicating low contamination, although elevated when compared to the control site. Copper concentrations range from 0.013 at SP A to 0.032

at SP B, with pollution indices ranging from 0.00026 to 0.00064, far below the threshold of 1. The copper levels are minimal, indicating no significant pollution.

For chromium, the value ranges from 0.0948 to 0,112, also indicating low concentration. Zinc and sulphate values range from 0.246341 SP C to 1.021138 at SPB for zinc and 0.6 to 1.2 for sulphate. The result shows that Zinc (SP B) and Sulphate (SP A) exceeded PI = 1, indicating localized pollution hotspots.

The value for phosphate PI values (49–104) is extremely high across all sites, indicating a serious contamination. Overall, most heavy metals (Chromium, Copper, Lead) are below PI =1, signifying that contamination is present but not elevated. But for zinc, at SPB and sulphate at SPA, that exceeded PI=1. Of serious concern is the phosphate values that showed severe contamination across sample points.

4 Conclusion

This study manifested a noticeable soil contamination near the Awka dumpsite, with increased phosphate(about 9888.9mg/kg, sulphate (1000mg/kg), while heavy metals like lead(was up to 42.2mg/kg as against 85mg/kg and copper (44.2mg/kg as against 100mg/kg in sampled points A, B and C .the concentration generally increased from topsoil (0-15cm) to subsoil (15-30cm) and a decrease with distance from the dumpsite(SP A>B>C. The study revealed moderate contamination from most of the heavy metals examined, except for Zinc and sulphate. Notwithstanding, the contamination from phosphate was relatively high across all sampled points, pointing to a serious risk. Of particular interest is the contamination from sample point B that was mostly elevated more than the other sampling points. In general, an overload of nutrients could become a serious environmental issue that requires urgent management to safeguard the people and environment in the vicinity of the dumpsite. This study therefore recommends that regular monitoring of zinc, copper, chromium, sulphate, and phosphate levels, particularly at SPB, as well as the promotion of waste segregation at the source, should be encouraged, and that recycling and composting of waste should be encouraged.

Acknowledgments

We wish to appreciate Engr. Ugochuckwu of the Centre of Excellence in Procurement, Environment and Social Standards, Federal University of Technology, Owerri, for his support in sample collection and laboratory experiment. We also express our appreciation to the anonymous reviewers for their valuable contribution.

Conflict of Interest: We, the authors, declare that there are no known conflicts of interest

Compliance with Ethical Standards: Not applicable, as human samples were not involved in the study

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