

# Evaluation of heavy metal contamination and associated health risks in dumpsites soils of Idah and Igalamela/Odolu in Kogi State, Northcentral, Nigeria.

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## ABSTRACT

This study assessed the concentration and environmental implications of heavy metals in soils from selected dumpsites in parts of Idah and Igalamela/Odolu in Kogi State, North-Central Nigeria. Twenty soil samples were collected at depths of 10–50 cm from major dumpsites in the study area. The samples were air-dried, digested using aqua regia, and analyzed for lead (Pb), cobalt (Co), nickel (Ni), copper (Cu), manganese (Mn), cadmium (Cd), zinc (Zn), and chromium (Cr) using Atomic Absorption Spectrophotometer (AAS). The measured concentrations were compared with WHO/DUTCH permissible limits to evaluate contamination levels and potential risks. Results revealed that Pb (12.413–150.761 mg/kg), Mn (0.121–3.423 mg/kg), Cd (0.002–14.463 mg/kg), and Zn (1.875–126.795 mg/kg) recorded average concentrations above recommended limits, indicating substantial contamination. Although Co, Ni, Cu, and Cr showed mean values below permissible limits, elevated concentrations were observed at specific locations, suggesting localized pollution hotspots. The order of metal abundance was Cd > Mn > Zn > Pb > Cr > Ni > Cu > Co, reflecting the dominance of toxic metals in the studied soils. The elevated heavy metal levels were primarily attributed to anthropogenic activities such as improper waste disposal, vehicular emissions, and dumping of agricultural and industrial residues. The findings highlight significant ecological and public health concerns, particularly due to the cultivation of edible crops on these contaminated soils. This study underscores the urgent need for continuous monitoring, improved waste management practices, and remediation strategies to mitigate soil degradation and safeguard human health in the study area.

**Keywords:** Heavy metals; Dumpsites; Atomic absorption spectrometry; Concentrations; Permissible standards.

## 1.0 INTRODUCTION

In the ecosystem, heavy metals occur naturally with substantial variations in concentrations. The heavy metals are sourced from the lithogenic activities such as rock weathering, soil erosion volcanic activities; and anthropogenic activities which include agricultural, industrial, and mining activities and emission from vehicles (Dong et al. 2023). The toxicity of the heavy metals in the ecosystem greatly affects the flora and fauna species living in the environment as it goes beyond their tolerance limit (Ahamad, et al, 2024).

Heavy metals are group of metallic and metalloid compounds which are naturally occurring with a relatively high density above 5 g/cm<sup>3</sup> (Ohiagu et al, 2022; Ojiego et al, 2022; Abdulrahman et al, 2026). These metals are essentially transition metals, elements occupying the lower left part of the periodic table, and some metalloids. Examples include cadmium (Cd), mercury (Hg), chromium (Cr), lead (Pb), tin (Sn), arsenic (As), cobalt (Co), nickel (Ni), copper (Cu), aluminum (Al), manganese (Mn), gold (Au), scandium (Sc), molybdenum (Mo), strontium (Sr), beryllium (Be),

and bismuth (Bi). These metals are not biodegradable and are recalcitrant in nature making them persist in the environment for longer periods (El Fadili et al, 2022; Ale et al, 2024).

It is a common practice in urban and sub-urban areas in Nigeria to use dumpsites as farm lands. This is because decayed and composted wastes dumped in the sites enhance soil fertility (Owonikoko and Alimba, 2024). Unfortunately, the cultivation of the varieties of edible crops on the dumpsites is without routine evaluation of the risks associated with the health and ecology (Agboeze et al, 2025; Ohiagu et al, 2022). The waste which is made up of heavy metals in several forms at different contamination levels, finds their ways into plants through the soil or they are washed into surrounding water bodies by rain or flood. Animals and human, which depend on the plants and water for survival, ingest the high concentrations of the heavy metals into their bodies (Ahamad et al, 2024) and the resultant effect is threat to their health.

Owing to the increasing and persistent nature of the heavy metals and their possible toxic effects on

plants, animals and humans in the study area, there are needs to analyze the affected soils in order to determine the concentrations of the heavy metals and proffer solutions in curbing further contamination of the soils.

### Location, Extent and Accessibility of the Study Area

The study area lies between longitudes  $6^{\circ}41'50''\text{E}$  and  $6^{\circ}44'13''\text{E}$  and latitudes  $7^{\circ}04'27''\text{N}$  and

$7^{\circ}05'57''\text{N}$  (Figure 1) in the north-central part of Nigeria. The area is bounded to the west by the River Niger, to the east, south and north by parts of Kogi State. Accessibility is enhanced by good road network. The area is accessed through the Ega-Ajaka road, and Sabongeri road (Figure 1).

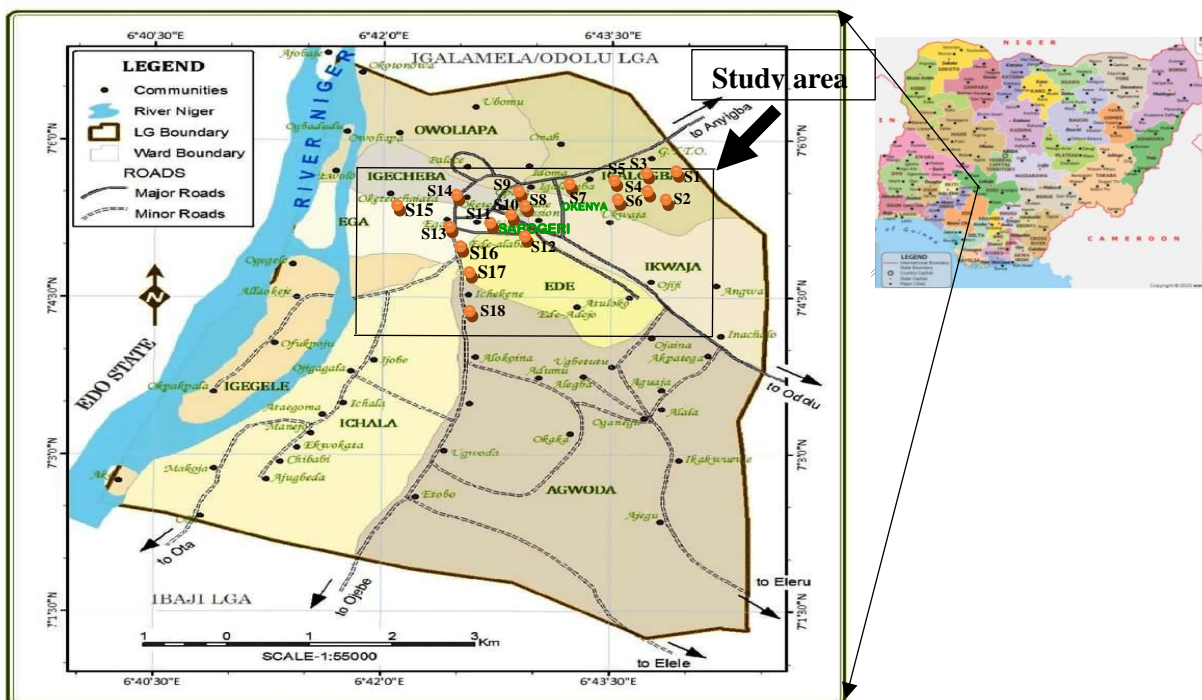


Figure 1. Location of the study area projected from administrative map of Nigeria

## 2.0. MATERIALS AND METHODS

### 2.1 Field Studies

#### 2.1.1. Sample collection

The sampling involved collection of about 100g each of 20 soil samples at depths of 10 to 50cm using a hand driven soil auger within the dumpsite locations. Sampling locations fall mostly within Ajaka, Igalogba, Okenya,

Sabongeri, Ega, Ede, and Ikwaja towns of Kogi State, north-central Nigeria (see Table 1). The heavy metals were determined in the Ecotoxicology and Environmental Forensics Laboratory of University of Nigeria, Nsukka, Nigeria. Samples locations and their coordinates are shown in Table 1.

Table 1. Summary of sample locations, coordinates and sampling depths

Serial No.	Sample code	Location name	Coordinates		Sampling depth (m)
			Longitude (E)	Latitude (N)	
1	S1	Ajaka	$7^{\circ}05'52''$	$6^{\circ}43'55''$	0.1
2	S2	Igalogba 1	$7^{\circ}05'43''$	$6^{\circ}43'47''$	0.1
3	S3	Igalogba 2	$7^{\circ}05'47''$	$6^{\circ}43'44''$	0.15
4	S4	Igalogba 3	$7^{\circ}05'48''$	$6^{\circ}43'40''$	0.22
5	S5	Igalogba 4	$7^{\circ}05'45''$	$6^{\circ}43'30''$	0.3
6	S6	Igalogba 5	$7^{\circ}05'40''$	$6^{\circ}43'33''$	0.45

7	S7	Okenya 1	7° 05'45"	6° 43' 15"	0.48
8	S8	Okenya 2	7° 05'39"	6° 42' 51"	0.36
9	S9	Okenya3	7° 05'42"	6° 42' 49"	0.4
10	S10	Sabongeri 1	7° 05'34"	6° 42' 47"	0.27
11	S11	Sabongeri 2	7° 05'32"	6° 42' 33"	0.3
12	S12	Sabongeri 3	7° 05'20"	6° 42' 46"	0.34
13	S13	Ega 1	7° 05'20"	6° 42' 19"	0.44
14	S14	Ega 2	7° 05'44"	6° 42' 27"	0.24
15	S15	Ega 3	7° 05'37"	6° 42' 06"	0.33
16	S16	Ede 1	7° 05'15"	6° 42' 22"	0.25
17	S17	Ede 2	7° 04' 57"	6° 42' 32"	0.2
18	S18	Ede 3	7° 04' 38"	6° 42' 40"	0.21
19	S19	Ukwaja 1	7° 05'14"	6° 43' 33"	0.5
20	S20	Ukwaja 2	7° 04' 45"	6° 43' 42"	0.44

## 2.2 Laboratory Analysis

In the laboratory, soil samples were collected at depths of 10–50 cm from major dumpsites air-dried at ambient temperature, gently disaggregated, and homogenized. The dried samples were ground using a porcelain mortar and pestle and sieved through a 2 mm mesh to remove debris and ensure uniform particle size. Prepared samples were stored in clean polyethylene containers until digestion.

Heavy metals were extracted from the soil samples using an acid digestion method. Approximately 1.0 g of each prepared soil sample was accurately weighed into a digestion flask. A mixture of concentrated nitric acid (HNO<sub>3</sub>) and hydrochloric acid (HCl) known as aqua regia in a 1:3 ratio (aqua regia) was added to the flask. The mixture was heated on a hot plate at 95–120 °C until complete digestion was achieved and a clear solution was obtained.

After digestion, the samples were allowed to cool to room temperature and subsequently filtered through Whatman No. 42 filter paper. The filtrates were diluted to a known volume (50 ml) using deionized water and stored in acid-washed polyethylene bottles prior to analysis. Calibration standards for each target heavy metal (Pb, Co, Ni, Cu, Mn, Cd, Zn, and Cr) were prepared by serial dilution of certified 1000 mg/l stock solutions

using deionized water. A reagent blank was prepared using the same digestion procedure without soil.

Heavy metal concentrations were determined using an Atomic Absorption Spectrometer (AAS Bulk Scientific 210 VGP). The solution is aspirated or introduced into either a flame atomizer or graphite furnace, where thermal energy converts metal ions into free ground-state atoms. A hollow cathode lamp specific to the target metal emits radiation at its characteristic wavelength. The free atoms absorb part of this radiation, and the decrease in intensity is measured by a detector. According to the Beer–Lambert law, absorbance is directly proportional to concentration. A calibration curve prepared from standard metal solutions is used to determine the concentration of heavy metals in the soil sample, typically expressed in mg/kg (ppm).

## 3.0 RESULTS OF ANALYSIS

The results of the AAS analysis of standard samples for heavy metals are summarized in Table 2, the range values and average concentrations of the heavy metals in the soil samples are presented in Table 3, while the WHO/DUTCH Permissible Limits for Heavy Metals in Soil is summarized in Table 4.

Table 2. Summary of Result of AAS Analysis of the Soil Samples (mg/kg)

Locations	Pb (mg/kg)	Co (mg/kg)	Ni (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Cd (mg/kg)	Zn (mg/kg)	Cr (mg/kg)
Ajaka	124.821	0.005	21.367	0.010	10.804	22.428	78.575	107.361
Igalogba 1	98.617	5.235	29.913	1.346	25.654	4.463	62.163	193.623
Igalogba 2	12.413	0.007	38.463	9.429	16.972	14.958	49.725	77.701
Igalogba 3	26.204	0.009	8.546	0.002	14.854	44.891	11.875	155.505
Igalogba 4	90.743	56.443	28.191	37.311	12.442	0.111	54.600	80.754
Igalogba 5	100.707	95.158	71.332	63.396	13.121	0.157	70.563	140.595
Okenya 1	96.204	0.004	25.624	0.021	6.750	2.975	57.575	102.003
Okenya 2	90.008	22.438	29.913	0.006	10.804	0.002	69.379	44.509
Okenya 3	96.087	86.180	79.021	80.938	8.112	4.194	65.764	105.741

Sabongeri 1	90.011	7.479	7.821	0.006	10.804	0.050	56.492	102.221
Sabongeri 2	120.020	37.392	18.963	2.695	22.954	2.976	111.363	105.573
Sabongeri 3	150.761	125.101	68.333	54.006	13.423	10.196	80.256	107.221
Ega 1	108.204	7.479	4.275	1.346	1.350	0.004	82.888	103.808
Ega 2	116.204	22.438	38.463	0.021	16.204	4.463	93.450	128.138
Ega 3	113.461	48.815	79.114	121.659	65.371	86.342	126.795	115.467
Ede 1	91.192	86.343	36.011	36.939	4.980	10.066	53.069	112.196
Ede 2	70.255	45.397	22.373	15.644	0.113	0.195	40.169	30.347
Ede 3	61.620	25.624	23.800	21.779	0.227	0.524	20.628	60.852
Ukwaja 1	81.212	45.363	14.461	27.665	0.521	0.004	12.666	15.598
Ukwaja 2	40.653	15.978	18.082	18.098	0.811	0.125	32.469	30.602

Table 3. The Range Values and Averages of the Heavy Metals in the Soil Samples (mg/kg)

Heavy Metals	Concentrations (mg/kg)	
	Range	Average
Pb	12.413 – 150.761	88.970
Co	0.004 – 125.101	36.644
Ni	4.275 – 79.114	33.203
Cu	0.002 – 121.659	24.616
Mn	0.121 – 3.423	0.764
Cd	0.002 – 14.463	4.406
Zn	1.875 – 126.795	61.523
Cr	15.598 – 193.623	95.991

Table 4: WHO/DUTCH Permissible Limits for Heavy Metals in Soil

Elements	Target Value of soil (mg/kg)
Cadmium (Cd)	0.8
Zinc (Zn)	50
Copper (Cu)	36
Lead (Pb)	85
Nickel (Ni)	35
Manganese (Mn)	0.3
Cobalt (Co)	85
Chromium (Cr)	100

\*Target values are specified to indicate desirable maximum levels of elements in unpolluted soils:

Source: Denneman and Robberse (1990); Ministry of Housing, Netherlands (1994); World Health Organization (1996)

Lead (Pb) concentration ranges from 12.413 to 150.761 mg/kg with an average of 88.970 mg/kg. Concentrations above the WHO/DUTCH permissible limit of 85 mg/kg were recorded in Ajaka, Igalogba 1, Igalogba 4, Igalogba 5, Okenya 1, Okenya 2, Okenya 3, Sabongeri 1, Sabongeri 2, Sabongeri 3, Ega 1, Ega 2, Ega 3, Ede 1 and Ukwaja 1. Concentrations below the permissible limit were observed at Igalogba 2, Ede 2, Ede 3 and Ukwaja 2. Cobalt (Co) concentration ranges between 0.004 and 125.101 mg/kg with an average of 36.644 mg/kg. Concentrations above 85 mg/kg were observed at Igalogba 5, Okenya 3, Sabongeri 3 and Ede 1, while other locations recorded values below the permissible limit. Nickel (Ni) concentration ranges from 4.275 to 79.114 mg/kg with an average of 33.203 mg/kg. Concentrations above the permissible limit of 35 mg/kg were recorded at Igalogba 2, Igalogba 5, Okenya 3,

Sabongeri 3, Ega 2, Ega 3 and Ede 1, while other locations were below the limit. Copper (Cu) concentration ranges between 0.002 and 121.655 mg/kg with an average of 24.616 mg/kg. Values above the permissible limit of 36 mg/kg were recorded at Igalogba 4, Igalogba 5, Okenya 3, Sabongeri 3, Ega 3 and Ede 1, while others were below the limit.

Manganese (Mn) concentration ranges from 0.121 to 3.423 mg/kg with an average of 0.764 mg/kg. Concentrations at Igalogba 2, Igalogba 3, Igalogba 4, Igalogba 5, Ede 2 and Ede 3 were below the permissible limit of 0.3 mg/kg, while other locations exceeded it. Cadmium (Cd) concentration ranges from 0.002 to 14.463 mg/kg with an average of 4.406 mg/kg. Values above the permissible limit of 0.8 mg/kg were noted at Ajaka, Igalogba 1, Igalogba 2, Igalogba 3, Okenya 1, Okenya 3, Sabongeri 2, Sabongeri 3, Ega 2, Ega 3 and

Ede 1, with other locations below the limit. Zinc (Zn) concentration ranges from 1.875 to 126.795 mg/kg with an average of 61.523 mg/kg. Values above 50 mg/kg were recorded at several locations including Ajaka, Igalogba 1, Igalogba 4, Igalogba 5, Okenya 1, Okenya 2, Okenya 3, Sabongeri 1, Sabongeri 2, Sabongeri 3, Ega 1, Ega 2, Ega 3 and Ede 1. Chromium (Cr) concentration ranges from 15.598 to 193.623 mg/kg with an average of 95.991 mg/kg. Values above the permissible limit of 100 mg/kg were recorded at Ajaka, Igalogba 1, Igalogba 3, Igalogba 5, Okenya 1, Okenya 3, Sabongeri 1, Sabongeri

2, Sabongeri 3, Ega 1, Ega 2, Ega 3, Ede 1, Ukwaja 1 and Ukwaja 2.

The percentage concentrations of the metals listed in Table 5 include lead (105%), cobalt (43%), nickel (95%), copper (65%), manganese (255%), cadmium (551%), zinc (123%) and chromium (96%). The average values of lead, manganese, cadmium and zinc exceed the WHO/DUTCH permissible limits, while cobalt, nickel, copper and chromium are below the limits. The order of metal concentration in descending order is: cadmium > manganese > zinc > lead > chromium > nickel > copper > cobalt.

Table 5. Percentage of Concentration of Heavy Metals in the Soil (%)

Elements	Percentage of Concentration (%)
Cadmium (Cd)	551
Zinc (Zn)	123
Copper (Cu)	68
Lead (Pb)	105
Nickel (Ni)	95
Manganese (Mn)	255
Cobalt (Co)	43
Chromium (Cr)	96

#### 4.0 DISCUSSION

Elevated concentrations of lead in the study area are likely linked to automobile exhaust emissions, tire wear and brake lining degradation. High levels of lead pose serious health risks including damage to the brain, kidneys and nervous system, and may result in death at extreme exposure levels. Cobalt contamination appears to be influenced by agricultural activities, particularly the disposal of phosphate fertilizer bags. Excess cobalt in soil is toxic and can cause cardiomyopathy, impairing the heart's ability to pump blood effectively. This corroborated the findings of Chaudhary et al (2021) and Agboeze et al (2025). Increased nickel concentrations may be associated with the burning of coal, fuel oil, waste and sewage infiltration into the soil. Nickel toxicity depends on exposure route and is linked with allergic reactions, kidney and cardiovascular diseases, lung fibrosis, emphysema and nasal cancer. Copper enrichment in the soil is attributed to anthropogenic activities such as improper waste management, disposal of fertilizer bags, pesticides and animal manure. Excess copper can cause liver and kidney damage, gastrointestinal disorders, anemia and even death (Agboeze et al, 2025).

High manganese levels are partly natural due to its presence in parent rock materials, but are exacerbated by fossil fuel emissions and erosion of manganese-rich

soils. Elevated manganese exposure can lead to neurological disorders such as tremors, muscle spasms and hearing problems. Cadmium contamination is likely caused by dumping of fertilizer bags, batteries and plastic materials. Prolonged exposure results in serious health conditions including lung damage, osteoporosis, cardiovascular diseases and several types of cancer. High zinc levels may be linked to the disposal of containers for anti-oxidants and motor oil additives, as well as vehicular emissions and tire wear. Excess zinc can lead to kidney damage, brain impairment, anemia and general weakness (Ohiagu et al, 2022; Dong et al, 2023). Chromium pollution may originate from cement dust, asbestos erosion, tobacco waste and fuel combustion. High chromium exposure is associated with lung, nasal and sinus cancers, as well as acute kidney damage (Ohiagu et al, 2022; Agboeze et al, 2025).

Overall, the results indicate significant anthropogenic influence on soil quality in the study area, with several heavy metals exceeding safe limits and posing serious environmental and public health risks to the local population.

#### 5.0 CONCLUSION

The study reveals widespread heavy metal contamination in dumpsite soils across parts of Idah and Igalamela/Odolu, Kogi State, with several metals

exceeding WHO/DUTCH permissible limits. Cadmium, manganese, zinc, and lead pose the greatest environmental and health risks, as their average concentrations are above safe levels, while cobalt, nickel, copper, and chromium generally fall below permissible limits but show localized exceedances. This indicates that although some metals appear less threatening on average, hotspots of contamination still exist and may worsen with continued waste accumulation.

The elevated levels of these metals are largely linked to anthropogenic activities such as indiscriminate dumping of municipal waste, disposal of fertilizer bags, batteries and plastics, and emissions from vehicular traffic. These practices have intensified natural background concentrations influenced by the local geology. The inconsistent distribution of metals across sampling locations further highlights the uneven nature of pollution and the influence of site-specific human activities.

The contamination poses significant risks to human health and the ecosystem, particularly due to the common practice of cultivating crops on dumpsites. Long-term exposure may lead to neurological, renal, cardiovascular, and carcinogenic effects in humans, as well as ecological degradation. The overall trend of metal concentration follows the order cadmium > manganese > zinc > lead > chromium > nickel > copper > cobalt, underscoring the urgent need for improved waste management, routine soil monitoring, and remediation strategies to safeguard public health and environmental sustainability.

### Statements and Declarations

I, Friday Daniel Onwe-Moses declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere. I confirm that the manuscript has been read and approved by above-named author and that there is/are no other person(s) who satisfied the criteria for authorship but are not listed. I understand that the Corresponding Author is the sole contact for the Editorial process. Hence, the progress, submissions of revisions and final approval of proofs will be known only by him.

### Data Availability Statement

The author confirms that the data supporting the findings of the study are available within the article and its supplementary materials.

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### Conflict of Interest

The author declares that there is no conflict of interest.

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### Authors Contributions

The author, Onwe-Moses Friday Daniel, obtained samples for the analysis, analyzed the samples in the laboratory, interpreted the data, discussed the result and arranged the manuscript.

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