
HEAVY METAL ACCUMULATION IN ROOTS OF SOME MEDICINAL PLANTS FOUND ON DUMPSITES

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Abstract

Dumpsites can act as localized sources of potentially toxic metals that may enter plants growing on or around waste-disposal sites. This study evaluated lead (Pb), cadmium (Cd), and chromium (Cr) accumulation in roots of *Amaranthus spinosus*, *Cleome rutidosperma*, and *Luffa cylindrica* collected from Ogoloma Dumpsite in Okrika Local Government Area and the Ignatius Ajuru University of Education (IAUOE) Dumpsite in Obio-Akpor Local Government Area, Rivers State, Nigeria. Mature roots were collected from each dumpsite and from corresponding control locations approximately 100 m away. Samples were authenticated by a plant taxonomist and analyzed by flame atomic absorption spectrophotometry following acid digestion adapted from USEPA Method 3050B. The results reported in the study showed significant differences in metal concentrations among species and locations ($p < 0.001$). Root Pb was highest in *L. cylindrica* from Ogoloma Dumpsite (15.23 ± 1.95 mg/kg), closely followed by *C. rutidosperma* (15.21 ± 1.94 mg/kg) and *A. spinosus* (15.19 ± 1.85 mg/kg). Root Cd was highest in *A. spinosus* at Ogoloma Dumpsite (1.67 ± 0.03 mg/kg), whereas root Cr was highest in *A. spinosus* at the same site (11.29 ± 0.01 mg/kg). Across the three species, dumpsite samples generally contained higher concentrations of Pb, Cd, and Cr than corresponding control samples, with Ogoloma generally showing the highest values. The findings provide baseline evidence of metal accumulation in plants occurring on the investigated dumpsites and support the need for continued environmental monitoring before plants from contaminated sites are considered for medicinal or food-related use.

Keywords: *Amaranthus spinosus*; *Cleome rutidosperma*; *Luffa cylindrica*; lead; cadmium; chromium; dumpsite; root accumulation; Nigeria.

1. Introduction

Dumpsites are important interfaces between municipal waste disposal and the surrounding soil–plant environment. Inadequately managed waste sites may receive domestic refuse, commercial wastes, discarded batteries, electronic materials, metal-containing products and other wastes capable of introducing potentially toxic elements into soil. Recent Nigerian studies have documented elevated metal concentrations around waste-disposal sites and demonstrated that plants growing on contaminated soils can accumulate these elements (Olayiwola *et al.*, 2017; Adeyi & Oyeleke, 2017; Ekere *et al.*, 2020).

Heavy metals and other potentially toxic elements are persistent because they are not destroyed by ordinary biological processes. Their environmental behavior is controlled by factors such as soil pH, organic matter, redox conditions, metal speciation and interactions with mineral surfaces. These factors influence metal mobility and plant availability (Guerra Sierra *et al.*, 2021; Zulfiqar *et al.*, 2023). In tropical environments, the diversity of plant species growing naturally on disturbed soils creates an important opportunity for studying species-specific accumulation and tolerance responses.

Roots are a critical interface in the soil–plant transfer of metals because they are the first plant organs to contact contaminated soil solution. Cadmium, for example, may enter roots through apoplastic and symplastic pathways and can subsequently be retained in root tissues or transferred to aerial organs. Plant species differ in their ability to absorb, bind, compartmentalize and translocate metals, so accumulation can vary substantially among species exposed to the same soil environment (Al-Khayri *et al.*, 2023). Chromium behavior is similarly influenced by its chemical form, soil properties and plant physiology (Zulfiqar *et al.*, 2023).

Evidence from Nigerian dumpsites reinforces the environmental relevance of this process. Olayiwola *et al.* (2017) reported greater accumulation of several metals in plants from dumpsites than in plants from a control area in Ibadan. Ekere *et al.* (2020) also found elevated heavy metals in soils and crops associated with an urban open dumpsite in Enugu, with cadmium exceeding recommended levels in the plant samples. More recently, Omada *et al.* (2024) reported substantial heavy-metal contamination of soil around the Gosa Dumpsite in Abuja and detected elevated Pb, Cd and Fe in several plant species. These studies demonstrate the need for site-specific investigations because metal concentrations vary with waste composition, soil conditions, plant species and sampling location.

Medicinal plants require particular attention because contamination may compromise their suitability for traditional or commercial use. A study of medicinal plants in northern Nigeria reported measurable concentrations of Pb, Cr, Cd and other metals and emphasized the importance of routine monitoring of medicinal plant materials (Sulaiman *et al.*, 2024). The present study therefore focuses specifically on the roots of *Amaranthus spinosus*, *Cleome rutidosperma* and *Luffa cylindrica* growing at two dumpsites in Rivers State. The objective was to determine the concentrations of Pb, Cd and Cr in the roots and compare accumulation between dumpsites and nearby control locations.

2. Materials and Methods

2.1 Study area and sampling

The study was conducted at Ogoloma Dumpsite in Okrika Local Government Area and the Ignatius Ajuru University of Education (IAUOE) Dumpsite in the Obio-Akpor area of Rivers State, Nigeria. The dumpsites of study both stood as long-standing municipal dumpsites receiving mixed domestic, commercial and industrial wastes. The three investigated plant

species were *Amaranthus spinosus* (Amaranthaceae), *Cleome rutidosperma* (Cleomaceae) and *Luffa cylindrica* (Cucurbitaceae). Mature roots were collected from each dumpsite, while corresponding roots were collected approximately 100 m away to serve as controls. The Plant specimens were identified and authenticated by a taxonomist in the Department of Plant Science and Biotechnology, Rivers State University. At each sampling site, at least 20 mature, healthy roots per species were reportedly harvested, excluding diseased roots, placed in clean labelled polythene bags and transported to the laboratory.

Table 1. Sampling locations reported in the study.

Location	Status	Approx. latitude	Approx. longitude
Ogoloma Dumpsite	Dumpsite	4°44'6.70" N	7°5'2.32" E
IAUOE Dumpsite	Dumpsite	4°48'23.48" N	6°56'23.48" E
Ogoloma Control	Control	4°44'13.08" N	7°5'3.44" E
IAUOE Control	Control	4°48'24.75" N	6°56'21.11" E

Note: Coordinates above are indicative of the general locality; exact coordinates of each composite sampling point were determined on-site using a handheld GPS receiver (Garmin eTrex 22x) and recorded in the field log.

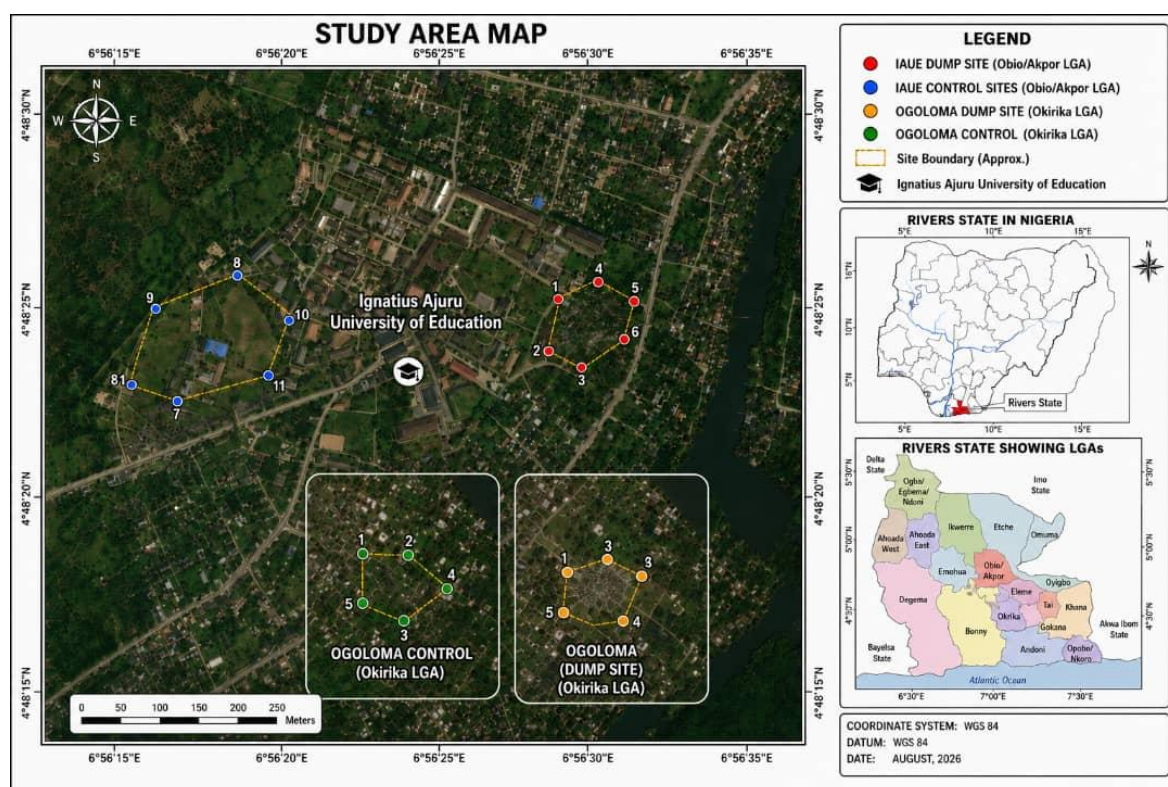


Figure 1. Study-area map showing the sampling stations for Ogoloma and IAUOE.

2.2 Sample preparation and acid digestion

Root samples were oven-dried, powdered and subjected to wet digestion. Three grams of powdered sample were weighed into a conical flask and 5 mL of a tri-acid mixture (H₂SO₄:HNO₃:HClO₄, 40:40:20) was added. Digestion was carried out in a fume cupboard

until white fumes appeared. The digest was cooled, filtered into a 100 mL volumetric flask and made up to volume with metal-free distilled water.

2.3 Determination of Lead, Cadmium and Chromium

Lead, cadmium and chromium were quantified using a Solar Thermo Elemental Flame Atomic Absorption Spectrophotometer (Model S4-71096) fitted with element-specific hollow cathode lamps. The instrument was allowed to stabilize, the burner and nebulizer were optimized with standards, and reagent blanks were used. Working standards were prepared from 1000 mg/L stock solutions by serial dilution to 0, 0.5, 1.0, 2.0, 4.0 and 8.0 mg/L. Calibration curves with $r^2 \geq 0.995$ were accepted. Digests were aspirated in triplicate and concentrations were obtained from the calibration curves. The procedure for this study was done using the digestion procedure adapted from USEPA Method 3050B (U.S. EPA, 1996).

2.4 Calculation and statistical presentation

Metal concentration was calculated as: Metal concentration (mg/kg) = $(C \times V)/W$, where C is the concentration of metal in the digest (mg/L), V is the final digest volume (L), and W is the mass of sample digested (kg). All quantitative data generated from the heavy metals analyses were subjected to descriptive statistical analysis, including mean and standard deviation, using the Statistical Package for the Social Sciences (SPSS), version 25. The significant differences among plant species and locations were recorded as $p < 0.001$ and provides least significant difference (LSD) values for mean separation at $p < 0.05$.

3. Results

Root concentrations of Pb, Cd and Cr varied among plant species and sampling locations. In general, roots collected directly from the dumpsites contained higher metal concentrations than roots collected from the corresponding control locations. The study reports significant differences in heavy-metal concentrations among species and locations ($p < 0.001$).

Lead concentration was highest in *L. cylindrica* from Ogoloma Dumpsite (15.23 ± 1.95 mg/kg), followed closely by *C. rutidosperma* (15.21 ± 1.94 mg/kg) and *A. spinosus* (15.19 ± 1.85 mg/kg). At IAUOE Dumpsite, *A. spinosus* had the highest root Pb concentration (14.20 ± 0.06 mg/kg). The lowest Pb concentration in the species-specific table was 0.77 ± 0.01 mg/kg in *C. rutidosperma* from Ogoloma Control.

Table 2. Lead concentration (mg/kg) in roots of selected plants.

Plant species	IAUOE dump	IAUOE control	Ogoloma dump	Ogoloma control	LSD
<i>A. spinosus</i>	14.20 ± 0.06^a	1.72 ± 0.02^b	15.19 ± 1.85^a	1.06 ± 0.01^b	1.744
<i>C. rutidosperma</i>	11.48 ± 0.09^b	1.29 ± 0.01^c	15.21 ± 1.94^a	0.77 ± 0.01^c	1.825
<i>L. cylindrica</i>	12.17 ± 0.01^b	1.46 ± 0.03^c	15.23 ± 1.95^a	0.90 ± 0.02^c	1.840

Cadmium showed the same general spatial pattern. The highest root Cd concentration was recorded in *A. spinosus* at Ogoloma Dumpsite (1.67 ± 0.03 mg/kg), followed by *L. cylindrica* (1.42 ± 0.01 mg/kg) and *C. rutidosperma* (1.29 ± 0.01 mg/kg). The lowest value was recorded in *C. rutidosperma* at IAUOE Control (0.07 ± 0.00 mg/kg).

Table 3. Cadmium concentration (mg/kg) in roots of selected plants.

Plant species	IAUOE dump	IAUOE control	Ogoloma dump	Ogoloma control	LSD
<i>A. spinosus</i>	1.34 ± 0.04 ^b	± 0.12 ± 0.01 ^d	1.67 ± 0.03 ^a	0.84 ± 0.01 ^c	0.060
<i>C. rutidosperma</i>	1.07 ± 0.01 ^b	± 0.07 ± 0.00 ^d	1.29 ± 0.01 ^a	0.60 ± 0.01 ^c	0.020
<i>L. cylindrica</i>	1.13 ± 0.01 ^b	± 0.08 ± 0.00 ^d	1.42 ± 0.01 ^a	0.71 ± 0.02 ^c	0.021

Chromium concentration was highest in *A. spinosus* from Ogoloma Dumpsite (11.29 ± 0.01 mg/kg). *L. cylindrica* recorded 9.72 ± 0.05 mg/kg and *C. rutidosperma* 8.95 ± 0.05 mg/kg at the same site. At IAUOE Dumpsite, *A. spinosus* again recorded the highest Cr concentration (9.60 ± 0.04 mg/kg). The lowest value was 0.78 ± 0.02 mg/kg in *C. rutidosperma* from Ogoloma Control.

Table 4. Chromium concentration (mg/kg) in roots of selected plants.

Plant species	IAUOE dump	IAUOE control	Ogoloma dump	Ogoloma control	LSD
<i>A. spinosus</i>	9.60 ± 0.04^b	1.34 ± 0.02^c	11.29 ± 0.01^a	1.08 ± 0.01^d	0.060
<i>C. rutidosperma</i>	7.21 ± 0.03^b	0.95 ± 0.03^c	8.95 ± 0.05^a	0.78 ± 0.02^d	0.060
<i>L. cylindrica</i>	7.82 ± 0.04^b	1.15 ± 0.03^c	9.72 ± 0.05^a	0.92 ± 0.02^d	0.060

Discussion

The higher concentrations of Pb, Cd and Cr in roots collected from the dumpsites than in the corresponding controls indicate a strong spatial association between the dumpsite environments and metal accumulation in the investigated plants. Similar patterns have been reported in Nigerian waste-disposal environments. Olayiwola *et al.* (2017) found higher concentrations of several metals in plants growing on dumpsites than in plants from a control site in Ibadan, while Ekere *et al.* (2020) reported substantial metal contamination of soils and crops associated with an urban open dumpsite in Enugu. More recently, Omada *et al.* (2024) reported elevated Pb, Cd and other metals in soil and plant samples around the Gosa Dumpsite in Abuja.

The level of Pb accumulation in the present study is particularly notable at Ogoloma Dumpsite, where the three species had root concentrations of approximately 15 mg/kg. The clustering of Pb values among the three species at Ogoloma suggests that the local contamination environment may exert a strong influence on root exposure, although species-specific uptake differences were also evident at IAUOE. Heavy metals introduced by mixed municipal wastes can persist in soil and become available for plant uptake depending on soil chemistry and metal speciation. Studies of Nigerian dumpsites have documented elevated Pb and Cd in contaminated environments and linked these patterns to anthropogenic waste inputs (Adeyi & Oyeleke, 2017; Olorunfemi *et al.*, 2021).

Cadmium concentrations were lower numerically than Pb concentrations in all species, but the consistent increase at the dumpsites remains environmentally important. Cadmium is readily taken up by plants through transport systems that can also carry essential nutrient ions. Roots are the initial contact point and can either retain Cd or facilitate its movement to aerial tissues through apoplastic and symplastic pathways (Al-Khayri *et al.*, 2023). The present results, therefore, are consistent with the role of roots as a primary site of metal interception and accumulation. The particularly high Cd value in *A. spinosus* at Ogoloma may reflect species-level differences in uptake, binding or sequestration.

Chromium also showed a clear increase at the dumpsites, with the highest concentration occurring in *A. spinosus* at Ogoloma. Chromium uptake is strongly influenced by its chemical speciation and by soil characteristics such as pH, redox conditions and organic matter.

Differences among the three plant species indicate that accumulation is not controlled solely by site contamination. At Ogoloma, *L. cylindrica* had the highest Pb concentration, whereas *A. spinosus* had the highest Cd and Cr concentrations. At IAUOE, *A. spinosus* had the highest concentration of each of the three measured metals. Such differences are consistent with the recognized influence of plant physiology, root characteristics and metal transport mechanisms on uptake and internal sequestration (Guerra Sierra *et al.*, 2021; Al-Khayri *et al.*, 2023). The results should therefore be interpreted as species- and site-specific rather than as evidence that all plants growing on dumpsites will accumulate metals to the same extent.

The medicinal relevance of these findings is important but should be interpreted cautiously. Sulaiman *et al.* (2024) demonstrated that heavy-metal contamination can be relevant to the safety assessment of medicinal plant materials in Nigeria. However, the present study analyzed roots collected from dumpsite environments and did not perform dietary exposure, estimated daily intake, hazard quotient, hazard index or carcinogenic-risk calculations. Consequently, the measured root concentrations alone should not be interpreted as a quantitative human-health risk estimate. Additional work involving soil metal concentrations, bioavailability, transfer factors, plant consumption patterns and established exposure parameters would be needed for a formal health-risk assessment.

Overall, the results support the interpretation that the investigated dumpsites constitute environments in which Pb, Cd and Cr can accumulate in plant roots. This is consistent with the broader literature showing that tropical plants can absorb and sequester metals in contaminated soils and that naturally occurring plants may have value for environmental monitoring or phytoremediation research (Guerra Sierra *et al.*, 2021). Nevertheless, accumulation should not automatically be equated with phytoremediation suitability: assessment of tolerance, biomass production, bioconcentration factor, translocation factor and ecological consequences would be required before recommending any species for remediation.

Conclusion

This study demonstrates measurable accumulation of Pb, Cd and Cr in roots of *Amaranthus spinosus*, *Cleome rutidosperma* and *Luffa cylindrica* growing at Ogoloma and IAUOE dumpsites in Rivers State, Nigeria. Root concentrations were generally higher at dumpsites than at corresponding control locations, and Ogoloma generally recorded the highest concentrations. *Luffa cylindrica* had the highest Pb concentration at Ogoloma, whereas *A. spinosus* recorded the highest Cd and Cr concentrations at that same site. The findings provide baseline information for environmental monitoring of plant communities occurring on contaminated waste-disposal sites. Because the study did not include formal human-health exposure calculations or metal speciation, further investigation should quantify soil metal

bioavailability, plant–soil transfer factors, translocation to edible or medicinal organs, and human-health risk where plant use is anticipated.

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