

# Trace metal levels in castor plants growing on refuse dumpsites in wukari metropolis, Nigeria

## Abstract

A preliminary survey of the risk assessment of selected trace metal (Cd, Cr, Cu, Pb and Zn) levels of castor (*Ricinus communis* L.) plant growing on refuse dumpsites in Wukari Metropolis, Taraba State was investigated. Duplicate samples each of whole castor plants and decomposed remains of the refuse dumpsites were collected from three locations namely Kwararafa 1 (Abo prisoners), G.R.A (Barikr) and Marmara 1 (Abattior) based on population density and out of the 10 locations surveyed. Triplicates pH readings of the decomposed refuses at the three locations were recorded. Trace metal levels and pH were determined by the flame AAS using acetylene/air and pH meter respectively. Selected risk assessment techniques such as soil-plant transfer coefficient (TC), plant uptake factor (PUF) and translocation factor (TF) were worked out for the castor plants. Results revealed a high TC value (1.405) for whole castor plant above the permissible limits (value >1) than PUF and TF with less than unity value revealing the potential possible transfer of metals into the plant body. Higher levels of Zn and Cd were evident, followed by Cu according to the Joint FAO/WHO Food standards 2006. Health risk assessment of metals from refuse dumpsites is a good technique for predicting potential threat to life.

**Keywords:** castor plant, refuse dumps, trace metals, risk assessment factors, decomposed remains, flame, AAS

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**Abbreviations:** TC, transfer coefficient; PUF, plant uptake factor; TF, translocation factor; MSW, municipal solid wastes; DRML, decomposed remains metal levels; WPML, whole plant metal levels

## Introduction

The use of refuse dumpsites as farmland is a common practice in urban and sub-urban centers in Nigeria because the decayed and composted wastes enhance soil fertility.<sup>1,2</sup> The fully decomposed residues of these wastes are used on vegetable farms like cabbage, spinach, okra, tomato, etc. Also several plants especially *Amaranthus spinosa*, *Ricinus communis* etc utilised by the populace for culinary, medicinal and cosmetic purposes naturally thrive around these dumpsites. Castor bean plant has been traditionally cultivated for income generation and fermented food condiments (ogiri-isi)<sup>3,4</sup> in some parts of Southern Guinea Savanna. The plants spread over sandy soil areas, creek banks and gullies.<sup>5</sup> It is often abundant along water courses and flood plains, disturbed or waste lands and roadside with high tolerance for growth under harsh environmental condition such as low rainfall and heat.<sup>6</sup>

Castor bean (*Ricinus communis*) which belongs to the spurge family (Euphorbiaceae) is one of the most diverse and numerous clades of the angiosperms, including several species of great economic importance as rubber tree (*Hevea brasiliensis*), cassava (*Manihot esculenta*), and some oil seed crops, as candlenut (*Aleurites moluccana*) and physic nut (*Jatropha curcas*). Castor bean is a perennial scrub and a single member of the African genus *Ricinus* (subfamily Acalyphoideae) and also known as palma (e) Christi or wonder tree. Castor bean is also a herbaceous annual which can reach to nearly 15 feet tall when growing in open spaces in warm climates. Historically, castor oil plants have been extensively used for various purposes.<sup>4</sup> In the last couple of years, demand for castor oil has kept increasing in the international market, assured by more than 700 uses, ranging from medicine and cosmetic to biodiesel, plastic, and lubricants, the oil has advantages over petroleum base oils, especially at high and low melting point.

Besides reducing greenhouse gases because of its high oil content, it produce relatively high crop yield with relatively low input.<sup>4,7</sup>

Castor plant is an appropriate plant to be used as indicator plant for Cd and tolerant for Pb in concentrated solution and it can be potentially used for phytoremediation of contaminated areas. *Ricinus communis* L. was found more tolerant to salinity and drought in presence of Cd, and it can produce twelve fold wet and dry weight (Souza *et al.*, 2013). Yashim *et al.*,<sup>6</sup> looked at the potential of *Ricinus communis* L. of remediated sites polluted with mine tailing containing high concentrations of Cu, Zn, Pb and Cd and as energy crop. The plant species has attracted considerable attention because of its ability to grow in heavily polluted soil together with its capacity for metal ion accumulation. However, majority of the literature focuses on the uptake of chemicals by plants from sludge or biosolids and only little literature has focused on the uptake and transfer of metals in castor plants growing municipal solid waste refuse dumpsites.

Municipal solid wastes (MSW) often contain heavy metals in various forms and at different contamination levels. MSW contains such heavy metals as As, Cd, Co, Cu, Fe, Hg, Mn, Pb, Ni, and Zn which end up in the soil as sink when they are leached out from the dumpsites. Heavy metals accumulation in soil and in the environment generally, may be related to the phenomenon of bioaccumulation ability of living organisms. Some heavy metals like As, Cd, Hg and Pb are particularly hazardous to plants, animals and humans.<sup>8</sup>

There is an increasing risk of public exposure to heavy metals because of the consumption of food grown in sewage wastewater,<sup>9</sup> biosolid sludges,<sup>10</sup> refuse dumpsites,<sup>2</sup> agricultural soils etc.<sup>11,12</sup> There are numerous reports in the literature supporting these assertions.<sup>5,13</sup> The problem of heavy metals entering the food chain requires systematic assessments for making timely decisions to avoid severe health effects because of the invisible mode of heavy metal toxicity.<sup>8</sup> Heavy metals can cause severe phytotoxicity and may act as powerful force for the evolution of tolerant plant populations. Therefore, it is possible to identify metal-tolerant plant species from natural

vegetation in the field sites that are contaminated with various heavy metals.<sup>14</sup>

Toxic metals may be classified according to their capability of being transferred from soil to plants in mobile metals, such as Cd, and poorly mobile metals, such as Pb. This property may affect their bioaccumulation in plants.<sup>15</sup> The toxicity depends on several factors including dose, route of exposure and chemical species, as well as the age, gender, genetics and nutritional status of exposed individuals. Several plants have the ability to accumulate high metal concentrations.<sup>16</sup> Many studies have reported data for the transfer of heavy metals from soil to plants and vegetables through roots and shoot.<sup>17</sup> However there is scanty data on the status of metal accumulation in *Ricinus communis* L. and their toxicity.

The current study was designed to investigate the potential human health risks associated with the growth of castor bean plant on refuse dumps and its safety level. The monitored heavy metals included Cd, Cr, Cu, Pb and Zn for their toxicity factors to provide baseline data regarding environmental safety.

## Materials and methods

The study was carried out in Wukari metropolis in Taraba State located in the Northern Guinea Savanna region of Nigeria. The map of Taraba State with the surrounding boundary states and other characteristics and the map of Nigeria inset are shown in Figure 1. Figure 2 illustrates the sixteen local government areas in Taraba State. Wukari metropolis is gradually expanding since the establishment of the two Universities (between 2007- 2012) which has attracted commercial activities like banking facilities, modern housings, business/commercial centers, hospitals etc. resulting to increased population density, solid waste generation and refuse dumpsites. The refuse consists of solid wastes from markets, residential and commercial housings like eateries, restaurants, hotels, lodging accommodation, cinemas, banks, offices, supermarkets, hospitals, slaughter houses, mechanic sites etc and are collectively called municipal solid wastes (MSW). The ten (10) Council Wards and other surrounding locations in Wukari from which 3 locations were selected as shown in Figure 3. However, during a research in 2017, the 10 council wards were basically categorized into three (3) wards namely Hospital Ward, Puje and Avyi in Wukari Metropolis from which data were obtained based on the presence of refuse dumps with castor plants in this present research. They include Kwararafa (Abo prisoners), Mission Quarters 1, Mission Quarters 2, New Market (Concord), rice mills, New site and Timber shed from Puje ward; Marmara 1 (Abattior), Marmara 2 (Veterinary farm site), T- junction, Maiko in Hospital ward (African church) and GRA (Bariki) in Avyi ward. Puje ward is the largest ward followed by Hospital ward, then Avyi the smallest. A survey of the wards with refuse dumpsites was conducted and one representative per ward namely Kwararafa 1(Abo prisoners), G.R.A (Barikr) and Marmara 1(Abattior) were selected based on population density and size/volume of refuse dumps. Duplicate whole castor plant samples and corresponding triplicate decomposed refuse samples just above the soil were collected in mid June 2018. Soil auger was used in collecting the decomposed refuse samples at a depth of 15cm, air dried and taking to the laboratory for further analysis. The pH of the decomposed refuse samples was determined using a pH meter in a 1:2:1 ratio. Prior to the analysis of the plant materials; the leaves, stems and roots each for the two crops were placed under running tapwater to washed off particles, separated and placed in large paper

bags to air-dry at room temperature and were separated into leaves, stems and roots, and air dried for two weeks before taking to the laboratory for metal (Cd, Pb, Cr, Cu, Zn) analysis. The trace metal analysis was determined using flame AAS using acetylene/air at the Adamawa State University, Mubi. The trace metal data was used to compute the soil-plant transfer coefficient (TC), plant uptake factor (PUF) and translocation factor (TF).

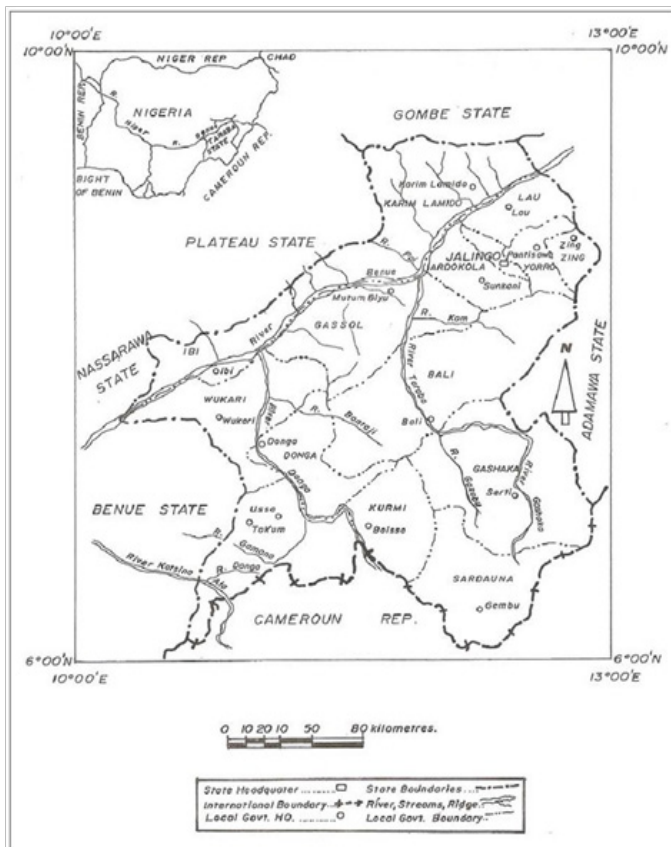


Figure 1 Map of Taraba State showing the physical characteristics.

## Data/statistical analysis and graphical illustration

Heavy metal levels of the metals from the three locations were compared with the maximum permissible levels of trace metals from the Codex Alimentarius Commission of the Joint FAO/WHO food standards<sup>18</sup> and the values used are those applicable to soils and food crops. These values have been produced to protect the food quality of the ecologically adapted food crops. Tabular presentations of the characteristics of the metals and castor plants and graphical illustrations were used to reflect differences among metals and locations.

## Results and discussion

The characteristics of the three locations are shown in Table 1. The three locations ranged from sparsely/lowly-populated through moderately populated to highly populated areas. Whole plant metal levels (WPML) of *Ricinus communis* L. among the selected metals, was highest for Cu and Zn and lowest for Cr at the three locations respectively (Table 1). The decomposed remains metal levels (DRML) was higher at Kwararafa (4.24) followed by Marmara (3.99) and GRA (3.82). Among the three risk assessment factors TC was the

highest at the three locations being  $>1$ , while PUF and TF were lowest being  $<1$ . The soil pH just underneath the decomposed remains of the refuse dumps, are shown in Table 1. The pH ranged from 8.43 to 9.40 indicating a slightly alkaline environment. Metal mobility has

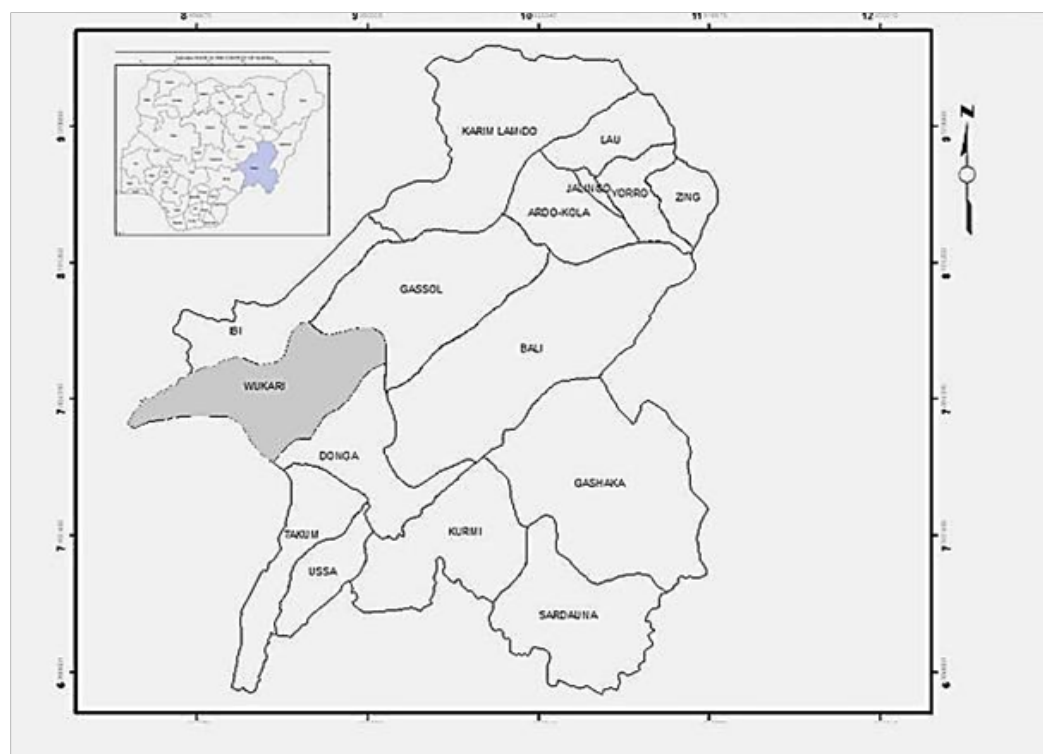
been shown to increase with decreasing soil pH resulting to decreased metal levels of castor plants in this study. However Cu and Zn levels are higher indicating addition from municipal solid wastes onto the geological materials.

**Table 1** Characteristics of the three locations

Locations	Marmara					Kwararafa					GRA				
Metals	Cd	Cu	Pb	Zn	Cr	Cd	Cu	Pb	Zn	Cr	Cd	Cu	Pb	Zn	Cr
WPML	0.42	7.97	0.45	13.84	0.1	0.79	12.54	0.8	12.5	0.13	0.54	10.67	0.82	14.2	0.12
DRML	3.99					4.24					3.82				
TC	1.14					1.263					1.405				
PUF	0.115					0.624					0.705				
TF	0.48					0.477					0.412				
Soil pH	8.43					9.4					8.63				

**Key:**

WPML, whole plant metal levels; DRML, decomposed remains metal levels; TC, soil-plant transfer coefficient; PUF, plant uptake factor; TF, translocation factor



**Figure 2** The sixteen (16) Local Government Areas in Taraba State (Inset: Map of Nigeria).

High metal levels in the plant parts could indicate phytoremediation potentials (phytoextraction, phytostabilization and rhizofiltration).<sup>5</sup> Phytoremediation is an environmentally friendly, ecologically and cost-effective bioremediation process that uses various types of plants for cleaning up of contaminated soils. Phytoremediation is defined as the use of plants to remove pollutants from the environment and presents an effective alternative in removing heavy metals from soil, wastewater and sludge. Phytoremediation is primarily used for

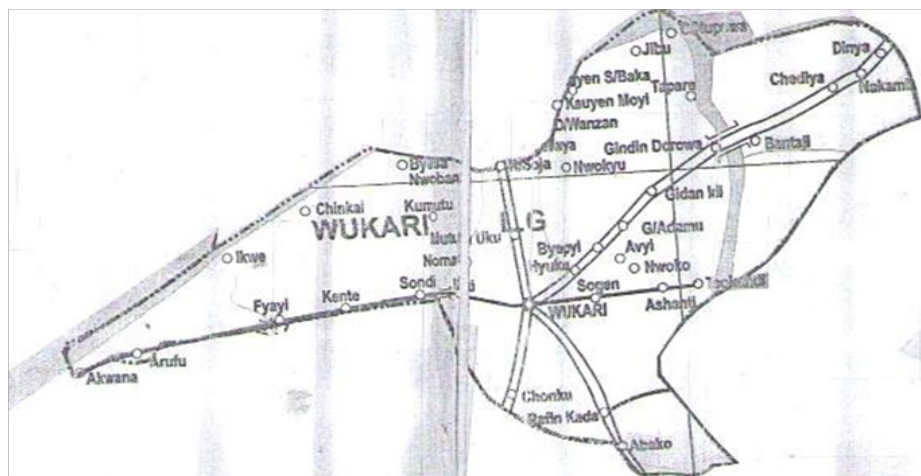
cleaning terrestrial and aquatic polluted areas containing heavy metals and organic contaminants by green plants.

Enrichment coefficients are a very important factor, which indicate phytoremediation of a given species.<sup>19</sup> Plants have developed three basic strategies for growing on contaminated and metalliferous soils (Baker and Walker, 1990). Metal excluders are plants which effectively prevent metal from entering their aerial parts over a board range of metal concentrations in the soil. However, they can still



contain large amounts of metals in their roots. Metal indicators are plants which accumulate metals in their above-ground tissues and the metal levels in the tissues of these plants generally reflect metal level in the soil. They tolerate the existing concentration level of metals by

producing intracellular metal binding compounds (chelators), or alter metal compartmentalization pattern by storing metals in non-sensitive parts.



**Figure 3** Map of Wukari showing the ten (10) Council Wards and other surrounding locations.

Accumulators are plant species (hyperaccumulators) which can concentrate metals in their above-ground tissues to levels far exceeding those present in the soil or in the non-accumulating species growing nearby (Baker and Walker, 1990). Baker & Brooks<sup>20</sup> have defined metal hyperaccumulators as plants that contain more than 0.1% of copper, cadmium, chromium, lead, nickel and cobalt, or 1% of zinc or manganese in dry matter. For cadmium and other rare metals, it is more than 0.01% by dry weight.<sup>20,21</sup>

The TC at the three locations were greater than unity (1.140, 1.263 and 1.405 at Marmara, Kwararafa and GRA respectively), and according to Kloke et al.,<sup>22</sup> the value of 0.50 is based on root uptake of metals and 0.2 for leafy plants which indicates anthropogenic contamination. High transfer coefficient reflects relatively poor retention in soils or greater efficiency of plant to assimilate metals. Low coefficient reflects the strong sorption of metals to the soil colloids.<sup>7,10,23,14</sup> A higher TC at the three locations indicate anthropogenic contamination from the refuse dumps suggesting relatively moderate retention in soils or potential in efficiency of castor plants to absorb metals. This agrees with the work of Olayiwola et al.,<sup>24</sup> that the water leaf and spinach obtained from dumpsites (experimental) had higher TF (transfer factor) than their counterpart obtained from normal agricultural soil (control).

The PUF at the three locations were lower than unity (value <1): GRA, Marmara and Kwararafa with 0.705, 0.115 and 0.624 respectively reflecting anthropogenic origin of the metals from refuse dumps. PUF is used to evaluate the ability of plants to accumulate heavy metals. PUF was categorized further as hyperaccumulator, accumulator and excluder to those samples which accumulated metals >10 $\mu$ g/g, >1 and <1 respectively.<sup>14,25-27</sup>

TF values at Marmara (0.480), Kwararafa (0.477) and GRA (0.412) were also less than unity value. This indicates that the castor plants did not translocated metals effectively from root to stem at the three locations.

In comparison of the mean trace metal levels (Cd, Cr, Cu, Pb and

Zn) of whole castor plant (Table 1) with the critical levels by the Joint FAO/WHO Food Standards 2006; Cd(0.01mg/kg), Cr(1.30mg/kg), Cu(10.00mg/kg), Pb(2mg/kg) and Zn(5.00mg/kg), Cd and Zn were above the critical level while Pb and Cr were below the critical level at the three locations. However Cu was above the critical levels at Kwararafa (12.54mg/kg) and GRA (10.67mg/kg) only.

A comparison of the metal levels or concentrations among the three locations in plant parts and decomposed remains are shown in Figures 4–6. Metal levels were highest in the decomposed remains than in the plant parts at the three locations then, followed by the roots (Figures 4–6). Cu and Zn recorded the highest in concentrations and lowest in Cd, Pb and Cr (Figures 4–6). This indicates that the metal levels in the plant parts of *Ricinus communis* L. originated from the municipal solid wastes at the refuse dumps.

Zinc and copper are used as components of vehicle lubricating oils. They are also used in the manufacture of some components of vehicle engines.<sup>28</sup> In normal situation zinc acts as micronutrient but at higher concentration becomes phytotoxic.<sup>29</sup> Pb is a component of leaded fuel that acts as an anti-knocking agent. Low levels of Pb could be attributed to low traffic density in the study area due to the low phase of urbanization, its slightly insoluble nature in the soil, and the slightly alkaline environment of the decomposed remains.

Low levels of Cr in the plant parts have been attributed to its insolubility under most soil conditions,<sup>30</sup> and it did not affect the plant growth unless the concentrations were very large.<sup>31</sup> This supported the findings of Ghani et al.,<sup>32</sup> and Anongo et al.,<sup>10,11</sup>

Cadmium is an important heavy metal pollutant and its presence in agricultural soils and crops is of great concerns.<sup>12</sup> It is a common finding that Cd can easily be taken up by most plants. Cd is readily accumulated by plants and may get to levels which are adverse to the plants themselves, consequently posing a significant threat to animals and humans that consume plants. Awareness of the health hazards of Cd has made the uptake of Cd by vegetables and agricultural crops a subject of extensive research.<sup>10,11</sup>

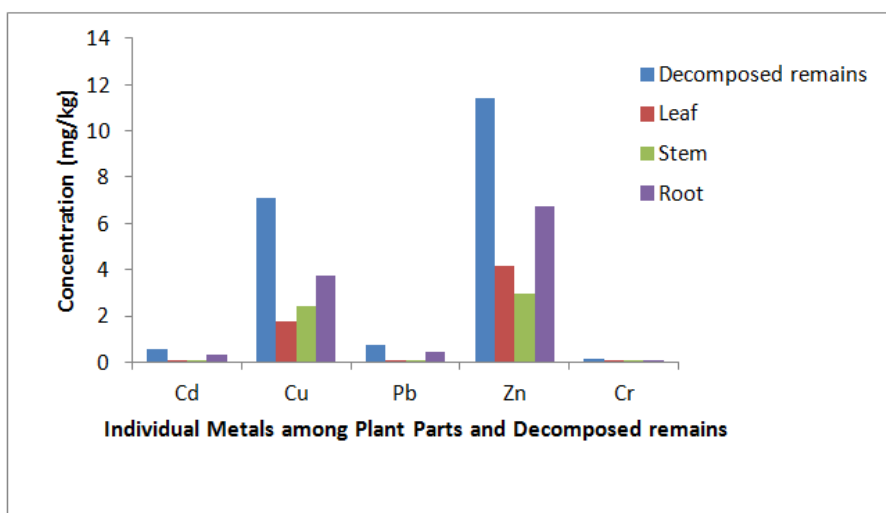


Figure 4 Individual metals among plant parts at Marmara.

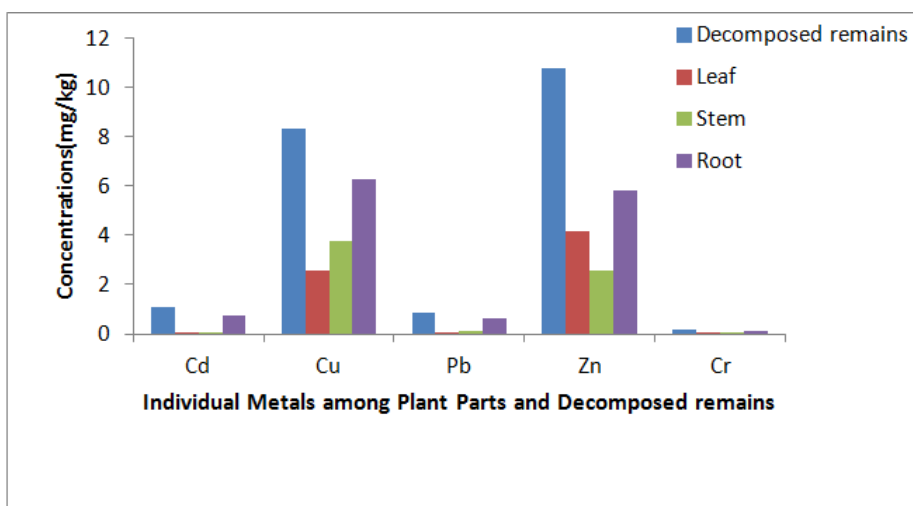


Figure 5 Individual metals among plant parts at Kwararafa.

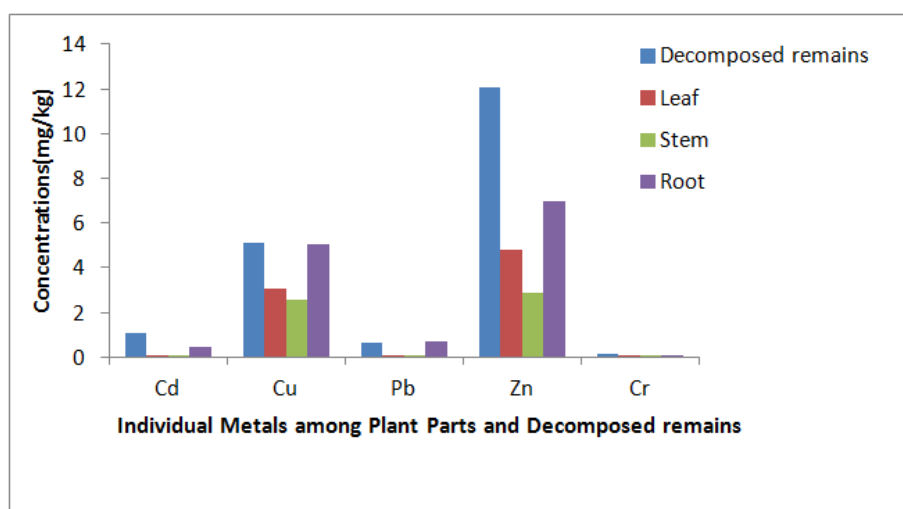


Figure 6 Individual metals among plant parts at GRA.

Higher metal in leaf than in decomposed remains and higher TC indicates bioavailability of the metals to the castor plant and subsequent transfer from the decomposed remains of the refuse dumps to the above plant parts. The metal concentrations in leaf were invariably higher than that in sediment and ECL was also higher than 1.0. Scientists reported that this situation indicated a special ability of the plant to absorb and transport metals from sediment and then stored them in their above-ground part.<sup>33–37</sup>

## Conclusion

Zn, Cd and Cu were reportedly higher in *Ricinus communis* L. growing on refuses dumpsites than the permissible limits according to the Joint FAO/WHO Food standards 2006. Among the three risk assessment techniques (plant uptake factor - PUF, soil-plant transfer coefficient - TC and translocation factor-TF) used in this study, the TC has greater than 1 indicating contamination from the soil to the plant, while PUF and TF were less than unity. The castor plant has the potential of extracting metals from municipal solid wastes (MSW) thereby reducing or preventing its translocation or leachages into the soil and subsequent contamination of ground water. Therefore, whole castor plant could be a potential candidate as phyto-extractor. However, further studies on the heavy metal levels of the seeds used mainly as condiments in Wukari should be investigated.

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## Conflicts of interest

The authors declare that there is no competing of interest.

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