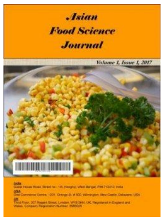

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Level of Heavy Metals in Selected Vegetables Collected from Ijagun Dumpsite in Ogun State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author DAO designed the study, wrote the protocol, supervised the work, performed the statistical analysis and wrote the first draft of the manuscript. Author COA carried out the laboratory work and edited the manuscript. Author TCA collected the samples, managed the literature searches, carried out the laboratory experiments and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Wastes from dumpsites constitute a major challenge for plants, human and environmental health. This study investigated the levels of heavy metals in stems and leaves of three (3) Vegetables and soil samples obtained from Ijagun dumpsite, located in Ijebu Ode, Ogun state. The samples were digested with mixed acids and aliquots of the extracts were analyzed for Zinc (Zn), lead (Pb), Cobalt (Co) and Copper (Cu) using the Atomic Absorption Spectrometry (Perkin Elmer A Analyst 700 model). The results obtained showed that there was an increase in the level of selected heavy metals observed in the topsoil compared with the underground soil collected from the dumpsite. The level of the metals present in the topsoil was in the order Zn > Pb >Cu > Co. The stem of *Celosia argentea* and *Cochorus olitorius* accumulate more heavy metals compared with the leaf. The level of these selected heavy metals were observed to be far above the WHO/FAO and

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NAFDAC permissible values in plant except Co in the stem and leaf of *Celosia argentea* and *Talinum triangulae,* indicating that the leaf and stem of vegetables from Ijagun dumpsite pose serious health threat to human. However, *C. olitorius* and *C. argentea* with high absorption ability for Zn, Pb and Cu could serve as a phytoremediator for soils contaminated with these metals.

Keywords: Vegetables; dumpsite; heavy metals; spectrometry; phytoremediator.

1. INTRODUCTION

Heavy metals occur naturally in the ecosystem with large variations in concentrations. In modern times, anthropogenic sources of heavy metals, i.e. pollutions from the activities of humans, have introduced some of these heavy metals into the ecosystem. The presence of heavy metals in the environment is of great ecological significance due to their toxicity at certain concentrations, translocation through food chains and non-biodegradability which is responsible for their accumulation in the biosphere [1]. Heavy metal contamination of food item is one of the most important aspects of food quality assurance; international and national regulation on food qualities have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk these metals pose to food chain contamination. Heavy metals persistent environmental contaminants which absorbed by tissues of vegetables; plant takes up heavy metals by absorbing them from deposits on part of the plants exposed to dumpsite [2].

The consumption of vegetables as food offer rapid and least means of providing adequate vitamins, supply minerals, and fibers [3]. Vegetables act as neutralizing agents for acidic substances formed during digestion, as human activities increases, especially with the application of modern technology, pollution, and contamination of food chain, have become inevitable [4]. Vegetables that are used as food include those used in making soup or serve as integral parts of the main source of meal examples include: *Celosia argentea* (Efo Shoko), *Cochorus olitorius* (Ewedu) and *Talinum triangulae* (Waterleaf).

Waterleaf (*Talinum triangulare*) is one of the most common leafy vegetables in Nigeria. It is available almost throughout the year, even during the dry seasons, because of its ability to survive drought. It is a perennial herbaceous plant widely grown and consumed as a vegetable [3]. *Celosia argentea* (Lagos Spinach) is a vigorous, broadleaf belonging to the Amaranth family (*Amaranthaceae*). *C. argentea* is grown successfully in temperate as well as tropical regions. It grows wide spread across northern South America, tropical Africa, the West Indies and tropical Asia where it grows as a native or naturalized wild flower, it is cultivated as a nutritious leafy green vegetable. It is one of the leading leafy green vegetables in Nigeria, where it is known as 'sokoyokoto', meaning 'make husbands fat and happy' [5]. *Cochorus olitorius* (Ewedu) or jute mallow belongs to a family of Malvaceae [6]; the plant is tall, usually annual herbs, reaching a height of 2–4 m, unbranched or with only a few side branches. The leaves are alternate, simple, lanceolate, 5–15 cm long, with an acuminate tip and a finely serrated or lobed margin. The flowers are small (2–3 cm diameter) and yellow, with five petals; the fruit is a many-seeded capsule. It thrives almost anywhere, and can be grown year-round [7].

Leafy vegetables occupy a very important place in human diet [3] but unfortunately constitute a group of food which contributes maximally to nitrate and other anions, as well as heavy metal consumption, Heavy metals deposition, are associated with a wide range of sources such as small scale industries (including battery, metal smelting, and cable coating industries); vehicular emission, and diesel generator sets [8].

The use of dumpsites as farm land is a common practice in urban and sub-urban centers in Nigeria because of the fact that decayed and composted wastes enhance soil fertility [9]. Increasing demand for leafy vegetables and attractive nature of the vegetables from dumpsites, humans now harvest vegetables from abandon dumpsites for consumption or sold in markets to consumers. Thus, the occurrence of these heavy metals on dumpsites and their bioaccumulation in vegetables required urgent attention to reduce the incidence of metal toxicities. Several reports have been presented on the harmful effects of bioaccumulation of heavy metals, the rate of consumption of vegetables harvested from dumpsites still persist. Therefore, intermittent assessment of these heavy metals in leafy vegetables to enlighten the consumers is necessary. This study investigates the level of selected edible vegetables and soils collected from dumpsite within Ijagun metropolis in Ogun state, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Location

Ijebu ode is a city located in southern-west Nigeria with an estimated population of 222,653 it is the second largest city in Ogun state after Abeokuta. The city is located 110 km by road north-east of Lagos, it is within 100km of the Atlantic ocean in the eastern part of Ogun state and possess a warm tropical climate and lies within the longitude 3º56^1 E and latitude 6º49^1 N [5].

2.2 Site Location

The study area lies within the sedimentary terrain of south-western Nigeria grouped under the Cretaceous sediments of Abeokuta group [10] and located between longitude E003º47’˙377’ to E003 47’.483” and latitude N06º56’.393” to N003º56'.564" at ijagun community in odogbolu, Ogun state. Ijagun is located along the Sagamu-Benin highway that linked Western and Eastern part of Nigeria and it is also accessible through a network of major and minor roads.

2.3 Studied Samples

Surface and underground soils and selected commonly consumed vegetables were used as samples for the analysis of the heavy metals (Zn, Pb, Co, Ni, Cd, and Cu), the vegetables include *Celosia argentea* (Efo Shoko), *Cochorus olitorius* (Ewedu) and *Talinum triangulae* (Waterleaf) were collected on 7th of August, 2018 and the analysis were carried out at the central research laboratory, Federal University of Technology, Akure, Ondo State, Nigeria.

2.4 Soil Samples

Surface and underground soil samples were collected from the dumpsites in Ijagun metropolis. The underground soil sample was obtained by drilling the soil using soil auger from the topsoil to the depth of 20 cm. Plastic hand trowel was used to scoop and transfer the drilled soil into a well-labeled polythene bag, after which they were conveyed to the laboratory for analysis. The soil samples were air-dried to constant weight, crushed with mortar and pestle and sieved with 2 mm mesh sieve before storing in airtight containers prior to acid digestion for metals analysis.

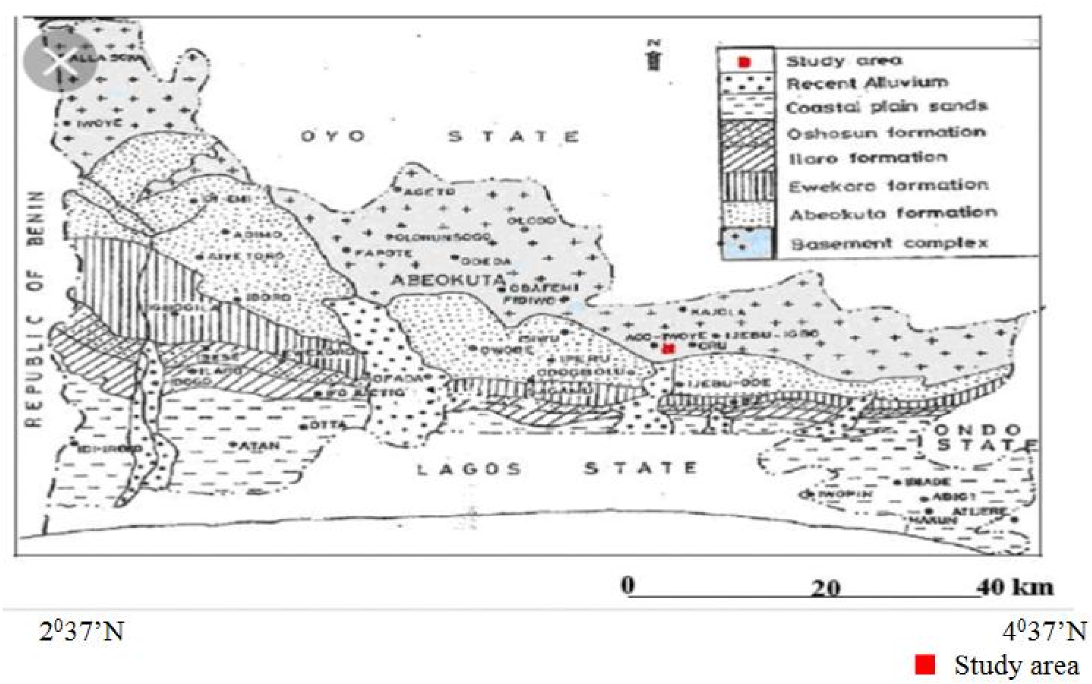

Fig. 1. Map of Ogun state showing the studied area [11]

Fig. 2. Diagram of Ijagun dumpsite, Ijebu Ode, Ogun State, Nigeria

2.5 Vegetable Samples

The leaf and stem of three (3) different edible vegetables from Ijagun dumpsite (*Celosia argentea* 'Shoko', *Cochorus olitorius* 'Ewedu' and *Talinum triangulae* 'Water leaf'). They were randomly harvested with a stainless steel knife and transferred to the laboratory in polythene bags. At the laboratory, 250 – 300 g of the stem and leaf of the vegetable samples were sorted, rinsed with distilled water to remove dust particles, chopped into small pieces using stainless steel knife and oven dried at 60ºC to constant weight. The dried samples were ground to a fine powder using agate mortar and pestle and stored in airtight containers for further analysis. The vegetables were the most commonly cultivated and consumed in the environment.

2.6 Physico-chemical Analysis

The pH of the surface soil sample was determined using digital pH meter (Jenway) standardized with a buffer of pH 4 and 9. The soil particle size was carried out using Shedrick and Wang, [12] method. Organic matter in the soil was determined according to the method of Schulte, [13].

2.7 Determination of Heavy Metals in Soil

The soil heavy metal content was determined using standard methods as described by Orubite et al. [14]. Five grams of the ground and the sieved sample was weighed into a digestion vessel placed in the fume cupboard, 3.0 ml of concentrated HNO_3, 9.0 ml of HCl and 25 ml of distilled water were added to the sample. This solution was thoroughly mixed together and then transferred to the hot plate at the temperature of 105ºC. The solution heated until a pale yellow clear solution was observed and the brown fume of HNO_3 ceased. The solution was then removed from the hot plate and allowed to cool before it was filtered through a 0.2 mm Whatman filter paper into a 100 ml volumetric flask. The distilled water was used to rinse the funnel and the wall of the digestion beaker into the filtrate in the volumetric which was later made to the 100 ml mark with distilled water, Aliquots of this filtrate was nebulized into the Atomic Absorption Spectrometer (Perkin Elmer A Analyst 700 model) for heavy metal analyses.

2.8 Determination of Heavy Metals in Vegetables

Powdered samples of the vegetables, 2 g, each was accurately weighed into the digestion vessel in a flame hood, 5 ml to concentrated HNO_3 was added and covered with perforated net and evaporated on a hot plate to the lowest volume possible (15 ml). Thereafter 10 ml each of concentration HNO_3 and $HClO_4$ were added with the content of the beaker, evaporated gently on a hot plate until white fume of $HClO_4$ just appeared. The appearance of a light coloured, clear solution indicated complete digestion. The solution was not allowed to dry during digestion. The beaker containing the digestion sample was washed with deionized water and filtered. The filtrate was put into 100 ml volumetric flask cooled and diluted to mark and mix thoroughly [15]. A portion of this solution was taken for required metals determination by aspirating it into the Atomic Absorption Spectrometer (AAS) (Perkin Elmer A Analyst 700 model).

2.9 Statistical Analysis

All determinations were carried out in duplicates and the data analyzed statistically with one-way ANOVA followed by *posthoc* multiple comparisons, *P*-values < 0.05 were accepted to be significant, using SPSS 17 computer software.

3. RESULTS

3.1 Physico-chemical Characteristics of Soil Samples from Ijagun Dumpsite

Table 1 showed the percentage level of the physico-chemical characteristics of the surface soil from the dumpsite. The result revealed a pH of 7.66 ± 0.21. The percentage organic matter, sand, clay and silt level was observed to be 4.71 ± 0.16%, 65.57 ± 0.69%, 15.17 ± 0.39% and 19.27 ± 0.49% respectively.

Table 1. Physico-chemical determination of Ijagun dumpsite surface soil

Physico-chemical parameters	Level
pH	7.66 ± 0.21
Organic Matter (%)	4.71 ± 0.16
Sand (%)	65.57 ± 0.69
Clay (%)	15.17 ± 0.39
Silt (%)	19.27 ± 0.49

Mean ± SD of duplicate determination

3.2 Heavy Metal Contents of Soil Samples from Ijagun Dumpsite

The level of heavy metals in the surface soil was observed to be higher compared with the underground soil. The order of heavy metal contents of the surface soil was Zn > Pb > Cu > Co while that of the underground soil was Cu > Pb > Zn > Co. The metals present in the surface soil were far above the WHO/FAO permissible values as shown in Table 2.

3.3 Heavy Metal Accumulation in Selected Vegetables from Ijagun Dumpsite

The result of the heavy metal concentrations measured in the leaf and stem of selected vegetables is shown in Table 3. *Celosia argentea* was observed to accumulate the heavy metals at high concentration compared with other vegetables. The stem of *C. argentea* was reported to absorb Zn, Pb, Co and Cu at high concentration compared with the leaf.

Table 2. Level of metals (ppm) in the dumpsite soils

Soil samples	Zn	Pb	Co	Cu
Surface Soil	142.3 ± 2.83	125.00 ± 1.45	10.00 ± 1.41	105.00 ± 4.52
Underground Soil	28.00 ± 1.41	32.00 ± 2.83	3.20 ± 1.41	63.50 ± 2.84
WHO/FAO PVS	50.00	85.00	5.00	36.00

Mean ± SD of duplicate determination; PVS: Permissible values of soil (FAO/WHO, 1996)

Table 3. Level of heavy metals (ppm) in selected vegetables from dumpsite

Samples		Zn	Pb	Co	Cu
Celosia argentea	(Leaf)	52.00 ± 1.40	13.00 ± 0.71	5.00 ± 0.23	53.00 ± 1.41
	(Stem)	1986.00 ± 2.83	306.00 ± 1.41	11.00 ± 1.41	219.00 ± 4.24
Cochorus olitorius	(Leaf)	171.00 ± 1.41	5.00 ± 0.71	0.00 ± 0.00	20.00 ± 2.83
	(Stem)	846.00 ± 2.83	131.00 ± 1.41	2.00 ± 0.00	86.00 ± 1.41
Talinum triangulae	(Leaf)	37.00 ± 1.41	3.00 ± 0.71	0.00 ± 0.00	44.00 ± 2.83
	(Stem)	76.00 ± 2.83	35 ± 1.41	0.00 ± 0.00	22.00 ± 1.41
WHO/FAO PVP		0.60	2.00	2.00	10.00
NAFDAC PVP		50.00	2.00	2.00	20.00

Mean ± SD of duplicate determination; PVP: Permissible value in plants (ppm)

Table 4. Logarithm of heavy metals coefficient in selected vegetables from dumpsite

Samples		Logarithm concentration ratio			
		Zn	Pb	Co	Cu
Celosia argentea	(Leaf)	-0.44	-0.98	-0.30	-0.30
	(Stem)	1.10	0.39	0.04	0.32
Cochorus olitorius	(Leaf)	0.08	-1.40	0.00	-0.72
	(Stem)	0.77	0.02	-0.40	-0.09
Talinum triangulare	(Leaf)	-0.59	-1.62	0.00	-0.38
	(Stem)	-0.28	-0.55	0.00	-0.68

3.4 Logarithm Concentration Ratio of Heavy Metals Coefficient in Selected Vegetables from Dumpsite

The logarithm of heavy metal coefficient shown in Table 4 revealed the comparison of the metals between the vegetables and surface soil samples. All the metals in the stem of *C. argentea* were lesser than the level in surface soil while the leaf of *C. argentea* shows a higher level of heavy metals than the surface soil. Pb, Co and Cu were observed to be lesser in *C. olitorius* compared with the surface soil while the Zn level was higher in *C. olitorius* compared with surface soil from Ijagun dumpsite. *T. trianglae* was observed to possess a higher level of heavy metals compared with the surface soil from the dumpsite.

4. DISCUSSION

Waste from dumpsites altered the concentration of heavy metals in the soil as well as increasing the absorption of these heavy metals by the plant grown on the dumpsite thereby increasing the accumulation of the metals in various parts of the plants. The level accumulation of four selected heavy metals (Zn, Pb, Co, and Cu) in the leaves and stems of three selected leafy vegetables harvested from Ijagun dumpsite in Ogun state, Nigeria were analyzed.

The results of the physicochemical characteristics of the surface soil from the dumpsite were presented in Table 1; the results could be attributed to the nature of wastes dumped on the site. The surface soil was observed to be slightly alkaline with pH of 7.66. This might reduce the presence of heavy metals in the soil solution as the alkalinity of soil solution enhances the dissolution of metals and their bioaccumulation in soil [16]. Organic bound heavy metals dissociate as unbound ions and participate in cation exchange [17] therefore; the level of organic matter observed in soil sample might influence the bioaccumulation of heavy metals. The clay and sand composition of the surface soil plays a critical role in the rate at which heavy metals percolate into the soil for further uptake by the underground roots into the stem and leaf of the plants. The result of the physicochemical content of the surface soil observed in this study is consistent with the findings of Aiyesanmi and Idowu, [16] who reported the same trend in three dumpsite soil from Akure metropolis.

Excessive waste dump on soil may increase the accumulation of heavy metal content in the soil and its environment. The results of the heavy metal determination in the surface and underground soil from the dumpsite were presented in Table 2. The result showed that the level of heavy metals in the surface soil is far above the underground soil; such high values above the WHO/FAO permissible limits may have a harmful implication on the soil function and might pose a challenge to a healthy environment [18].

The uptake and bioaccumulation of heavy metals by plants pose public health implication especially when the plants are edible to humans and animals [18]. The results of the accumulation of heavy metals (Zn, Pb, Co, and Cu) estimated in the stem and leaf of three vegetables (*Celosia argentea, Cochorus olitorius,* and *Talinum trianglulae*) harvested from Ijagun dumpsite were presented in Table 3. The pattern of heavy metal accumulation in the stem of the three vegetables were observed to follow the same other Zn > Pb > Cu > Co. The leaves of the vegetables also showed similar trend of heavy metals bioaccumulation consistent with the stems except Pb interchanging position with Cu compared with the observed trend in the stems of the vegetables i.e Zn > Cu > Pb > Co. the estimated levels of these heavy metals in the three vegetables indicated their corresponding contents observed in the surface soil sample, this agreed with previous findings that, absorption of heavy metals by plants is largely influenced by the level of the heavy metals in the soil [19,16]. All the selected heavy metals showed a high rate of bioaccumulation in the stems of the vegetables than the leaves with exception of Cu concentration in *T. triangulae* where the level in the leaf was observed to be higher compared with the stem of the same vegetable. The level of heavy metals in the stems and leaves of the vegetables were observed to be far above the WHO/FAO and NAFDAC permissible values for plant with the exception of Co concentration in the leaves and stems of *C. olitorius* and *T. triangulae*.

The excessive retention of heavy metals in various parts of the vegetables from this dumpsite might be attributed to the type of wastes deposited on the site. This contains a large number of compounds containing these heavy metals. This agrees with the findings of Tanee and Eshalomi-Mario, [18] who reported heavy metal content of plants and soils in an abandoned solid waste dumpsite in porthacourt, Nigeria.

Interaction between the levels of heavy metals in the vegetables and surface soil was presented in Table 4. The logarithm coefficient concentration was defined as the ratio of heavy metal concentrations in plant part (stem and leaf) to the heavy metal concentrations in surface soil [20,16]. From the table, the negative axis values revealed that the concentration of the heavy metals in vegetables were lesser compared with that of the surface soil while the positive values showed that, the concentration of heavy metals in the vegetables were higher compared with that of surface soil.

5. CONCLUSION

The production of waste is rapidly increasing as a result of human activities. Investigation on heavy metal concentration in soils and vegetables harvested from Ijagun dumpsites indicated bioaccumulation of Zn, Pb, Co and Cu in the soil and vegetables studied, which might result from improper treatment of waste and abandonment of the dumpsite. This has caused great harm to the environment through the accumulation of heavy metals in the soil and increases absorption by the edible plants around the dumpsite. Therefore, waste sorting should be encouraged before dumping; the consumption of vegetables and other crops harvested around the dumpsite should be discouraged to avoid heavy metal toxicity. However, *Celosia argentea* and *Cochorus olitorius* could be adopted as effective phytoremediator to remediate soils contaminated with Zn, Pb, and Cu.

SIGNIFICANCE STATEMENT

This study discovered the level of heavy metals in three commonly consumed vegetables (*Celosia argentea* (Efo Shoko), *Cochorus olitorius* (Ewedu) and *Talinum triangulae* (Waterleaf)) harvested from Ijagun dumpsite, Ogun state, Nigeria that can be beneficial for the consumers of these vegetables within the metropolis and this study will help the researchers to uncover the critical areas of phytoremediation of heavy metals from contaminated farmland by these vegetables that many researchers were not able to explore. Thus a new theory on environmental toxicology may be arrived at.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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