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Determination of Heavy Metal Contamination in Lagos Dumpsites Using Earthworms as Bio-indicators

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Authors' contributions

This work was carried out in collaboration between the two authors. Author OO designed the study, wrote the protocol, contributed to the correction of the draft and supervised the work. Author FI wrote the draft of the manuscript, managed the literature searches, designed the figures and made statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

In an attempt to determine the level of heavy metals contamination and factors affecting their adsorption in living organisms, soil and earthworms (*Eudrilus eugeniae*) were used at four registered dumpsites within Lagos metropolis. Three of the dumpsites were active; Abule Egba, Olusosun and Soluos while the fourth Oke Afa was inactive. Soil and earthworms used were sampled during the wet season (July 2006), digested using concentrated HNO_3, and analysed with an atomic absorption spectrophotometer. Concentrations of Pb(364µg/g), Cu(428µg/g), Cd(4.2µg/g), Ni(19.3µg/g) and Zn(2110µg/g) were highest at Oke Afa while Cr(14.5µg/g) was highest at Abule Egba. Correlation between earthworms and soil was positive in all the dumpsites

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with the least (R^2=0.59) reported at Oke Afa. The relation between metals in soil and earthworms in all the dumpsites was greatly influenced by soil organic matter, pH and metal concentrations in the soil. Our findings show that most of the metals in the dumpsites exceeded the Canadian environmental guideline and Toronto public health guide for soil. This could lead to possible heavy metal poisoning of residents living close to the dumpsite through ground water contamination by leachate.

Keywords: Heavy metals; contamination; earthworms; dumpsite.

1. INTRODUCTION

Pollution is the addition to the ecosystem of toxic substances which have detrimental effect on the natural environment. One of the most important causes of pollution is the high rate of energy usage by modern growing populations [1]. Environmental pollution is broadly divided into air, water and land pollution. Land pollution is the degradation of the earth’s land surface through misuse of the soil by poor agricultural practices, mineral exploration, industrial waste dumping and indiscriminate disposal of urban waste. It includes visible wastes and litter as well as pollution of the soil itself. Soil pollution is mainly due to run-offs from agro-chemicals like herbicides (weed killers) and pesticides. Litter is waste material dumped in public places; the accumulation of these wastes threatens the health of people in residential areas by turning urban areas into unsightly dirt and unhealthy places [2].

The post independent periods in Nigeria has witnessed gradual growth of the nation’s economy through industrialization made possible from the benefits accruing to the country from mineral resource exploration and exploitation. As a result, old and new cities that are now state capitals in the country, expanded in size and population. These changes, particularly the demographic expansion of Nigerian cities, the urban centers, including the commercial and industrial activities have brought about phenomenal increase in the volume and diversity of solid waste generated daily in the country.

Lagos is Nigeria’s largest commercial nerve center with large seaports and industries. Industries include food processing, manufacturing of metal products, textiles, beverages, chemicals, pharmaceuticals, soaps and furniture. Due to high levels of industrialization and urbanization, the level of solid waste in Lagos has become offensive. These pollutants contaminate soil, leading to soil acidification, which causes nutrients to leach from the soil and subsequently damage trees and vegetation [1]. Achankeng [3] reported the per capita solid waste generated per person in Lagos to be 0.3kg while in 2003, Osibanjo et al. [4] reported that every man, woman and child in Lagos generate over 0.45kg per person and the number is expected to increase. Heaps of refuse and garbage are a common sight in the state capitals and urban areas of the federation. The solid waste problem has today become number one serious environmental problem facing the country with consequent effect on the pollution of water, air and land, not to mention its hazards to health and other resources of social and economic importance [5].

Waste management operations in Lagos involve land filling which is the simplest and cheapest mode of municipal waste disposal [6] followed by heating or burning of municipal solid waste. This has led to the gradual depletion of the ozone layer, causing global warming, [7] and also affects the quality of local air; also leachate formed as a result of percolation of rainfall and moisture through waste in landfills [8,9] contains various contaminants and toxic substances especially heavy metals which can migrate, infiltrate and descend in the soil profile to contaminate the adjacent surface water and groundwater [10]. Landfills are considered one of the major threats to groundwater [11,12]. Due to the toxicity and non-biodegradability of heavy metals, their introduction into the environment poses serious threat to life [13,14], and unlike other kinds of pollution (atmosphere and water), the soil environment has a much lower ability to recover [15]. Furthermore, over 99% of environmental pollutants is bound to soil and sediment particles [16], which interacts with clay minerals, humic substances, microorganisms, inorganic and organic ligands [8,9]. The effects of heavy metals depend on their bio-availability and they have been extensively studied for their consequences on human health. Exposure to lead has been reported to cause mental retardation in children, kidney failure, anaemia [17,18] and possibly may lead to lung cancer

[19]. Cadmium is a priority environmental contaminant because it induces kidney damage and causes cancer [20,21,22]. Copper, zinc, nickel and chromium have been studied to have adverse effects such as damage to the nervous membrane, kidney and liver failure, cancer and fatigue [18,23]. Mercury emission from municipal solid waste incinerators was found to contribute 20% of the overall background mercury concentration at locations surrounding the incinerator [7]. Incineration of these wastes also leads to toxic releases of dioxins and heavy metals into the surrounding soils and water bodies through rainfall, landslides and runoffs. This has raised concerns for determining the level of risk of residents living around dumpsites.

Bio-indicators have been used to determine the condition of the soil and bio-availability of contaminants. They effectively indicate the conditions of their environments due to their response to environmental stress and give a quantitative determination of the levels of pollutants. It has been suggested that earthworms are excellent bio- indicators of the relative health of the soil ecosystem [24,25,26]. They are a major component of the soil fauna, easily identified, relatively immobile and widely distributed. Earthworms are in full contact with the soil in which they live in, and swallow large amounts of earth. In addition, they do not add anything to the soil that was not already there. As a consequence, the effect on the level of contaminant is minimal or of negligible effect. The soil swallowed passes through the digestive tract and contaminants are adsorbed in the tissue of the earthworm, thereby accumulating these contaminants in its tissue. The use of earthworm as a bio- indicator for heavy metal pollution has been documented by many authors [27-35]. Bamgbose et al. [31], in a study of heavy metals in dumpsites in Abeokuta, Nigeria, showed that levels of metal concentrated in earthworms to soil is less than one with the exception of cadmium and chromium. He explained that the observation may be due to chemical changes which occur in the alimentary tract of the earthworms, rendering various metals available to plants. Data on earthworms collected near roadsides show an accumulation of heavy metal above the amount found in earthworms from non-polluted sites [27,32,36,37]. Gish, Christensen [27] reported a considerable amount of cadmium, nickel, lead and zinc in the tissues of earthworms from soil adjacent to roads. Amounts decreased with increasing distance from the roadside. The correlation between residues in earthworms and soil decreased with decreasing atomic weight (Pb>Cd>Zn>Ni). Higher concentrations were found in the soil and earthworms in sites closer to the smelting complex [36,38].

Earthworm population count has been said to decrease with exposure to higher heavy metal concentrations [39-42]. Brkovicovic and Popovic [43] also studied the effect of heavy metals on survival and respiration rate of tubificid worms. Earthworms that tolerate high environmental concentrations of toxic heavy metals, do not absorb the metal, accumulate it in a non-toxic form or excrete it efficiently [44]. The influence of heavy metal on earthworm is complex and needs further study [45,46].

Lagos State health and environmental officials acknowledge that most of the garbage and sewage collected by private operators, as well as the effluents from industries ends up in the lagoons and creeks. Much of the rest is burnt either in numerous illegal open dumps that dot the city or in the three official dumps operated by the government. The aim of the study is to assess the pollution status of the dumpsites (with respect to heavy metal contamination of Zn, Pb, Cu, Cd, Ni, and Cr) by direct comparison with international limits for polluted soils and also determine factors that influence heavy metal absorption by earthworms *Eudrilus eugeniae*. The effects of these heavy metals depend on their bio-availability; therefore it is important to monitor their levels to determine the relative exposure to residents in order to avoid an epidemic as in the case of Minamata Bay in Japan (1956) and the Love canal in USA (1977-1978) whose effects were seen decades after contamination. *E. eugeniae* is widely spread in warm regions of tropical Africa and are easy to handle and harvest. They belong to the group of epigeic earthworms that live in the uppermost soil layer and in the litter layer feeding mainly on organic matter and process waste quickly under ideal conditions with high rate of reproduction [47]. The result of this study is vital as it provides information on the soil quality and bio-availability of heavy metal concentrations by measuring levels in both polluted soil and earthworms *E. eugeniae* to allow for adequate documentation at local levels, and also foster further studies.

2. MATERIALS AND METHODS

The study covers four government registered dumpsites in Lagos shown in Fig. 1, three of which are active; Olusosun, Abule Egba and Soluos while Oke Afa Isolo is non-active .Apart from the fact that the selected dumpsites were the only government registered dumpsite as at the time of study, they also serviced areas of high population density where huge waste is being generated in quantum. Common to all the dumps is the co-disposal of domestic and industrial solid waste with scavengers seen sorting out the waste. Olusosun is the largest in the state and is situated in the Northern part of Lagos within Ikeja local government. It receives approximately 40% of the total waste deposits from Lagos and occupies 42.7 hectares with a residual life span of 20 years. Olusosun is generally characterised with large amount of sandy soil mixed with clayey soil [48]. Abule Egba, Soluos and Oke Afa are smaller compared to Olusosun dumpsite. Large amount of metal scraps were found at Abule Egba which were being sorted by scavengers and sold for recycling. Abule Egba occupies about 10.2 hectares in the Western part of Lagos in Alimosho Local government and is lined with both clayey and sandy soil [48]. It receives waste from the densely populated area and its residual life span is approximately 8 years. Soluos is situated along Lagos State University – Iba Road. Soluos is on 7.8 hectares of land with an average life span of 5 years and characterised with clayey and sandy soil types distributed around the dump [48]. Oke Afa Isolo which has been non-active since 1995 is now a small community with metal shacks built all over the dump. Oke-Afa site was originally a marshy land in the early 60s, but later filled with waste matter mostly industrial and municipal waste [48]. It is largely characterised with clayey soil type. The four dumpsites sampled are located in the center of the city where they are surrounded by buildings, business activities and traffic.

2.1 Sampling, Pre-treatment and Analysis

Soil and earthworms were sampled randomly by using number tables marked on the map of the study area, on each dumpsite in the month of July (wet season) 2006 [49]. Soils from the upper soil layer were sampled using a spade and earthworms in the soil were collected by hand sorting. Earthworms from a single dump were washed free of adhering soil particles using distilled water. The earthworms were divided into two decontaminated glass jars; one, containing 4% formalin to preserve the earthworm for taxonomy and the other was empty for metal analysis. The jars were decontaminated by soaking in 1% nitric acid for 24hours. Earthworms for metal analysis were refrigerated overnight [27] to allow time to purge the soil in the guts [27,31,50,51]. They were then rinsed and placed in decontaminated jars and frozen. Soil samples collected were allowed to dry at room temperature for 14days and passed through a 2mm sieve after manual removal of stones, woods and other objects.

3g of thawed earthworm (*Eudrilus eugeniae*) was measured for each dumpsite and macerated using previously cleaned and decontaminated laboratory mortar. Residues of lead, zinc cadmium, chromium, nickel and copper in the tissue were extracted using 2ml of concentrated nitric acid. It was heated to dryness on a hot plate and the digest was re-dissolved in 1ml concentrated nitric acid and made up to 50ml with distilled water in a volumetric flask. Agilent 240AA Atomic Absorption Spectrometer was used for the determination of all the elements, simultaneous background corrections were made using a deuterium lamp.

5g of sieved soil sample was weighed, 10ml concentrated nitric acid was added and digested over a hot plate for 2hours. The suspension was filtered and the solution was made up 25ml with distilled water in a volumetric flask. Metals were estimated using Agilent 240AA Atomic Absorption Spectrophotometer. A blank determination was also carried out using the above procedure to correct for contamination and impurities.

2.2 Soil pH

Soil pH was determined in air dried soil in a 1:1 w/v ratio with distilled water. 10g of air dried soil was weighed into 50ml beaker and 10ml of distilled water added. The mixture was stirred thoroughly for 1minute and allowed to stand for 30minutes to allow suspended particles to settle before pH reading. The pH was determined using a calibrated pH meter.

2.3 Organic Matter Determination

IITA [52] procedure was adopted for the determination of organic matter. 0.5g of air dried soil was weighed into a 100ml conical flask, 5ml 1M potassium dichromate solution was added. 10ml concentrated sulphuric acid was immediately added. This was mixed by swirling the flask for about a minute and left to stand for 30minutes. 20ml of deionized water was added and cooled with tap water. 3 drops of ferroin indicator were then added. The solution was titrated with 0.5N ferrous sulphate solution until the colour changed from deep green trough bright green to reddish brown (maroon). A blank was carried out through the procedure to correct for impurities from reagent and contamination during the process.

The percentage organic carbon is given by the equation:

$$\frac{(MeK_2\,Cr_2\,0_7 - MeFeSO_4) \times 0.0031 \times 100 \times F}{\text{Mass (g) of air dried soil}}$$

F = Correction factor (1.33)
Me = Normality of solution x ml of solution used
% organic matter in soil = % organic carbon x 1.729.

2.4 Statistical Analysis

Pearson correlation analysis was used to identify all possible combinations to determine the bioaccumulation of heavy metals by earthworms in soil. Correlation analysis of soil and earthworms for all the metals in each dumpsites was carried out which lead to further investigation by correlating each metal concentration in soil and earthworms in all the dumpsites. T test analysis was also carried out to ascertain the relationship between concentrations of each metal in soil and earthworms in all the dumpsites. Statistical hypothesis testing was used to determine the significance of the results obtained using the 95% confidence interval, where values less than .05 are considered to be statistically significant and the null hypothesis be rejected while for values greater than .05, the null hypothesis will be accepted [53].

Pearson correlation is based on the mathematical expression given below.

$$R = \frac{\sum_{i=1}^{n}(X_i - \ddot{X}_i)(Y_i - \ddot{Y}_i)}{\sqrt{\sum_{i=1}^{n}(X_i - \ddot{X}_i)^2}\ \sqrt{\sum_{i=1}^{n}(Y_i - \ddot{Y}_i)^2}}$$

Where, R is Pearson correlation coefficient, $\ddot{X}$ and $\ddot{Y}$ mean of the variable X and Y respectively.

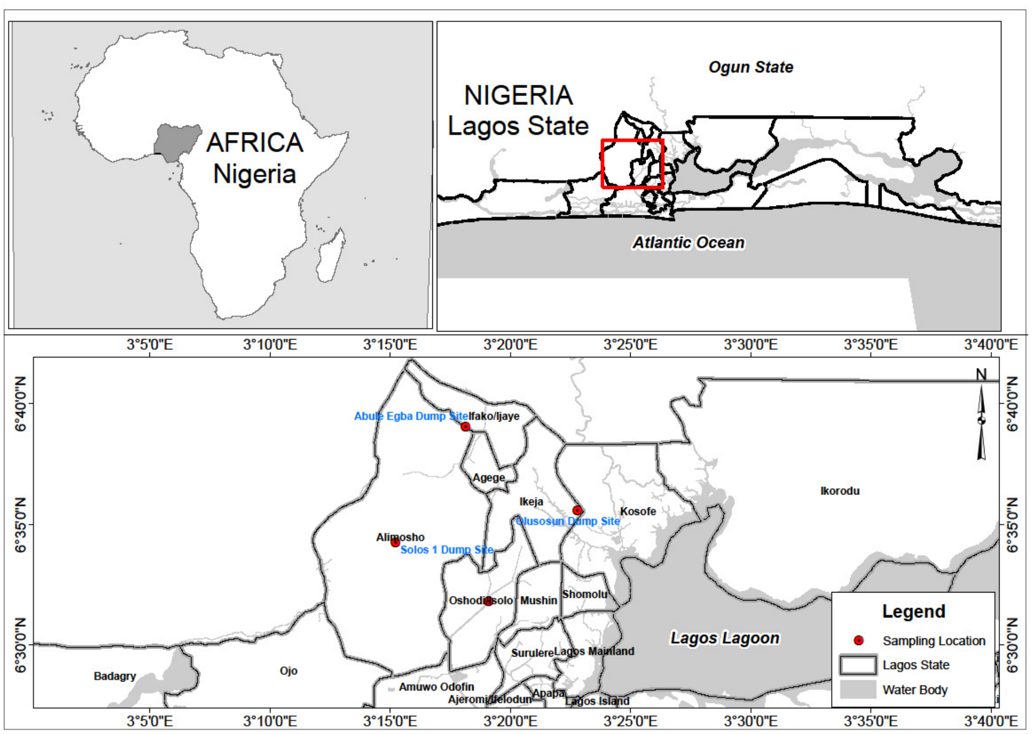

Fig. 1. Description of the study area

3. RESULTS AND DISCUSSION

Results presented in Table 1 show the soil pH, percentage organic matter and metal concentrations in soil samples from contaminated dumpsites in Lagos. The concentrations of heavy metal contents in earthworms from different dumpsites are given in Table 2. The concentration factor (Table 3) is the ratio of the amount of heavy metal per gramme of the earthworm to the amount of heavy metal per gramme of the soil. Correlation coefficients for heavy metal levels in earthworms to soil at different dumpsites and correlation coefficients of heavy metal concentrations in soil and earthworms in the dumpsites are presented in Table 4 and 5 respectively. Table 6 shows the T test analysis on metal concentrations in soil and earthworms in the dumpsites. Graphical representation of heavy metal concentrations in earthworm and soil were shown in Figs. 2 and 3 respectively.

The maxima for Pb (364 µg/g), Cu (428 µg/g), Cd (4.20 µg/g), Zn (2110 µg/g) and Ni (19.3 µg/g) in soil samples from Oke Afa is presented in Table 1. Oke Afa was also shown to have the highest percentage organic matter content of 4.65%; giving the soil the ability to form complexes with heavy metals present within the soil matrix. This is in consonance with the work of Shuman [54], who pointed out that metals are associated with insoluble soil organic matter and specially adsorbed on inorganic soil constituents when introduced into the environment through human activities. This was further explained by Shuman [55] who reported that metals are higher in fine textured high organic matter soil than in coarse textured low cation exchange capacity soil. As a result, the ratio of metal concentration in earthworms (*E. eugeniae*) to soil was less than one for Pb (0.36), Cu (0.27), Cd (0.46), Zn (0.08) and Cr (0.79) at Oke Afa. Also, soil containing greater than 3.4% organic matter has been said to maintain the physical, chemical and biological conditions of the soil [56,57]. This also reflected in the square of correlation coefficient value (R^2 = 0.59) at this location which represented the least correlated of all the dumpsites (Table 4). Furthermore, high heavy metal content in Oke Afa could be due to the fact that it was the oldest dumpsite studied. Although it was closed down by the state government, the dumpsite was still being used by local scavengers. Olusosun is presently the biggest dumpsite in Lagos, and waste dumped, is relatively dispersed on the vast land mass. This fact, coupled with the positive square correlation (R^2 = 0.93) accounts for the relatively low concentrations shown in both soil and earthworms at Olusosun as presented in Tables 1, 2 and 4. Highest pH value of 8.15 was reported at Olusosun and being weakly alkaline, the mobility of the metal cations is reduced [58], resulting to a less than one concentration factor of earthworms to soil for Pb (0.45), Cu (0.64), Zn (0.27) and Cr (0.53) as shown in Table 3. Changes in soil environmental conditions over time such as degradation of organic waste matrix, changes in pH or soil solution composition may enhance metal mobility [59]. Metal content of Pb (293 µg/g), Cu (176 µg/g), Cd (3.95 µg/g), Zn (754 µg/g) and Cr (12.7 µg/g) in earthworm (*E. eugeniae*) (Table 2) were highest in Abule Egba. This could be as a result of the type of waste dumped at this location, which are mostly metal scraps. High concentrations of metals were found in both soil and earthworms in Abule Egba with positive square correlation coefficient (R^2) of 0.96. Despite the high level of metal contamination at Abule Egba as shown in Table 1, levels of metal in the soil were relatively lower than that of Oke Afa. This establishes the fact that the relatively low percentage organic matter at Abule Egba allowed heavy metals to be easily absorbed by earthworm (*E. eugeniae*) tissue. As a result, the ratio of metal concentration in earthworms (*E. eugeniae*) to soil is greater than one in Abule Egba for Pb, Cu, Cd and Ni. Heavy metal concentrations at Soluos were found to be higher than concentrations at Olusosu with the exception of Cd (1.30 µg/g) but lower than Abule Egba and Oke Afa with the exception of Cu(85 µg/g) and Ni(3.85 µg/g) at Abule Egba and Cr(13 µg/g) at Oke Afa. There was a positive square correlation coefficient between heavy metal concentration in earthworm and soil as indicate in Table 4 (R^2=0.98). The statistical approach showed that metal concentrations in earthworm and soil was positively correlated in all the dumpsites with P=.001 at Abule Egba, .P=.075 at Oke Afa, P=.002 at Olusosun and P<.001 at Soluos. P values less than .05 shown in all the dumpsites (with the exception of Oke Afa) shows that the null hypothesis on the correlation for all the metals in soil and earthworms be rejected [53], which suggests that the metals behave differently in both soil and earthworms [60,61,62] hence, correlation analysis was carried out for each metal in soil and earthworms for the dumpsites (Table 5).

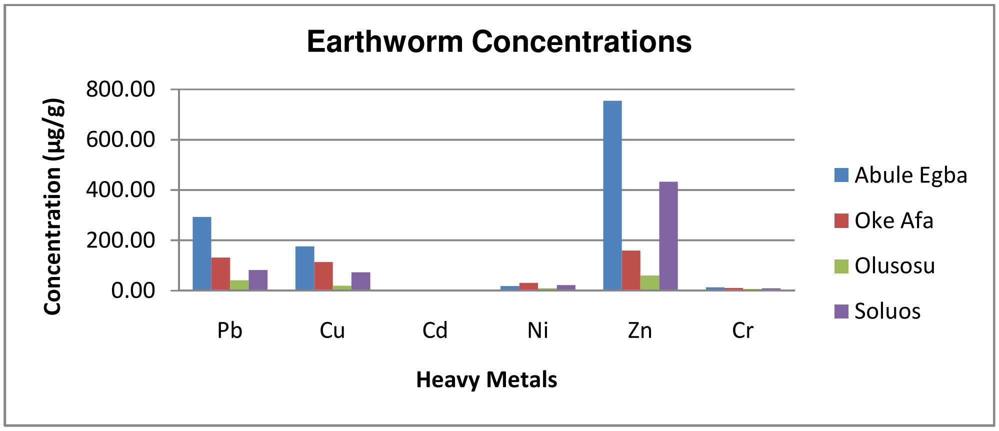

Fig. 2. Heavy metal concentrations (µg/g) in earthworm (*E. eugeniae*) from contaminated dumpsites in Lagos

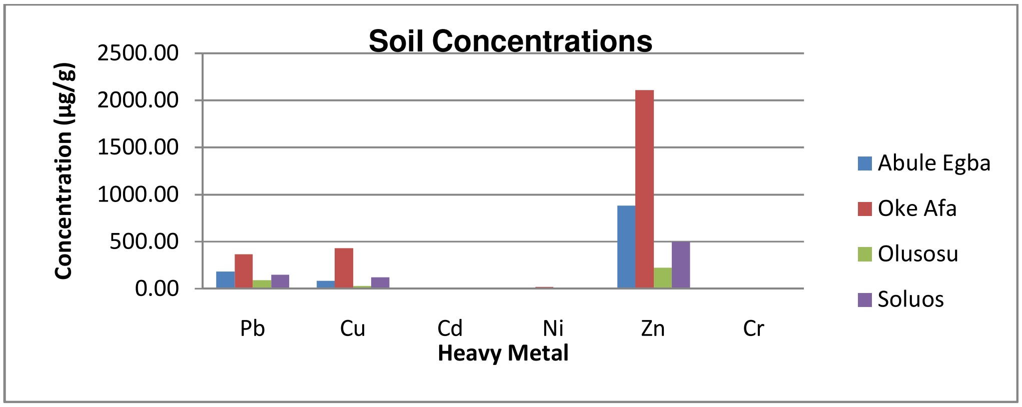

Fig. 3. Heavy metal concentration (µg/g) in soil samples from contaminated dumpsites in Lagos

At all the dumpsites, concentration factors in earthworms (*E. eugeniae*) to soil for Ni were greater than one and was shown to be positively correlated (*P*=.24) in Table 5. This could be due to increased Ni mobility in soil through the formation of complexes with both inorganic and organic ligands [59]. Although a positive correlation between earthworms and soil was observed for Cr (Table 5), concentration ratios of earthworms (*E. eugeniae*) to soil was less than one in all the dumpsites (Table 3).Some metals such as Cr, As, Se and Hg are transitional in soil, thereby reducing their mobility [59]. Concentration factor for zinc (Table 3) in all the dumpsites were less than unity and was negatively correlated (*P*=.9) in earthworm and soil (Table 5). This suggests that Zn, which is an essential metal, is regulated by the earthworms [61]. The negative correlation (*P*=.78) in earthworms and soil observed for cadmium (Table 5), could be explained by cadmium desorption kinetics which depends on the soil properties [63]. Sanitillan and Jurinak [64], using stability diagrams predicted that solution activity of Cd is consistently higher than that of Pb indicating that Cd may be more mobile in the environment. This theory is supported by the concentration factors given in Table 3. Factors greater than one for Cd was found in Abule Egba, Olusosun and Soluos as compared to Pb where the concentration factor was only greater than one at Abule Egba. With the exception of Cu at Abule Egba, Cu and Zn concentrations at pH range of 7.61 to 8.15 in earthworms (*E. eugeniae*) were found to have lower concentrations than in soil in all the dumpsites, indicating higher retention of these metals by soil. Such influence of pH on metal ion mobility has been reported by Alloway [58] and McBride, Blasiak [65]. Also, the presence of phosphate at high concentrations in soil has been shown to block the specific absorption sites of Cu and Zn [66].

Table 1. Soil pH, percentage organic matter and Heavy metal concentration (X±SD) (µg/g) in soil samples from contaminated dumpsites in Lagos

Sample site	Soil pH	Organic matter	Pb	Cu	Cd	Ni	Zn	Cr
Abule Egba	7.68	1.77	185.00±1.02	85.00±1.14	2.98±0.19	3.85±0.18	886.00±3.73	14.50±1.45
Oke Afa	7.61	4.65	364.00±2.07	428.00±2.10	4.20±0.03	19.30±0.90	2110.00±6.23	13.00±0.98
Olusosu	8.15	1.70	91.00±0.58	30.50±0.45	1.59±0.02	7.05±0.53	226.00±2.02	13.30±1.85
Soluos	7.89	2.85	147.00±2.80	123.00±0.05	1.30±0.02	8.00±1.50	501.00±1.67	13.40±1.25

Table 2. Heavy metal concentrations (X±SD) (µg/g) in earthworm (*E. eugeniae*) from contaminated dumpsites in lagos

Sample site	Pb	Cu	Cd	Ni	Zn	Cr
Abule Egba	293.00±1.09	176.00±3.01	3.95±0.03	18.30±1.11	754.00±4.28	12.70±0.56
Oke Afa	132.00±2.13	114.00±0.73	1.95±0.06	31.00±0.84	159.00±2.77	10.20±1.87
Olusosu	40.50±1.50	19.50±0.43	2.10±0.18	9.83±0.12	60.30±1.60	7.00±0.88
Soluos	82.60±1.10	73.40±1.07	3.28±0.49	23.30±0.16	434.00±2.40	10.00±0.67

Table 3. Concentration factor (µg/g of earthworm (*E. eugeniae*)/µg/g of soil)

Sample site	Pb	Cu	Cd	Ni	Zn	Cr
Abule Egba	1.58	2.07	1.33	4.75	0.85	0.88
Oke Afa	0.36	0.27	0.46	1.61	0.08	0.79
Olusosu	0.45	0.64	1.32	1.39	0.27	0.53
Soluos	0.56	0.60	2.52	2.91	0.87	0.75

Table 4. Correlation analysis of metal concentrations in soil and earthworms for each dumpsite

Sample site	R	R^2	P-Val
Abule Egba	0.9785	0.9574	0.001
Oke Afa	0.7669	0.5882	0.075
Olusosu	0.9633	0.9279	0.002
Soluos	0.9899	0.9799	<.001

Tables 5 and 6 shows the null hypothesis to be greater than .05, indicating no significant difference between concentrations of heavy metals in soil and earthworms. As a result, earthworms can serve as bio-indicator of Pb, Cu, Ni and Cr [53] while Zn and Cd which have been said to have similar physical and chemical properties [62]; have been suggested to be regulated in earthworm and soil.

Table 5. Correlation analysis of metal concentrations in soil and earthworms in the Dumpsites

Metals	R	R^2	P-Val
Pb	0.2618	0.0686	0.74
Cu	0.2709	0.0734	0.73
Cd	-0.2160	0.0466	0.78
Ni	0.7643	0.5842	0.24
Zn	-0.0969	0.0094	0.90
Cr	0.6984	0.4877	0.30

The metal concentration in both earthworm (*E. eugeniae*) and soil followed a general trend of Zn>Pb>Cu>Ni>Cr>Cd. This conforms to the work of Sposito [67] on trace metal in arid zone soils amended with sewage sludge who reported the trend Mn>Zn>Pb>Cu>Cr>Cd in both soil and earthworms. The various trends in metal absorption by earthworms at the different dumpsites aligns with the work of Ma et al. [68] which shows that the amount of heavy metals accumulated within earthworm tissues is partly dependent on the absolute concentration of metal and physicochemical interaction within a given soil.

Table 6. T test analysis of metal concentrations in soil and earthworms in the Dumpsites

Metals	T-Val	P-Val
Pb	0.7	0.49
Cu	0.8	0.50
Cd	-0.4	0.73
Ni	-2.0	0.10
Zn	1.3	0.26
Cr	3.0	0.06

Using the Canadian environmental guideline for contaminated site remediation [69] and Toronto public health (TPH) guide for soil testing in urban gardens [70] in Table 7 and 8 respectively. It was shown that Cr and Ni did not exceed the permissible level for all the dumpsites. Cd concentration required medium concern with levels greater than one in all the dumpsites (Table 8). Permissible levels in residential and parkland areas for Pb were exceeded in Abule Egba, Oke Afa and Soluos (Table 7), and high concern for Pb concentration was observed at Oke Afa (Table 8). With the exception of Olusosun, Cu and Zn in the dumpsites require action for remediation as they were observed to be above the considered international standards (Table 7 and 8). From this study, it was observed that structures were not put in place for leachate collection, thereby exposing residents living close to the dumpsites to heavy metal pollution through ground water contamination.

Table 7. Remedial criteria for contaminants in soil (ppm)

Substance	Agriculture	Residential/Parkland	Commercial	Industrial
Cadmium	1.4	10	22	22
Chromium	64	64	87	87
Copper	63	63	91	91
Lead	70	140	260	600
Nickel	50	50	50	50
Zinc	200	200	360	360

Source: Canadian environmental guideline for contaminated site remediation

Table 8. Urban gardening soil screening values (ppm)

Substance	SSV1	SSV2
Cadmium	1	10
Chromium	390	630
Copper	180	660
Lead	34	340
Nickel	34	340
Zinc	500	1800

Concentrations below SSV1 are of low concern; concentrations over SSV1 but less than SSV2 are of medium concern; concentrations above SSV2 are of high concern. Source: Toronto public health guides for soil testing in urban gardens

4. CONCLUSION

The results of this study show that there is no statistical significant difference between heavy metal concentrations in soil and earthworms (*E. eugeniae*) which indicates that earthworms (*E. eugeniae*) can serve as bio indicators in heavy metal monitoring in dumpsites. However, the negative correlation shown for Zn and Cd could be explained by the regulation of Zn by earthworms and Cd desorption kinetics. Oke Afa, which was the oldest dumpsite with the highest percentage organic matter, had the highest level of metal contamination in soil. The type of waste was seen to influence the level of heavy metals in both earthworms and soil at Abule Egba. Results obtained also show that most of the metals in soil exceeded the Canadian environmental guideline and Toronto public health guide for soil. This could possibly lead to heavy metal poisoning of residents living close to the dumpsite through ground water contamination by leachate. It is recommended that the Lagos state government should lay emphasis on the need to improve dumpsite management practices in the state.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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