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Earthworm (*Eudrilus eugenia* Kinberg) as Bio-Indicator of the Heavy Metal Pollution in Two Municipal Dump Sites of Two Cities in Northern Nigeria

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Abstract: Concentration of some metals (Cd, Cu, Fe, Pb and Zn) was measured in *Eudrilus eugenia* and used to indicate soil pollution resulting from dumpsites located in two cities of northern Nigeria. The result of the current experiment showed that samples from the uncontaminated and dump sites showed in most cases levels of metal to be lower in earthworm than in soil samples. The ratios of the level of metals in earthworm to soil obtained for this work were in all cases less than unity. The metal concentration in both soil and earthworm followed the trend Cu>Fe>Zn>Pb>Cd Dump sites located closest to the highways showed high Pb concentrations.

Key words: *Eudrilus eugenia*, soil pollution, dump-sites, heavy metals

INTRODUCTION

Heavy metals may be important trace elements in the nutrition of plants, animals or humans (e.g., Zn, Cu, Mn, Cr, Ni, V), while others are not known to have positive nutritional effects (e.g., Pb, Cd, Hg). However, all of these may cause toxic effects (some of them at a very low content level) if they occur excessively (Spiegel, 2002). Under certain environmental conditions (such as climate, soil type, soil pH etc.), heavy metals may accumulate to a toxic concentration and may cause ecological damage (Ramos *et al*., 1999a). Cadmium and lead are not required by man even in small amount (Borgmann, 1983), on the other hand, metals such as Cu and Zn are classified as essential to man due to their physiological involvement in certain processes, but at elevated levels can also be toxic (Spear, 1981).

The level of Cd and Pb in the environment has increased tremendously in the past decades as a result of human inputs and activities (Awofolu, 2005). Motor vehicles have been reported to introduce quite a number of chemicals into the environment among which are Cd, Pb, Zn and Cu and these are increasingly detected in vegetation and soil (Fatoki and Hill, 1994; Dudka *et al*., 1996) and also in lower animals inhabiting soils along major roads (Marinussen *et al*., 1997; Nuortera and Elberg, 1999). It is not uncommon to find ruminant feeding on grasses and birds that feed on insects and earthworm along these roads. Transfer of such trace metals from contaminated soil to plants and from plants to livestock with the subsequent transfer through the food chain to man, have been reported in some studies (Oskarson *et al*., 1992).

Monitoring of trace toxic substances in the environment using biological indicators have been well established (Edwards and Lofty, 1977; Spiegel, 2002; Bamgbose *et al*., 2005). The bioaccumulation of heavy metals over large territories and long time periods, which may result in the gradual damage of living organisms, necessitates careful monitoring of the input, mobility and effects of these pollutants. Earthworm are found in every type of soil except very dry or very acid soils and play an important role in processing organic material derived from natural and anthropogenic substrates such as sewage sludge (Edwards and Lofty, 1977; Yoloye, 1988). It has been known that earthworms are able to

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accumulate heavy metals such as Pb, Cu, Cd and Hg in their bodies without any harm to them and can thus serve as a bio-indicator in dumpsite environments (Bamgbose *et al*., 2005). Significant positive correlation between the earthworm and total (nitric acid extractable) soil Cu, Pb and Zn from various contaminated sites have also been reported (Morgan and Morgan, 1988; Stafford and McGrath, 1986). This study presents the levels of Cd, Cu, Fe, Pb and Zn in earthworm (*E. eugenia*) from different dumpsite environments in two northern Nigerian Cities (semi-arid regions) and also compares the results with those obtained for *Lybrodrilus violaceous* in some southern cities of Nigeria, characterized with much higher rainfalls and soil organic content.

MATERIALS AND METHODS

Sample Collection and Preservation

This study was carried out in the northern Nigeria cities of Kaduna and Zaria in August 2005. Kaduna however, is more urban than Zaria, each having about eight and five major dump sites, respectively. The soils in these areas as most West African Savannas are mainly silt-clay with low organic content (Udo, 1970). They are sticky and heavy when wet but hard and characterized by cracks when dry. Five locations were chosen for sampling in each of the cities, selected according to dump characteristics. An extra urban area, mainly residential and wastes are mainly domestic wastes are referenced sites 1. To a greater extent, sites 2 are located on major highways characterized by metal scraps and domestic wastes. At sites 3, relatively small dumpsites exposed to few moving cars. More domestic and slower traffic flow characterized site 4. Sites 5 are remote locations, no anthropogenic source of pollutants were noted at the sites and are taken as the background uncontaminated samples. The degrees of heavy metal input into the environment is site 1>site 2>site 3>site 4>site 5. Because Kaduna is more urbanized than Zaria, the overall degrees of heavy metal inputs are K1>Z1, K2>Z2, K3>Z3, K4>Z4 and K5>Z5.

Mature earthworm samples were collected from dumpsites in Zaria (Z1, Z2, Z3, Z4 and Z5) and Kaduna (K1, K2, K3, K4 and K5). The earthworms were long (between 11 and 15 cm), pointed at ends, bilaterally symmetrical body and bluish-purple dorsally and lighter ventrally. The body is divided into segments (120-150) by a series of circular constrictions. The mouth is situated ventrally in the first segment, the anus is terminal. Saddle shaped clitellum were noticed in segments 14-17 with slightly lighter colour from the remaining segments. Male genital aperture (segment 17) and single spermathecal pore (segment 13) were also noticed. The earthworm identified as *Eudrilus eugenia* in the Department of Biological Sciences, Ahmadu Bello University, Zaria were collected by spraying the soil with 0.05% formalin. They were washed free of adhering soil particles and placed in Petri dishes and refrigerated at 5°C for 24 h in order to purge the soil in the gut. Thereafter the soil was removed and the earth was rinsed slightly with distilled water and dried at 40°C in a well ventilated oven for 24 h pending analysis.

Composite samples of soil were also collected at each dump site and uncontaminated sites with the aid of plastic spoon at a depth of about 30 cm and transferred to cellophane bags. The samples were dried at 40°C for about 20 h in an air oven, screened across a 2 mm mesh sized synthetic sieve and homogenized in an agate mortar.

Determination of pH

The soil pH values were determined in slurries of air dried soil samples and distilled water. A sample of 20 g soil was allowed to equilibrate with 50 cm^3 distilled water for 5 min and pH was measured using Criso MicropH 2000 Digital pH meter with a glass-calomel electrode (Spiegel, 2002).

Determination of Organic Matter

The organic matter content of soils was determined by loss-on-ignition. Soil (1 g) was heated in a muffle furnace at 600°C to a constant weight.

Determination of Cation Exchange Capacity of Soil

The Cation Exchange Capacity (CEC) was determined and calculated using a standard method described by Agbeni (1995).

Digestion of Earthworm and Soil

The dried earthworm samples (3 g) were weighed and digested separately with 10 cm^3 concentrated nitric acid (sp. gr. 1.42) and heated in a Kjeldahl flask to dryness on a heating mantle. The digest was re-dissolved in 5 cm^3 concentrated nitric acid and quantitatively transferred into a volumetric flask and was made up to 50 cm^3 with distilled water (Awofolu, 2005).

Concentrated nitric acid (10 cm^3, sp. gr. 1.42) was added to the dried soil samples (0.5 g). The mixture was refluxed in a Kjeldahl flask for 45 min and later evaporated to dryness. Aqua regia (5 cm^3) was added and again evaporated to near dryness after which 10 cm^3 of distilled water was added and the suspension filtered. The filtrate was then quantitatively transferred to a 50 cm^3 volumetric flask and diluted to mark (Agbeni, 1995).

The digested samples were analyzed for metals using Atomic Absorption Spectrophotometer (SOLAR 32) at the chemistry laboratory of National Research Institute for Chemical Technology, Zaria, Nigeria.

RESULTS AND DISCUSSION

In these samples, the pH of soil samples collected at dumpsites were in all cases higher than values obtained as background values from uncontaminated samples (Z5 and K5). Similarly, the organic matter and cation exchange capacities of dumpsites were all higher than the uncontaminated soil samples (Table 1).

The result shows that the concentration of Cd was higher in earthworm samples collected from dumpsites than those collected from the uncontaminated sites. The highest value was obtained from the K2 samples (Table 2). These values were slightly below the range 0.00-0.05 $\mu g\ g^{-1}$ (dry tissue),

Table 1: pH, organic matter and cation exchange capacity of soil samples collected from dumpsites

Sites	pH (in H_2O)	Organic matter (%)	Cation exchange capacity (Cmol kg^{-1})
Z1	8.20±0.06	6.24±0.12	22.20±0.42
Z2	8.50±0.03	5.23±0.21	15.00±0.33
Z3	9.00±0.12	7.40±0.08	28.00±0.43
Z4	7.40±0.09	6.90±0.17	23.60±0.37
Z5	6.50±0.07	3.44±0.13	10.20±0.67
K1	8.00±0.02	7.09±0.05	17.40±0.88
K2	8.80±0.03	7.10±0.19	18.80±0.79
K3	8.70±0.06	5.53±0.22	17.60±0.91
K4	8.20±0.11	5.50±0.14	15.80±0.49
K5	6.30±0.04	1.96±0.01	8.60±0.56

Table 2: Metal ion concentration ($\mu g\ g^{-1}$) in earthworm *Lumbricus terrestris* from dumpsites and uncontaminated sites in Zaria and Kaduna, Nigeria

Sample site	Cd	Cu	Pb	Zn	Fe
Z5	0.0010±0.00	0.0832±0.004	0.0081±0.00	0.0496±0.010	0.0052±0.00
Z1	0.0324±0.001	0.1231±0.006	0.0098±0.001	0.0336±0.004	0.7368±0.08
Z2	0.0113±0.00	0.5831±0.012	0.0314±0.00	0.0448±0.002	0.5289±0.01
Z3	0.0001±0.00	1.2580±0.052	0.0327±0.00	0.0746±0.006	0.9899±0.07
Z4	0.0045±0.00	1.0524±0.102	0.0148±0.001	0.0532±0.012	0.8431±0.04
K5	0.0001±0.00	0.4788±0.006	0.0025±0.00	0.0483±0.008	0.0015±0.00
K1	0.0050±0.002	0.9571±0.005	0.0251±0.003	0.0070±0.001	0.8985±0.19
K2	0.0410±0.003	1.3681±0.112	0.0689±0.005	0.0489±0.015	0.7852±0.08
K3	0.0385±0.005	0.8039±0.092	0.0594±0.008	0.0236±0.004	0.3214±0.05
K4	0.0242±0.00	0.9719±0.072	0.0634±0.011	0.0468±0.037	0.7582±0.11

by Awofolu (2005) in a related survey using the earthworm (*L. violaceous)* and also below the range of 0.74-7.55 $\mu g\ g^{-1}$ ($p<0.05$), in *L. violaceous* by Bamgbose *et al*. (2005) in dumpsites located in the more urban areas of southern Nigeria which are characterized by more and heavier rainfalls. This difference could therefore be attributed to the relatively higher levels of pollution reported by these workers or differences in the nature of the habitats.

The concentrations of Cu, Fe, Pb and Zn in soil samples were also found to be higher in dumpsite samples than in the uncontaminated soil samples. However, the highest concentration of Cu was obtained in site K2 samples, which also has the highest soil pH, organic matter and CEC. The values obtained for Pb were similar to 0.00-0.07 $\mu g\ g^{-1}$ range given by Awofolu (2005) but lower than 4.55-381.72 $\mu g\ g^{-1}$ range ($p<0.05$) given by Bamgbose *et al*. (2005). The high value of lead in site K2, K3 and Z2, Z3 may be as a result of their location i.e., by the side of highways. The general trend of the metals concentrated in the earthworm show that Cu had the highest concentration while Cd had the lowest (Table 2). The general trend obtained for this work is Cu>Fe>Zn>Pb>Cd which is slightly different from the trend obtained by Bamgbose *et al*. (2005), Pb>Zn>Cu>Cd for their work on trace metals in the forest zone soils of southern Nigeria.

Although the amount of metals accumulated within earthworm tissues is partly dependent on the absolute concentration of the metal within the given soil, it is strongly co-determined by physiochemical edaphic interaction, including factor such as pH, calcium concentration, organic matter content and cation exchange capacity (Ma *et al*., 1983; Morgan and Morgan, 1993). Some of the soil parameters determined was correlated with the concentration of metals in the earthworm from the various sampling locations using the Pearson's Correlation. Statistically for samples where $n = 4$, $p<0.05$ the critical correlation coefficient, r was found to be 0.81. Therefore the values greater than 0.81 are adjudged to be significant and values lower than 0.81 are not significant. Cd, Cu and Pb showed a level of correlation with soil pH in the K samples while only Pb is correlated to pH in the Z samples. Table 3a-c. shows that Cu, Zn and Fe are correlated to the soil organic matter in the K samples, while in Z samples only Cu and Fe. The cation exchange capacity of the soil was found to be correlated with Cu in K samples while in the Z samples Cu and Fe are correlated.

The ratio for Cd in most cases was less than unity except for the K4 sample, where the concentration accumulated by earthworm is similar to the concentration in the soil (Table 4a). The relationship between fractionation of trace Cd and the levels in earthworm (*Allolobophora molleri*) has been found to be related to the soil fraction it is bound to (Ramos *et al*., 1999a). The ratio of Cu in earthworm to soil was found to be higher in uncontaminated soils than in the dumpsites with the K4 samples accumulating more Cu than all other sites. It was also found by Gonzalez *et al*. (1994) and

Table 3a: Pearson correlation coefficient between soil pH and metal concentration in earthworm

	Pearson correlation coefficient (r)	
Metals	K samples	Z samples
Cadmium	**0.85**	0.30
Copper	**0.80**	0.65
Lead	**0.91**	**0.80**
Zinc	0.43	0.63
Iron	0.66	0.75

Table 3b: Pearson correlation coefficient between soil organic matter and metal concentration in earthworm

	Pearson correlation coefficient (r)	
Metals	K samples	Z samples
Cadmium	0.52	0.16
Copper	**0.87**	**0.94**
Lead	0.65	0.43
Zinc	**0.82**	0.63
Iron	**0.90**	**0.99**

Table 3c: Pearson correlation coefficient between cation exchange capacity and metal concentration in earthworm

	Pearson correlation coefficient (r)	
Metals	K samples	Z samples
Cadmium	0.71	0.15
Copper	0.83	0.91
Lead	0.79	0.35
Zinc	0.62	0.70
Iron	0.78	0.96

Table 4a: Ratio of earthworm/soil in samples collected in Kaduna and Zaria (the present work)

Sample site	Cd	Cu	Pb	Zn
Z1	0.32	0.13	0.17	0.02
Z2	0.14	0.28	0.42	0.03
Z3	0.02	0.49	0.41	0.03
Z4	0.09	0.47	0.35	0.03
Z5	0.01	0.61	0.39	0.03
K1	0.04	0.61	0.41	0.03
K2	0.39	0.60	0.41	0.02
K3	0.27	0.49	0.41	0.03
K4	1.00	8.32	3.12	4.96
K5	0.00	0.48	1.32	2.54

Table 4b: Ratio of earthworm/soil in samples collected in south-western Nigeria (Bamgbose *et al*., 2005)

Sample site	Cd	Cu	Pb	Zn
Adatun	1.18	0.84	0.88	0.89
Asero	1.23	0.87	0.87	0.86
Ibere	1.21	0.78	0.87	0.90
Ijaye	1.18	0.86	0.85	0.89
Imo	1.17	0.87	0.89	0.91
Isale-Igbehin	1.17	0.87	0.88	0.83
Ita-Oshin	1.16	0.84	0.86	0.87
Kato	1.18	0.86	0.92	0.92
Lafenwa	1.17	0.88	0.88	0.86
Obantoko	1.60	0.83	0.86	0.91

Ramos *et al*. (1999b) that Cd had a higher rate of accumulation than Cu; the low concentrations of Cd in earthworms obtained in this work could be as a result of the low concentrations of the metal found in the soils. The ratio for Pb is in most cases next to the results obtained for Cu. The metals Cu and Zn are essential for elements for earthworms and the availability of these metals is decreased as the soil pH is raised, (Morgan and Morgan, 1988). Zinc concentration in the earthworm were generally low and in all cases were found to be lower than concentrations found other species of earthworm (Ramos *et al*., 1999b; Bamgbose *et al*., 2005).

The present study was compared with a similar work carried out by Bamgbose *et al*. (2005) on *L. violaceous* in south-western part of the country. The earthworm to soil ratio were determined and presented in Table 4b for comparative purposes. In their research, Cd had ratios greater than unity, while Cu, Pb and Zn had ratios less than unity but in all cases these ratios are higher for each metal than ratios obtained in this study. The low ratios observed in this study may also be as a result of the environment, the low concentration or immobilization of these metals in the soil. However, Weigmann (1991) reported higher levels metals in earthworms from more polluted sites and found that irrespective of the degree of pollution, the ratio of metal concentration in earthworm to soil samples was less than unity except of few metals such as Cd.

The result of this study suggests that though the levels of metals found in earthworms is dependent on the concentration in the dumpsites, the levels in earthworm do not consistently reflect the metal contamination levels present in the dumpsites. This fact may be due to the maturity of individual earthworm since in earthworms, accumulations of Cd, Pb and Zn may significantly increase with developmental stage (Ma *et al*., 1983). Furthermore, the differences observed between this study and previous studies in southern part of the country suggest that earthworm habitat could affect bioaccumulation of these metals.

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