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Earthworms as bio-indicators of metal pollution in dump sites of Abeokuta City, Nigeria

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Abstract: Metal concentrations (Zn, Pb, Mn, Cu, Cd and Cr) and contents were measured in earthworms (*Libyodrilus violaceus*) and soil samples from three non-contaminated sites and ten dump sites located in Abeokuta, Nigeria. Samples from control sites show (in general) levels of metals to be higher in earthworms than in soil samples, as shown by the mean concentrations, (earthworms-soil: - Zn:7.02, 6.74, Pb:5.04, 4.94, Mn 10.54, 10.41, Cu:1.03, 1.60, Cd: 0.80, 0.81 and Cr:0.55, 0.49 μg/g) while for samples from dump sites, irrespective of the degree of pollution, the ratio of metal concentration in earthworms to soil samples were less than unity with the exception of Cd and Cr. The availability of metals in soils was also co-determined by the soil pH and soil organic matter which accounted for the trend of metal concentration at the various dump sites. For the control sites, the pH ranged from 5.40 - 6.74 and soil organic matter from 3.25 % to 3.40 %, while for the dump sites, values of 7.44-10.10 and 5.79 % - 7.59 % were obtained for soil pH and soil organic matter respectively. The metal ion concentration in both soil and earthworm samples followed the trend Pb > Zn > Mn > Cu > Cr > Cd. Dump sites with high levels of Pb were located by roadsides of busy highways.

Key words: Earthworms, metals, dump sites, soil, organic matter.

Ireland (1983) reported that earthworms can accumulate in their tissues heavy metals in contaminated and non-contaminated environments. That earthworms could serve as bio-indicators for metal pollution was shown by Morgan & Morgan (1988a, 1988b) and Stafford & McGrath (1986) who reported significant positive correlation between the earthworms and total (concentration of nitric acid extractable) soil Cu, Pb and Zn concentration from various metal contaminated sites.

As reviewed by Edwards & Lofty (1997) earthworms consume a significant amount of dirt and in this process help in enriching the soil and improving growing condition for plants. Dumpsites provide suitable environments for earthworm activity, by increasing the degree of mixing with soil microflora, facilitating further enzyme activity (Stafford *et al.* 1986) and increasing the overall decomposition of organic matter (Hamilton & Dindal 1989).

This paper reports on the use of earthworms as bio-indicators of metal pollution in dumpsite environments.

MATERIALS AND METHODS

Sampling and sample preservation: Ten dumpsites (Adatan, Ijaiye, Isale-Igbein, Imo, Iberekodo, Lafenwa, kuto, Obantoko, Ita-Oshin and Asero) in Abeokuta, Nigeria were selected as the sampling sites along with samples collected from the Alabata campus of the University of Agriculture, Abeokuta, which served as controls (uncontaminated sites). The earthworms, identified as *Lybyodrilus violaceus* were collected by spraying the soil with 0.05 % formalin and washed free of adhering soil particles and placed in petri dishes, then refrigerated at 100°C for 24hrs in order to purge the soil in the gut, thereafter were then removed and rinsed slightly with deionised water and then frozen for pending analysis. Soil samples were also collected at each of the dumpsites with the aid of a plastic spoon and transferred to cellophane bags.

Sample identification: Reddish colour but the clitellium is greenish length: 9.2-11.5cm, width: 0.2-0.4cm, shape: round, segmentation: clear, Number of segments: 122-198, Prostomium: epilobus, spermathecal pore: unpaired located on segment 13, male pore: Unpaired located on segment 17, clitellium: Annular shaped on segment 13 - 17, Dorsal pore: nil, Anus:- posteriorly located.

Sample digestion: 3g of the thawed earthworm samples were weighed and digested with 2ml concentrated nitric acid and heated to dryness on a hotplate. The digest was redissolved in 1 ml concentrated nitric acid after which it was made up to 50ml with distilled water. The soil samples were allowed to dry at room temperature and passed through a 2 mm sieve, 5g of the sieved soil sample were weighed and 10 ml concentrated nitric acid added. The mixture in a beaker was covered with a watch glass and refluxed for 45 min. The watch glass was then removed and the content in the beaker evaporated to dryness, 5 ml aqua regia was added and evaporated to dryness after which 10 ml 1M nitric acid was added and the suspension filtered. The filtrate was then diluted to volume with distilled water in a 50 ml volumetric flask.

Organic matter determination: The soil samples were ground using a 0.5 mm sieve after which they were weighed in duplicate and transferred to a 250 ml erlenmeyer flask. Exactly 10 ml of 1M potassium dichromate was pipetted into each flask and swirled gently to disperse the soil followed by addition of 20 ml concentrated sulphuric acid. The flask was swirled gently until soil and reagents were thoroughly mixed. The mixture was then allowed to stand for 30 min. on a glass plate. 100 ml distilled water was added followed by addition of 3-4 drops of ferroin indicator, after which it was titrated with 0.5N ferrous sulphate solution. A blank titration was similarly carried out.

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.

Soil pH: 20g of the air dried soil was weighed into a 50 ml beaker and 20 ml of distilled water added. The mixture was allowed to stand for 30 minutes with occasional stirring with a glassrod. The electrodes of the calibrated pH meter were then inserted into the partly settled suspension and the pH of the soil measured.

Quantitative analysis: The sample digests were analysed using a Perkin Elmer 403 atomic absorption spectrometer at wavelengths specific to each metal at the soil laboratory, Ring Road, Ibadan, Oyo state, Nigeria.

RESULTS

The results are presented in Tables 1, 2 and 3. Table 1 shows the results obtained from the control sites (uncontaminated) while Table 2 and 3 show the metal ion levels in the soil samples and earthworms samples respectively from the waste dumps (contaminated site).

TABLE 1

Soil pH, organic matter % and metal ion concentration from uncontaminated sites

SAMPLE SITE	SOIL pH	ORGANIC MATTER %	Zn		Pb		Mn		Cu		Cd		Cr	
			S	E	S	E	S	E	S	E	S	E	S	E
ALA1	6.74	3.25	5.88	6.05	45.71	4.81	10.45	10.91	1.44	1.50	0.89	0.74	0.51	0.58
ALA2	6.25	3.40	6.54	6.96	5.68	5.77	11.36	10.83	1.70	1.60	0.71	0.88	0.42	0.47
ALA3	5.90	3.36	7.80	8.04	4.42	4.55	9.42	9.87	1.65	1.80	0.82	0.78	0.55	0.60
Mean	6.30	3.34	6.74	7.02	4.94	5.04	10.41	10.54	1.60	1.63	0.8	10.80	0.49	0.55

S = Soil, E = Earthworm ALA_1: Colplant Farm Area, ALA_2: Water Reservoir Area, ALA_3: Students Hostel Area

TABLE 2

Soil pH, organic matter % and metal ion concentration in soil samples from contaminated sites (waste dumps) in Abeokuta City, Nigeria

SAMPLE SITE	SOIL pH	ORGANIC MATTER %	Zn	Pb	Mn	Cu	Cd	Cr
Adatan	9.62	6.20	95.25	96.40	187.55	39.27	6.41	11.52
Asero	8.18	7.07	67.18	57.60	86.67	23.55	4.32	9.48
Iberekodo	10.10	6.10	84.27	300.41	101.48	26.41	4.74	7.15
Ijaye	9.98	6.03	204.66	218.54	148.31	42.84	5.11	14.20
Imo	7.44	5.89	68.36	82.45	77.26	34.26	4.38	7.92
Isale-Igbehin	9.85	5.79	101.74	61.38	78.82	27.81	3.71	8.31
Ita-Oshin	10.10	7.59	296.19	314.82	116.67	81.13	4.21	6.45
Kuto	8.77	6.24	207.44	443.36	132.44	35.38	5.04	7.22
Lafenwa	9.45	6.31	112.38	170.11	98.17	21.11	4.28	6.18
Obatonko	8.50	7.10	79.65	105.48	105.63	33.82	2.91	5.56

Data are in µg/g dry weights.

TABLE 3:

*Metal ion concentration in earthworms (*Libyodrilus violaceus*) from contaminated sites (waste dumps) in Abeokuta City, Nigeria.*

SAMPLE SITE	Zn	Pb	Mn	Cu	Cd	Cr
Adatan	84.77	84.86	171.54	33.15	7.55	13.10
Asero	57.64	51.12	80.73	20.49	5.31	10.79
Iberekodo	75.51	266.35	92.36	20.67	5.72	8.20
Ijaye	182.43	185.29	137.42	36.75	6.01	16.31
Imo	62.15	73.31	72.07	29.80	5.11	8.97
Isale-Igbein	84.72	54.03	71.51	24.26	4.35	9.68
Ita-Oshin	257.44	271.89	103.33	68.19	4.89	7.43
Kuto	190.23	381.72	122.84	30.38	5.94	8.41
Lafenwa	96.18	148.95	94.13	18.47	5.01	7.12
Obatonko	72.75	90.74	99.19	28.00	4.67	6.4

Data are in µg/g dry weights

DISCUSSION

Soil pH: Soil pH has being defined as the parameter most widely accepted as exerting a controlling influence on the availability of micro-nutrients to plants (Sanders 1982). The pH values of soil from the uncontaminated sites obtained from the Alabata campus of the University of Agriculture, Abeokuta, ranged from 5.90-6.74 which is normal for ordinary soil as reported by Banjoko & Sobulo (1990) for some Nigeria soils, especially forest and savannah soil with a range of 5.70 -6.50.

The pH for the soil samples from the contaminated sites ranged from a lowest value of 7.44 for the Imo dump site to a highest value of 10.10 for the Ita-Oshin and Iberekodo dump sites. It has also been reported by Sposito *et al.* (1982) that domino and greenfield composted sites have a pH value of 7.8 and 7.1 respectively, showing that waste contaminated soils have relatively high pH values which may affect plant growth.

Soil organic matter: The organic matter content of soils from both uncontaminated and contaminated sites are presented in Table 1 and 2. For the uncontaminated sites, the soil organic matter ranged from 3.25 -3.40 % while for the contaminated sites, it ranged from 5.79 % for the Isale-Igbehin site to 7.59 % for the Ita-Oshin dump site.

For West African soil, Ahm (1970) had reported that a good forest top soil contains between 3-4 % organic carbon, equivalent to 5-7 % obtained in this study and that waste contaminated soil tend to have relatively higher organic matter than non-waste contaminated soils. The low values obtained for the control sites may be due to the mono-cropping agricultural practice of the Alabata farmers

Level of heavy metals in soils and earthworms from control sites: The results of the levels of accumulated metals in soil and earthworms from uncontaminated sites are presented in Table 1. The levels showed slight variations in the metal concentrated and in nearly all cases the concentrations in the earthworms (*Libyodrilus violaceus*) being slightly higher than those of the soil samples as seen from the mean concentrations (μg/g) of the metals in the earthworm and soil respectively, e.g. Zn (6.74, 7.02), Pb(4.94,5.04), Mn (10.41, 10.54), Cu (1.60, 1.63), Cd (0.81, 0.806) and Cr (0.49, 0.55), the only exception being that of Cd in which there was no marked difference in its concentration in either of the samples. On a comparative basis the concentration of Mn was the highest (9.42-11.36 $\mu g g^{-1}$) for all the metals analysed while the lowest was Cd with a concentration range of 0.71 - 0.82 $\mu g g^{-1}$ in the soil samples.

This trend of a highest Mn concentration and a lowest Cd concentration obtained in this study, is similar to the reported work of Anderson & Laursen (1982) who worked on *Lumbricus terrestris* in uncontaminated soils. Furthermore, the mean concentration of the metals were also comparable to the range obtained in this study (Mn 11.71 -12.81 μg/g, Pb.5.21 -5.44 μg/g, Cd 0.77- 0.82 μg/g)

Levels of heavy metals in soil and earthworms from contaminated sites: In contrast to the earlier observation of earthworm metals concentration being higher than soil metal concentration we observed that in nearly all cases, the concentration of metals in the soil samples were higher than those of the earthworm samples, with the exception of Cd and Cr concentrations which had higher concentrations in earthworms than in soil samples. This observation may be due to the chemical changes which occur in the alientary tracts of earthworms and hence render various metals more available to plants. Also mineralization of dead earthworms releases accumulated heavy metals back to the environment (Morgan & Morgan 1993). This trend also conforms with the work of Weigmann (1991) who reported higher levels of metals in worms from more polluted sites and that irrespective of the degree of pollution, the ratio of metal concentration in earthworms to soil samples is less than unity with the exception of a few metals such as Cd. (For the metals Zn, Pb, Mn and Cu in this study, this ratio was less than unity while for Cd and Cr the ratio is higher than unity).

The percentage of each metal ion concentration in an earthworm to a soil sample was computed based on the mean concentrations of each metal accumulated in all dump sites and were found to range between 85 % to 91 %. These percentages are similar to those obtained, by Saciragic *et al.* (1990) for the metals Zn (81 %), Pb(79 %), Mn (79 %) Cu (88 %), Cd (90 %) and Cr (87 %) in earthworms.

Similarly, the Adatan dump accumulated the highest concentration of Mn (187.55 μg/g) and Cd (6.41 μg/g) for soil samples and for earthworm samples (Mn 171.54 μg/g, Cd 7.55 μg/g) while the highest concentration of Pb and Cr in both soil and earthworms were found at the Kuto and Ijaiye dumpsites respectively. Whereas the amount of metals accumulated within earthworm tissues is partly dependent on the absolute concentration of the metal within a given soil, it is strongly co-determined by physicochemical edaphic interactions, including factors such as pH, Ca concentration, organic matter content and cation exchange capacity (Ma *et al.* 1983, Morgan & Morgan 1993). The metals Mn, Cu and Zn are essential for plant growth and the availability of these metals is decreased as the soil pH is raised, (Morgan & Morgan 1988b). This is in line with the observation that the Ita-Oshin waste dump with a high pH of 10.10 also had the highest concentration of zinc and copper, while the Adatan dump with a pH of 9.02 had the highest Mn concentration.

Shuman (1979) reported that Zn, Mn, and Cr are higher in fine textured high organic matter soils than in coarse textured low cation exchange capacity soils, as observed in this study for the Ita-Oshin dump site with an organic matter of 7.59 % and the highest concentration of Zn and Cu, while the Adatan dump, also with an organic matter of 6.20 %, had the highest Mn level of 187.55μgg^{-1}.

The general trend of the metals concentrated, either in the soil or in the earthworms, show that Pb (381.72 - 443.36 μg/g) had the highest concentration, while Cd had the lowest (6.41 - 7.55 μg/g) and follow a general trend of Pb > Zn > Mn > Cu > Cr > Cd. Though this trend may not be exclusive, it follows to an extent the reported trend of Sposito (1992) on his work on trace metal in arid zone soils amended with sewage sludge of which the trend Mn > Zn > Pb > Cu > Cr > Cd was reported. The main variation observed lies with the lead concentration. However, it has also been reported (Gish & Christensen 1973, Ash & Lee 1980) that soils near to busy roads are more polluted with respect to lead (due to the combustion of petrol in motor vehicles which account for over 80 % of lead in air) and accounting for the high levels of Pb in soil and earthworms of their report. The difference in lead concentration (trend) as reported by Sposito (1992) has been explained by the fact that the study was carried out farther away from busy roads, while the waste dumps used in this study were located inside the town and near busy roads. This accounts for the Kuto market waste dump which is located by the road side in having the highest Pb concentration of 443.36 μg/g. Other dumps like the Iberekodo with a Pb concentration of 300.40 μg/g and Ita-Oshin (Pb concentration of 314.81 μg/g) are all located along the path of a busy highway. The lowest Pb concentration of 51.60 μg/g obtained for the Asero dump may also be as a result of its location which is far from a market place or indeed a busy network of roads.

In conclusion, this study confirms that the earthworm (*Lybyodrilus violaceus*) can serve as a bio-indicator in dump site environments and that the levels of metals concentrated in the earthworms as a ratio to that in the soil samples is less than unity with the exception of Cadmium and Chromium. Furthermore, the availability of metals in soils were influenced by the soil pH and the soil organic matter accounting for the variation in metal concentrations from one dump site to the other. Finally, highest concentration of lead was found at dump site located at roadsides.

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