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Full Length Research Paper

Evaluation of physicochemical properties and distribution of Pb, Cd, Cr and Ni in soils and growing plants around refuse dumpsites in Akure, Nigeria

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The physicochemical properties and distribution of Pb, Cd, Cr and Ni in soils and growing plants around refuse dumpsites in Akure, Southwestern Nigeria were evaluated to ascertain the impact of the wastes on these soil quality indices and edible plants. The soils close to the dumpsites were more acidic (pH, 5.50) compared with the soils away (25.0 m) from the sites. Also there were corresponding increases in the organic carbon and cation exchange capacities of the soil indicating measurable levels of biodegradability of the wastes. Pb, Cd, Cr and Ni have maximum concentrations of 23.00, 2.91, 9.00 and 24.00 mg/kg respectively in the soils. The amount of Cd determined in the soils was consistent with the critical level obtained for agricultural soils. Results obtained from the plant tissues analysed showed that 0.84 mg/kg Pb was detected in the root of *Zea mays*, while 0.25 mg/kg Ni was obtained in the root of *Sorghum vulgare. Talinum triangulare* and *Amaranthus crucantus* did not possess detectable levels of these metals. The present study has justified the need to continually assess the quality of soils, and the concentration of certain heavy/toxic metals in growing plants around refuse dumpsites.

Key words: Dumpsites, metal loads, toxic metals, biodegradable, harzadous.

INTRODUCTION

Solid waste management has become a serious environmental problem and is one of the major growing concerns for urban areas all over the world (Moqsud and Rahman, 2004). Despite the lower level of commercial, industrial and institutional activity in developing countries, their solid waste is not necessarily devoid of hazardous wastes (Barrera and Navarro, 1995) because the regulatory framework and enforcement system to segregate and separately collect such wastes are nearly non-existent or dysfunctional.

It is common therefore to find waste dumps on bare land (both cultivated and uncultivated). This makes the soil a major sink for various contaminants and toxicants including heavy metals such as Pb, Cd and Cr when they exceed natural background levels. Certain edible crops are also fund growing on these heaps of refuse and soils adjacent to the dumps. These plants which include vegetable are harvested by residents close to the sites and processed for consumption and sometimes sold in the open markets. Vegetables grown at contaminated sites could take up and accumulate metals at concentrations that are toxic (Weigert, 1991). Furthermore, the physicochemical characteristic of the receiving soil environment determines to a significant extent the level of metal retention, mobility and availability in the soil (Pierzynski, 1997).

It is pertinent to mention that studies on heavy metals concentration in waste dump sites have increased in the past decade (Ukpebor et al., 2003; Ideriah et al., 2006). However a major drawback in these assessments has been the lack of data on the levels of these metals in plants found at such sites. In the present study, the physicochemical properties and distribution of Pb, Cd, Cr and Ni in soils and plant tissues around major refuse dump sites in Akure, South Western Nigeria were determined.

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MATERIALS AND METHODS

Study area

The refuse dumpsites located at Igbatoro road, Idanre road, Oke-Ijebu, Oja Oshodi and Ijapo estate in Akure metropolis were chosen for the study. The wastes comprise household materials, hospitals disposables, metal scraps, polyethylene bags and paper, plant materials and debris amongst other substances.

Sample collection

Soils were collected with the aid of a stainless soil augar at the base (0), 12.5 and 25.0 m away from the various dumpsites. The soils were sampled at 0 - 15 and 15 – 30 cm depths respectively and then transferred into well labeled polyethylene bags for storage and laboratory analyses. Similarly, plants found growing on the refuse dump soils which include *Zea mays*, *Sorghum vulgare*, *Amaranthus cruentus*, *Lycopersium esculentum* and *Talinum triangulare* were uprooted, labeled and taken to the laboratory for the analysis of their partitioned parts (leaf, trunk and root).

Soil preparation and physicochemical analyses

In the laboratory, the soils were dried at ambient temperature (25°C), crushed in a porcelain mortar and sieved through a 2 mm (10 mesh) stainless sieve. Air dried < 2 mm samples were stored in polyethylene bags for subsequent analysis. The < 2 mm fraction was used for the determination of selected soil physicochemical properties. Soil pH was determined using H_2O according to Folson et al. (1981). The soil/solution ratio was 1:2. Soil organic carbon was determined by Walkey-Black rapid dichromate oxidation technique (Nelson and Sommers, 1982) with the use of correction factor 1.3 to account for the incomplete oxidation of organic compound. Cation exchange capacity (CEC) was estimated by summing the exchangeable cations (Na, K, Ca and Mg) (Jackson, 1960). Particle size analysis was achieved according to the method of Bouyoucos (1962). Available phosphorus was determined by the Bray and Kurtz (1945) method, while N was analysed using a micro-Kjeldahl method.

Determination of total heavy metals

1 g of the soil samples was introduced into digesting tubes following the addition of 10 ml concentrated HNO_3. The samples were placed in the digestor for 8 h at 96°C with intermittent stirring. Upon complete digestion, the samples were filtered into 100 ml volumetric flasks using Whatman no. 42 filter paper. The samples were made up to the 100 ml mark in the volumetric flask using distilled-deionised water. The concentrations of Pb, Cd, Cr and Ni in the supernatant solutions were determined using atomic absorption spectrophotometer (AAS), Bulk Scientific Model GVP 210. All samples were analysed in duplicates.

Determination of heavy metals in the plant tissues

The plant tissue samples were dried in a force-air oven at 60°C, ground to 20 mesh using a stainless steel Wiley mill, and digested using concentrated nitric and perchloric acids. The samples were diluted to 25 ml, filtered through Whatman no. 42 filter paper. The supernatant were made up to 50 ml mark in the volumetric flask and then analysed for Pb, Cd, Cr and Ni using atomic absorption spectrophotometer Bulk Scientific Model GVP 210. All analyses were done in duplicates.

RESULTS AND DISCUSSION

The results obtained from the entire study are shown in Tables 1 – 5, while Table 6 represents typical concentrations of heavy metals in non-polluted soils and plants (Mac Lean et al., 1997). The physicochemical properties of the soil (Table 1) indicate varied and measurable levels of the soil quality indices. Though the pH of the entire soils was acidic, lower pH values were observed at the base of the refuse dumps (0 m). This phenomenon suggests progressive decomposition of biodegradable substances leading to the release of hydrogen ions and favourable reducing soil conditions. This is also consistent with the higher amounts of organic carbon obtained at the base and 0 – 15 cm depth of the refuse dumps irrespective of the site or location. Mean organic carbon content at these points was 2.83%, while 2.34 and 1.94% were determined at 12.5 and 25.0 m away from the base of the dumpsites respectively (Table 4). Cation exchange capacity of the soils was moderately low with mean values ranging from 3.27 – 13.25 cmol/kg. However, calcium dominated the exchange sites. Higher values of CEC at the top soil and base of the refuse dumps are further evidences of mineralization or decomposition (Ideriah et al., 2006) of biodegradable matter since over 7% of soil CEC is contributed by humic substances which are sources of organic carbon (Oviasogie et al., 2003). The entire soil textural class was sandy loam with high amounts of sand and clay particles.

The distribution of Pb, Cd, Cr and Ni in the soils (Table 2) showed that there were detectable loads of these metals at four of the five locations evaluated. The highest amount of Pb (23.00 mg/kg) was recorded at the top soil at Oke-Ijebu dumpsites. High Cd amount of 2.91 mg/kg soil was detected at Igbatoro road while Cr (9.00 mg/kg) and Ni (24.10 mg/kg) were equally recorded at Oke-Ijebu. These metals were not uniformly distributed in the soil at the various dumpsites since their standard deviations were generally higher than their corresponding mean values (Table 5). It is pertinent to state that the maximum amount of Cd determined in the present study is significantly the critical level found in non-polluted agricultural soils (Table 6).

Similarly, the occurrence of these elements in the various plant tissues (dry matter) revealed that 0.84 mg/kg Pb (Table 3) was detected in the root of *Z. mays* at the base (0 m) of the refuse dump at Igbatoro road while Cd, Cr and Ni had 0.14, 0.08 and 0.25 mg/kg respectively. *S. vulgare* root collected from Idanre road dumpsite contained 0.34, 0.08, 0.04 and 0.28 mg/kg Pb, cd, Cr and Ni respectively. The other plant tissues (*T. triangulare* and *A. cruentus*) did not possess detectable levels of these metals. However, 0.03 mg/kg Ni was detected in the root of *L. esculentum.* These metals as determined in the plant tissues of the different plants are below the tissues implies that these edible plants can bioaccumulate these elements especially in favourable soil conditions when their concentration exceed natural

Table 1. Selected physicochemical properties of soil at the refuse dumpsites.

S/N	Location	Distance from base of the dump (m)	Soil depth (cm)	pH	Concentration (cmol/kg)					P (mg/kg)	Concentration (%)				
					Na	K	Ca	Mg	CEC		C	N	Clay	Silt	Sand
1	Igbatoro Road	0.0	0 – 15	5.85	0.98	2.09	4.66	1.40	8.77	45.30	2.57	0.40	16.4	11.6	73.00
2		0.0	15 – 30	5.69	0.91	1.95	1.20	0.63	4.69	15.98	1.94	0.21	19.2	10.2	70.60
3		12.5	0 – 15	7.26	0.92	1.50	4.12	0.76	7.30	18.54	2.23	0.26	15.6	8.40	76.00
4		12.5	15 – 30	6.50	0.67	0.80	1.43	0.53	3.43	15.2	0.84	0.10	21.8	7.20	76.00
5		25.0	0 – 15	6.57	0.64	0.90	2.93	0.65	5.20	12.07	1.65	0.22	26.0	5.10	68.90
6		25.0	15 – 30	6.55	0.42	0.62	1.14	0.49	2.67	10.94	0.74	0.13	27.10	4.90	68.00
7	Idanre Road	0.0	0 – 15	4.93	0.60	0.79	9.22	1.00	11.61	52.44	2.35	0.27	18.80	10.8	70.40
8		0.0	15 – 30	4.63	0.46	0.30	1.42	0.58	2.76	18.54	1.22	0.16	20.40	8.80	70.80
9		12.5	0 – 15	6.58	0.58	0.52	9.15	0.87	11.12	48.00	1.95	0.23	24.90	7.20	67.90
10		12.5	15 – 30	6.00	0.28	0.18	2.77	0.32	3.55	22.10	1.05	0.11	26.70	7.40	65.90
11		25.0	0 – 15	6.10	0.40	0.48	8.25	0.80	9.93	36.15	1.90	0.28	24.30	14.2	61.50
12		25.0	15 – 30	5.39	0.36	0.20	1.22	0.22	2.00	16.40	1.10	0.19	26.50	13.1	60.40
13	Oke – Ijebu	0.0	0 – 15	5.74	0.79	1.54	8.95	1.30	12.58	61.71	3.42	0.35	18.80	9.80	61.50
14		0.0	15 – 30	5.67	0.62	1.36	5.18	1.01	9.17	22.92	2.85	0.25	21.40	7.80	60.40
15		12.5	0 – 15	4.95	0.59	1.22	4.10	1.11	7.02	50.37	2.05	0.21	23.70	8.40	71.40
16		12.5	15 – 30	4.70	0.57	0.60	2.78	0.76	4.71	40.21	1.51	0.16	25.20	7.90	70.80
17		25.0	0 – 15	6.14	0.54	1.18	3.54	0.97	6.23	46.38	1.86	0.12	30.60	7.50	67.90
18		25.0	15 – 30	6.05	0.52	0.75	2.69	0.81	4.77	25.99	0.76	0.10	32.60	7.50	66.90
19	Oja Oshodi	0.0	0 – 15	6.20	0.16	1.69	14.78	1.96	18.59	103.70	3.16	0.14	21.30	12.6	61.90
20		0.0	15 – 30	6.00	0.85	1.21	10.11	1.59	13.76	82.66	1.70	0.17	24.50	11.2	60.20
21		12.5	0 – 15	6.21	1.10	1.52	10.74	1.34	14.7	101.10	3.04	0.28	24.20	11.8	66.10
22		12.5	15 – 30	6.05	0.70	1.10	8.20	0.96	10.96	74.48	1.42	0.12	25.40	10.2	64.30
23		25.0	0 – 15	6.21	0.95	1.25	6.48	1.10	9.78	96.52	2.50	0.22	26.80	10.6	64.00
24		25.0	15 – 30	5.77	0.60	0.95	2.50	0.08	4.85	412.10	1.20	0.10	27.00	8.40	64.40
25	Ijapo Estate	0.0	0 – 15	4.79	1.02	1.12	6.00	1.16	14.15	49.55	2.63	0.49	190.0	10.6	70.40
26		0.0	15 – 30	4.21	0.6	0.88	2.07	0.79	4.34	16.72	1.70	0.23	24.30	6.80	68.90
27		12.5	0 – 15	5.47	0.47	1.00	3.47	1.03	5.97	17.78	2.41	0.32	24.30	7.30	67.90
28		12.5	15 – 30	4.78	0.42	0.76	0.93	0.63	2.74	12.46	1.50	0.22	27.30	6.30	66.40
29		25.0	0 – 15	5.73	0.40	0.85	1.55	0.67	3.47	16.11	1.68	0.26	30.30	6.80	62.90
30		25.0	15 – 30	5.23	0.29	0.62	0.75	0.41	2.07	9.58	0.99	0.14	35.20	4.40	60.40

Table 2. Concentration (mg/kg) of Pb, Cd, Cr and Ni in the refuse dump soils.

Location	Distance from base of the dump (m)	Soil depth (cm)	Concentration (mg/kg)			
			Pb	Cd	Cr	Ni
Igbatoro Road	0.0	0 - 15	13.00	2.91	9.00	17.00
	0.0	15 - 30	5.00	0.85	3.42	4.80
	12.5	0 – 15	9.00	0.60	3.51	2.50
	12.5	15 – 30	4.00	ND	1.47	0.90
	25.0	0 – 15	6.00	ND	ND	ND
	25.0	15 – 30	2.00	ND	ND	ND

Table 2. Contd.

Idanre Road	0.0	0 – 15	15.00	2.20	3.50	9.50
	0.0	15 – 30	8.00	1.00	1.00	4.20
	12.5	0 – 15	12.00	ND	2.15	ND
	12.5	15 – 30	10.00	ND	0.80	ND
	25.0	0 – 15	8.00	ND	ND	ND
	25.0	15 – 30	3.00	ND	ND	ND
Oke – Ijebu	0.0	0 – 15	23.00	ND`	ND	24.00
	0.0	15 – 30	11.00	ND	6.25	8.00
	12.5	0 – 15	ND	ND	2.11	3.20
	12.5	15 – 30	ND	ND	ND	0.80
	25.0	0 – 15	ND	ND	ND	ND
	25.0	15 – 30	ND	ND	ND	ND
Oja Oshodi	0.0	0 – 15	18.00	ND	ND	ND
	0.0	15 – 30	6.00	ND	ND	ND
	12.5	0 – 15	3.00	ND	ND	ND
	12.5	15 – 30	1.00	ND	ND	ND
	25.0	0 – 15	ND	ND	ND	ND
	25.0	15 – 30	ND	ND	ND	ND
Ijapo Estate	0.0	0 – 15	ND	ND	ND	ND
	0.0	15 – 30	ND	ND	ND	ND
	12.5	0 – 15	ND	ND	ND	ND
	12.5	15 – 30	ND	ND	ND	ND
	25.0	0 – 15	ND	ND	ND	ND
	25.0	15 – 30	ND	ND	ND	ND

ND = Not detected.

Table 3. Concentration (mg/kg dry matter) of Pb, Cd, Cr and Ni in the various tissues of the plant.

Location/plant	Tissue	Distance from base of the dump (m)	Concentration (mg/kg)			
			Pb	Cd	Cr	Ni
Igbatoro Road – *Zea mays*	Leaf	0.0	13.00	2.91	9.00	17.00
	Trunk	0.0	5.00	0.85	3.42	4.80
	Root	12.5	9.00	0.60	3.51	2.50
	Leaf	12.5	4.00	ND	1.47	0.90
	Trunk	25.0	6.00	ND	ND	ND
	Root	25.0	2.00	ND	ND	ND
Idanre Road- *Sorghum vulgare*	Leaf	0.0	ND	ND	0.02	0.08
	Trunk	0.0	ND	ND	0.03	0.11
	Root	12.5	0.84	0.14	0.08	0.25
	Leaf	12.5	ND	ND	ND	ND
	Trunk	25.0	ND	ND	ND	ND
	Root	25.0	ND	ND	ND	0.10
Oke – Ijebu – *Amaranthus creantus*	Leaf	0.0	ND	ND`	0.01	0.01
	Trunk	0.0	ND	ND	0.01	0.18
	Root	12.5	0.34	0.08	0.04	0.28
	Leaf	12.5	ND	ND	ND	ND
	Trunk	25.0	ND	ND	ND	ND
	Root	25.0	ND	ND	ND	0.09

Table 3. Contd.

Oja Oshodi – *Lycypersium esculentum*	Leaf	0.0	ND	ND	ND	ND
	Trunk	0.0	ND	ND	ND	ND
	Root	12.5	ND	ND	ND	ND
	Leaf	12.5	ND	ND	ND	ND
	Trunk	25.0	ND	ND	ND	ND
	Root	25.0	ND	ND	ND	ND
Ijapo Estate – *Titanium triangulare*	Leaf	0.0	ND	ND	ND	ND
	Trunk	0.0	ND	ND	ND	ND
	Root	12.5	ND	ND	ND	0.03
	Leaf	12.5	ND	ND	ND	ND
	Trunk	25.0	ND	ND	ND	ND
	Root	25.0	ND	ND	ND	ND

ND = Not detected.

Table 4. Results of the statistical analysis of the physicochemical properties.

Distance from dump site (m)	Soil depth (cm)		pH	Concentration (cmol/kg)					P (mg/kg)	Concentration (%)				
				Na	K	Ca	Mg	CEC		C	N	Clay	Silt	Sand
0	0 – 15	Mean	5.50	0.96	1.70	9.05	1.54	13.25	62.54	2.83	0.33	18.86	11.08	70.26
		S.D	0.61	0.35	0.51	3.90	0.39	1.82	23.76	0.45	0.13	1.73	1.06	2.56
		CV%	11.13	49.30	34.92	44.74	30.29	30.63	38.02	5.78	40.26	9.20	9.60	3.64
0	15 – 30	Mean	5.24	0.69	1.14	4.20	0.99	6.94	31.36	1.88	0.20	21.96	8.96	69.08
		S.D	0.77	0.19	0.61	3.88	0.41	4.50	28.80	0.60	0.04	2.36	1.77	2.79
		CV%	14.78	27.18	53.40	92.40	44.61	64.72	91.83	31.94	18.86	10.75	19.80	4.04
12.5	0 – 15	Mean	6.09	0.73	1.15	6.32	1.03	9.22	47.16	2.34	0.26	22.54	8.62	68.74
		S.D	0.91	0.27	0.41	3.37	0.22	3.63	33.92	0.43	0.04	3.90	1.87	4.40
		CV%	14.96	36.32	35.90	53.36	21.52	39.37	79.93	18.45	16.54	17.32	21.68	6.40
12.5		Mean	5.61	0.53	0.69	3.22	0.64	5.08	32.89	1.26	0.14	25.38	7.80	66.72
		S.D	0.82	0.18	0.34	2.90	0.24	3.36	25.64	0.30	0.05	2.14	1.46	2.06
		CV%	14.53	33.44	48.93	90.01	37.58	66.24	77.96	23.94	34.64	8.44	18.73	3.09
25.0	15 - 30	Mean	6.15	0.59	0.93	4.55	0.84	6.92	41.45	1.92	0.22	27.60	8.84	54.56
		S.D	0.30	0.23	0.31	2.74	0.19	2.85	33.88	0.34	0.06	2.70	3.60	21.46
		CV%	14.87	38.79	32.84	60.25	23.19	41.23	81.74	17.90	28.02	10.00	40.70	39.33

Table 4. contd.

25.0	15 – 30	Mean	5.80	0.44	0.63	1.66	0.55	3.27	21.00	0.96	0.13	29.62	7.66	62.70
		S.D	0.53	0.12	0.28	0.87	0.26	1.43	13.44	0.20	0.04	3.91	1.51	3.48
		CV%	9.12	28.26	43.75	52.68	46.88	43.65	64.01	21.30	28.04	13.21	16.92	5.55

background or acceptable limits. These may pose related health risk problems when the plants are consumed.

Conclusion

The evaluation of the soil physicochemical properties in this study showed that the refuse dumped at the various sites had detectable and measurable changes on the investigated soil qualities. The refuse had measurable load of biodegradable or decomposable matter and also contributed to increased amounts of the metals investigated especially Pb and Cd. This should be of serious environmental concern since both metals are notable toxicants in soil-water-biota ecosystem. There is need therefore to carry out periodic assessment of the levels of these metals in soils and plants around refuse dumpsites.

REFERENCES

Barrera R, Navarro JC (1995). Public service deficiencies and Aedes aegypti breeding sites in Venezuella. Bulletin of PAHO 29 (3): 193-205

Bouyoucos GJ (1962). Improved hydrometer method for making particle size analysis of soils. Agron. J. 54: 464-465.

Bray RH, Kurtz LT (1945). Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59: 39-45.

Folson BL, Lee CR, Bates DJ (1981). Influence of disposal environment on availability and plant uptake of heavy metals in dredged material. Tech. Rep. E1-81-12 U.S. Army, Washington D.C.

Ideriah TJK, Omuaru VOT, Adiukwu PU (2006). Soil quality around a solid waste dumpsite in Port Harcourt, Nigeria. Afr. J. Ecol. 44: 388-395.

Jackson ML (1960). Soil Chemistry Analysis.Prentice-Hall New York.

Mac Lean KS, Robinson EA, Schroeder WH (1997). Bioavailable Cd, Pb and Zn in wet and dry deposition. The science of the total Environment. 63: 161-173.

Moqsud MA, Rahman MH (2004). Biochemical quality of compost from kitchen garbage in Bangladesh. Environmental Informaities Archives 2: 635-640.

Nelson DW, Sommers LE (1982). Total carbon, organic carbon and organic matter. In methods of soil analysis, Pagenet A. Z al (ed). Part 2, 2nd ed. ASA, SSSA, Madison W, pp. 539-579.

Oviasogie PO, Aisueni NO, Oviasogie FE (2003). Humic substances in the environment: Characteristics and characterization–a review–Benin Sci. Digest 1: 53-67.

Pierzynski GM (1997). Strategies for remediating trace elements contaminated sites. In: Remediation of soils contaminated with metals. Iskandar A, Adriano DG (eds). Science Reviews, Northwood, U.K. pp. 67-84.

Ukpebor EE, Oviasogie PO, Unuigbe CA (2003). The Distribution of Mn, Zn, Cu, Cr, Ni and Pb around two major refuse dumpsites in Benin City, Nigeria. Pak. J. Sci. Indies. Kes. 46 (6): 418-423.

Weigert P (1991). Metal loads of food of vegetable origin including mushrooms. In: metals and their compounds in the environment: Occurrence, analysis and biological relevance merian E, (ed) Weinheim: VCH 458-468.