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Characteristics of Soils and Crops' Uptake of Metals in Municipal Waste Dump Sites in Nigeria

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ABSTRACT In Nigeria, soils in municipal waste dump sites commonly serve as fertile ground for the cultivation of a variety of fruits and leafy vegetables and the soils are also used as 'compost' by farmers without regards for the probable health hazards the heavy metal contents of such soils may pose. It was this concern that informed the characterization of soils and crop plants in selected dump sites in Nigeria with particular reference to the heavy metal content, and the assessment of the potential of the crops to mine and deploy heavy metals to their edible portion. The result showed that soils in municipal waste dump sites are higher in heavy metals: Zn, 63.2-102.11; Co, 36.0-132.14; Cu, 36.5-72.99; Pb, 63.58-418.58 and Cd, 17.00-47.06 µg/g and that crops growing in the dump sites bio-accumulate considerably higher metal contents than those in normal agricultural soils. It was also observed that crops differ in their ability to up-take metals. Therefore to minimize heavy metal load of soils in dump sites, sorting of wastes at source, provision of an enabling statutory regulation on waste management, and the enforcement of the compliance of such statutory regulation to be the responsibility of a unit of the Health Department, in the Local Government Council, are suggested. Those wastes that pose greater health hazards should be properly land-filled to reduce environmental pollution and /or soil degradation.

INTRODUCTION

Solid waste handling and disposal is a major environmental problem in many urban centers in Nigeria. In a few cases, the municipal wastes, mostly garbage and wastes from food processing plants are incinerated or simply dumped. City dwellers have long contended that any form of waste, with proper compositing and processing, can be made into fertilizers that farmers will gladly pay for. However, the modern farmer is not willing to accept this position since he is an astute businessman who has to be convinced that the risk and cost involved are small enough to benefit him (Carlson, 1976). Municipal refuse may contain paper, food wastes, metals, glass, ceramic and ashes. Recently, many studies have shown that heavy metals - metals and metalloids with an atomic density > 6g /cm^3 – from these wastes can accumulate and persist in soils at environmentally hazardous levels (Carlson, 1976; Alloway, 1996). Purves (1973), in a study of trace – element content of municipal wastes, reported wide ranges of B, 3.8 to 103 ppm; Pb, 44 to 352 ppm; Cu, 25 to 215 ppm; Ni, 7 to 21 ppm; and Zn, 400 to 655 ppm. In spite of the foregoing, most abandoned waste dump sites in many towns and villages in Nigeria attract people as fertile ground for cultivating varieties of crops. The cultivated plants take up the metals either as mobile ions present in the soil solution through the roots (Davies, 1983) or through foliar adsorption (Chapel, 1986). The uptake of the metals by crops results in the bioaccumulation of these elements in plant tissues. This is known to be influenced by the metal species, plant species and plant species and plant part (Juste and Mench, 1992). Indeed, it has been reported that plants grown on soils possessing enhanced metal concentration due to pollution have increased heavy metal ion content (Alloway and Davies, 1971; Grant and Dobbs, 1977). If the consumption of these metals through plant sources is not carefully regulated, it may lead to accumulation in man with attendant health hazards. Yet man is the target of numerous other chemical influences in the environment. The objective of this study, therefore, was to provide more information on the potentials of crops growing in dump sites to mine and bio-accumulate heavy metals. Such information is expected to guide in formulating an appropriate land use and management policy for such unique ecosystems.

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MATERIALS AND METHODS

The study was conducted at two locations: the Obafemi Awolowo University, Ile-Ife refuse dump site, representing a typical urban centre, and a rural community (Bode – Osi) refuse dump site, with both sites located within Osun State, Nigeria. The municipal garbage in both places is generally unsorted and sometimes burnt in the open. Over the years, the refuse dump areas had expanded in areal extent and it is a common practice by the site workers to cultivate a variety of crops in some of the temporarily abandoned sections of the dump site. Also, farmers from nearby areas often come to collect "soils" from the dump site to be used as compost on their farms. This is because it is generally believed that the native fertility of the soil from waste dump sites is high. The areas to be sampled in each location were divided into four quadrants, each 5 m^2 and five crop samples were collected from each quadrant in a diagonal basis following the method of Nounamo et al. (2002). In Ife, okro (*Abelmoschus esculentus*) – a fruit vegetable, and *Talinum triangulia* (water – leaf) – a leafy vegetable, were sampled from each quadrant. Samples were collected in quadrants from the dump site and those from a control site located up-slope of the dump site. The *T. triangulia* plants were carefully uprooted and bagged while the succulent/edible okro fruits were harvested and similarly bagged. Three composite samples of the top soil (0 - 15 cm) were taken from each of the quadrants. Each composite soil sample comprised 9 core soil samples (taken also in diagonal basis) bulked and homogenized before sub-sampling for laboratory analysis. In Bode – Osi, the same sampling procedures for soil and plant were applied except that cocoyam (*Xanthosoma* sp) and pawpaw (*Carica papaya*) were sampled. The corm and fresh succulent leaves of cocoyam which are the commonly edible portions were sampled, while fruits and leaves of pawpaw were similarly sampled. Pawpaw leaves are commonly used to feed giant land snail (*Archachatina maginata*), a terrestrial mollusk, eaten as delicacy. In the laboratory, the plant samples were placed under running tap water to wash off soil particles from the leaves, fruits and roots. Stainless steel knife was used to cut the plant samples into different parts. The plant parts were dried in an oven maintained at 80^0C, and then pulverized to fine powder using a laboratory stainless grinder. Ground plant samples collected in labeled polythene bags were placed in a desiccator. From each plant sample, 2g was accurately weighed into clean platinum crucibles, ashed at 450^0C and then cooled to room temperature in a desiccator. The ash was completely dissolved in 5ml of 20% HCI and the solution was made up to volume in a 100ml volumetric flask. Analysis of the digest for the heavy metal content was carried out using the atomic absorption spectrophotometer. The soil samples were air – dried, crushed and passed through a 2mm sieve. The fine (less – than – 2mm) earth fraction was retained for analysis. 1g of the soil sample was digested in a 1:1 mixture of concentrated nitric acid and perchloric acid by heating the mixture plus sample in a water bath in a fume cupboard. The solution was heated to dryness while the residue was re-dissolved in 5ml of 2.0M HCI (Alloway, 1996). The soil pH was determined using the glass electrode pH meter method of Peech (1965).

RESULTS AND DISCUSSION

Heavy Metal Content of the Soils: The total heavy metal content of the 0 to 15 cm top soil from both sites is indicated in Tables 1 and 2. The investigation of the total content of heavy metals in the soils was restricted to the top 15 cm since previous studies showed that surface soils

Table 1: The pH and heavy metal content (µg/g) of soils in Bode – Osi (rural community)

Soil parameter	*Dump site*	*Control site*	*Range in soils**
pH	6.2	6.4	-
Zn	63.20	41.98	1-900
Fe	925.93	722.2	-
Co	36.00	16.74	0.5- 65
Cu	36.5	28.30	2- 250
Pb	63.58	19.86	2- 300
Cd	17.00	5.70	0.01- 2.0

* *Source:* Alloway (1996)

Table 2: The pH and heavy metal content (µg/g) of soils in OAU, Ife (municipal)

Soil parameter	*Dump site*	*Control site*
pH	5.9	6.1
Zn	102.11	26.7
Fe	2527.34	1658.7
Co	132.14	15.11
Cu	72.99	36.60
Pb	418.58	18.7
Cd	47.06	36.13

are better indicators of metallic burdens (Nyangababo and Hamya, 1986). The results show that soils from the control sites in both locations do not differ significantly in their content of total metals studied except for total Fe and Zn. Smyth and Montgomery (1962) grouped soils in Ife and Bode – Osi areas as Iwo Association i.e. soils that developed in coarse textured granite and gneiss member of the Pre - Cambrian basement complex rocks. It was observed that soils from the refuse dump sites in rural settlement (Bode – Osi) were lower in their content of heavy metals compared to those sited in the city (OAU) Ife. This is thought to be as a result of the differences in the living standards, consumption patterns and level of industrial development between cities/towns and rural communities. Modern and highly developed communities such as the Obafemi Awolowo Univer-sity, Ile – Ife generate wastes that contain less leaves and food remnants but more paper, rag, plastic/polythene, tins and metals, bottles, glasses, industrial and/or laboratory wastes/ chemicals, and a variety of miscellaneous materials (Ademoroti, 1996). In order to minimize those wastes that may increase the heavy metal load of the dump site soils while the wastes decompose or corrode, careful sorting at source should be encouraged among the general public in towns and cities particularly in Nigeria. The current statutory regulation on waste management in Nigeria focuses on industrial and/or corporate institutions, and compliance is enforced by the Federal and the State Environmental Protection Agencies. There is also the need for an enabling statutory regulation and means of enforcing compliance, to ensure proper waste management/handling by the general public. To ensure enforcement and compliance, a unit of the Health Department of the Local Government Council could be assigned this responsibility. Those wastes that pose greater health hazards need to be properly land – filled so as to reduce the incidence of environmental pollution and/or degradation.

Heavy Metal Content of the Crops: The heavy metal content of the plants sampled from Bode – Osi is shown in Table 3. The data presented were restricted to the edible parts of the crop plants. Generally, crops harvested in soils of the refuse dump site presented higher levels of the metals when compared to those crops from the control sites (Tables 3 and 5). This is interpreted to mean that if the level of these metals in soils is significantly increased, the test crops have the potential of showing increased uptake of the metals. Alloway and Davies (1971) and Grant and Dobbs (1977) reported that plant grown on soils possessing enhanced metal concentrations have increased heavy metal ion content. The uptake of metal ions has been shown to be influenced by the metal species and plant parts (Juste and Mench, 1992). On the basis of this, the transfer ratio of the metals by each plant species was computed using the method of Oyedele et al. (1995). The transfer ratio as computed indicates the level of the metal in the edible plant as a fraction of the soil total. From the ratios obtained, it was observed that the uptake of each metal differs from one plant to the other. For instance, while the Zn transfer ratio in cocoyam (*Xanthosoma* sp) corm and leaves is 0.40, it is 0.17 for pawpaw (*Carica papaya*) fruits and leaves (Table 4), 0.44 for water – leaf (*Talinum triangulia*) and 0.18 for okro (*Abelmoschus esculentus*) fruits (Table 6). Furthermore, this ratio is higher for some crops grown in the dump site than for those in the control site. Examples are Fe and Zn for cocoyam and water – leaf, while in others the reverse is the case as it affects Zn in pawpaw and okro (Tables 4 and 6). This shows that some other soil factors in addition to the soil content of the metals also influence uptake. Such factors need to be further investigated. Of particular concern is the transfer ratio of Cu and Pb into the edible

Table 3: Heavy metal content (μg/g) of the crop plant tissue from Bode-Osi

Metal type	*Dump site*				*Control site*			
	Cocoyam		*Pawpaw*		*Cocoyam*		*Pawpaw*	
	Corm	*Leaves*	*Fruits*	*Leaves*	*Corm*	*Leaves*	*Fruits*	*Leaves*
Zn	15.93	9.34	4.95	5.49	3.08	4.75	3.30	4.40
Fe	149.9	211.64	169.19	70.55	52.9	38.88	121.42	67.70
Co	10.29	8.80	0.63	3.00	10.10	8.12	0.25	0.30
Cu	9.20	3.85	5.55	8.25	6.50	3.6	4.30	3.30
Pb	3.00	13.99	9.70	17.03	1.60	3.97	2.14	4.70
Cd	0.50	1.20	0.36	2.00	0.12	0.13	0.05	0.66

parts of pawpaw and water – leaf. The ratios obtained for pawpaw were particularly high. In Bode – Osi (a rural setting), ratios of 0.37 (Cu) and 0.42 (Pb) from the dump site, and 0.27 (Cu) and 0.34 (Pb) for the control (Table 4) were observed. For water – leaf, similarly high values were obtained. From the dump site, transfer ratios were 0.71 (Cu) and 0.28 (Pb) and for the control, 0.53 (Cu) and 0.44 (Pb). These show the potential of these crops, pawpaw and water – leaf in particular, and other test crops in general, to mine from the soil and deploy these metals to their edible parts. With increasing metal load in soils where these crops are grown, there is a greater tendency for their bio-accumulation. An enabling act advising and enforcing the non – use of refuse dump sites for farming is desirable. This will keep in check possible excessive consumption of these metals along with crops harvested from such areas. If the suggested regulation on waste management by the general public is put in place and its compliance is enforced, the fear of heavy metal contamination of crop in refuse dump sites would have been allayed, since wastes suspected to be sources of heavy metals would be properly land – filled.

Table 4: Transfer ratio of the heavy metals in Cocoyam and Pawpaw (Bode -Osi)

Metal	*Dump site*		*Control site*	
Type	*Cocoyam*	*Pawpaw*	*Cocoyam*	*Pawpaw*
Zn	0.40	0.17	0.19	0.03
Fe	0.39	0.26	0.13	0.26
Co	0.25	0.10	0.49	0.03
Cu	0.36	0.37	0.36	0.37
Pb	0.27	0.42	0.28	0.34
Cd	0.10	0.14	0.04	0.12

Socio-economic Impact of the Study on Man and the Environment: From the study, it was established that soils in municipal waste dump sites are higher in heavy metals and that crops growing in the dump sites bio-accumulate considerably higher metal contents than those in normal agricultural soils. It was also observed that crops differ in their ability to up-take metals. Therefore to minimize heavy metal load of soils in dump sites following waste decomposition and /or corrosion, sorting of wastes at source among the general public in towns and cities was suggested in addition to the provision of an enabling statutory regulation on waste management in the country. The enforcement and compliance of such statutory regulation should be the responsibility of a unit of the Health Department of the Local Government Council. An enabling act advising and enforcing the non – use of refuse dump sites for farming is also desirable. Those wastes that pose greater health hazards should be properly land-filled to reduce environmental pollution and /or soil degradation.

Table 6: Transfer ratio of the heavy metals in water leaf and Okro O.A.U, Ife

Metal	*Dump site*		*Control site*	
	Water-leaf	*Okro*	*Water-leaf*	*Okro*
Zn	0.44	0.18	0.82	0.46
Fe	0.05	0.01	0.03	0.02
Co	0.08	0.03	0.04	0.12
Cu	0.71	0.30	0.53	0.51
Pb	0.28	0.01	0.44	0.08
Cd	0.06	0.002	0.005	0.003

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Table 5: Heavy metal content (μg/g) of the crop plant tissue from O.A.U, Ife

Metal	*Dump site*			*Control site*		
	Water-leaf Okro			*Water-leaf Okro*		
	Leaves	*Roots*	*Fruits*	*Leaves*	*Roots*	*Fruits*
Zn	19.23	24.73	18.38	11.42	10.48	12.09
Fe	44.09	88.18	35.27	24.00	19.91	26.33
Co	8.82	2.79	4.41	0.09	0.50	1.80
Cu	29.20	22.85	21.90	11.00	8.25	18.75
Pb	83.92	34.97	3.40	3.99	4.20	1.50
Cd	1.03	2.01	0.08	ND	0..03	0.02

ND = Not detected

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