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Short Communication

Urban agricultural production: heavy metal contamination of *Amaranthus cruentus* L. grown on domestic refuse landfill soils in Ibadan, Nigeria.

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Abstract: Cultivation of various pot herbs (vegetables) in urban and peri urban centers in Nigeria is a common practice. Many of these cultivated sites serve as waste disposal grounds and the decayed and composted materials portend high soil fertility, hence the common practice of cultivating vegetables on such sites. Lead (Pb) and Cadmium (Cd) concentrations in soils of four Ibadan landfill sites and a control site were determined. The accumulation of these heavy metals in the tissue of *Amaranthus cruentus* L. was also determined. Analysis of the landfill soil samples showed a range of 110.5 to 678.5ppm for lead and 2.01 to 3.20ppm for cadmium. Different quantities of these metals were recorded in the tissues of *Amaranthus cruentus* L plants grown on these soils in black polythene bags. Metal accumulation in the plant tissues was found to be proportionate to the level of soil concentrations for Pb while Cd level in the crop tissues exceeded that in the soil. Growth and yield of the crop were significantly reduced due to Pb and Cd contamination of the soil. It is concluded that Ibadan landfills are unsafe for *Amaranthus cruentus* cultivation. The concentrations of the heavy metals found in the tissues of the vegetable grown on the landfills were much higher than the optimum allowed by FAO/WHO for dietary consumption.

Key words: Cadmium, heavy metal pollutants, Lead, plant tissues, vegetable production.

الإنتاج الزراعي المعاصر: تلوث القطيفة الأرجوانية المزروعة في مكبات النفايات المنزلية بالعناصر الثقيلة في عبدان، نيجيريا

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ملخص: زراعة الأعشاب الخضرية في الأصص تعتبر من الممارسات الشائعة في مراكز المدن في نيجيريا. العديد من مواقع الزراعة تستخدم كمكبات نفايات والتي تطرح فيها الفضلات على الأرض والتي تعطي قيمة سمادية عالية للتربة بعد تحلل هذه الفضلات ولهذا تعتبر زراعة الخضروات في المواقع من الممارسات الزراعية الشائعة. تم تحليل وتقدير تركيز كل من عنصري الرصاص والكادميوم في التربة وذلك في أربع مواقع لمكبات النفايات ومقارنة ذلك بالتربة فقط (كمعاملة شاهد). كما وتم تحليل تراكيز هذه العناصر الثقيلة في أنسجة القطيفة الأرجوانية. أظهرت نتائج تحليل عينات التربة من مواقع مكبات النفايات الأربعة أن تركيز الرصاص في التربة يتراوح من ١١٠,٥-٦٧٨,٥ جزء بالمليون بينما تراوح تركيز الكادميوم من ٢,٠١-٣,٢٠ جزء بالمليون. كما سجلت تركيز هذه العناصر في أنسجة القطيفة الأرجوانية المزروعة في هذه الترب في أكياس من البولي اثيلين مستويات متفاوتة، حيث كانت مستويات تراكيز هذه العناصر في أنسجة النبات تتناسب مع تلك الموجود في التربة. انخفض الإنتاج بشكل معنوي نتيجة تلوث التربة بعنصري الرصاص والكادميوم. يستنتج من هذه النتائج أن مكبات نفايات عبدان غير آمنة الاستخدام لزراعة القطيفة الأرجوانية او الخضروات والتي يتراكم بها العناصر الثقيلة بمستويات تتجاوز الموصى به من منظمة الصحة العالمية ومنظمة الأغذية والزراعة الدولية وذلك لإغراض الاستهلاك الغذائي.

كلمات مفتاحية: الكاديوم، التلوث بالعناصر الثقيلة، الرصاص، الأنسجة النباتية، إنتاج الخضروات

Introduction

Sanitary landfill operations involve depositing solid wastes in natural or man-made depressions or trenches, compacting them into smallest practical volume and covering them up with compacted earth or other materials (Faniran, 1994). This system of waste disposal suffers a great setback due to lack of adequate equipment, men and capital to remove the refuse and more often than not, sites are quickly taken over by urban development. Thus, most Nigerian cities and towns are notorious for displaying mountains of undisposed solid wastes in illegal dumps. Most of these dumps are being used as farm sites because of the apparent decay and composted wastes accumulating around such sites. Short term duration crops, such as vegetables (local pot herbs) are grown especially when such dumps are located near perennial streams, without considering the health implications.

Although the physical, chemical and biological properties of soils improve following the addition of organic wastes (Paglia and Vittori Antisari, 1993; Jackson et al. 2000) a limiting factor to their continual and generalized agronomic utilization is the problem of heavy metal accumulation (Johnson et al. 1999). Heavy metals accumulate in the food chain and may become toxic to humans. Ogunyemi et al. (2003) reported hazardous concentrations of Pb and Cd in leafy vegetables grown in high density area in Ibadan, Nigeria, and that the contents are traceable to aerial deposition and foliar adsorption. Several reports are available on various sources of heavy metal pollution (Grosser et al. 1994; Rayment, 1995) and their effect on some vegetable crops (Khan and Khan 1983; Narwal et al.1990; Jinadasa et al. 1997). However, very few works have documented heavy metal contamination of crops via landfills (Glen and Riggle 1991; Boon and Soltanpour 1992) and none exists in relation to *Amaranthus cruentus* which is one of the most popular leafy vegetables in Nigeria. The relative importance of lead (Pb) and cadmium (Cd) in relation to other heavy metals regarded as environmental pollutants have been stressed (Alloway 1990).

This report highlights the lead and cadmium status in soils from four landfills in Ibadan and accumulation of the heavy metals in the tissues of *Amaranthus cruentus* grown on the soils.

Material and Methods

Four designated landfill sites [Aperin, Ring Road, Lapite and Awotan] and a control (no refuse forest land) site in Ibadan, Southwestern Nigeria, were used in this study in 1999. Ibadan (70 24’N; 30 54’E; 234 m above sea level) is located in the rainforest-savanna transition zone with a rainfall:evaporation ratio of about 1.0 (Awodoyin and Ogunyemi, 2003). Two of the landfills (Aperin and Ring Road) were established in the early sixties but are now abandoned while the other two sites were established in the late nineties and are currently in use. The control site is an area of well-drained land under established forest trees within the Faculty of Agriculture and Forestry, University of Ibadan. Soil samples (50 kg) were collected at each of the sites from the top 10 cm depth. About 1.5 kg of bulked sample from each site was air dried for four days, ground using a ceramic mortar and pestle to homogenize the sample. After large and irregular particles, including fragments of glass, metal and plastic, had been removed, the samples were sieved through a 2 mm sieve. They were then digested using the nitric/perchloric acid digestion procedure, as described by Odu et al. (1986), and the heavy metals (Pb and Cd) determined using atomic absorption spectrophotometry (AAS) (Bulk scientific 200A model). Soil pH was determined by electrometric method using 1:1 sample/water ratio.

Seeds of *Amaranthus cruentus* (NH84/44) collected from the Genetic Resources Unit of the National Horticultural Research Institute, Ibadan, were planted in black polythene bags (18.5cm in length and

7.5cm in diameter) filled with 1.6kg from each of the five sites. The bags were arranged on raised iron benches and were watered twice daily. The study was repeated two times using a completely randomized design with 16 and 18 replications in the first and second trials respectively. The plants were thinned to one plant per bag at two weeks after planting (WAP). At vegetative maturity (6 WAP) the plants were assessed for growth parameters by taking the stem height from soil surface (using meter rule), stem diameter at 1cm above soil level (using a pair caliper) and count of number of leaves.

The plants were harvested before the emergence of the inflorescence at 7 WAP, washed thoroughly under tap water and rinsed in distilled water. They were drained and separated into leaves, stems and roots. The plant materials were then oven-dried for 48 hours at 70^oC and weighed on Gallenkamp top loading balance to determine their dry weight.

The various plant parts were then bulked together for each of the five treatments (refuse sites and control) and ground in a laboratory mill. Sub-samples were digested in 2:1 v/v of conc. HNO_3 in a microwave oven, diluted into appropriate concentrated volume with ultra pure water and analyzed with respect to Pb and Cd using electrothermal AAS (Bulk Scientific 200A Model). Growth and yield parameters were subjected to analysis of variance and the least significant differences and coefficient of variability were also determined.

Results

Heavy metal levels in landfill soils

Aperin site had the highest Pb concentrations while Lapite site had the highest Cd level. The control site recorded the lowest levels of Pb and Cd. Soil pH of all landfills was between neutral and slightly alkaline while the control soil showed a slightly acidic level (Table 1).

Table 1. pH and total heavy metal (Pb and Cd) concentrations in soils (0-10cm) of Ibadan landfill sites.

		Metal Concentration (ppm)	
Sites	**Soil pH**	**Pb**	Cd
Aperin	7.4	678.5	3.07
Ring Road	7.3	451.0	2.58
Awotan	7.4	245.0	2.01
Lapite	7.6	110.5	3.20
Control	6.2	15.5	0.23

Heavy metal levels in *Amaranthus cruentus.*

Analyses of heavy metal concentrations in the leaves, stems and roots showed that Pb concentration was in the order of roots>leaves>stems. Values obtained in the leaf, which is the part of *Amaranthus* plant demanded for consumption, were in the range of 8.96 ppm for plants grown on control soil and 13.01 ppm for plants grown on Ring Road soil (Table 2). Cadmium levels in the various plant tissues did not follow a specific trend. Nevertheless, the concentrations of Cd in the leaves and roots were higher than concentrations in the stems except in the stem of plants grown on Aperin soil in the first trial (Table 2). The concentration in the leaves was lowest (2.03ppm) in plants grown on Aperin soil and highest (2.72 ppm) in plants grown on Awotan soils.

Table 2. Pb and Cd concentration (ppm) in tissues of *Amaranthus cruentus* grown on soils from Ibadan landfill sites.

Sites	Pb			Cd		
	Leaves	Stems	Roots	Leaves	Stems	Roots
			1st Trial			
Aperin	N.A.	15.02	77.95	N.A.	3.21	2.19
Ring Road	N.A.	11.04	38.18	N.A.	1.70	2.49
Awotan	N.A.	26.52	29.41	N.A.	1.96	2.24
Lapite	N.A.	9.23	22.44	N.A.	1.56	2.11
Control	N.A.	8.39	17.08	N.A.	1.89	2.27
			2nd Trial			
Aperin	10.16	8.29	44.67	2.03	1.66	2.34
Ring Road	13.01	7.41	24.65	2.68	1.69	1.71
Awotan	11.65	5.65	23.01	2.72	2.12	2.30
Lapite	9.76	7.08	21.05	2.23	1.91	2.74
Control	8.96	N.D.	15.40	2.27	2.17	2.31

N.A. = Not available (leaves were eaten accidentally by stray goats before harvest).
N.D. = Not detectable (value lower than the sensitivity limit of spectrophotometer).

Performance of *A. cruentus* on landfill soils.

The growth analysis of the *A. cruentus* plants in the various soil samples 6 WAP is shown in Table 3. The control plants had the best height values of 20.7 cm and 18.3 cm in the first and second trials respectively. The plants grown on Aperin soil had lowest height values of 11.4 cm and 13.9 cm in the first and second trials respectively. Also, the stem diameters of the control plants were significantly higher in the two trials than any other plant. The sites were not significantly different with regards to the number of leaves found on the plants among the sites. Plants grown on control soil had the highest number of leaves of 13.17 and 13.50 for the first and second trials respectively (Table 3).

Table 3. Growth of *Amaranthus cruentus* on soils of Ibadan landfills 6 weeks after planting.

Sites	Stem height (cm)		Basal Stem Diam. (cm)		No. of leaves	
	1st Trial	2nd Trial	1st Trial	2nd Trial	1st Trial	2nd Trial
Aperin	11.4	13.9	0.49	0.54	12.60	12.88
Ring Road	16.0	16.7	0.58	0.64	12.69	13.13
Awotan	18.8	14.5	0.62	0.58	12.67	13.10
Lapite	14.5	15.7	0.56	0.58	12.69	13.38
Control	20.7	18.3	0.68	0.66	13.17	13.50
LSD (P=0.05)	1.33	1.83	0.02	0.07	NS	NS
CV (%)	10.98	11.34	4.74	11.90	8.34	8.91

NS=Not significant CV=coefficient of variability
Each figure represents the mean of 16 and 8 replicates for 1st and 2nd Trials respectively.

Dry matter yields in the leaves, stems and roots of the control plants were also significantly higher than the yields of other plants grown on landfill soils (Table 4). Plants grown on Aperin soil had the lowest dry matter yield. The five sites were significantly different in the two trials with regards to dry matter distribution in the leaves, stems and roots.

Table 4. Dry matter yield of *Amaranthus cruentus* grown on soils of Ibadan landfill sites seven weeks after planting.

	Dry matter yield (g/plant)					
	Leaves		**Stems**		**Roots**	
Sites	**1st Trial**	**2nd Trial**	**1st Trial**	**2nd Trial**	**1st Trial**	**2nd Trial**
Aperin	N.A.	1.09	0.79	0.90	0.84	0.77
Ring Road	N.A.	1.35	1.19	1.37	1.11	1.22
Awotan	N.A.	1.19	1.46	0.92	1.42	0.93
Lapite	N.A.	1.29	1.12	1.07	1.10	1.08
Control	N.A.	1.50	1.83	1.55	1.84	1.48
LSD (P=0.05)	-	0.03	0.24	0.35	0.25	0.30
CV (%)	-	18.79	25.72	29.00	26.75	27.00

N.A. = Not available (leaves were eaten accidentally by stray goats before harvest).

Discussion

The results of the soil analyses showed that all the landfill sites were polluted when compared to the level of heavy metals obtained in the control soil. DOE/NWC (1981) reported an upper limit of 250 ppm for Pb and 3.0 ppm for Cd while Spittler and Feder (1979) reported that concentrations greater than 500 mg/kg total Pb in soils were considered hazardous to humans if ingested. FAO/WHO (1978) recommended maximum tolerable daily Pb intake of 7 µg/kg-body weight, and WHO/UNEP (1976) recommended daily Cd intake of 57.14 – 71.43 µg/kg-body weight. In the present study Pb concentration of 678. ppm and 451 ppm found in Aperin and Ring Road landfill soils respectively demonstrate a hazardous level of lead pollution in the soils. Awotan and Lapite are younger landfills and had relatively low Pb contamination (Awotan 245 ppm, Lapite 110.5 ppm). These results may suggest that Pb builds up in landfill soils over years of persistent dumping and presence of lead-containing refuse. The implication of this build up is that Pb contamination in the older and even abandoned landfills may continue to increase and the health hazards of vegetables grown on such sites continue to accumulate. The control site had heavy metal contamination that was within the normal range for agricultural soils (Sanchez-Camazano et al. 1994). Soil pH values were similar to that reported by Sommers et al. (1987) on sludge.

Lead concentrations in the plant tissues had a linear and significant increase with the Pb concentration in the soils (Table 2). This is consistent with the result of Nicklow et al. (1983) who worked on six vegetable crops grown on soils that contained three ranges of lead. The roots recorded the highest Pb value, which may be attributed to the low rate of translocation of Pb from the roots to the shoots (Chappelka et al. 1991), and adsorption, especially of lead-contaminated soil particles, to the roots, so much that washing with only water may not adequately remove the particles. The level of Cd in the plant tissues that is higher than that in the soil agreed with the work of Turner (1973). The high Pb content recorded in the control plants might be due to proximity of the experimental garden to a car park where vehicular emission may cause some aerial deposition. Also, the plants could receive deposition of fine grained air-borne Pb from surrounding distant roads. Hana and Al-Basam (1983) reported that 25% of Pb emitted by vehicle is coarse grained and deposited within the vicinity, while the remaining 75% is fine grained and may be air-borne over a long distance.

Plant growth and dry matter yield reductions observed in the contaminated crops (Tables 3 and 4) are in line with those reported on corn (Narval et al. 1990), and tomato and eggplant (Khan and Khan 1983).

The reduction of growth could have been due to metal inhibition of protein synthesis in the roots (Foy et al. 1978) and inhibition of root respiration (Billet et al. 1974).

Conclusion

The study revealed that the landfills in Ibadan are contaminated with Pb and Cd. The accumulation of these metals reduced the growth and yield of *A. cruentus* grown on soils from the polluted sites. The bioaccumulation of cadmium in the human body, especially in the liver and kidney, is implicated in hypertension and cardiovascular diseases while that of Pb interferes with functioning of mitochondria, thereby impairing respiration, and also cause, constipation, anaemia, swelling of the brain, paralysis and eventual death (Chang, 1992). Further research is necessary to ascertain the actual amount of heavy metals translocated into the plant tissues from landfills by eliminating possible aerial deposition on the plant. Also heavy metals in different forms differ in mobility and bioavailability and consequently have different potentials for environmental contamination (Petruzzell 1989). Therefore, it may be important to know the distribution of each metal in various chemical forms than just total metal content.

References

Alloway, B. J. 1990. Cadmium. In: B. J. Alloway (ed.) Heavy metals in soils. John Wiley and Sons, New York pp. 100-124.

Awodoyin, R. O. and O. Sola. 2003. Sicklepod in improved fallow management: Distribution in natural habitat, diversity and phenology. Muarik bulletin 6: 35-43.

Billet, J. E., D. E. Koeppe and R. J. Miller. 1974. Sorption of heavy metals cations by corn mitochondria and the effects on electron and energy transfer reaction. Physiol. 30: 226-230.

Boon, B. Y. and P. N. Soltanpour. 1992. Lead, Cadmium and Zinc contamination of Aspen garden soils and vegetation. J. Environ. Quality 21: 82-86.

Chang, L. W. 1992. The concept of direct and indirect neuro toxicity and concept of toxic metal/essential element interactions as a common biomechanism underlying metal toxicity, In The vulnerable brain and environment risk, Vol. 2, Toxins in Food. Plenum Press, New York. pp 61.

Chappelka, A. H., J. S. Kush, G. B. Runion, S. Meier and W. D. Kelly 1991. Effects of soil applied lead on seedling growth and ectomycorrhizal colonization of Loblolly Pine. Environ. Pollu. 72: 307-316.

DOE/NWC 1981. Report of the sub-committee on the disposal of sewage sludge to land. Standing Tech. Committee Report No. 2. Dept. of Environment, London.

Faniran, A. 1994. Solid waste Management. In: Filani, M. O., F. O. Akintola, C. O. Ikporupo (eds.), pp.231-243. Ibadan Region. Dept. of Geography, University of Ibadan.

FAO/WHO 1978 List of maximum levels recommended for contaminants by joint FAO/WHO codex. Alimentaries commission 3rd series Rome, FAO/WHO. CAL/FAL 4-1978.

Foy, C. D., R. L. Chaney and M. C. White. 1978. The physiology of metal toxicity in plants. Ann Rev. Plant Physiol. 29: 511-566.

Glenn, J. and D. Riggle. 1991. The state of garbage in America. Biocycle 31(4): 34-38.

Grosser, J., R. V. Hagelgam, T. Heutschel and M. Prester. 1994. Heavy metals in the stream sediments. A gold mining area near Los Andes, Southern Colombia, S. A. Ambio 23(2): 146-149.

Hana, A. A. K. and K. S. Al-Bassam. 1983. Water, Air and Soil Pollution. 19:3

Jackson, M. J., M. A. Line, S. Wilson and S. J. Heterington. 2000. Application of composted pulp and paper mill sludge to a young pine plantation. J. Environ. Qual. 29: 407-414.

Jinadasa, K. P. B. N., P. J. Milham, C. C. Hawkins, P. S. Cornish, P. A. Williams, C. J. Kaldor and J. P. Conroy. 1997. Survey of Cadmium levels in vegetables and soils of Greater Sydney, Australia. J. Environ. 26: 924-933.

Johnson, C. A., H. Moench and S. Bradenberg. 1999. Assessing the long term of the landfill fraction of sorted denudation wastes. J. Environ. Qual. 28: 1061-1067.

Khan, S. and N. Nazer Khan. 1983. Influence of Lead and Cadmium on the growth and nutrient concentration of tomato eggplant. Plant and Soil 74: 387-394.

Narwal, R. P., M. Singh and D. J. Dahiya. 1990. Effect of Cadmium on plant growth and heavy metal contents of corn (Zea mays). Crop Res. 3(1): 13-20.

Nicklow, C. W., P. H. Comas-Haezebrouck and W. A. Feder. 1983. Influence of varying soil Lead levels on Lead uptake of leafy and root vegetables. J. Am. Soc. Hortic. Sci. 108: 193-195.

Odu, C. T. I., O. Babalola, E. J. Udo, A. O. Ogunkunle, T. A. Bakare and G. O. Adeoye. 1986. Laboratory manual for agronomic studies in soils, plants and microbiology. Dept of Agronomy, Univ. of Ibadan. 83pp.

Paglia M. and L. Vittori Antisari. 1993. Influence of waste organic matter on soil micro- and macro-structure. Bioresource Technol. 43: 205-213.

Petruzzell, G. 1989. Recycling waste in Agric: Heavy Metals bioavailability. Agric. Ecosy. Environ. 27: 493-503.

Rayment, G. E. 1995. Sources of Cadmium in agriculture products. Workshop on Cadmium levels in food and agricultural products, Camberra, Australia. 1-2 May 1995. National Food Authority of Australia.

Sanchez-Camazano, M., M. J. Sanchez-Martin and L.E. Lorenzo. 1994. The content and distribution of Cadmium in soils as influenced by the soil properties. The Sci. Total Environ. 156: 183-190.

Sommers, L. E., V. V. Volks, P. M. Giordana, W. E. Sopper and R. Bastian. 1987. Effects of soil properties on accumulation of trace elements by crops. In: A.L. Page (ed.) Land application of sewage sludge – food chain implication. Lewis, Chelsea, M.L. pp.5-24.

Spittler, T. M. and W. A. Feder. 1979. A study of soil contamination and plant Lead uptake in Boston urban gardens. Comm. Soil Sci. Plant Anal. 10: 1195-1210.

Sola, O., O. O. Bamgbose and R. O. Awodoyin. 2003. Heavy metal contamination of some leafy vegetables growing within Ibadan metropolis, South-western Nigeria. Tropical Agricultural Research and Extension 6: 71-76.

Turner, M. A. 1973. Effect of Cadmium treatment on Cadmium and Zinc uptake by selected vegetable species. J. Environ. Qual. 2: 118-119.

WHO/UNEP 1976. WHO-1977 UNEP/WHO, Geneva. Environmental Health criteria 3: Lead.