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Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria

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ABSTRACT

The level of heavy metals (As, Cd, Co, Cu, Fe, Ni, Pb and Zn) in soils, plant leaves and crops from farmlands around dumpsites were determined using digestion and Atomic Absorption Spectrophotometer methods (AAS). Soil and plant samples were collected from farms around the dump sites (sites A and B) and other samples from an area where there were no dump sites, which served as control. The concentration of metals in soil samples in mg/kg from site 'A' determined were As(0.66), Cd(0.48), Co(0.58), Cu(0.91), Fe(0.63), Ni(0.31), Pb(0.49), and Zn(0.38) while that of site 'B' were As(0.55), Cd(0.84), Co(0.63), Cu(0.82), Fe(0.64), Ni(0.42), Pb(0.53), and Zn(0.40). The metal concentrations in plant leaves and crops showed high level of Co(0.33) and Fe(0.32) in roselle leaves; Cu(0.71) and As(0.37) in groundnut; Cu(0.48) and As(0.28) in maize grains; As(0.36) and Co(0.32) in spinach leaves; and Cu(0.36) and Co(0.32) mg/kg in okro. The values of all the metals analyzed for samples from dumpsites were higher than those from the control site suggesting possible mobility of metals from dumpsites to farmlands through leaching and runoffs, but were below values recommended by the World Health Organization (WHO), but there is need for further monitoring since the inhabitants depend on these areas for farming.

Key words: Heavy metals, soil, crops, dumpsite, farmland.

INTRODUCTION

Environmental pollution by heavy metals, even if it is at low concentrations and the long- term cumulative health effects that go with it, is of major health concerns all over the world. For instance bioaccumulation of lead (Pb) in the human body interferes with proper functioning of the mitochondria thereby impairing respiration as well as causing constipation, swelling of the brain, paralysis and could eventually lead to death [1].

Heavy metals occur naturally in the ecosystem with large variations in concentrations. In modern times, anthropogenic sources of heavy metals, i.e. pollutions from the activities of humans, have introduced some of these heavy metals into the ecosystem. The presence of heavy metals in the environment is of great ecological significance due to their toxicity at certain concentrations, translocation through food chains and non-biodegradability which is responsible for their accumulation in the biosphere [2]. Heavy metals like iron, tin, copper, manganese and vanadium occur naturally in the environment and could serve as plant nutrients depending on their concentrations. Mercury, lead, cadmium, silver, chromium and many others that are indirectly distributed as a result of human activities could be very toxic even at low concentrations. These metals are non-biodegradable and can undergo global ecological circles [2].

The use of dumpsites as farm land is a common practice in urban and sub-urban centers in Nigeria because of the fact that decayed and composted wastes enhance soil fertility [3]. These wastes often contain heavy metals in various forms and at different contamination levels. Some heavy metals like As, Cd, Hg and Pb are particularly hazardous to plants, animals and humans [4]. Municipal waste contains such heavy metals as As, Cd, Cu, Fe, Hg, Mn, Pb, Ni and Zn which end up in the sink when they are leached out from the dumpsites. Soil is a vital resource for sustaining two human needs of quality food supply and quality environment. Plants grown on a land polluted with municipal, domestic or a land polluted with municipal, domestic or industrial wastes can absorb heavy metals inform of mobile ions present in the soil through their roots or through foliar absorption. These absorbed metals get bioacumulated in the roots, stems, fruits, grains and leaves of plants [5].

The present study is aimed at assessing the pollution status of the farm lands around the dumpsites in Lafia, the extent to which the crop plants grown on these farmlands were exposed to heavy metals, and hence, the safety levels of the plant leaves and crops produced for human consumption.

MATERIALS AND METHODS

Collection of samples

The sampling sites are two main dumpsites, one located at some few kilometers from the State Polytechnic Campus, site A ; the second location is the dumpsite along Shandam road, site B and control samples were taken from few kilometers from College of Agriculture Campus, Lafia, where there was no dumpsite or any form of human activities that could generate wastes. Five sampling spots at a distance of 50 m from each other were mapped out for soil samples collection within the sampling sites, using clean stainless steel shovel from 0-15 cm depth. A soil sample to serve as control was also collected. The collected dried soil samples were thoroughly mixed in clean plastic bucket to obtain a representative sample, crushed and sieved with 2 mm mesh before stored in labeled polythene bags prior to analysis. Five edible plant samples – maize grains (*Zea mays*), roselle (*Hibiscus sabdarifa*), okro fruits (*Abelmuschus esculentus*), spinach leaves (*Amaranthus dubius*) and groundnut seeds (*Arachis hypogea*), grown within the vicinity of the refuse dumpsites were randomly collected with a stainless steel trowel and knife. Plant samples of the same species were also collected as control from farms around the control site. Plant leaves were rinsed with distilled water and dried to a constant weight in an oven at a temperature of 70^0C. Other samples (fruits, grains and seeds) were similarly dried to constant weight. The dried samples were pulverized using an agate pestle mortar and kept in polythene bags.

Sample treatment

Two grammes (2.0 g) of prepared soil sample was digested with 15.0 ml nitric acid, 20.0 ml perchloric acid and 15.0 ml hydrofluoric acid and placed on a hot plate for 3h. On cooling, the digest was filtered into a 100.0 ml volumetric flask and made up to the mark with distilled water [6].Similarly, dry powdered crop samples were digested with 60% $HClO_4$, concentrated HNO_3 and H_2SO_4 [1]. Blanks were prepared to check for background contamination by the reagents used.

Metal analysis

The digest samples were analyzed for heavy metals (As, Cd, Co, Cu, Fe, Ni, Pb and Zn) using atomic absorption spectrophotometer (AAS VGB 210 System) in ATBU, Bauchi, Nigeria. The instrument setting and operational conditions were done in accordance with the manufacturers' specifications.

RESULTS AND DISCUSSION

Table1 shows the heavy metal concentrations in soil and plants grown around two dumpsites in Lafia metropolis, Nasarawa State, Nigeria. The concentrations of metals determined are less than one (<1.0 mg/kg) in the soil and plant samples. The concentrations obtained for the metals are 0.66, 0.48, 0.58, 0.91, 0.63, 0.31, 0.49 and 0.38 mg/kg in soil sample from site A and 0.55, 0.84, 0.63, 0.82, 0.64, 0.42, 0.53 and 0.40 mg/kg in soil sample from site B, for As, Cd, Co, Cu, Fe, Ni, Pb and Zn respectively .These values obtained for both sites are all far below the values reported for these metals in soil samples from farmlands in the vicinity of the refuse dump site of Obafemi Awolowo University, Ile-Ife, Nigeria which were investigated during two major seasons of Nigeria [1]. The values are also below the elemental concentrations of a typical soil except for Cd (0.48 and 0.84 mg/kg) which are higher compared to 0.35 mg/kg [7].

Table 1: Metal concentrations in soils and plants (mg/kg)

Location	Sample	As	Cd	Co	Cu	Fe	Ni	Pb	Zn
Site A	Soil	0.66	0.48	0.58	0.91	0.63	0.31	0.49	0.38
	Roselle (leaves)	0.26	0.22	0.33	0.30	0.32	0.01	0.02	0.04
	Groundnut (Grains)	0.37	0.21	0.13	0.71	0.31	0.02	0.10	0.02
	Maize (Grains)	0.28	0.11	0.05	0.48	0.20	0.01	0.03	0.03
	Spinach (Leaves)	0.36	0.21	0.32	0.28	0.24	0.02	0.07	0.03
	Okro (fruits)	0.17	0.12	0.28	0.36	0.23	0.03	0.02	0.04
Site B	Soil	0.55	0.84	0.63	0.82	0.64	0.42	0.53	0.40
	Roselle (leaves)	0.10	0.31	0.34	0.49	0.30	0.02	0.05	0.02
	Groundnut (Grains)	0.23	0.26	0.22	0.07	0.28	ND	0.12	0.03
	Maize (Grains)	0.02	0.14	0.07	0.24	0.34	0.01	0.23	0.05
	Spinach (Leaves)	0.08	0.43	0.36	0.33	0.23	0.02	0.03	0.04
	Okro (fruits)	0.03	0.27	0.26	0.47	0.28	0.03	0.20	0.03
Control	Soil	0.23	0.32	0.33	0.34	0.27	0.21	0.10	0.30
	Roselle (leaves)	0.05	0.03	0.09	0.06	0.07	0.01	ND	0.01
	Groundnut (Grains)	0.01	0.06	0.03	0.08	0.03	ND	0.03	0.04
	Maize (Grains)	ND	0.04	0.01	0.03	ND	ND	0.02	0.01
	Spinach (Leaves)	0.03	0.02	0.05	0.07	0.02	0.02	ND	0.06
	Okro (fruits)	ND	ND	0.02	0.01	ND	0.04	0.01	ND

ND = Not detected

The values of all metals determined were below the tolerable limits recommended by World Health Organization (WHO) and European Union (EU) except for lead (0.49 and 0.53 mg/kg) in soil samples from both site A and site B respectively which were above the standard maxima of 0.01 mg/kg [8]. On the other hand, the concentration of lead was lower than EU upper limit of 300 mg/kg [9] and was at lower concentration than the maximum tolerable levels proposed for agricultural soil, 90-300 mg/kg [10]. However, concentration of lead in the soil which could be as a result of its sources from automobile exhaust fumes as well as dry cell batteries, sewage effluents, runoff of wastes and atmospheric depositions could cause its bioaccumulation in plant via uptake from the soil and eventual entry into the food chain. Lead is known for lead poisoning in humans as well as chronic neurological disorders especially in featuses and children. The sequence of occurrence is Cu > Cd > As > Fe > Co > Pd > Zn > Ni in soil samples from site A and Cd > Cu > Fe > Co > As > Pb > Ni > Zn in soil sample from site B.

Table1 also shows the level of heavy metals (As, Cd, Co, Cu, Fe, Ni, Pb and Zn) in plant leaves (roselle and spinach leaves) and okro fruits, all vegetables as well as other crops, maize grains and groundnut. The concentrations of these metals in roselle leaves, spinach leaves and okro fruits from sites A and B are all below those obtained for these plants from the control site. This is also evident in the case of the soil which could be attributed to the mobility of metals from dumpsites to farmlands through leaching and runoffs. The results showed that for metal levels in vegetables the highest level of Cu (0.49 mg/kg) in roselle leaves from site B and the lowest level of Ni (0.01 mg/kg) in roselle leaves from site A were recorded. The levels of As, and Co in roselle, spinach and okro from both sites A and B are above those of the control samples and are below the values of these metals recorded in leaves of *Manihot esculenta, Xanthosoma mafaffa* and *Talinum triangulare* grown within the vicinity of the refuse dump site of Obafemi Awolowo University, Ile-Ife, Nigeria [1]. However, the levels of Cd, Cu, Fe, Ni, Pb and Zn in roselle, spinach and okro studied were below the levels recommended by WHO/FAO and NAFDAC for metals in foods and vegetables and are also within the normal range of metals in plants (Table 2).

Table 2: **FAO/WHO guidelines for Metals in foods and Vegetables**

Metals (mg/kg)	WHO/FAO	NAFDAC	EC/CODEX	Normal Range in Plant
Cd	1	_	0.2	<2.4
Cu	30	20	0.3	2.5
Pb	2	2	0.3	0.50-30
Zn	60	50	<50	20-100
Fe	48	_	_	400-500
Ni	_	_	_	0.02-50

The results also showed the highest level of Cu (0.71mg/kg) and the lowest value of Ni (0.01 mg/kg) for the other crops, groundnut and maize grains respectively. The levels of As and Co in maize grains and groundnut recorded in this research are far below those reported for maize grains and groundnut from farmlands in the vicinity of the refuse dump site of Obafemi Awolowo University, Ile-Ife, Nigeria and Azara derelict baryte mining area in Nigeria respectively [1, 11]. The concentrations of all the other metals in these crops (groundnut and maize grains) analyzed are all above those obtained for the control site but were however, within the normal range of metals in plants [12]. The variations of the various heavy metals concentration in the plants were observed to be according to plant species which agrees with the report of the work on seasonal variations in Heavy Metal Concentrations in soil and some selected crops at landfill in Nigeria [1].

The heavy metal levels in the control soil were within the background level range for farming. Among all metals determined for sites A, copper (Cu) had the highest concentration of 0.91 mg/kg and 0.71 mg/kg in soil and plants (groundnut) respectively while nickel has the lowest concentration of 0.31 mg/kg and 0.01 mg/kg in soil and plants (maize grains) respectively. For samples from site B, cadmium (Cd) had the highest concentration of 0.84 mg/kg soil and copper (Cu) with 0.49 mg/kg in plants (roselle leaves), while zinc (Zn) has the lowest concentration of 0.40 mg/kg in soil and nickel (Ni) with 0.01mg/kg in plants (maize grains). The high levels of Copper in soil were also reported by various researchers [13, 14]. The higher concentration of metals around dump sites is due to wastes, which originates mostly from domestic and industrial activities which generate wastes and refuse that are sources of these heavy metals [2]. This is what leads to higher concentrations of metals in farmlands around the dump site due to the mobility of metals from dumpsites to farmlands through leaching and runoffs and the eventual uptake by plants and crops resulting in bioaccumulation and transfer to food chain.

Table 3: Transfer factor (tf) of heavy metals from soil to plants

Location	Samples	Metals							
		As	Cd	Co	Cu	Fe	Ni	Pb	Zn
Site A	Roselle (leaves)	0.40	0.46	0.47	0.32	0.52	0.04	0.05	0.11
	Groundnut (Grains)	0.56	0.44	0.22	0.78	0.50	0.05	0.21	0.08
	Maize (Grains)	0.42	0.23	0.10	0.53	0.33	0.04	0.06	0.09
	Spinach (Leaves)	0.54	0.43	0.55	0.31	0.37	0.08	0.14	0.08
	Okro (fruits)	0.26	0.25	0.48	0.30	0.36	0.09	0.04	0.09
Site B	Roselle (leaves)	0.18	0.36	0.54	0.59	0.47	0.05	0.09	0.05
	Groundnut (Grains)	0.42	0.30	0.35	0.08	0.44	ND	0.23	0.08
	Maize (Grains)	0.04	0.16	0.11	0.29	0.53	0.02	0.43	0.13
	Spinach (Leaves)	0.14	0.51	0.57	0.39	0.36	0.05	0.06	0.10
	Okro (fruits)	0.05	0.32	0.41	0.56	0.53	0.07	0.38	0.08
Control	Roselle (leaves)	0.04	0.19	0.09	0.24	0.11	ND	0.30	0.13
	Groundnut (Grains)	ND	0.13	0.03	0.09	ND	ND	0.20	0.03
	Maize (Grains)	ND	ND	0.06	0.03	ND	0.19	0.10	ND
	Spinach (Leaves)	0.03	0.02	0.05	0.07	0.02	0.02	ND	0.06
	Okro (fruits)	ND	ND	0.02	0.01	ND	0.04	0.01	ND

ND = NOT DETECTED

Table 3: shows the transfer factor (tf) of heavy metals from the soil to plants, which is the ratio of the concentration of metals in plants to the total concentration in the soil. The tf for the same metal in the farm lands were significantly different from those for control and according to the type of plants and crops. Cu, Co and As had high transfer factors which are 0.78, 0.57, and 0.56 respectively. The highest tf value obtained for roselle were Co(0.57) and Fe(0.52); groundnut Cu(0.78) and As(0.56); maize Cu(0.53) and Pd(0.43); spinach Co(0.57) and As(0.54); and okro

Cu(0.56) and Fe(0.53). The study gave a generalized transfer coefficient in the soil-plant system as: As, Co, Fe, Cd, Pd, Cu and Zn (0.01-0.8) and (0.01-0.1). The tf of all elements are within normal range in plant. Plants are known to take up and accumulate trace metals from contaminated soil [15], hence detection in plant leaves and crop samples was not surprising. Although the levels of these metals are within normal range for plants, however continual consumption could lead to accumulation and adverse health implication particularly for Pd, As, and Cd [16]. Also the variation in values obtained for these heavy metals in the soil and crop plant samples as against those from control sites is an indication of their mobility from the dumpsites to the farmlands around particularly through leaching and runoffs. This is in agreement with the report of Oluyemi *et al.*, 2008.

CONCLUSION

The concentration of heavy metals determined were in sequence Cu > As > Fe > Co > Pb > Cd > Zn > Ni and Cd > Cu > Fe > Co > As > Pb > Ni > Zn for soil from sites A and B respectively and they are all found in plants grown around the dump sites studied with copper (Cu) having the highest concentration in the plant sample, while nickel had lower concentration. Although these metals were found in soils and plant around the dump sites, it is worthy of note that they were below WHO permissive levels. However lead was found to be above the WHO standard maxima of 0.01mg/kg though is still safe i.e. the values are below the tolerable levels of 90-300mg/kg recommended by EC, 1986, but in very high concentrations plants may pose danger to consumers of plants around these areas. Also continuous usage of these farmlands for growing crops could lead to bioaccumulation of these metals and their eventual entry into the food chain with the associated health risks being manifested.

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