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Full Length Research Paper

Environment, health and risk assessment: a case study of the use of an abandoned municipal waste dump site for agricultural purposes

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The study was carried out on abandoned municipal waste dump site which has been converted to agricultural land. Three profile pits each of 100 cm depth were dug along a toposequence on the land. The profile pit P1 was dug on the crest while P2 and P3 were on the middle and down slope (valley bottom), respectively. Soil samples were collected at 10 cm interval from each profile and cassava (*Mannihot esculenta* Cranz) and cocoyam (*Colocesia esculenta*) were selected at random and harvested from the whole farm. Heavy metal content (Pb, Ni, Cd, Cu and Zn) of soils and the crops (roots and leaves) were determined. The level of Pb was found to be highest in both soils and food crops with the total mean concentration of 133.74±10.60 mg/kg in soil. The Pb level was 83.02±27.84 and 105.37±45.37 mg/kg in the roots and leaves of cocoyam, respectively, and 76.6±19.94 and 111.51±17.78 mg/kg in the roots and leaves of cassava, respectively. Cadmium had the least mean concentration in both soil and food crops with 2.08±0.12 mg/kg in soil and 4.10 in the roots and leaves of both cassava and cocoyam. When the individual profile pits were examined, no regular variation of heavy metal was observed but there was tendency of accumulation of heavy metal in soils of down slope P3 because it had the highest mean concentration of all the heavy metal except for Zn. Correlation analysis was used to examine the dependency of the heavy metals upon themselves, Cu and Zn had positive correlation with Pb, Cd with Zn, and Zn with Cu.

Key words: Abandoned waste site, heavy metal, food crop.

INTRODUCTION

The question of whether vegetable, fruits and food crops cultivated in polluted soils are safe for human consumption is of great interest to public especially now that the environmental quality of food productions are of major concern (Chiroma et al., 2001). The soil has traditionally been an important medium for waste disposal (Nyles and Ray, 1999; Anikwe and Nwobodo, 2002). Hence the role of soil in environmental health cannot be over emphasized because human being and other living organism depend greatly on the quality of food produced from these soils.

Municipal waste dump soils are always high in organic matter (Anikwe and Nwobodo, 2001). The soil fertility, physical and chemical properties can be improved at these municipal wastes to some extent. Studies revealed that the chemical composition of the municipal waste include organic combustible and non-combustible materials (Isirimah, 2002; Alloway and Ayres, 1997). But excessive input of unsorted municipal waste may likely lead to changes in soil physical and chemical characteristics (Nyles and Ray, 1999). The increasing toxicity urban waste due to rapid industrialization make the use of abandoned municipal waste dump hazardous for agricultural purpose.

However, it is a common practice of small farmers to

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make use of abandoned waste dump site for crop production due to lack of resources to acquire fertilizers for getting meaningful harvest (Ano, 1991, 1994). Chaney (1980) and Smith et al. (1996) cautioned on the use of waste in crop production since it may be possible for heavy metal from waste to accumulate in soils and therefore enter the food chain and cause health hazard. In recent times, heavy metals have been reported in vegetable grown in abandoned polluted areas (Jeanne and Siddle, 1991; Ihenyen, 1991; Ndiokwere, 1984). At the biochemical level, the toxic effects caused by excess concentration of heavy metals include competition for sites with essential metabolites, replacement of essential ion, reactions with –SH groups, damage to cell membranes and reactions with the phosphate groups (Alloway and Ayres, 1997).

Therefore, this work focuses on the environment, health and risk assessment of using abandoned waste dump site for food crop production by determining the level of total heavy metal content in the soils and harvested food crops from the site.

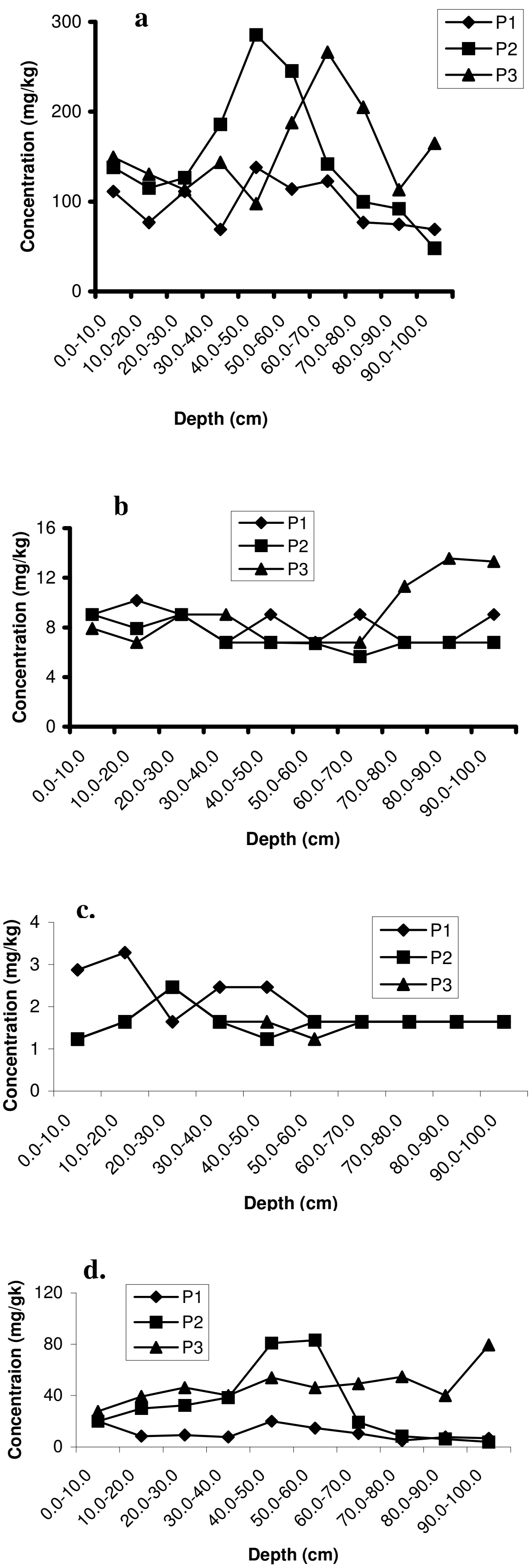
MATERIALS AND METHODS

The study was carried out on an abandoned municipal waste dump site in urban Umuahia, Capital of Abia State in Southern Nigerian. The dumpsite has now been converted to an agricultural land. Crops like cassava (*Mannihot esculenta* Cranz) and cocoyam (*Colocesia esculenta*) were being grown on the land.

Three profile pits with depth of 100 cm were dug along a toposequence. The first profile pits (P1) was dug at the crest, the second pit (P2) was at the middle slope and the third profile pit (P3) was at the valley bottom. The soils were sampled from top at 10 cm intervals; 0 – 10 cm, 10 – 20 cm, etc. The collected soil samples were placed in labeled plastic bags. Cassava and cocoyam plants (three each) were randomly selected from the whole farm, which were then harvested. The edible part of the crops: leaves (cocoyam and cassava) and the cassava root and cocoyam tubers were carefully removed and placed inside labeled plastic bags.

The soil samples were air-dried and passed through 2 mm sieve. The roots and tubers were sliced and sun-dried and were then placed in labeled envelopes. The leaves were also sun-dried and placed in labeled envelopes. Then all the plant samples were oven-dried at 105℃ and milled after drying. Thereafter, 10 g of the 2 mm sieve soil samples were further homogenized. 1 g of the homogenized soil sample was weighed into a beaker (100 ml) and 10 ml nitric acid was added. This was heated until dryness. Then, 10 ml $HN0_3$ and 3 ml $HClO_4$ were added and the solution was heated until fuming. The sample solution was obtained by processing the residue with 4 ml of hot 6 M HCl, which was then filtered and diluted with water to 50 ml (MAFF, 1981). The Pb, Ni, Cd, Cu and Zn in these solutions were determined by Atomic Absorption spectrophotometer (AAS) of UNICAM 919 model.

2 g of milled plant samples were weighed into 50 ml flask. 1 ml of 60% perchloric acid, 5 ml concentrated nitric acid and 1 ml concentrated sulphuric acid (1:5:1) were added and digested at moderate heat of about 50 – 80℃ with hot plate until white fumes were evolved. Heat was strongly applied for a few minutes to drive off most of the perchloric acid and it was allowed to cool. The digest was filtered with Whatman No.1 filter paper and diluted to 50 ml volume. A blank solution was also prepared (Allen et al., 1979). The sample digests were analyzed for Pb, Ni and Cd with AAS equipment UNICAM 919 model.



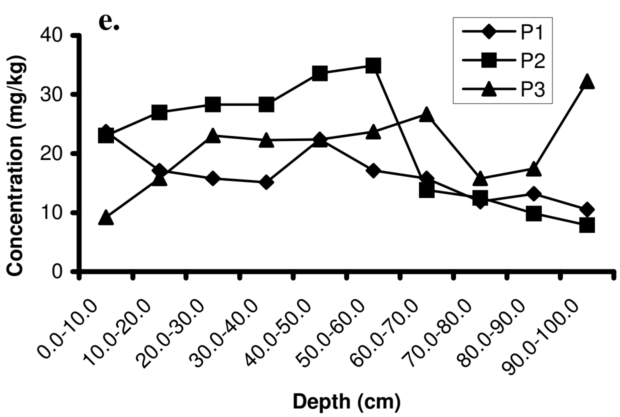


Figure 1. Levels of heavy metals at different levels of the contaminated soil. a. Pb, b. Ni, c. Cd, d. Cu and e. Zn.

RESULTS AND DISCUSSION

The distributions of Pb, Ni, Cd, Cu and Zn in the various profiles are shown in Figures 1a, b, c, d and e. Table 1 shows the mean concentration (mg/kg) of the Heavy metal in soils. Lead had the highest concentration (Figure 1a) ranging from 7.62 to 137.93 mg/kg with a mean of 96.45±8.05 mg/kg in the first profile at the crest (P1) and 91.96 to 285.44 mg/kg with a mean of 147.70±22.85 mg/kg in the second profile (P2) at the middle slope. The range and mean value of Pb in soils of the valley bottom profile (P3) were 113.03 to 266.28 mg/kg and 157.09±16.19 mg/kg, respectively. The overall mean concentration of Pb in the three profiles was 133.74±10.60 mg/kg. Cadmium (Cd) had the least concentration (Figure 1c) ranging from 1.64 to 3.28 mg/kg with a mean of 2.09±0.20 mg/kg at the crest (P1), 1.23 to 2.46 mg/kg with a mean of 1.64±0.11 mg/kg at the middle slope (P2) and 1.64 to 4.10 mg/kg with a mean of 2.05±0.23 mg/kg at the valley bottom (P3). The overall Cd mean concentration was 2.08±0.12 mg/kg. Nickel (Figure 1b) had a range from 6.78 to 10.77 mg/kg with a mean of 8.25±0.41 mg/kg, 5.65 to 9.04 mg/kg with a mean of 7.23±0.35 mg/kg and 6.78 to 13.35 mg/kg with a mean of 8.90±0.76 mg/kg at the crest (P1), middle slope (P2) and valley bottom (P3), respectively and overall mean concentration of 8.14±0.33 mg/kg. Copper (Figure 1d) ranged from 5.01 to 20.22 mg/kg with a mean of 10.92±1.72 mg/kg at the crest (P1), 3.85 to 83.18 mg/kg with a mean of 32.27±9.05 at the middle slope (P2) and 27.73 to 79.33 mg/kg with a mean of 47.68±4.32 mg/kg at the valley bottom (P3) with overall mean of 30.31±4.30 mg/kg. Zinc (Figure 1e) ranged from 10.53 to 23.70 mg/kg with a mean of 16.26±1.52 mg/kg, 7.90 to 34.89 mg/kg with a mean of 21.92±3.17, and 9.02 to 32.25 mg/kg with a mean of 20.09±2.06 mg/kg at P1, P2 and P3, respectively, and overall mean concentration of 19.69±1.37 mg/kg.

The levels of Pb obtained in this study is within the range of 30 – 300 mg/kg reported by Kabata-Pendias and Pendias (1984) and well above the permissible level for soils recommended by USEPA (1986). Nickel and Cd were found to be below the critical permissible concentration of 50 mg/kg and 3.0 mg/kg, respectively, as given by MAFF (1992) and EC (1986). Though these heavy metal concentrations fell below the critical permissible concentration level, their persistence in these soils of the dump site may lead to increase uptake by plants, though their transfer ratio differ from crop to crop. Copper level was within the normal range in soils (2 – 250 mg/kg) as given by Kabata-Pendias and Pendias (1984) and below 300 mg/kg recommended by MAFF (1992) and EC (1986). Zinc was also found to be within the normal range in soil (10 – 30 mg/kg) observed by Logan (2000) and below the 100 mg/kg recommended by MAFF (1992) and EC (1986). Miller and Miller (2002) noted that Zn and Cu are toxic to plants before they accumulated in sufficient concentrations to affect animals or human. Consequently, high concentrations of Zn and Cu kill or stunt plants growth thereby minimizing opportunities for poisoning of animal and human consuming the plants.

Furthermore, the relationship existing between the heavy metals among themselves were examined (Table 2). Cu and Zn correlated positively and significantly with Pb; Cd correlated positively and significantly with Ni. Also Zn correlated positively and significantly with Cu. The fact that significant and positive relationship exist between the heavy metal shows that their presence is from the same source.

The mean concentrations (mg/kg) of the heavy metals in plants are shown in Table 3. Lead had the highest mean concentration of 111.75±17.78 and 76.63±1994 in the leaf and root of cassava, respectively; 105.37±45.37 and 83.02±27.84 in the leaf and root of cocoyam, respectively. Cadmium had the least mean concentration of 4.10 in both leaf and root of cocoyam and cassava, while Ni had 22.59±0.001 in both leaf and root of cocoyam, and 24.47±1.88 in both root and leaf of cassava. These values aree well above the normal range. Alloway (1995) based largely on Bowen (1979) gave the normal range of metal concentration in plants leaves as 0.1 – 2.4 mg/kg for Cd, 0.02 – 5.0 mg/kg for Ni and 5.0 – 10.0 mg/kg for Pb. The high concentration of heavy metal may be attributed to the waste dump. Similar work by Ademoronti (1995) showed that vegetable accumulate considerable amount of heavy metal in roots and leaves. Anikwe and Nwobodo (2002) and Amusan et al. (1999) reported high concentrations of heavy metals in vegetables grown in waste dump soils. Furthermore, Alloway and Ayres (1997) reported that Cd, although present in lower concentration (<10 mg/kg), is relatively easily taken up by food especially leafy vegetables and enters the human diet.

Table 1. Mean ± SEM values of concentration (mg/kg) of heavy metal in soils.

Profile	Pb	Ni	Cd	Cu	Zn
P_1	96.45±8.05	8.25±0.41	2.09±0.20	10.92±1.72	16.26±1.32
P_2	147.70±22.85	7.23±0.35	1.64±0.11	32.27±9.50	21.92±3.17
P_3	157.09±16.19	8.93±0.79	2.50±0.23	47.68±4.32	20.90±2.06
Overall	133.74±1060	8.14±0.33	2.08±0.12	30.31±4.30	19.69±1.37

Sample size of each profile = 10.
SEM: Standard Error of Mean.

Table 2. Coefficient of correlation (r-value) among heavy metals in the abandoned waste dump soils.

Pb	–				
Ni	0.061^{ns}	–			
Cd	0.111^{ns}	0.495**	–		
Cu	0.740**	0.160^{ns}	0.235^{ns}	–	
Zn	0.572**	0.179^{ns}	0.085^{ns}	0.763**	–

**Correlation is significant at the 0.01 level.
^{ns}Correlation is not significant at the 0.05 level.

Table 3. Mean concentration (mg/kg) of heavy metals in plants harvested from the abandoned waste site.

Plant	Pb		Ni		Cd	
	Root	leaf	Root	leaf	Root	leaf
Cassava	76.6±19.94	111.57±17.78	24.47±1.88	24.47±1.88	4.10±0.00	4.10±0.00
Cocoyam	83.02±27.84	105.37±45.37	22.59±0.001	22.59±0.001	4.10±0.00	4.10±0.00

Sample size of each crop = 3.

The level of concentrations of these heavy metals in soils and food crop harvested from the abandoned municipal waste dumpsite raises environmental concern. Consequently, people depending on these crops as their source of food are indirectly ingesting heavy metals Animals in grazing pasture may also ingest considerable amounts directly as soil and material coating the leaves and are thus exposed to these metals even without direct plant up-take. There is also likelihood of contamination of surface and underground water. Therefore, there is high risk on the environment and health associated the use of abandoned municipal waste dump site for food crop production.

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