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Heavy Metal Concentrations in Some Vegetables Grown in a Farm Treated With Urban Solid Waste in Kuru Jantar, Jos South, and Plateau State

Abstract

The use of dumpsite soils as organic manure is wide spread in developing countries like Nigeria. This study investigates the concentration of some heavy metals in vegetables grown in a farm treated with dumpsite soils in Kuru Jantar, Jos-South. Soil samples and vegetables from the farm were collected and prepared using standard analytical procedures. The concentrations of metals in both soil and vegetables were determined using atomic absorption spectrophotometer (AAS). The results showed that the farm was polluted with the metals (Cd, Cr, Cu, Mu, Fe, Pb, Zn, Ni) determined. The Enrichment Factor (E/F) showed that some metals had minimal enrichment while Cd (13.93) had significant enrichment at the farm. The Pollution index (P/I) calculations showed that at the farm, the pollution ranged from very slight contamination to very severe contamination. The overall order of the metals at the dumpsite was Fe> Mn> Zn> Cu> Cr> Ni> Pd> Cd while the order of the metal concentrations at the farm was Fe> Mn> Zn> Ni> Cd> Pd. The pH value of the soil at the dumpsite was basic while at the farm was acidic. In spinach plant species, metal concentrations decreased in the order Fe>Zn>Mn>Cd>Pb, in Cabbage Mn> Fe> Zn>Cu>Cd; in Radish, Fe>Mn>Cu>Cr>Zn, in pepper Fe>Cu>Mn>Ni. In general, the metal concentrations were within the recommended limit of USEPA and FEPA standards for agricultural soils and vegetables except Cd in vegetables. The concentrations were however higher in the farm than in the control. Thus, the farm was polluted with heavy metals from the dumpsite soils.

Keywords: Heavy metals, dumpsite, vegetables, pollution, organic manure, Enrichment Factor

INTRODUCTION

The use of dumpsite soils as organic manure is widespread in Plateau state, Nigeria. This practice has been shown to improve soil properties such as organic matter, nutrients, porosity, aggregate stability, bulk density and water retention and as a result, increase plant productivity [1, 2]. It is however a known fact that some of the waste products contain hazardous metals such as Ni, Pb, Cd, Zn, and Hg [3], which perturb the distribution and concentration of these metals in the environment. Recent studies have also revealed that the waste dumpsite can transfer significant levels of these toxic and persistent metals into the soil environment [4,5].

Heavy metals are toxic pollutants that therefore, severely limit the beneficial use of dumpsite soil as organic manure. Heavy metals are very harmful because of their non-biodegradable nature, long biological half life and their potential to accumulate in different body

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parts [6]; even low concentrations of heavy metals are toxic because there is no good mechanism for their elimination from the body. The bioaccumulation of metals as a major route through which increased levels of the pollutants are transferred across food chain web has been reported [7]. The presence of heavy metals in the ecosystem therefore, has far reaching implication directly to the soil and indirectly to man. Metal uptake by plants can be affected by several factors including metal concentrations in soils, soil pH, cation exchange capacity, organic matter, types and varieties of plants and plant age. [8]. It is generally accepted that the metal concentration in soil is the dominant factor and the concentrations of heavy metals are higher in soils than vegetables grown on the same soils [9]. It has also been reported that vegetable crop plants have high ability to accumulate metals from the environment, which may pose risks to human health when they are grown on or near contaminated lands and consumed. Thus, accumulation of heavy metals in the edible parts of vegetables represents a direct pathway for their incorporation into the human food chain [10, 11]. The health risk will depend upon the chemical composition of the waste material, its physical characteristic, types of vegetables cultivated and the consumption rate[12, 13].

This study therefore assessed the uptake of metals by plant vegetables grown on a farm treated with urban solid waste in Kuru Jantar, Jos-South.

Materials and methods

STUDY AREA

The farm used in this study is located about 200m from Kuru Jantar dumpsite on longitude 08^0 53'E and latitude 090 42 N (Garmin GPS model etrex 20). The farm used urban solid wastes from the dumpsite as organic manure (See Figure 1).

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Figure 1: A Farm from Kuru Jantar Using Manure from Dumpsite

Heavy Metal Analysis

The soil samples collected from the farm in the dry season were air-dried, crushed and sieved to pass through a 2mm sieve. Triplicate samples of 3.0g of the sieved soil samples were digested with 25ml of aqua regia (HCl + HNO_3, 3:1 v/v) at 120^0C on a water bath in a fume cupboard. The solution was heated to dryness and the residue was re-dissolved in $5cm^3$ of 2.0M HCl [14 – 16]. Digested samples were filleted into a 100ml volumetric flask and made up to the mark with distilled water. The concentrations of the metals in the digested soil sample solutions were determined using Buck scientific VGP 210 Atomic Absorption Spectrophotometer at wavelengths specific to each metal. The metals analyzed were: Pb, Cu Cr, Ni, Zn, Fe, Cd, Mn.

Vegetable Analysis

The vegetables harvested at the same spots where the soil samples were collected were washed with distilled water to remove soil particles. The vegetables were cut with plastic knives before drying in oven at 70^0C until stable weights were obtained. The dried samples were ground in mortar and sieved. Triplicate (1g) samples were weighed into different conical flasks and digested with conc. HNO_3 to a clear solution. Digested samples were filtered into a 100ml volumetric flask

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and made up to the mark with distilled water [17]. Heavy metals were determined using Buck scientific VGP 210 Atomic Absorption spectroscopy (AAS).

pH Determination

Triplicate quantities (20g) of air-dried of the soil samples were weighed into a $50cm^2$ beaker and $20cm^3$of distilled water was added. The mixture was allowed to stand for 30 minutes with occasional stirring using a glass rod. The electrode of the calibrated pH meter, MI 806 pH/EC/Temperature Portable Meter inserted into the partly settled suspension and the pH value read [14]

Organic Matter Determination

The soil samples were ground to pass through 0.5mm sieve after which they were weighed in duplicate and transferred to $250cm^3$ Erlenmeyer flasks. Exactly $10cm^3$ of IM potassium dichromate was pipette into each flask and swirled gently to disperse the soil followed by addition of $20cm^3$ of concentrated, tetraoxosulphate (IV) acid. The flask was swirled gently until soil and reagents were thoroughly mixed. The mixture was then allowed to stand for 30 minutes on a glass plate to allow for the oxidation of potassium dichromate to chromic acid. Distilled water ($100cm^3$) was added then 3-4 drops of ferroin indicator, after which the mixture was titrated with 0.5M ferrous sulphate solution. A blank titration was similarly carried out. [14]. The % organic carbon is given by the following equation:

$$\frac{M_1e_1\ K_2Cr_20_7 - M_2e_2\ Feso_4 \times 0.0031 \times 100 \times F}{\text{Mass (g) of air-dried soil.}}$$

F= correction factor (1.33), $M_{1\ =\ mole}$ of $K_2\ Cr_2\ O_7$, E_1= volume of $k_2\ Cr_2\ O_7$ M_2 = mole of $Feso_4$, E_2 = volume of $FeSo_4$, % = organic matter in soil = organic carbon × 1.729.

RESULTS AND DISCUSSION

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The physicochemical properties of the soil collected from the farm such as pH, cation exchange capacity (CEC), electrical conductivity (EC) and organic matter (OM) were determined. These properties have been reported to have profound influence on the mobility and bioavailability of heavy metals and uptake by plants [18, 19]. The results of the physicochemical properties are presented in Table 1.The results showed that the dumpsite with a pH of 8.30 was slightly alkaline in nature. This may be attributed to the buffering effect of soil organic matter against pH changes in addition to the release of basic cations during the organic matter decomposition [5]

The pH of the farm soil was 6.71 which indicated that the soil was slightly acidic. This could be attributed to the inorganic fertilizer and other chemicals used on the farms. This is also expected as most soils in the tropics have their range from acidic to slightly neutral [5]. Soil pH is an important parameter that directly influences sorption / desorption, precipitation / dissolution, complex formation and oxidation – reduction reactions [20]. The results of the available phosphorus in the dumpsite soil were very similar to that in the farm ranging from 0.03 – 0.12mg/kg. The concentration of phosphorus contributes to the growth of plants [21]. The concentrations of the exchangeable cations (CEC) were higher at the dumpsite than the farm. However, the concentration at the farm was higher than the control, which indicated that the dumpsite could be implicated with the amendment of soil properties of the farm.

The organic matter (OM) content of the dumpsite soil was 5.8% while the farm had 2.40% and the control had 1.12%. The percentage of the OM of the soils might be attributed to the activities of the microorganisms involved in the organic matter decomposition thereby accumulating more organic matter in the soils [18]. The OM content of the control site was significantly lower compared to the farm and dumpsite soils (see Table 1). Thus, the results showed that the use of the urban solid waste as manure influenced the organic matter in the farm. The organic matter content of the soil plays an important role in absorption reaction in the soil and

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total cation exchange site [21]. The organic matter is also an important indicator of the soil as a rooting environment [20].

Table 1: Some Selected Soil Physicochemical Properties of Kuru Dumpsite and Farm Treated with the Dumpsite

	Dumpsite	Farm [F1]	Control
pH	8.30	6.71	6.15
Organic Matter %	5.80	2.40	1.12
Total Nitrogen %	0.63	0.35	0.35
Exchangeable Na (cMol Kg^{-1})	1.86	0.30	0.24
Exchangeable K (cMol Kg^{-1})	21.60	0.76	0.87
Exchangeable Mg (cMol Kg^{-1})	5.20	0.50	0.45
Exchangeable Ca (cMol Kg^{-1})	11.12	4.65	1.80
Available P (mg/Kg)	0.11	0.11	0.03
CEC (cMol Kg^{-1})	40.50	6.53	3.68
Texture	Sand	Sand	Sand

The concentration of the exchangeable cations (CEC) in the dumpsite soil (40.50 cMolkg-^{1}) was much higher than in the farm which was 6.53cMolkg$^{-1.}$ The concentrations of the exchangeable cations were however, higher than the control which implicated the use of the dumpsite soil to have affected the farm positively. This could be due to difference in the heterogeneous nature of waste [5], which is expected to impact differently on soil properties. The available phosphorous in the farm and dumpsite were the same 0.11mg/kg which was higher than the value for the control farm (03mg/kg). The percentage of nitrogen was 0.35%.

The physicochemical parameters indicated that the organic matter, cation exchange capacity, nitrogen and phosphorus content of the farm were moderate with moderate values of C:N

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ratio implicating the urban solid waste to be fertile. Thus, the results of the physicochemical parameters revealed that the soils were fertile to support plant growth but this cannot be compared to the adverse effect of using this solid waste as manure. This may serve as a source of metals into the food chain.

The average concentration of metals in soil samples collected from the dumpsite and farm treated with the solid waste are presented in Table 2. The concentration of copper (Cu) was much lower than the average concentration in the dumpsite soil. However, the concentration of Cu in the farm was higher than the control which was not detected. This implies that the use of dumpsite soil as manure contributed to the increase of concentration of Cu in the farm. This is in agreement with the observation of other researchers [7]. The concentration of Cu was however, within the recommended maximum limit for agricultural soil of 100mg/Kg [9, 13].

The concentration of manganese (Mn) was 219.60mg/kg in the farm which was also lower than the concentration at the dumpsite. However, the concentration were much higher than the control but were within [22, 23] recommended maximum value (2000mg/kg) for agricultural soil as reported by [17, 24]. Manganese in soil functions like iron and is also an essential trace element (micro nutrient).

The concentrations of the other metals, iron, cadmium, nickel and zinc were lower than the concentrations at the dumpsite but were also higher than the control values. Therefore, there are apparent indications of the adverse effects of the dumpsite on the values of metals as compared to their values in the control. Similar observations have been reported [20 and 21]. The levels of the metals were within the recommended maximum limit as reported by other researchers [25].

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Table 2. Average Concentrations of Metals in Soil Samples Collected from the Dumpsite and Farm

Element	Farms			
	Dumpsite	Control	F1	Control
Cu	30.19±2.30	2.45±0.05	63.23±25.36	6.07±0.04
Mn	422.72±28.67	28.99±9.11	219.60±57.88	45.20± 9.55
Fe	2436±105.95	249.00±7.43	408.20±78.38	74.18±42.22
Cd	28.06±2.03	ND	2.30±0.14	0.03±0.01
Ni	26.32±2.85	ND	15.60±0.12	3.03±0.62
Zn	246.39±10.75	8.92±3.12	66.23±8.96	23.08± 5.02
Pb	23.30±5.70	9.13±3.25	25.33±0.38	4.58±1.01

The metal concentration correlation analysis between the farm and the dumpsite was conducted using Pearson correlation coefficient (r) values to determine the level of association. The results showed perfect positive correlation values above 0.9 between the farms and the dumpsites, which indicated that there was a strong association or similarity between them. At both $p<0.05$ and $p<0.01$ level of significant, all the correlations were significant. This implies that the similarity in the concentrations between the farm and dumpsite was quite high.

The concentrations of the metals in the farm (F1) decreased in the order Fe > Mn > Zn > Pb > Cu > Ni > Cd. Enrichment Factor (EF) of the heavy metals in soil from farm 1 showed that Cu(0.49), Mn(0.88), Fe(1), Ni(0.94), Zn(0.52) and Pb(0.88) had minimal enrichment while Cd(13.93) had significant enrichment (see Table 3).

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Table 3: **Enrichment Factor (EF) and Contamination /Pollution (C/P) Index of Heavy Metals in Soil samples from the Farm (F1)**

	Cu	Mn	Fe	Cd	Ni	Zn	Pb
C (M –S)	16.32	219.6	408.20	2.30	15.60	66.33	22.27
C (Fe- S)	408.20	408.20	408.20	408.20	408.20	408.20	408.20
C (M-C)	6.07	45.20	74.18	0.03	3.03	23.08	4.58
C (Fe-C)	74.18	74.18	74.18	74.18	74.18	74.18	74.18
EF	0.49	0.88	1.00	13.93	0.94	0.52	0.88
C/P Index	0.90	0.50	0.08	0.77	0.45	0.22	0.09

The use of urban solid waste as manure could be implicated with the high enrichment of Cd at the farms. The soil Cd could also be due to the application of phosphate fertilizers [26]. This therefore poses serious concern as crops grown on these farms could bioaccumulate the metal. The Pollution Index (P/I) of the metals at F1 ranged from 0.08 to 0.90 which showed that the farm had very slight contamination to very severe contamination with the metals.

Metal Content in Vegetables grown on the Farm

The main sources of heavy metals to vegetable crops are their growth media from which these are taken up by the roots. A better understanding of heavy metals sources, their accumulation in the soil and subsequent uptake by plant species seem to be particularly important in present day research on risk assessment [27]. The uptake of metal ions has been shown to be influenced by the metal species and plant parts.[26]. The results in the farm [F1] showed that spinach, bio-accumulated Cu, Mn, Fe, Cd, Zn and Pb and the concentration of the metals were in the order Fe > Mn > Zn >Cd >Ni> Pb (See Table 5). This could be a reflection of the concentrations of the metals in the soil. Leafy vegetables have been shown to accumulate relatively high concentrations of heavy metals in compare to fruit vegetables [24]. The

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concentration of Cd was 3.21mg/kg which was much higher than the recommended maximum levels in vegetables (0.20mg/kg) [28]. Cadmium is relatively easily taken up by the food crops especially by vegetables in the addition to foliar absorption of Cd from atmospheric deposition on plant leaves [29]. Cd is relatively mobile in soil under range of pH, O.C and CEC conditions. This shows that some other soil factors in addition to the total soil contents of the metals also influenced metal uptake. The other metals were within the recommended maximum limits in vegetables with Mn and Fe (500.30mg/Kg) and Zn (99.40mg/Kg) [30].

Table 5.Mean Concentrations of Metals in Vegetable Samples Collected from the Farm [F1].

Element	Vegetables					
	Spinach	Cabbage	Raddish	Tomatoes	Pepper	*RMLV
Cu	25.26±5.87	31.33±4.01	51.10±4.12	18.45±6.44	53.25±12.50	73.30
Mn	220.65±33.24	191.75±15.14	92.10±22.36	ND	29.85±8.35	500.00
Fe	103.00±88.44	85.00±30.11	93.55±33.56	77.63±35.22	80.69±38.77	425.50
Cd	3.25±0.12	0.71±0.02	5.70±0.55	ND	ND	0.20
Ni	13.00±0.15	ND	ND	ND	ND	67.90
Zn	53.77±22.11	33.54±4.02	O.89±0.05	ND	21.22±5.98	99.40
Pb	3.21±0.05	ND	ND	ND	ND	0.30

RMLV: Recommended Maximum Levels in Vegetables

* Source: [17 and 29]

Cabbage, bio-accumulated Cu, Mn, Fe, Cd and Zn from the soil and the concentrations of the metals were in the other Mn > Fe > Zn > Cu > Cd. The concentration of Cd in cabbage was also higher than the recommended maximum levels in vegetables (0.20mg/kg) [30]. This could be attributed to the urban solid waste used as manure in this farm. The other metals bio-accumulated in cabbage were also below the recommended maximum limits.

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The results showed that radish in bio-accumulated only the metals Cu, Mn, Fe, Cr and Zn in its roots in the sequence Fe > Mn > Cu > Cr > Zn. The metals bio-accumulated were also below the recommended maximum limits for vegetables (see Tables 5). Tomatoes on the other hand bioaccumulated only Cu, Fe and Cd, in decreasing order of Fe > Cu > Cd. the concentration of Cd was also higher than the recommended maximum limit in vegetables. Pepper bio-accumulated Cu, Mn, Fe, Ni and Zn in the order Fe > Cu > Mn > Zn > Ni. The metals in pepper were within the recommended limit.

Generally, the concentration of iron was highest in almost all the vegetables. The higher concentration of Fe could be as a result of its oxygen carrier ability for chlorophyll production and also for protein synthesis [31]. The concentrations of Mn and Cu only were higher in cabbage than spinach. The results also showed that spinach, cabbage and radish, bioaccumulated more metals than pepper and tomato. This is in agreement with the reports of other researchers [24, 31]

Based on the pattern of metal accumulation in the vegetables, it could be suggested that radish and pepper could be safely grown on Cd contaminated soils. On the other hand, vegetables like spinach, cabbage, radish, may not suitable for cultivation on Cu, Mn, Fe, Zn and Cd contaminated soils. However, some fruit type vegetables like tomato and pepper could be safely grown on Cr, Ni, and Pb contaminated soils. Root type vegetable like radish could be cultivated on Cd, Cr, Ni and Pb contaminated soils. Heterogeneous accumulation of heavy metals in different crop species has been reported [7, 32], which could be attributed to their diverse morphological characteristics.

Conclusion

From this study, it could be concluded that the dumpsite was polluted with the metals Cu, Mn, Fe, Cd, Cr, Ni, Zn and Pb. The used of the dumpsite soil as manure, contaminated the farm studied. The concentration of the metals in the farm were in the order Fe> Mn> Cu> Zn> Ni> Cd>

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Pb. The vegetable grown in these farm bioaccumulated some of the metals analyzed. The differences in respect of metal uptake could be emphasized for selection of vegetable crops for cultivation on metals contaminated soils depending on their metal uptake potential. The results of the Pearson correlation coefficient (r) showed perfect positive correlation values above 0.9 between the concentration of metals in the farm and the vegetables, which indicated that there was a strong association or similarity between them. At both $p<0.05$ and $p<0.01$ level of significant, all the correlations were significant. This implies that the similarity in the concentrations between the farm and vegetables were quite high.

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