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Environmental risk assessment of heavy metals content of municipal solid waste used as organic fertilizer in vegetable gardens on the Jos Plateau, Nigeria

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Abstract: This study was conducted on vegetable gardens in and around Jos on the Jos Plateau, North central Nigeria; a city which has had strong European influence as a result of a long history of tin mining activity in the area. The study seeks to assess the degree of accumulation and/or contamination of the heavy metals in compost from municipal solid waste due for application as organic fertilizer in vegetable gardens as well as the potential human health risk associated with the consumption of vegetables grown with such organic fertilizer. Three waste dumpsites in Jos and gardens were selected where vegetables cultivation (cabbage, lettuce, spinach, turnip, carrot, radish, beet root, tomato and spring onions) are practiced. The representative samples of compost material, agricultural soil and vegetables were collected and analyzed for heavy metals such as: As, Cd, Co, Cr, Ni, Pb, Cu, Zn, Sb and Se. Geochemical results show that the concentrations of these elements in the compost are higher (in decreasing order of As>Cd>Zn>Pb>Cu>Cr) compared to that in the soils yet to be applied the organic fertilizer. The degree of contamination of the soils and the compost, the transfer factor (TF) from the agricultural soil to vegetables and its health risk index (HRI) were calculated. Results show that in general, the agricultural soils are severely contaminated by As, Cd, Zn and Pb (CF= 10-25). Other elements such as Cr, Cu and Ni have moderately contaminated the soil. All the vegetables seem to have been severely contaminated by Se and As (Se>As>Zn) and therefore are good accumulators of these toxic metals. The leafy and the root vegetables appear to be the major accumulator of Se and As respectively. The TF of As in all the different varieties of vegetables is >1, indicating that this element is readily absorbed by these plants. The HRI value for As, Pb and Zn is >1 for the all the vegetables and therefore is unsafe posing serious human health risks.

Keywords: Heavy Metals, Vegetable Gardens, Organic Fertilizer, Human Health Risks

1. Introduction

With increasing urbanization, Municipal Solid Waste (MSW) is increasingly becoming a major source of environmental pollution in and around metropolitan cities in Nigeria. The municipal solid wastes are dumped indiscriminately in the city on arable land and along River Channels. Leachates discharged from such wastes apart from being important breeding sites for diseases vermin, it infiltrates into the underground or surface water system becoming a major source of environmental pollution when left unattended to. The making of composts from such waste so as to improve soil fertility and to boost crop yield is also on the increase. However, the application of composts has raised serious doubts as it relates to public health safety of its use to grow crops destined for human consumption.

Research has shown that the heavy metals content in composts have the potential to contaminate crops especially for vegetables grown using it (James *et al.*,(2000); William, (2000); Fisseha, (2002); Baltrenaite and Butkus, (2004); David *et al.*, (2008); Defra (2004); Michael and Enzo, (2004); Chove *et al.*, (2006); Duruibe *et al.*, (2007); Hogarh *et al.*, (2008); Mohsen and Mohsen, (2008); Mahmoud *et al.*,(2009); Prabu, (2009); Ghaly and Alkoaik, (2010) and Fatima *et al.*, 2011). However, certain heavy metals such as Fe, Cu, Zn, Ni are important for proper functioning of biological systems, however, their deficiency or excess could lead to a number of human health disorders (Dmek *et al.*, 2003). Thus, a better understanding of heavy metals content in the composts and their availability for uptake by plants grown on them is of primary importance in assessing the health risk such plants could cause when consumed by man (Koenig *et al.*, 1990; Mench *et al.*, 1994).

Thus, this paper assesses the human health risks associated with the application of municipal solid waste as organic fertilizer in vegetable gardens on the Jos Plateau known for its cultivation of temperate crops (cabbage, lettuce, spinach, turnip, carrot, radish, beet root, tomato, spring onions etc.) and to recommend remediation strategies to reduce its negative effects on human health.

2. Vegetable Crops Grown on the Jos Plateau

Jos city is a metropolitan set-up with a population of over 8 million people (2006 Population Census), situated in central part of Nigeria (Figure 1a & 1b). It is known for its distinctively circular rock formations referred to as the Younger Granite complexes. The rocks are predominantly made up of constituent feldspar, quartz, biotite, and hornblende. These rocks also host cassiterite, columbite and associated lead/zinc sulfide mineralization. The Jos Plateau is also known for its high altitude (about 1200m above sea level), a pre-determinant of its temperate climate (average temperature of 18 ^{o}C) and high rainfall (1200 mm per year). The soil is fertile within the volcanic provinces supporting all year round commercial agriculture of perishable crops. Tin mining is synonymous with the Jos Plateau resulting in the devastation of arable land and the destruction of the ecosystem.

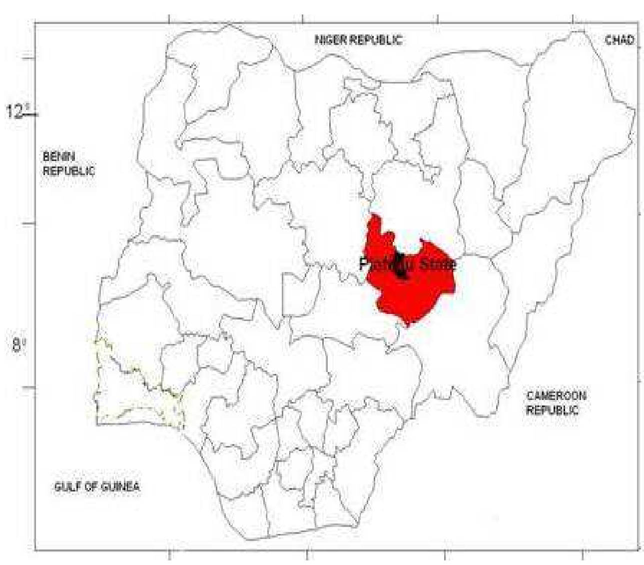

Figure.1a. *Location of the Jos Plateau, Nigeria*

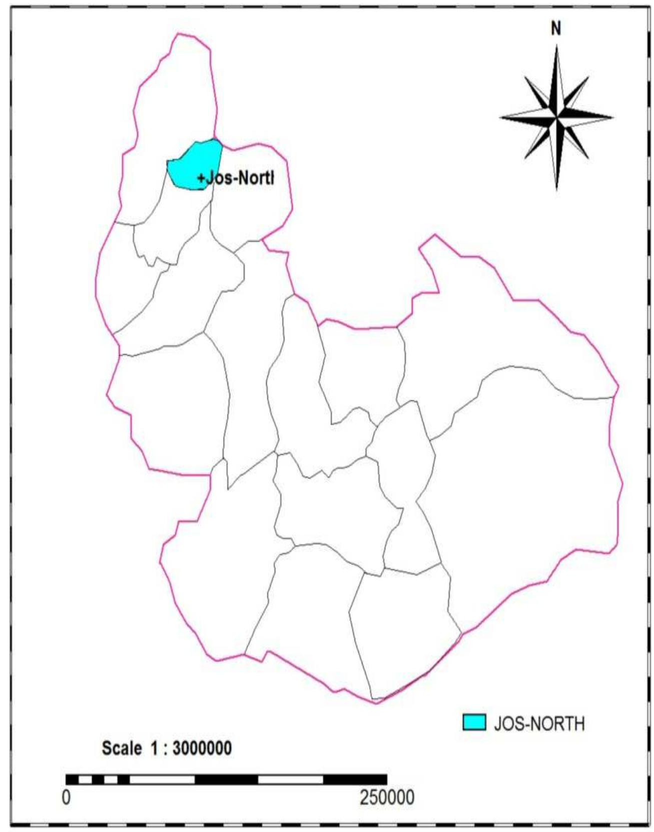

Figure 1b. *Location Map of Study Area.*

On the Jos Plateau, composts are widely applied in both rainy season and dry season agriculture/farming for the production of both crops and vegetables (such as cabbage, lettuce, celery, spinach, carrot, onion and radish etc.). It is affordable and cheaper compared to chemical fertilizers. Surveys have indicated that 90% of the vegetable grown on the Jos Plateau use MSW compost as the organic fertilizer. The compost despite its heterogeneous sources, its nutrients/heavy metals content is not carried out to determine its suitability or otherwise before application (Baltrenaite and Butkus, 2004). Its use is therefore already a mis-application. The introduction of excess nutrients/heavy metals or potentially harmful elements through the compost application could lead to accumulation of heavy metals in the vegetables and poses direct threat to human health (Wegelin et al., 1995). A recent preliminary work on the use of the waste as supplement for maintenance of soil fertility has been carried out on the Jos Plateau, Nigeria (Olowolafe, 2008), but led little emphasis on its heavy metals content and human health impact. The main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which they are taken up by the roots or foliage (Chove *et al.*, (2006).

3. Materials and Methods

3.1. Compost, Compost Making and Application

Compost is a mixture of organic wastes (decayed plant and other organic matter), converted into useful organic soils used by gardeners to provide nutrients to crops and enhance the tilth, fertility, and productivity of soils" (USDA, 1980; Encarta, 2008). The Compost undergoes natural biological process under controlled conditions; so as to hasten the decomposition of organic waste and reduces its volume, creating stable, soil-enriching humus. The compost acts as a soil conditioner, a fertilizer, addition of vital humus or humic acids, and as a natural pesticide for soil. No quality control in respect of its nutrients/heavy metals content is done. Non-decomposable materials such as big rock fragments, glass, plastic, polythene and metals are usually are removed. No hard and fast rule has been established in Nigeria in terms of the acceptable standard guidelines for compost making as it is the practice in the developed countries.

3.2. Sampling of Compost for Chemical Analysis

Sampling was carried out at the time when the compost was ready for application (Plates 2 and 3) and when the vegetables were in gloom (Plates 4 and 5); presumably the period of maximum uptake of elements by the plants. Four compost samples were collected by quartling system; nine different representative vegetable samples (carrot, cabbage, onion, lettuce, radish, spinach, tomato, beet root and turnip) were collected from seven gardens and thirteen soil samples were collected at the depth of about 20 cm (the zone of metal accumulation) (Figure 2).

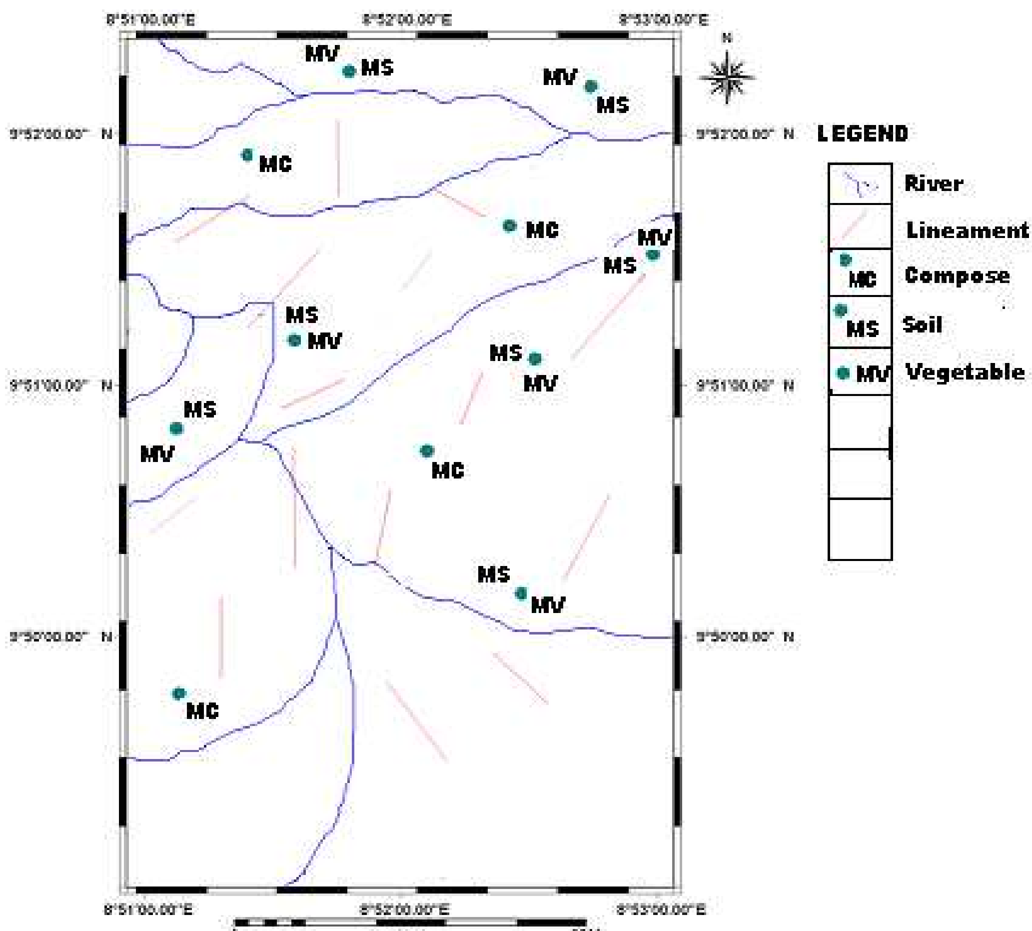

Figure 2. *Sample location map*

Plate 1A-D. *Municipal Solid Waste (MSW) Dump Site along Bauchi Road by Naraguta Hostel Gate of the University of Jos.*

2A – B Compost ready for use at Naraguta Village Gardens

2C – D Compost ready for use at Yelwa Village Gardens

Plate 2A-D. *Compost made from MSW ready for use in the gardens in Naraguta and Yelwa Villages.*

Plate 3A-D. *Compost applied to gardens of onion, lettuce, carrot, cabbage etc, in Naraguta Village*

Plate 4A-D. *Vegetables (lettuce, cabbage, onion, radish) grown with the compost fertilizer in Naraguta(4A - C) and Yelwa (4D) villages.*

Plate 5A-D. *Vegetables (carrot, onion, cabbage, Chinese cabbage) grown with the compost in gardens in Faringada and Naraguta villages*

3.3. Sample Preparations for Chemical Analysis

The compost and farm soil samples were separately air dried and ground into fine powder using pestle and mortar and passed through 2 mm sieve. A homogeneous sample of 1 g was weighed and each taken in Teflon crucibles and digested with aqua regia (3mls HNO_3 + 2mls HCl) heated on a sand bath at a temperature of about 250°C for 6 hours. After evaporation to near dryness, the samples were allowed to cool then re-dissolved with 10 ml of 2M Nitric acid, filtered and then diluted to 100 ml with distilled water. Vegetable samples such as beet root (*Beta vulgaris* L.), carrot (*Daucus carota* L.), onion (*Allium cepa* L.), Raddish (*Raphanus sativus* L.), tomato (*Lycopersicum esculentum* Mill.), cabbage (*Brassica oleracea* L. var.capitata), lettuce (*Lactuca sativa* L. longifolia), spinach (*Spinacea oleracea* L.) and turnip (*Brassica rapa)* were analyzed for total metals content. The vegetable samples were thoroughly washed with distilled water to remove all adhered soil particles and left to dry up in an oven at 25°C for 24 hours. The samples were ground in warm condition and passed through 1 mm sieve. Digestion of these samples (2g each) was carried out using aqua regia ($3HNO_3$ + 2 HCl), the same procedure used for the soil samples (USEPA, 2001b).

3.4. Analytical Techniques

The geochemical analyses were conducted in the Geochemistry Laboratory of the Department of Geology and Mining, University of Jos, Nigeria using an Inductively Coupled Plasma- Optical Emission Spectrometry (ICP- OES). International certified reference materials were analyzed at the beginning and end of each batch of samples. Internal control standards were also used in between every ten samples and a duplicate is run for every ten samples.

3.5. Data Analysis

The geochemical results were interpreted using the pollution indices such as Contamination Factor (CF), Transfer factor (TF) and Health Risk index (HRI)

3.6. Calculation of Contamination Index (CF)

CF is a quantification of the degree of contamination relative to either average crustal composition of respective metal or to the measured background values from geologically similar and uncontaminated area (Tijani *et al.*, 2004; Sutherland, 2000). It is expressed as:

$$CF = Cm/Bm \quad (1)$$

Where Cm = measured concentration, while Bm = background concentration of metal; either from literature (average crustal abundance) or directly determined from a geologically similar area. The Contamination factor (CF) of selected trace elements in soils within the study area is shown in Tables 2,3 and 3.

Table 1. *Concentration of Major (in weight %) and Trace elements (in mg/kg) in the agricultural soils.*

SampleID	Sample type	Coordinates	Al_2O_3 %	CaO %	Fe_2O_3 %	MgO %	K_2O %	Na_2O%	As mg/kg	Cd mg/kg	Co mg/kg
MS1	Soil	9º 58’ 54’’N, 8º 53’ 13’’E	2.35	4.94	2.70	0.46	0.32	0.08	75.96	1.625	4.378
MS2	″	9º 58’ 53’’N, 8º 53’ 26’’E	2.40	0.72	4.51	0.28	0.23	0.05	48.80	<DL	5.217
MS3	″	9º 58’ 51’’N, 8º 53’ 31’’E	7.44	0.04	4.51	0.56	0.67	0.14	<DL	″	14.39
MS4	″	9º 58’ 51’’N, 8º 53’ 31’’E	3.73	0.51	2.79	0.37	0.36	0.04	32.68	″	26.84
MS5	″	9º 58’ 52’’N, 8º 53’ 29’’E	2.37	3.09	3.95	0.29	0.28	0.12	<DL	″	10.93
MS6	″	9º 58’ 51’’N, 8º 53’ 34’’E	3.51	0.60	4.31	0.39	0.34	0.08	10.27	″	11.90
MS7	″	9º 58’ 52’’N, 8º 53’ 37’’E	4.70	0.87	4.06	0.47	0.44	0.03	<DL	″	13.30
MS8	″	9º 59’ 42’’N, 8º 54’ 26’’E	4.12	8.14	5.17	0.82	0.84	0.24	24.90	0.375	5.830
MS9	″	9º 58’ 54’’N, 8º 53’ 28’’E	3.44	1.32	4.42	0.41	0.32	0.11	40.05	<DL	12.08
MS10	″	9º 58’ 31’’N, 8º 53’ 31’’E	4.17	0.82	3.35	0.43	0.54	0.06	67.75	″	10.57
MS11	″	9º 58’ 52’’N, 8º 53’ 14’’E	2.45	0.05	1.31	0.44	0.38	0.02	50.86	″	4.48
MS12	″	9º 58’ 52’’N, 8º 53’ 14’’E	7.34	0.13	4.44	0.67	0.50	0.10	96.94	″	16.90
MS13	″		3.11	0.14	3.07	0.39	0.34	0.01	56.71	″	10.33
Mean									50.49	1	

Table 1. *Continued*

SampleID	Sample type	Coordinates	Cr mg/kg	Ni mg/kg	Pb mg/kg	Cu mg/kg	Sb mg/kg	Se mg/kg	Tl mg/kg	Zn mg/kg
MS1	Soil	9º 59’ 41’’N, 8º 54’ 28’’E	24.52	17.30	108.8	150.9	<DL	<DL	<DL	4980
MS2	″	9º 58’ 53’’N, 8º 53’ 26’’E	62.16	7.98	304.5	70.62	″	″	″	1012
MS3	″	9º 58’ 51’’N, 8º 53’ 31’’E	99.69	30.98	0.38	26.82	″	″	″	<DL
MS4	″	9º 58’ 51’’N, 8º 53’ 31’’E	32.44	14.42	21.49	45.47	″	″	″	595.4
MS5	″	9º 58’ 52’’N, 8º 53’ 29’’E	128.1	14.79	306.2	89.27	″	″	″	627.4
MS6	″	9º 58’ 51’’N, 8º 53’ 34’’E	97.13	19.83	34.97	28.54	″	″	″	37.12
MS7	″	9º 58’ 52’’N, 8º 53’ 37’’E	70.08	27.94	23.61	23.88	″	″	″	55.67
MS8	″	9º 59’ 42’’N, 8º 54’ 26’’E	130.8	11.28	92.79	116.0	″	″	″	5944
MS9	″	9º 58’ 54’’N, 8º 53’ 28’’E	129.0	15.74	30.00	35.81	″	″	″	158.8
MS10	″	9º 58’ 31’’N, 8º 53’ 31’’E	77.00	23.89	23.35	26.35	″	″	″	109.5
MS11	″	9º 58’ 52’’N, 8º 53’ 14’’E	13.78	3.29	2.16	12.28	″	″	″	<DL
MS12	″	9º 58’ 52’’N, 8º 53’ 14’’E	67.80	34.01	13.85	28.81	″	″	″	″
MS13	″		79.15	19.33	48.68	26.98	″	″	″	14.59
Mean			77.82	18.52	77.75	52.44				1353.45

Sample ID: MS- soil; MC-compost; MV-vegetable; <DL – below detection limit

3.7. Calculation of Oral Intake of Metals from Soil through Vegetables

The values of the oral intake of metals from the soil through the vegetable were determined based on the formular of Cui et al., (2004). The Daily consumption of metals (DIM) = daily vegetable consumption x mean vegetable metal concentrations (mg/day, fresh weight). Although, as specified by WHO guidelines (WHO, 1998), the required amount of vegetables in man’s daily diet should be 300-350g per person, for this study we have estimated 61.5g/day of vegetable consumed by Nigerians since Africans generally eat less of vegetables. We have also assumed an average human weight of 65kg for and average adult.

3.8. Calculation of Transfer Factor (TF)

The transfer factor (TF) of metals from soil to vegetables was calculated using the formular of Lokeshwari and Chandrappa, (2006) as follows:

$$TF = C_{plant}/C_{soil}$$

Where C_{plant} and C_{soil} represent the concentrations of the toxic metal in the plants and soils respectively.

3.9. Calculation of Health Risk Index (HRI)

The health risk index provides an indication of health risk level due to exposure to toxic metals. The estimated potential health risk to humans through the ingestion of vegetables was calculated using the United States Environmental Protection Agency (EPA) hazard quotient where

$$HRI = (DIM) \times (C_{metal})/RD \times Bo$$

Where DIM is the daily intake of metal through the vegetables (kg/day), (C_{metal}) is the concentration of in the vegetable (mg/kg), RD is the oral reference dose for the metal (mg/kg of body weight/day) and Bo is the human body weight (kg).

4. Results and Discussions

The geochemical results of the analysis carried out on the compost, soil and vegetables are presented in Tables 1, 2 and 3.

Table 2. *Concentration of major (in weight %) and Trace elements (in mg/kg) in the different vegetables.*

SampleID	Type of Vegetable	Coordinates	Al_2O_3 %	CaO %	Fe_2O %	MgO %	K_2O %	Na_2O%	As mg/kg	Cd mg/kg	Co mg/kg
MV1	Lettuce	9º 58' 31''N, 8º 53' 31''E	0.13	0.14	0.01	0.28	6.02	0.14	79.94	0.17	0.48
MV2	Cabbage	9º 59' 41''N, 8º 54' 28''E	0.10	2.23	0.09	0.44	8.86	0.12	86.46	″	0.04
MV3	Carrot	9º 58' 53''N, 8º 53' 26''E	0.01	0.08	0.01	0.45	4.83	0.64	52.27	″	1.22
MV4	Spinach	9º 58' 54''N, 8º 53' 13''E	0.02	0.50	0.01	0.31	4.84	0.27	80.19	″	0.69
MV5	Beet root	9º 58' 51''N, 8º 53' 31''E	0.06	0.85	0.04	0.55	3.36	0.53	26.60	″	2.94
MV6	Radish	9º 59' 42''N, 8º 54' 26''E	0.11	1.90	0.06	2.08	7.81	0.35	217.9	″	3.51
MV7	Onions	9º 58' 52''N, 8º 53' 29''E	0.09	1.22	0.05	0.65	4.36	0.43	149.5	″	3.70
MV8	Turnip	9º 58' 51''N, 8º 53' 34''E	0.09	2.02	0.12	0.76	6.40	0.55	127.3	″	3.98
MV9	Tomato	9º 58' 52''N, 8º 53' 37''E	0.12	1.30	0.07	0.74	7.85	0.57	158.9	″	4.40
Mean									108.74	0.17	

Sample ID: MS- soil; MC-compost; MV-vegetable; <DL – below detection limit

Table 2. *Continued*

SampleID	Vegetable	Coordinates	Cr mg/kg	Ni mg/kg	Pb mg/kg	Cu mg/kg	Sb mg/kg	Se mg/kg	Tl mg/kg	Zn mg/kg
MV1	Lettuce	9º 58' 31''N, 8º 53' 31''E	1.69	<DL	0.77	6.14	20.26	65.05	″	46.03
MV2	Cabbage	9º 58' 54''N, 8º 53' 13''E	<DL	″	5.07	3.67	12.18	65.36	″	157.4
MV3	Carrot	9º 58' 53''N, 8º 53' 26''E	″	″	2.96	27.53	22.53	25.23	101.5	97.97
MV4	Spinach	9º 58' 54''N, 8º 53' 13''E	″	″	0.52	3.99	17.78	69.94	19.03	137.4
MV5	Beet root	9º 58' 51''N, 8º 53' 31''E	″	″	<DL	0.92	<DL	<DL	<DL	648.7
MV6	Radish	9º 59' 42''N, 8º 54' 26''E	″	″	″	15.72	″	6.38	141.2	690.1
MV7	Onions	9º 58' 52''N, 8º 53' 29''E	″	0.52	″	2.564	11.86	1.76	<DL	692.1
MV8	Turnip	9º 58' 51''N, 8º 53' 34''E	″	<DL	″	2.97	<DL	<DL	″	614.2
MV9	Tomato	9º 58' 52''N, 8º 53' 37''E	″	″	″	3.44	4.73	27.22	29.60	739.0
Mean			1,69	0.52	2.33	7.44				424.77

Sample ID: MS- soil; MC-compost; MV-vegetable; <DL – below detection limit

Table 3. *Concentration of major (in weight %) and Trace elements (in mg/kg) in the Compost.*

SampleID	Sample type	Coordinates	Al_2O_3 %	CaO %	Fe_2O %	MgO %	K_2O %	Na_2O %	As mg/kg	Cd mg/kg	Co mg/kg
MC1	Compost	9º 58' 31''N, 8º 53' 31''E	2.39	12.35	1.16	1.29	0.85	0.51	159.1	1.749	7.97
MC2	″	9º 57' 53''N, 8º 53' 24''E	1.66	5.45	3.47	0.77	0.28	0.34	189.4	″	18.82
MC3	″	9º 58' 51''N, 8º 53' 34''E	3.41	10.23	2.75	1.14	0.72	0.64	259.4	2.911	11.65
MC4	″	9º 58' 54''N, 8º 53' 13''E	1.98	1.48	1.48	1.56	0.98	0.56	126.5	″	6.67
Mean									183.6	2.33	

Sample ID: MS- soil; MC-compost; MV-vegetable; <DL – below detection limit

Table 3. *Continued*

SampleID	Sample type	Coordinates	Cr mg/kg	Ni mg/kg	Pb mg/kg	Cu mg/kg	Sb mg/kg	Se mg/kg	Tl mg/kg	Zn mg/kg
MC1	Compost	9º 58' 31''N, 8º 53' 31''E	<DL	6.30	71.44	77.30	22.85	<DL	<DL	6219
MC2	″	9º 57' 53''N, 8º 53' 24''E	35.63	39.61	<DL	66.68	<DL	″	″	1386
MC3	″	9º 58' 51''N, 8º 53' 34''E	<DL	6.80	82.70	178.3	″	″	″	2419
MC4	″	9º 58' 54''N, 8º 53' 13''E	″	2.78	46.09	107.5	″	″	″	2285
			35.63	13.87	66.74	107.45				3077.25

Sample ID: MS- soil; MC-compost; MV-vegetable; <DL – below detection limit

4.1. Concentrations of Major Elements in the Compost and Soils

The average concentrations of the major elements (Al_2O_3, MgO, CaO, Fe_2O_3, K_2O and Na_2O) in the three sampled media are as follows; Compost: 2.36, 7.37, 2.22, 1.19, 0.71 and 0.51 wt% respectively; in the arable soil: 4.50, 0.51, 4.40, 0.43, 0.52 and 0.06 wt % respectively and in the vegetables: 0.10, 1.23, 0.05, 0.55, 6.40 and 0.55 wt % respectively.

4.2. Concentrations of Toxic Metals in Compost, Soils and Vegetables

The compost displays concentration in Arsenic from 126.5 – 259.4 mg/kg, slightly above the 10.27 – 96.94 mg/kg recorded in the soils (Tables1, 2 and 3). There is an enhancement of As in the vegetable crops, from 26.60 – 217.3 mg/kg. The concentration of Zn in the compost (1386 – 6219 mg/kg) is visibly high compared to that in the soils which varies from 14.59 – 5944 mg/kg. The vegetable crops also present significantly relatively high zinc content (46 – 739 mg/kg). Another element of concern is Pb with a range of concentration values ranging from 46.09 - 82.70 mg/kg in the compost. The soils equally have high Pb content of 0.38 – 306.20 mg/kg, while the vegetable crops have concentrations between 0.52 – 5.07 mg/kg. Cu in the compost has concentration values of the range 66.08 – 178.30 mg/kg as opposed to 12.28 – 150.90 mg/kg and 0.92 – 27.53 mg/kg in the soils and vegetables respectively. Cobalt presents concentration values ranging from 6.69 – 18.82 mg/kg in the compost and from 4.38 – 26.84 mg/kg and 0.04 – 4.40 mg/kg in the soil and vegetables respectively. There is more of Cd in the compost (1.75 - 2.91 mg/kg) than recorded in the soil (1.63 - 0.38 mg/kg). The concentrations of Cr in the compost and the soils are within the same ranges (35.03 mg/kg and 24.52 – 130.8 mg/kg respectively). Like Cr, Ni exhibits a relatively similar range of concentration values in the compost (2.78 – 29.61 mg/kg) compared to its values in the soils (3.29 – 34.01 mg/kg).

4.3. Contamination Factor (CF)

The Contamination Factor determines the level of contamination of the soils in terms of anthropogenic input. The calculated results for the contamination factors for the metals in the soils, compost and the vegetables are presented in Tables 4, 5 and 6). CF is classified into six categories due to severity of contamination: CF < 3 minimal contamination; 3-5 moderate contamination; 5-10 moderately severe contamination; 10-25 severe contamination; 25-50 very severe contamination and CF >50 extremely severe contamination. The soils are severely contaminated by As, Cd and Pb (CF = up to 20) and moderately contaminated in Cr, Cu, Zn and Ni (CF = 3-5). Equally the compost is severely contaminated by As (CF=25-37) and the contamination decreases in the order As>Cd>Zn>Pb>Cu>Cr. All the vegetable crops are extremely severely contaminated by Se (CF= >50). The degree of contamination decreases in the order Se>As>Zn>Cd. Except for the onions, the leafy vegetables (lettuce, cabbage, spinach) are severely contaminated with As. Also, the root (Carrot, Beet, Radish, Turnip) and the fruit vegetables are extremely severely contaminated by As in most cases (CF >50). The radish is the most contaminated in As followed by the tomato, turnip, carrot and beet.

Table 4. *The Contamination Factor of heavy metals in the agricultural soils*

Sample ID	Sample Type	As	Cd	Cr	Pb	Cu	Zn	Ni
MS1	Soil	15.19	27.083	0.25	10.88	5.03	99.6	0.43
MS2	”	9.76	-	0.62	30.45	2.35	20.24	0.19
MS3	”	-	-	0.99	0.04	0.89	-	0.78
MS4	”	6.54	-	0.32	2.15	1.52	11.91	0.36
MS5	”	-	-	1.28	30.62	2.98	12.55	0.37
MS6	”	2.05	-	0.97	3.49	0.95	0.74	0.49
MS7	”	-	-	0.70	2.36	0.79	1.11	0.69
MS8	”	4.98	6.25	1.31	9.28	3.87	118.88	0.28
MS9	”	8.01	-	1.29	3.0	1.19	3.18	0.39
MS10	”	13.55	-	0.77	2.34	0.88	2.19	0.59
MS11	”	10.17	-	0.14	0.22	0.41	-	0.08
MS12	”	19.39	-	0.68	1.38	0.96	-	0.85
MS13	”	11.34	-	0.79	4.87	0.89	0.29	0.48

Table 5. *The Contamination Factor of heavy metals in the Compost*

Sample ID	Sample Type	As	Cd	Cr	Se	Pb	Cu	Zn	Ni
MC1	Compost	31.82	29.15	-	-	7.14	2.58	124.38	0.16
MC2	”	37.88	-	0.356	-	-	2.22	27.72	0.99
MC3	”	51.88	48.517	-	-	8.27	5.94	48.38	0.17
MC4	”	25.30	-		-	4.61	3.58	45.70	0.07

Table 6. *The Contamination Factor of heavy metals in the vegetables analyzed*

	Leafy Vegetables			Root Vegetables			Fruit		
Element	**MV1 Lettuce**	**MV2 Cabbage**	**MV4 Spinach**	**MV7 Onions**	**MV3 Carrot**	**MV5 Beet**	**MV6 Radish**	**MV8 Turnip**	**MV9 Tomato**
As	31.98	34.58	32.08	59.8	20.91	10.64	86.9	50.92	63.56
Cd	56.66	-	-	-	-	-	-	-	-
Cr	-	-	-	-	-	-	-	-	-
Se	-	-	-	-	-	-	-	-	-
Pb	0.39	2.54	0.26	-	1.48	-	-	-	-
Cu	0.0205	0.012	0.13	0.009	0.09	0.003	0.052	0.010	0.015
Zn	0.046	0.16	0.14	0.69	0.10	0.65	0.69	0.61	0.74
Ni	-	-	-	-	-	-	-	-	-

4.4. Transfer Factors (TF) from Soil to Vegetables

Different heavy metals from soil to vegetation are one of the key components of human exposure to metals through the food chain. Table 7 shows the transfer factors for different heavy metals from soil to vegetables. All the vegetable crops display TF >1 for As (leafy: TF=3.96; root: TF=4.24 and fruit: TF=6.24) suggesting that the tomato is the major accumulator of As, followed by the root and finally the leafy vegetables. The TF for Cd in the leafy vegetable is anomalously high (TF=47.22). These indicate that the vegetables in question are good accumulator of these elements. The TF for Zn, Cu and Pb is < 1 in all the vegetables. Apparently, the TF for the leafy vegetables are significantly higher than non-leafy vegetables. The prolonged human consumption of these vegetables and the transfer of these toxic metals into the human body system could pose serious human health problems.

Table 7. *Estimated Daily Intake of Metal (DIM) and the Health Risk Index (HRI) through the ingestion of the vegetables.*

Elements	Mean Concentration of the Vegetables	Transfer Factor (TF)	Amount of Metal Consumed (mg/kg)	Daily Intake of Metal (mg/kg)	RD (mg/day)	Health Risk Index (HRI)
Leafy Vegetables (4)						
As	19.81	3.96	1218	1.59		5.3
Cd	2.83	47.22	172.2	0.23	0.070	3.21
Cr	0.017	-	-	-	105	-
Se	168.43	-	-	-		-
Pb	0.212	0.021	13	0.017	0.245	11.3
Cu	0.14	0.005	8.4	0.011	2.0-3.0	0.004
Zn	5.17	0.103	318	0.416	15.00	0.69
Root Vegetables (4)						
As	21.20	4.24	1304	1.71		5.68
Cd	-	-	-	-		-
Cr	-	0.030	-	-		-
Se	52.68	-	-	-		-
Pb	0.29	-	18	0.023		15.6
Cu	0.39	0.013	24	0.032		0.013
Zn	10.26	0.21	631	0.83		1.38
Ni	-	-	-	-		-
Fruit Vegetable (1)						
As	31.78	6.24	1954.47	2.56		18.53
Cd	-	-	-	-		-
Cr	-	-	-	-		-
Se	90.73	-	-	-		-
Pb	-	-	-	-		-
Cu	0.015	0.004	7.07	0.009		0.004
Zn	7.74	0.30	908.97	1.19		1.98
Ni	-	-	-	-		

4.5. Potential Human Health Risk Posed by the Consumption of the Vegetables

The values estimated daily intake of metals by human being from the consumption of the vegetables grown using organic fertilizer are presented in Table 7. In view of the dietary pattern on the Jos Plateau, Nigeria where less vegetable is taken as part of daily diet, we have here considered a daily average of 61.5g/day and an average human body weight of 65 kg. The daily intake of As, Cd, Pb, Cu and Zn from leafy vegetables = 1.59, 0.225, 0.017, 0.011 and 0.416 respectively. The daily intake of As, Pb, Cu and Zn from the root vegetables = 1.705, 0.0234, 0.032 and 0.825 respectively and from the fruit vegetable = As:2.56, Cu:0.0093 and Zn:1.189. From this data, it can be observed that the intake of As is relatively high from all the vegetable crops, but however decreases in the order fruit>root>leafy. The values of the Health Risk Index (HRI) are presented in Table 7. The Hazard Risk Index for As, Cd, Pb, Cu and Zn for the leafy vegetables is 5.3, 3.21. 11.3, 0.0044 and 0.69 respectively. For the root vegetables HRI for As, Pb, Cu and Zn is 5.68, 15.6, 0.013, and 1.37 respectively), whereas the fruit vegetables has As=18.53, Cu:0.0037 and Zn 1.98. The HRI for As and Pb are significantly high in fruit and root vegetables respectively. The sequence of HRI in generally for the elements in decreasing order is As>Pb>Zn>Cu. The HRI for As, Pb and Zn is >1 and therefore unsafe. HRI for Cu is < 1 for all the variety of vegetables which can be considered safe with no risk to human health. Arsenic is a toxic metal which can cause several human health problems such as cancer, keratosis, hyperthension etc. Human exposure to Pb can cause kidney damage and damage to the nervous system and impair mental development in children.

5. Conclusion

What has emerged from this study is the revelation that the application of municipal solid wastes as organic fertilizer in vegetable gardens is a major source of metal pollution into farmlands. Consequently food crops grown on such contaminated farmland with high heavy metals concentrations will absorb such metals depending on the metal uptake capabilities and storage. The transfer factor (TF) of different plant species vary from one type to another. Soil to plant transfer is a major pathway of human exposure to toxic metals via the food chain (Yeasmin et al, 2013). The transfer of metals from the compost into the soil and subsequently into the vegetables has been established.

The vegetables are severely contaminated by the following toxic elements in the decreasing order of Se>As>Zn. The variation of elemental concentration in the different varieties of vegetables analysed show clearly that the uptake capabilities of the plants vary (Pendias and Pendias, 2000). In general, the vegetables are good accumulators of toxic elements, however, the leafy vegetables (lettuce, cabbage and spinach) are the highest accumulator of toxic metals as compared to the non-leafy vegetables. The fruit vegetable (tomato) is the least accumulator of toxic metals followed by root vegetables (carrot, onion, radish and turnip).

The calculated HRI>1 for As in the vegetables indicate that all varieties are unsafe which may pose risk to human health. All except the leafy vegetables are unsafe in terms of its zinc content (HRI>1 for Zn). The HRI values for Pb in the root and leafy vegetables are far higher than 1, and therefore unsafe. Finally, this study has shown that vegetables grown from municipal solid waste are unsafe and therefore poses serious risks to human health. It is therefore recommended that the composition of organic fertilizer and the soils from which vegetable crops are grown should be monitored and regulated to reduce its adverse effects on human population.

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