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Quantification of Heavy Metals using Contamination and Pollution Index in Selected Refuse Dumpsites in Owerri, Imo State Southeast Nigeria

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Running title: Contamination and pollution level of heavy metals at dumpsites.

***Abstract*—** *Many sites in urban cities are used for dumping of domestic, industrial and municipal wastes because of high human population density in the area. Most often, people use these dumpsites for growing of crops without knowing the level of heavy metal contamination in soils of these areas. This study evaluated the quantification and contamination level of heavy metals in some refuse dumpsites in communities of the State Nigeria. Three replicate soil samples were collected from the dumpsites and at 20 m away from the non - dumpsite which do not receive sewage water within the root zone of 0 – 40 cm depth using soil auger sampler. Samples were analysed for soil properties and heavy metal concentrations using standard methods. The concentrations of the studied heavy metals (Cu, Pb, Zn and Cd) were compared with the permissible limits of other countries. Results showed that in the three studied locations, soil pH at dumpsites were 40 .6%, 39.4% and 38.9% higher than the values in the control sites while soil organic carbon were higher in the dumpsites by 50.1%, 31.3% and 41.1% as compared to the control sites. Cu concentrations at the three locations were below the standard limits of United Kingdom, European Union (EU), USA and WHO. The concentrations of the studied heavy metals passed the contamination stage and therefore will pose negative effect on plant and soil environment. Use of the dumpsite for crop cultivation or as compost materials should be avoided and construction of shallow wells near these areas should be discouraged.*

***Keywords*— Contamination, environment, heavy metal, municipal wastes, pollution.**

I. INTRODUCTION

Migration of people from rural to urban cities has increased human population density and hence has resulted to generation of large agricultural and municipal wastes [1]. Most often, people deposit these wastes on or along the road sides, unapproved areas, open dumpsites in the markets or in water ways [2] and management of these wastes has been an environmental challenge to Nigerian governmental [3]. Inappropriate disposal of these wastes causes environmental pollution and contamination of underground and surface water bodies [4]. Research works have shown that heavy metals such as lead, cadmium, nickel, manganese and chromium amongst others are responsible for certain diseases in man [5]. Large quantities of these toxic metals accumulate in soils used as dumpsites [6]. Accumulation of these metals in the soil affect soil ecosystem thereby causing significant loses of soil quality [7].

A lot of research has been conducted to evaluate the heavy metal concentrations in soils at refuse dumpsites [8]. [9] studied the vertical migration of heavy metals in dumpsites soil in Maiduguri Metropolis Nigeria, [10] evaluated the concentrations of heavy metals in municipal dumpsite soil and plants at Oke-ogi, Iree, Nigeria. These authors found out different concentrations of heavy metals in dumpsites with some heavy metals being above the permissible limit. Soil acts as a major sink and source of heavy metal ions [7]. Consumption of foods produced from dumpsites help in heavy metal accumulation in the body which is detrimental to life. This problem is common among farmers who make use of soils from dumpsites as manure or as soil amendments for the production of vegetable and other arable crops.

According to [11], contamination / pollution index is a method of comparing the concentration of soil heavy metals with an international standard to determine the degree of pollution or contamination of a given location and the effect of the concentration on soil plant and

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environment. Differences between soil contamination range and soil pollution range is given by the metal contamination/pollution index (MPI) [11]. This index represents the ratio between the heavy metal content effectively measured in soil by chemical analysis and reference value obtained from the control soil [12].

Heavy metal concentration at dumpsites often exceeds the permissible limits and could be detrimental to land users. [11] Suggested periodic evaluation of the concentration of heavy metal or toxic substances at dumpsites for policy making. There is a dearth of information on the quantification of heavy metals using contamination and pollution index in selected refuse dumpsites in the study area. The study therefore evaluated the quantification of heavy metals using contamination and pollution index in selected refuse dumpsites in Owerri, Imo State Southeast Nigeria.

II. MATERIALS AND METHODS

2.1. The study area

The study was carried out in Owerri (Imo State Capital) Nigeria. Three communities were studied namely Ihiagwa, Umuchima and Eziobodo communities. The sampling sites in these communities were selected based on human activities around each dumpsite. The sites' coordinates were taken with a Geographical Positioning System (GPS) as shown in Table 1.

Table.1: Coordinates of the study locations

Location	Land use	Longitude	Latitude
Ihiagwa1	Refuse dumpsite	5° 24' 11''N	7° 01' 22''E
Umuchima 1	Refuse dumpsite	5° 23' 35''N	6° 01' 26''E
Eziobodo 1	Refuse dumpsite	5° 22' 48''N	7° 01' 36''E
Ihiagwa2	Refuse dumpsite	5° 24' 16''N	7° 02' 26''E
Umuchima 2	Refuse dumpsite	5° 23' 31''N	7° 01' 21''E
Eziobodo 2	Refuse dumpsite	5° 23' 05''N	6° 01' 43''E
Ihiagwa 3	Refuse dumpsite	5° 24' 07''N	7° 01' 23''E
Umuchima 3	Refuse dumpsite	5° 24' 12''N	7° 03' 22''E
Eziobodo 3	Refuse dumpsite	5° 22' 45''N	6° 01' 31''E

The locations have an average annual rainfall range of 1950 mm – 2000 mm and annual temperature range of 27°C – 30°C with average relative humidity of 79%. The geological material of soil in the study area is an ultisol and classified as Typic Haplustult [13], derived from Coastal Plain Sands (Benin formation) of the Oligocene-Miocene geological era and are characterized by low organic matter, cation exchange capacity and are highly leached [14].

2.2. Soil sampling

A reconnaissance visit of the study area was carried out to demarcate the sampling points in the three communities under refuse dumpsite practices and a control soil 20 m away which do not receive sewage water. At each sampling site, three replicate samples of approximately 1kg of soil were randomly collected in each community from a mini pedon of 0 – 40 cm depth using soil sampling spiral auger sampler. The samples were mixed thoroughly and taken in labelled nylon bags to differentiate the sampling points. The samples were grounded, air dried and sieved through 2mm mesh sieve and taken to the laboratory for heavy metal content and routine soil analysis.

2.3. Laboratory Analysis

Particle size distribution (sand, silt and clay fractions) was determined by hydrometer method according to the procedure of [15]. Soil pH was determined using pH metre in soil / liquid suspension of 1: 2.5 according to [16]. Organic carbon was determined using chromic acid wet oxidation method according to [17]. . Total nitrogen was determined by kjeldahl digestion method using concentrated H_2S0_4 and sodium copper sulphate catalyst mixture according to [18]. Available phosphorus was determined according to [19]. Exchangeable Mg and Ca were extracted using ethylene diamine tetra acetic acid (EDTA) [20] while exchangeable K and Na were extracted using 1 N Neutral ammonium acetate (NH_4OAC) and then read using flame photometer [20]. Total exchangeable base (TEB) was obtained by the summation of exchangeable Ca, Mg, K and Na.

2.4. Determination of heavy metal

Heavy metals were determined by weighing 10 g of each soil sample into a 100 mL conical flask washed with deionized water. In each flask, 6 mL $HNO_3/HClO_4$ acid in the ratio 2:1 is added and left overnight. Each sample was digested at 150°C for about 90 minutes and the

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temperature was increased to 230°C for 30 minutes. HCl solution was added in ratio 1:1 to the digested sample and re-digested again for another 30 minutes. The digested sample was then washed into 100 mL volumetric flask. The mixture was cooled down to room temperature to avoid formation of insoluble perchloric compounds and late made up to mark with deionized water. Atomic absorption spectrometer is used to read the heavy metal concentration in the digest and the amount of each heavy metal was extrapolated from the calibration graph prepared.

2.5. Quantification of heavy metal contamination/pollution index (MPI)

The quantification of contamination/pollution index of heavy metals was derived by adopting the contamination/pollution index of metals in soil as defined by [11] as:

$$MPI = C_{hms} / R_s \quad \text{..... Equation 1}$$

Where MPI = contamination/pollution index

C_{hms}= concentration of heavy metal in soil

R_s = concentration of heavy metal in reference soil (control)

The difference between soil contamination range and soil pollution range is given by the metal contamination/pollution index (MPI). The value of this index represents the ratio between the heavy metal content effectively measured in soil by chemical analysis and reference value obtained from the control soil. Values of contamination/pollution index of soil greater than 1 (> 1), define the pollution range and those less than 1 (<1) define the contamination range. According to [11], the two ranges of values were divided into interval of values < 0.1 as very slight contamination, 0.10 – 0.25 as slight contamination, 0.26 – 0.5 as moderate contamination, 0.51 – 0.75 as severe contamination, 0.76 – 1.00 as very severe contamination, 1.1 – 2.0 as slight pollution, 2.1 – 4.0 as moderate pollution, 4.1 – 8.0 as severe pollution, 8.1 – 16.0 as very severe pollution and > 16.0as excessive pollution (Table 2).

Table.2: Interval of contamination/pollution index of heavy metals in soil and its significance

MPI	Significance	Remark
< 0.10	Very slight contamination	No negative effect on soil, plant and environment
0.10 – 0.25	Slight contamination	No negative effect on soil, plant and environment
0.26 – 0.5	Moderate contamination	No negative effect on soil, plant and environment
0.5 – 0.75	Severe contamination	No negative effect on soil, plant and environment
0.76 – 1.00	Very severe contamination	No negative effect on soil, plant and environment
1.1 – 2.0	Slight pollution	Will pose negative effect on plant, soil and environment
2.1 – 4.0	Moderate pollution	Will pose negative effect on plant, soil and environment
4.1 – 8.0	Severe pollution	Will pose negative effect on plant, soil and environment
8.1– 16	Very severe pollution	Will pose negative effect on plant, soil and environment
>16.0	Excessive pollution	Will pose negative effect on plant, soil and environment

Adapted from [11]

2.6. Statistical analysis and data presentation

Data collected from soil analysis were subjected to analysis of variance (ANOVA) and significant treatment means were separated using least significant difference (LSD) at 0.05 probability level.

III. RESULTS AND DISCUSSION

3.1. The physico-chemical properties of the studied locations

Particle size distributions of soil are presented in Fig 1. Sand fractions ranged from 829.6 – 856.27 g/kg, silt ranged from 56.27 - 89.87 g/kg while clay ranged from 78.87 – 100.8 g/kg. Sand fraction dominated the studied location irrespective of the influence of the dumping activity and the dumping activity did not change the textural class of the soils when compared to both the dumpsite and the control. This could be attributed to the parent material (coastal plain sand) that formed the soil. This observation was in line with [10] who recorded no significant difference in the particle size distribution for both the dumpsite and control site soils in the study that evaluated the determination of concentrations of heavy metals in municipal dumpsite soil and plants at Oke-ogi, Iree, Nigeria.

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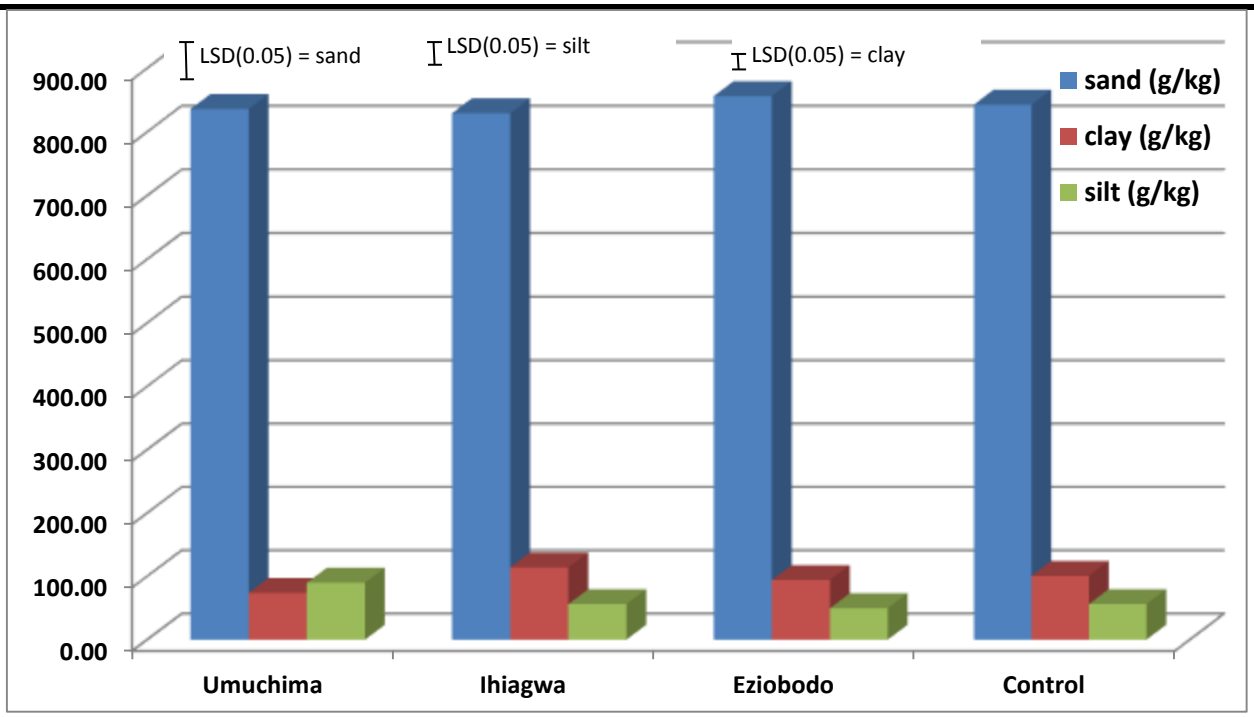
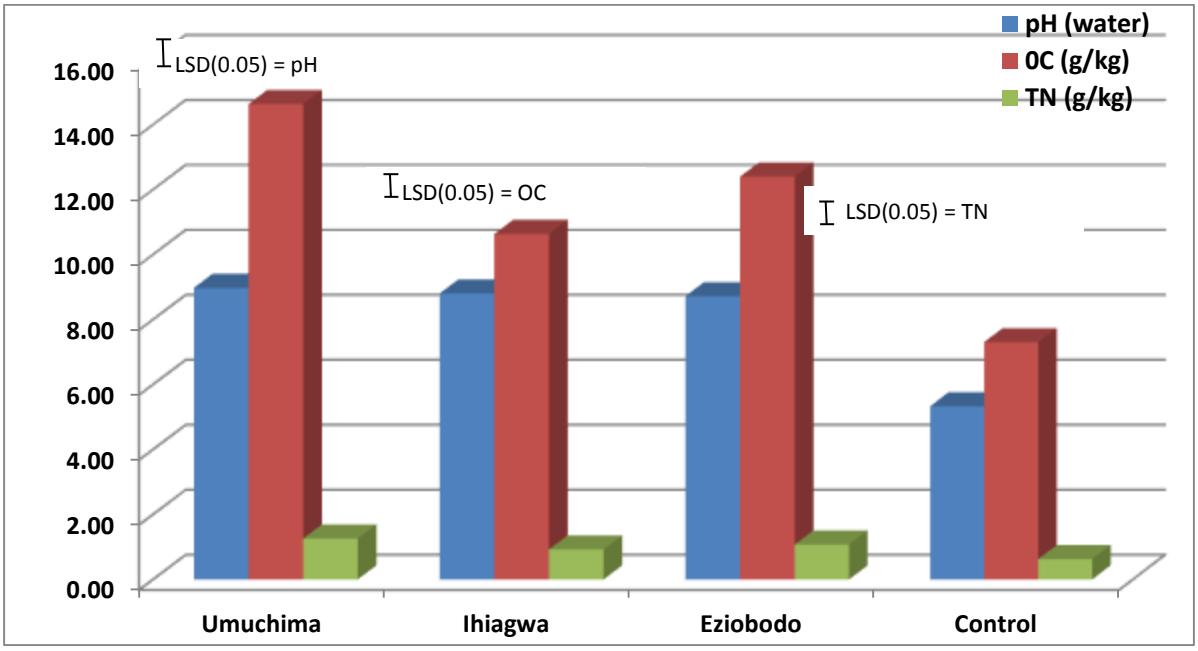


Fig.1: Particle size distribution of soil in the study locations.

The values of soil pH, soil organic carbon, and total nitrogen in the dump and non- dump sites are presented in Fig. 2. Soil organic carbon ranged from 10.63 – 14.63 g/kg in the dumpsites and at the control sites as compared to the value 7.30 g/kg in the control. The highest soil organic carbon was recorded at Umuchima dumpsites (14.63 g/kg). Similarly, the same trend was observed in soil pH. At the dumpsites, soil pH ranged from 8.97 – 8.80 as compared to the value 5.33 in the control sites. Soil total nitrogen ranged from 0.92 – 1.26 g/kg at the dumpsites with the highest value (1.26 g/kg) recorded at Umuchima dumpsites. Increase in soil organic carbon at the dumpsites may be attributed to accumulation of organic materials of varying stages of decomposition as well as higher soil pH that favours microbial activity. Higher soil total nitrogen recorded at the dumpsites could be attributed to higher soil organic matter and increased soil pH. [21] observed a positive correlation between soil organic matter and soil pH at refuse dumpsites.



OC = organic carbon, TN = total nitrogen

Fig.2: Soil pH, organic carbon and total nitrogen of soils in the study locations.

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The values of available phosphorus and total exchangeable bases are presented in Fig. 3. Results showed that available phosphorus ranged from 10.13 – 11.38 mg/kg in the dumpsites as against the value 4.69 mg/kg at the control. Total exchangeable bases ranged from 4.30 - 3.96 cmol/kg in the three dumpsites while at the control sites, the value was 1.26 cmol/kg. Higher values of available phosphorus and total exchangeable bases at the dumpsites could be attributed to higher organic matter and soil pH as recorded in Fig 2 since soil organic matter correlates positively with total exchangeable bases.

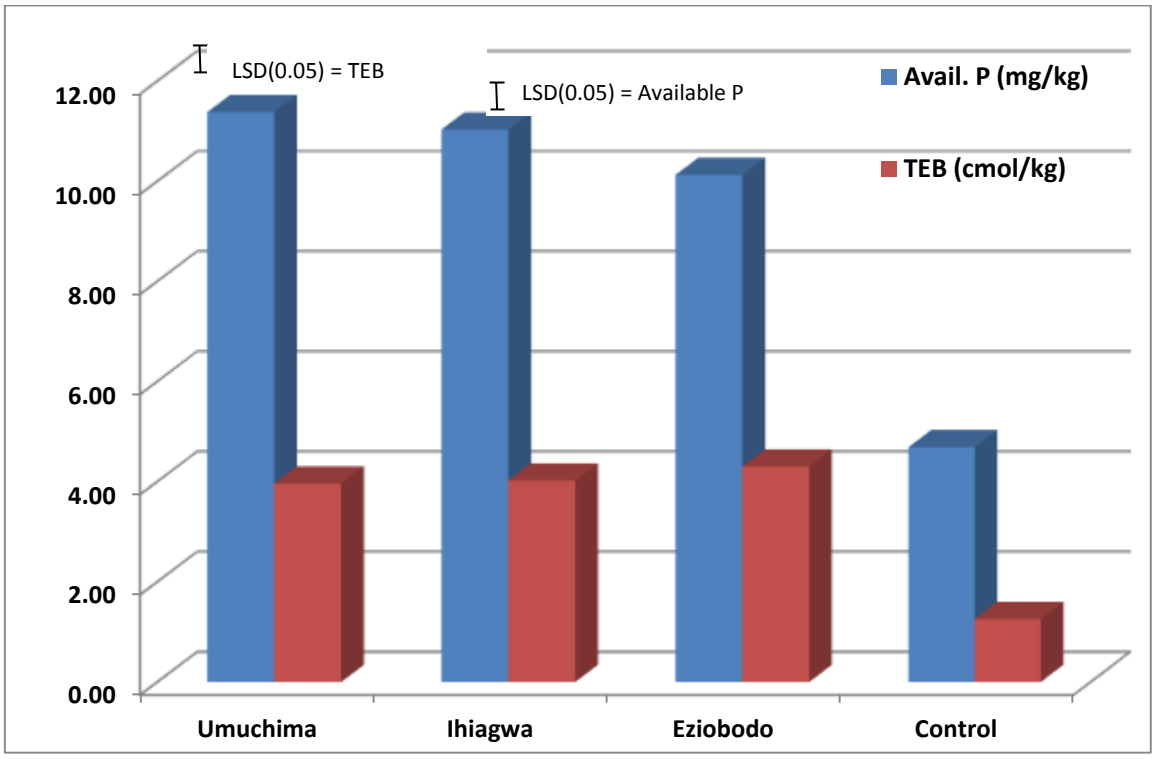

Fig.3: Soil available phosphorus and total exchangeable bases in the study

3.2. Contamination/pollution index of heavy metals in soil and its significance

Heavy metal contamination and pollution index (MPI) in the studied locations are presented in Table 3. Results showed that at Ihiagwa dumpsites, cadmium and lead were slightly polluted while Cu was severely polluted and Zn was excessively polluted. At Umuchima dumpsites, Cd and Pd were slightly polluted while Cu and Zn were moderately and very severely polluted respectively. At Eziobodo, the four heavy metals were slightly polluted. From these results, the concentrations of these heavy metals have passed the contamination stage and therefore will pose negative effect on plant and soil environment in the three dumpsites according to [11].

Table.3: Interval of contamination/pollution index of heavy metals in soil and its interpretation

Location	Heavy metal	MPI	Significance	Remark
Ihiagwa	Cd	1.80	Slight pollution	Will pose negative effect on plant, soil and environment
	Pb	1.36	Slight pollution	Will pose negative effect on plant, soil and environment
	Cu	4.22	Severe pollution	Will pose negative effect on plant, soil and environment
	Zn	22.37	Excessive pollution	Will pose negative effect on plant, soil and environment
Umuchima	Cd	1.20	Slight pollution	Will pose negative effect on plant, soil and environment
	Pb	2.0	Slight pollution	Will pose negative effect on plant, soil and environment
	Cu	2.67	Moderate pollution	Will pose negative effect on plant, soil and environment
	Zn	8.88	Very severe pollution	Will pose negative effect on plant, soil and environment
Eziobodo	Cd	2.0	Slight pollution	Will pose negative effect on plant, soil and environment
	Pb	1.14	Slight pollution	Will pose negative effect on plant, soil and environment
	Cu	1.17	Slight pollution	Will pose negative effect on plant, soil and environment
	Zn	1.32	Slight pollution	Will pose negative effect on plant, soil and environment

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3.3. Comparison of heavy metal concentrations in the studied locations with international standard limits

Table 4 showed the mean values of heavy metals at the studied locations as compared to standard limits using European Union, United Kingdom, United State of America and World Health Organization standards. Cd concentration at Ihiagwa, Umuchima and Eziobodo dumpsites was below EU standard, UK standard, USA standard and was above WHO standard by 0.01 mg/kg. Similarly, the concentrations of lead at three locations was below the standard limit of EU, UK and USA but was above that of WHO. Cu concentration at the three locations was below the standard limits of UK, EU, USA and WHO. The concentration of Zn at Ihiagwa was below the standard limits of EU, UK, USA and WHO but at Umuchima and Eziobodo, the concentration was above the WHO standard.

Table.4: Mean concentration of heavy metals at the study sites as compared to standard limits of heavy metals in Soil

Heavy metals (mg/kg)	**Depth Cm**	**Range Mg/kg**	**Ihiagwa Mean Mg/kg**	**Umuchi Mean Mg/kg**	**Eziobodo Mean Mg/kg**	**Control Mean Mg/kg**	**EU standard Mg/kg**	**UK standard Mg/kg**	**USA standard Mg/kg**	**WHO Standard** Mg/kg
Cd	0 – 30	0.08 – 0.10	0.09	0.06	0.10	0.05	3.0	1.4	3.0	0.01
Pb	0 – 30	0.84 – 1.48	1.01	1.48	0.84	0.74	300	70	300	0.10
Cu	0 – 30	0.13 – 0.79	0.79	0.48	0.21	0.18	140	63	80 – 100	1.5
Zn	0 – 30	1.40 – 34.89	34.89	13.86	2.06	1.56	300	200	200 – 300	15

EU =European Union Standard, USA =United State of America Standard, UK =United Kingdom standard

IV. CONCLUSION

The quantification of heavy metals at refuse dumpsites in three communities in Imo State Nigeria was evaluated to ascertain the level of heavy metal pollution / contamination in the sites. All the dumpsites studied passed the contamination stage.. Even though high values of soil organic matter and soil pH were recorded at these dumpsites but based on the contamination level of these soils, they could not be used as soil amendment or for crop production. It is therefore pertinent to evaluate the contamination level of dumpsites in our cities from time to time especially those sites used for vegetable production. The use of soils from dump site for crop production, particularly vegetables, should be discouraged as well.

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