



## **EFFECT OF MUNICIPAL SOLID WASTES ON HEAVY METAL CONTENT OF FARMLAND SOILS IN BAUCHI METROPOLIS, BAUCHI STATE, NIGERIA**

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### **ABSTRACT**

The level of heavy metal pollution (Cd, Cr, Pb, Ni, and Zn) in farmland soils treated with Municipal Solid Waste (MSW) and Inorganic fertilizer (NPK) in Bauchi metropolis, Bauchi state, Nigeria was evaluated. Soil samples were collected at a depth of 0-30cm from three farmland locations fertilized with municipal solid waste (MSW 1 treated soil, MSW 2 treated soil and MSW 3 treated soil), one with inorganic fertilizer (NPK), and one from uncultivated land. The soils were subjected to physicochemical and heavy metal analysis using standard procedures. The results showed that MSW treated soils had significantly more sand and less silt and clay than the NPK and control soils. Texturally, the MSW-fertilized soils were classified as loamy sand, while the NPK-treated and control soils were classified as sandy loam. The soil pH was neutral for MSW 2 and 3 treated soils and slightly acidic for the MSW 1 treated soils, NPK treated soils, and the control. Soils treated with MSW had significantly ( $P \leq 0.05$ ) higher levels of organic carbon, nitrogen, Cation Exchange Capacity (CEC), exchangeable bases, and Electrical Conductivity (EC) than NPK-treated soils and the control. Heavy metals concentration (Cd, Cr, Pb, Ni, and Zn) were also significantly ( $P \leq 0.05$ ) higher in MSW treated soils, followed by NPK treated soils, and the lowest concentrations were found in the control soils. The pattern of accumulation of the heavy metals were  $Zn > Ni > Pb > Cr > Cd$  in MSW fertilized soils and  $Zn > Pb > Ni > Cr > Cd$  in NPK treated soils and control. Heavy metal levels in NPK treated and the control soils were within the FAO/WHO recommended limits in soil. The concentration of Zn, Pb, and Cd in the MSW treated soils exceeded FAO/WHO permissible limits while Cr was within the permissible limits. Nickel concentrations were within the range for MSW 3 treated soil but exceeded the limit in MSW 1 and MSW 2 treated soils. The study concluded that fertilizing farmland soils with MSW increased heavy metal contamination of the soils thus, posing a serious risk to environmental sustainability. Based on the result of this study, effective implementation of the National and State policies on solid waste management by the relevant institutions is recommended.

**Keywords:** Municipal, Solid, Waste, Heavy metals, Concentration

### **INTRODUCTION**

Municipal Solid Waste (MSW) is defined as unwanted bi-products or undesirable materials ("garbage," or "trash") that are discarded (Suleiman *et al.*, 2018; Chinonso *et al.*, 2020), and it has become one of Nigeria's major environmental issues and a serious health hazard. In Nigeria, MSW generation has increased significantly in recent years. They frequently originate from household materials, economic activities, industrial sites, electronic wastes, hospitals and



clinical waste etc (Sarinas *et al.*, 2014). This rise in solid waste generation is as a result of unplanned urbanization, industrialization, and population growth in Nigerian towns and cities including Bauchi state. Annual solid waste generation in Nigeria is estimated at 42 million tons, with organic waste accounting for 52% of the total and only 20% - 30% being collected and managed properly (Adeniyi, 2023; Ike *et al.*, 2018). In most cases, municipal solid wastes are disposed indiscriminately on open dump sites in developing countries such as Nigeria, resulting in degradation of agricultural lands, obstruction of drainages and pollution of water bodies, possibly as a result of inadequate budgetary allocations for waste disposal or lack of effective and efficient waste management policies in many towns and cities. Other factors include corrupt practices and a general lack of responses to public awareness on how to properly dispose refuse. In Nigeria, as in most developing countries, open dumping and burning of MSW is commonly regarded as the simplest and cheapest method of solid waste management (Adeniyi, 2023). There are fewer or no centralized and modern waste management systems in most urban centres. Solid wastes are just being collected, transported, and indiscriminately dumped and sometimes uncontrolled burnt (Zhang *et al.* 2024).

## **MATERIALS AND METHODS**

### **Description of the Study Area**

Bauchi State is located in the Northern part of Nigeria and falls within the Guinea Savannah ecological zone of the country. It occupies a total land area of 49,119 km<sup>2</sup> representing about 5.3% of Nigeria's total land mass and is located between latitudes 9° 3' and 12° 3' North and longitudes 8° 50' and 11° East and lies at an altitude of about 600m above sea level. The state is bordered by seven states, Kano and Jigawa to the North, Taraba and Plateau to the South, Gombe and Yobe to the East and Kaduna and part of Plateau to the West (NBS,2009). The State has two ecological zones namely, the Northern guinea savannah in the South and the Sudan savannah in the North (Ibrahim, 2004). Soils in the State are formed from Basement Complex Rock (BCR) and the Sedimentary Rocks comprising the Keri-Keri (KKF) and the Chad (CF) formations. The BCR covers most part of the State (Mustapha and Fagam, 2007). On the basis of soil taxonomy, four soil sub-orders have been recognized in the state. Orthents, the shallow soils formed on basement complex, Ustalfs in parts of central and northern zones of the state; Psamments, the sandy soils of both central and northern zones and Fluvents, the *Fadama* soils (Ibrahim, 2004). With its rich land resources, agriculture is the main-stay of the people of Bauchi State. The major crops grown in the state include maize, sorghum, rice, soya beans, sweet potato, vegetables, groundnuts, millet and cowpea. The mean monthly annual rainfall was 94.45mm, mean monthly relative humidity was 51.46 during the period of the study (2013 cropping season)

### **Soil Sampling**

Preliminary survey of farmland soils was conducted and only locations previously fertilized with MSW were selected for the study. Three locations fertilized with MSW and one location fertilized with inorganic fertilizer (NPK) on which maize were grown along Bauchi – Ningi road were selected. An uncultivated land was identified and used as a control. The control was neither fertilized by MSW nor inorganic fertilizer. All locations (Table 1) selected were fully geo-referenced using Global Positioning System (GPS). From each of the sites, soil samples were collected randomly from five locations at a depth of 0-30cm using soil auger and a meter rule. The soil samples were air dried, ground using porcelain mortar and pestle and passed



through a 2mm sieve. The sieved soil samples were stored in properly labelled polyethylene bags and were used for all laboratory analyses using standard procedures

**Table 1:** Selected Sample Sites with their Coordinates

Sites	Longitude	Latitude
MSW site1	9° 50' 04"E;	10° 21' 59"N
MSW site 2	10° 22' 02"N	10° 22' 02"N
MSW site 3	9° 50' 00"E	10° 22' 59"N
Inorganic fertilizer (NPK)	9° 50' 48"E	10° 23' 06"N
Control site	9° 49' 55"E	10° 28' 23"N

**Key:** MSW- Municipal solid waste

### Laboratory Analyses

The heavy metals (Cd, Cr, Pb, Ni & Zn) were estimated by the method of Awokunmi *et al.* (2010). The pH was determined in 1:1 soil to H<sub>2</sub>O ratio and in 1N Calcium Chloride (CaCl<sub>2</sub>) solution using glass electrode pH -meter model CynoScan 2.0 based on the method described by Bates (1954) and adopted by Agbenin (1995). Total nitrogen was determined by micro-Kjeldahl method. Organic carbon content was determined by the method of Walkley and Black (1934) while available phosphorus was determined by the method of IITA, Ibadan (1979). Exchangeable bases were determined by extraction with neutral 1M NH<sub>4</sub>OAC solution (pH 7.0). From the extract, the concentrations of Na<sup>+</sup> and K<sup>+</sup> were determined on flame photometer while Ca<sup>2+</sup> and Mg<sup>2+</sup> were read on an Atomic Absorption Spectrophotometer. Particle size distribution was estimated by the hydrometer method of soil mechanical analysis described by IITA Ibadan (1979).

### Statistical Analyses

The data collected were subjected to Analysis of Variance (ANOVA) procedure. To establish significant difference among the means of parameters examined from different sites, Least Significant Difference (LSD) was used. The concentrations of heavy metals from the sites were compared with the European Union and WHO/FAO standards in soils.

## RESULTS AND DISCUSSION

### Physicochemical Properties of Soils from the Different Sites

The results of the physicochemical properties of the experimental soils as presented in Table 2 showed that, sand was the dominant fraction in the soils from all the sites (71.68-83.68%) followed by silt (8.56-18.56) and clay (7.76-11.76). This may be partly attributed to the chemical and mineralogical composition of the parent material (da Silva *et al.* 2022) and partly to the geological processes involving sorting of soil materials by biological activities, surface erosion etc (Silva *et al.* 2021 and Lawal *et al.*, 2013). The dominance of sand in the particle size fraction of the experimental soils is typical of Nigerian savannah soils as reported by Mustapha *et al.* (2010) and Hayatu *et al.* (2018). However, all the sites fertilized with municipal solid waste (MSW) had significantly ( $P \leq 0.05$ ) lower silt and clay content than soils fertilized with inorganic (NPK) fertilizer and the control. Sand content was significantly higher in MSW fertilized soils compared to the NPK fertilized soils and the control. This is contrary to the findings of Agbeshie



*et al.* (2020) who reported relative increase in silt and clay in soils at dumpsite in Sunyani, Ghana. The higher sand and lower silt and clay fraction in the soils fertilized with MSW may not be unconnected to the anthropogenic nature of these MSW which might be rich in coarse materials. Texturally, MSW site 1 and 2 were classified as loamy sand while site 3, inorganic fertilizer (NPK) site and the control were classified as sandy loam.

The pH of the soils ranges from 5.86-8.13 and 4.72-7.25 in water and  $\text{CaCl}_2$ , respectively. Soils fertilized with MSW significantly ( $P \leq 0.05$ ) had the highest pH followed by soils from MSW 3 treated site, NPK treated site, the control and MSW 1 fertilized soils. As per the rating scale given by Esu (1991), the soils are classified as moderately acidic to neutral. Farmland soils treated with MSW 2 and MSW 3 had a pH of 8.13 and 7.52 and were rated neutral while soils treated with NPK and the control had a pH of 6.09 and 6.54 respectively and were placed in the slightly acidic category. Only soils fertilized with MSW 1 with pH 5.86 was classified as moderately acidic. The higher pH observed in MSW 3 soils compared to the other soil types corroborates with earlier reports on dumpsites by Agbeshie *et al.* (2020) and Obasi *et al.* (2012). The authors concluded in their studies that dumpsites recorded pH values which are mostly alkaline in nature due to the abundance of alkali-earth metals/ liming materials and high activities by soil microorganisms on the municipal waste. The slightly acidic pH observed for the control and NPK fertilized soils may be attributed to the native composition of the parent material (da Silva *et al.* 2022).

The organic carbon content ranges from 0.95 - 2.63% and were significantly higher in MSW treated soils than the soils treated with NPK and control. The higher organic carbon in MSW sites may be adduced to the addition of various waste and the increased microbial activities. With respect to Esu (1991) rating, the soils fertilized with MSW were rated high, those fertilized with inorganic fertilizer (NPK) and the control were rated low. This is in agreement with the works of Amos-Tautua *et al.* (2014) and Antoniadis *et al.* (2008) on MSW, sludge and waste dumpsite. The organic carbon content of MSW fertilized soil was in the order of MSW 1 > MSW 2 > MSW 3. The decrease may be related to the amount of biodegradable materials present in each waste. The higher organic carbon in the control soil relative to the NPK fertilized soil might be due to the rapid mineralization of organic matter induced by the application of inorganic fertilizer in the NPK fertilized soils.

According to the rating scale, the Nitrogen content of the soils which ranged from 0.05-0.42% varied from low to high. Soils treated with MSW 1 showed significantly ( $P \leq 0.05$ ) highest N content and was rated high. Soils from MSW 2 and MSW 3 treated soils were rated medium and significantly higher than soils previously fertilized with NPK and the control which were placed in the low category.

Available Phosphorus content ranged from 10.54-19.63 mg Kg<sup>-1</sup> and was categorized in the medium phosphorus fertility category. However, soil treatments significantly ( $P \leq 0.05$ ) followed a decreasing trend toward the control. MSW 1 > MSW 2 > MSW 3 > Soil fertilized with NPK > Control soil. The Cation Exchange Capacity (CEC) range was 5.24-9.25 Cmol (+)/kg<sup>-1</sup>. Soils fertilized with MSW 1, 2, and 3 were placed in the medium category and were significantly ( $P \leq 0.05$ ) higher than soil fertilized with NPK and the control which were rated low.

The concentration of exchangeable bases of the soils from the sites differed significantly at  $P \leq 0.05$ . The Potassium ( $\text{K}^+$ ) content of the soils fertilized with MSW ranged from 0.31-0.37 Cmol (+) kg<sup>-1</sup>, 0.23 Cmol (+) kg<sup>-1</sup> and 0.3 Cmol (+) kg<sup>-1</sup> for NPK fertilized and control soils respectively. Soils fertilized with MSW significantly ( $P \leq 0.05$ ) had higher  $\text{K}^+$  content than soils





fertilized with NPK and control. However, the soil from the control site was significantly higher in  $K^+$  content than the NPK fertilized soil. The  $K^+$  content in all the soils fertilized with MSW rated high while soils fertilized with NPK and the control were classed as medium. The content of Calcium ( $Ca^{2+}$ ) ranged from 3.45-4.25Cmol  $kg^{-1}$  in soils fertilized with MSW and was significantly higher than NPK fertilized soils (2.63 Cmol (+)  $kg^{-1}$ ) and the control (3.29 Cmol  $kg^{-1}$ ). The content of  $Ca^{2+}$  in these sites fell within the medium category. Similarly, Magnesium ( $Mg^{2+}$ ) content of the soils fertilized with MSW (0.88-1.06 Cmol  $kg^{-1}$ ) were significantly ( $P \leq 0.05$ ) higher than the NPK fertilized soils (0.65 Cmol  $kg^{-1}$ ) and control (0.84 Cmol  $kg^{-1}$ ). Although, the control soil exhibited significantly higher  $Mg^{2+}$  than NPK fertilized soils. The soils fertilized with MSW were rated high while the control and NPK fertilized soils were rated as medium  $Mg^{2+}$  fertility. Sodium ( $Na^+$ ) content of the soils was significantly higher in NPK fertilized soils compared to other sites. Sodium content for other sites were statistically at par with medium Na fertility. The exchangeable bases content of the soils revealed that Calcium ( $Ca^{2+}$ ) was the dominant fraction followed by Magnesium ( $Mg^{2+}$ ), Potassium ( $K^+$ ) and then Sodium ( $Na^+$ ).

The Electrical Conductivity (EC) which is an indication of soluble salt concentration in the soil ranged from 140-580  $\mu S cm^{-1}$  for soil fertilized with MSW and 40  $\mu S cm^{-1}$  for control and NPK fertilized soils. However, MSW soils exhibited significantly ( $P \leq 0.05$ ) higher EC compared to other sites. The critical limits given by the U.S. salinity laboratory Staff (1954) placed the soils as low in EC and are free from soil salinity problem.

Nitrogen, P, CEC and exchangeable bases (Ca, Na, Mg, and K) and EC were higher in soils fertilized with MSW compared to NPK fertilized and the control soils (Table 3). This corroborated the report of Castro *et al.* (2009); Sabir *et al.* (2015); Blanchet *et al.* (2016) and Hossain *et al.* (2017) in which they observed that MSW increased the chemical properties of soil. Also, Agbeshie *et al.* (2020) found that application of MSW and other related wastes increase EC and nutrient availability of soils such as available N and P. Several authors (Lee *et al.*, 2004 and Nest *et al.*, 2016) have proved that the application of MSW and manure are more effective in increasing soil chemical properties (pH, P, N, CEC etc.) than application of inorganic fertilizer.

**Table 2:** Physicochemical Properties of the Sample Sites

Parameter	Soil Type				
	MSW 1	MSW 2	MSW 3	NPK Farm	Control Farm
pH in H <sub>2</sub> O(1:1)	5.86 <sup>c</sup> ±0.02	8.13 <sup>a</sup> ±0.01	7.52 <sup>b</sup> ±0.02	6.09 <sup>d</sup> ±0.03	6.54 <sup>c</sup> ±0.01
pH in CaCl <sub>2</sub> (1:2)	4.72 <sup>c</sup> ±0.01	7.25 <sup>a</sup> ±0.04	6.44 <sup>b</sup> ±0.01	5.02 <sup>d</sup> ±0.02	5.43 <sup>c</sup> ±0.02
Org. Carbon (%)	2.63 <sup>a</sup> ±0.01	1.29 <sup>b</sup> ±0.02	1.16 <sup>c</sup> ±0.03	0.43 <sup>e</sup> ±0.02	0.95 <sup>d</sup> ±0.01
Total Nitrogen (%)	0.42 <sup>a</sup> ±0.02	0.16 <sup>b</sup> ±0.05	0.11 <sup>c</sup> ±0.01	0.05 <sup>e</sup> ±0.01	0.09 <sup>d</sup> ±0.02
AVP (mg/kg)	19.63 <sup>a</sup> ±0.04	15.26 <sup>b</sup> ±0.06	14.11 <sup>c</sup> ±0.01	13.84 <sup>d</sup> ±0.02	10.54 <sup>e</sup> ±0.02
Exchangeable bases					
K <sup>+</sup> (Cmol kg <sup>-1</sup> )	0.37 <sup>a</sup> ±0.02	0.31 <sup>c</sup> ±0.02	0.34 <sup>b</sup> ±0.02	0.23 <sup>d</sup> ±0.03	0.30 <sup>c</sup> ±0.01
Ca <sup>2+</sup> (Cmol kg <sup>-1</sup> )	4.25 <sup>a</sup> ±0.03	3.71 <sup>b</sup> ±0.01	3.45 <sup>c</sup> ±0.02	2.63 <sup>e</sup> ±0.01	3.29 <sup>d</sup> ±0.01
Mg <sup>2+</sup> (Cmol kg <sup>-1</sup> )	1.06 <sup>a</sup> ±0.01	0.97 <sup>b</sup> ±0.02	0.88 <sup>c</sup> ±0.02	0.65 <sup>e</sup> ±0.01	0.84 <sup>d</sup> ±0.01
Na <sup>+</sup> (Cmol kg <sup>-1</sup> )	0.18 <sup>b</sup> ±0.01	0.19 <sup>b</sup> ±0.04	0.20 <sup>ab</sup> ±0.05	0.22 <sup>a</sup> ±0.01	0.17 <sup>b</sup> ±0.02
CEC (Cmol kg <sup>-1</sup> )	9.25 <sup>a</sup> ±0.02	6.38 <sup>c</sup> ±0.01	9.01 <sup>b</sup> ±0.03	4.58 <sup>e</sup> ±0.01	5.24 <sup>d</sup> ±0.01
EC (µSc/m)	580 <sup>a</sup> ±2.12	140 <sup>c</sup> ±2.01	240 <sup>b</sup> ±2.15	40 <sup>d</sup> ±2.12	40 <sup>d</sup> ±2.10
Particle-size distribution					
Silt (%)	8.56 <sup>c</sup> ±0.70	10.56 <sup>d</sup> ±0.72	12.56 <sup>c</sup> ±0.75	16.56 <sup>b</sup> ±0.70	18.56 <sup>a</sup> ±0.71
Clay (%)	7.76 <sup>c</sup> ±0.65	7.76 <sup>c</sup> ±0.71	9.76 <sup>b</sup> ±0.63	11.76 <sup>a</sup> ±0.69	9.76 <sup>b</sup> ±0.70
Sand (%)	83.68 <sup>a</sup> ±0.71	81.68 <sup>b</sup> ±0.68	77.68 <sup>c</sup> ±0.75	71.68 <sup>d</sup> ±0.72	71.68 <sup>d</sup> ±0.66
Texture	LS	LS	SL	SL	SL

**Keys:** LS – Loamy Sand, SL - Sandy Loam, MSW 1, MSW 2 and MSW 3 - farmland soils fertilized with Municipal Solid Waste, NPK Farm – farmland soil fertilized with inorganic fertilizer (NPK), Control Farm-Farmland soil without fertilizer (uncultivated land) AVP – Available Phosphorus, K<sup>+</sup> - Potassium, CEC – Cation Exchange Capacity, EC – Electrical Conductivity, Mg<sup>2+</sup> – Magnesium, Na<sup>+</sup> - Sodium, Ca<sup>2+</sup> Calcium

### Concentration of Heavy Metals in the Soils

Table 3 showed the concentration of heavy metals in the soils. The concentrations of Lead (Pb) ranged from 78.10-103.40mg/kg for the soils fertilized with MSW and 42.60mg/kg for farmland soils fertilized with inorganic fertilizer (NPK) while the control soil recorded 30.30mg/kg (Table 3). The values obtained for the MSW fertilized soils were significantly ( $P \leq 0.05$ ) higher than the other sites and were also higher than the maximum permissible limit recommended for agricultural soils by the European Union. However, the concentration of the metal (Pb) in the farmland soil fertilized with NPK and the control were within the recommended limits. Concentration of Chromium (Cr) in the farmland soils fertilized with MSW varied from 28.60 - 42.30mg/kg. These values were significantly ( $P \leq 0.05$ ) higher than the values obtained in soils fertilized with NPK (11.30mg/kg) and control (6.30mg/kg) and lower than the permissible limit of 150mg/kg recommended for agricultural soils by the European Union. Cadmium (Cd) level in the soils ranged from 0.95 -11.30mg/kg. The soils fertilized with MSW had significantly ( $P \leq 0.05$ ) higher concentration of Cd than soils fertilized with NPK and the control.

Cadmium concentration in soils fertilized with MSW was higher than the limits of 3.0mg/kg recommended by FAO/WHO Codex Alimentarius Commission while the NPK fertilized soil and the control were lower than the permissible limit. Nickel (Ni) and Zinc (Zn) concentrations ranged from 10.10 - 436.20mg/kg and 486.00 - 925.00mg/kg respectively. Both



heavy metals were significantly ( $P \leq 0.05$ ) higher in soils fertilized with MSW than soil fertilized with NPK and the control. However, the concentration of Ni in the MSW fertilized soils was higher than the recommended limit set by the FAO/WHO Codex Alimentarius Commission while its concentration in the NPK fertilized soils and the control were within limits. The concentration of Zn in all the different soil types was above the permissible limit recommended by the European Union for agricultural soils.

Generally, the concentration of heavy metals (Cd, Cr, Pb, Ni and Zn) in the MSW fertilized soils recorded higher metal concentrations than their corresponding levels in the NPK fertilized and control soils. This is in agreement with the results obtained in similar studies (Amor *et al.*, 2014; and Teka *et al.*, 2018). High levels of these metals in the MSW soils may be associated with its anthropogenic nature (i.e. composition of the MSW dumped on the soil which comprised materials such as plastics, polythene bags, rubber slippers, textile materials, plastic gallons, metal scraps, ceiling board, empty sachet of drugs, animal bones, granite tiles, mobile phone chargers, lighters, asbestos, wood, fluorescent bulbs, PVC pipes and paint containers). Similarly, Wang *et al.* (2022) and Adelekan and Alawode (2011) also reported higher levels of some heavy metals in soils around designated MSW dumpsites compared to control sites.

It could be noted in the concentration of the heavy metals that Zn had the highest concentration relative to the other metals. Its concentration in MSW fertilized soils followed the order  $Zn > Ni > Pb > Cr > Cd$  and  $Zn > Pb > Ni > Cr > Cd$  for NPK and control soils (Table 3). The high level of Zn in the soils could be adduced to Zn containing organic waste, such as Zn batteries, and fluorescent lamps. Amor *et al.* (2014) also reported higher Zn concentration than other heavy metals in MSW amended soil. Rai *et al.* (2019) and Rashid *et al.* (2023) pointed out that Pb, Cd, Cr and Ni are potentially toxic to plants and animals and have been shown to accumulate in the food chain. The same authors confirmed that Zn is an essential micronutrient for plant growth but at high concentration, it is phytotoxic and may reduce the productivity of agricultural soils. It is worthy of note that heavy metals levels of the NPK and control soils were still within the recommended limit by FAO/WHO (2006) in soil. Soil fertilized with MSW had Zn, Pb and Cd level above the permissible limit while Cr was within the limit. Nickel concentration was within range for the MSW 3 fertilized soil and above in MSW 1 and MSW 2 fertilized soils (Table 3).

The Pb concentrations in the soil were lower than those reported by Teka *et al.* (2017) and comparably similar to the result by Huncahew and Sandipn (2011) for MSW amended soil in Addis-Ababa. The concentration of Pb in MSW fertilized soils were higher than the NPK fertilized and control soil and this could be attributed to the decomposition of Pb containing materials such as Pb batteries, Pb-based paints and pipes found in the soils.

The variation in the heavy metal levels in the MSW fertilized soils could be attributed partly to the age and decomposition of the wastes as a result of moisture and temperature and partly to the type of materials contained in the waste deposited on each site (Amor *et al.*, 2014).



**Table 3:** Concentration of heavy metals (mg/kg) of the sample sites

Soil Type	Heavy Metal Concentration (mg/kg)				
	Cd	Cr	Ni	Pb	Zn
MSW 1	11.38 <sup>a</sup> ±0.33	42.38 <sup>a</sup> ±0.57	436.24 <sup>a</sup> ±0.57	103.46 <sup>a</sup> ±0.49	925.08 <sup>a</sup> ±0.53
MSW 2	9.58 <sup>b</sup> ±0.53	35.48 <sup>b</sup> ±0.54	346.58 <sup>b</sup> ±0.62	91.38 <sup>b</sup> ±0.54	816.08 <sup>b</sup> ±0.55
MSW 3	5.68 <sup>c</sup> ±0.50	28.48 <sup>c</sup> ±0.16	294.48 <sup>c</sup> ±0.37	78.18 <sup>c</sup> ±0.51	775.08 <sup>c</sup> ±0.54
NPK Farm	2.11 <sup>d</sup> ±0.49	11.38 <sup>d</sup> ±0.44	22.18 <sup>d</sup> ±0.16	42.68 <sup>d</sup> ±0.59	486.08 <sup>d</sup> ±0.54
Control					
Farm	1.03 <sup>e</sup> ±0.54	6.38 <sup>e</sup> ±0.54	10.18 <sup>e</sup> ±0.64	30.38 <sup>e</sup> ±0.52	536.08 <sup>e</sup> ±0.72
*Maximum levels in non-polluted soils (FAO Std.)	3.0*	150**	300*	75*	300**

**Source:** \*FAO/WHO Codex Alimentarius Commission (2007), \*\* European Union (2002)

Key: MSW 1, MSW 2 and MSW 3 . farmland soils fertilized with Municipal Solid Waste, NPK Farm – farmland soil fertilized with inorganic fertilizer (NPK), Control Farm-Farmland soil without fertilizer (uncultivated land), Cd - Cadmium, Cr - Chromium, Pb - Lead, Zn – Zinc, Ni – Nickel, FAO - Food and Agriculture Organization

## CONCLUSION AND RECOMMENDATION

The results obtained in this study have shown that sites fertilized with MSW contributed to the increase in levels of toxic metals in the environment. The sequence of concentration of these metals in MSW sites were found to be in the order of Zn>Ni>Pb>Cr>Cd and Zn>Pb>Ni>Cr>Cd for NPK and control soils. Based on FAO/WHO (2006) safety limits in soil, soils fertilized with MSW were polluted with Zn, Pb and Cd above the permissible limits while Cr was within the permissible limit set by FAO/WHO. Nickel concentration was within normal range for MSW 3 treated soil and above the permissible limit for MSW 1 and MSW 2 treated soils. The heavy metal concentrations of NPK treated and control soils were below permissible limit. Consequently, plants grown on the MSW treated soils may likely accumulate higher concentration of these heavy metals than plants grown on NPK treated soil and the control which may cause serious health impacts when incorporated into human food chain. Hence, sorting, recycling and reducing of waste should be intensified to lessen the quantity of these heavy metals in soils when used for agricultural purposes. Furthermore, effective implementation of the National and State policies on solid waste management by the relevant institutions is recommended and good municipal solid waste management practices should be in place in order to save the agricultural soils.

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