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EVALUATION OF CHEMICAL CONDITION OF MUNICIPAL SOLID WASTE BEING USED IN SOIL FERTILITY MAINTENANCE IN ZARIA, NIGERIA

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Abstract

This paper reports the results of a study conducted to evaluate the chemical condition and heavy metal contents of MSW being used in soil fertility maintenance by local farmers in Zaria urban area. Samples of the wastes were collected from major dumpsites in six major areas of the town (namely Muchiya, Sabon Gari, Gaskiya, Samaru, Tudun Wada and Gyallesu). The wastes were sorted out to obtain the solid fractions which were digested and analysed for pH, N, P, C, Ca, Mg, K, Na, CEC, BS, Cu, Zn, Mn, Cr, Cd, Ni and Pb using standard procedures. The results obtained indicate that pH values range between 5.60 and 9.50, N 0.39 to 0.70%, P 29.32 to 56.0 ppm, C 2.35 to 4.63 %, Ca 6.20 to 23.44 Cmol/kg, Mg 2.16 to 13.46 Cmol/kg, K 3.82 to 9.32 Cmol/kg, Na 1.22 to 7.57 Cmol/kg, CEC 22 to 58.56 Cmol/kg, % BS 82.25 to 90.02, Cu 0.84 to 7.50 mg/kg, Zn 10.20 to 25.00 mg/kg, Mn 32.0 258.0 mg/kg, Fe, 62.0 to 864 mg/kg, Cr 1.30 top 33.36 mg/kg, Cd 1.45 to 6.20, Ni 1.20 to 53.35 and Pb 1.50 to 13.35. The results obtained thus indicate that the fertility rating of the wastes in the various areas is high to very high, except that of sodium which is rated as low. While Zn, Fe, Cr and Pb exist in high proportions and the remaining heavy metals exist in comparatively lower proportions in the waste samples. The soil fertility maintenance and public health implications of these results are discussed in light of the long term implications of sodium and heavy metal accumulations in soils receiving urban wastes applications in the area.

Keywords: Municipal, Solid, Waste, Chemical, Condition, Nigeria

1. Introduction

Of the many problems associated with urbanization in especially sub-Saharan Africa, waste management crisis has assumed an important position. Pasquini and Harris (2005) have explained that waste disposal constitutes an acute problem in numerous urban centres across Africa. Asomani-Boateng and Haight (1999) have reported that figures for formal waste collection range from 11% to 44% for households in cities such and Accra, Kinshasha, Lagos, Ibadan, Kaduna and Enugu. Nigeria has an enormous waste management problem and all over the country, there are examples of unsanitary, open dumps and industrial contaminations which are continuously discharged into streams and rivers without treatment (Agunwamba, 1998).

The problem posed by poor management of solid waste in urban areas of Nigeria has been an issue that has attracted much discourse among policy makers and enquiry by researchers. Urban waste crises in Nigeria can be ascribed to factors like rapid increase in urban population, heavy consumption pattern of urban dwellers and inefficiency of the authorities whose statutory responsibilities are to manage refuse in the cities. Currently, dumpsites have become prominent and permanent features of almost all urban areas in Nigeria. The wastes consists of garbages from households, markets and small scale industries, and simply dumped, rarely incinerated or burnt in the open (Ezeaku et al, 2003). Infact way back in 1994, a Chief Executive of Nigeria's Federal Environmental Protection Agency commented that one of the most embarrassing environmental problems that stare at the nation is the municipal solid waste disposal problem, with municipal waste dumpsites now being sadly used as landmarks and reference points for traveling directions.

With dumpsites now becoming permanent features of urban areas in the country, the sites in some locations are being converted into cultivated fields or locations from where manure for soil amendment could be obtained. Infact, with economic crisis now making chemical fertilizer beyond the reach of most resource-poor farmers, soil has remained the most important medium for waste disposal in sub-Saharan Africa. This certainly is expected since for long soil has been recognized to be an important medium for organic waste disposal (Allison et al., 1989). Deportes et al., (1995) have explained that composted urban wastes in many areas are being added to agricultural land for both waste disposal and to improve soil fertility. Such compost is rich in organic matter and serves as an important nutrient for plants. However, it may increase the level of potentially harmful trace metals and various persistent organic toxins (Nriagu, 1998). Long term application of urban waste on cultivated fields can undoubtedly improve soil fertility and provide crop nutrient needs of farmers, but it can likely lead to negative and potentially harmful changes in soil physical and chemical characteristics due to increasing toxicity (Ezeaku et al 2003). Elevated concentrations of these metals in soil may have adverse effects on crops, human and animal health when they are taken up by crops and transferred up the food-chain or are leached to groundwater (Kabata-Pendias, 2004). However, the effect of waste disposal on soil- crop qualities is varied and dependent on the composition of the waste (Ezeaku et al, 2003, Garcia et al, 2000, Gramatica et al, 2006) and character of the receiving soil. Hence, every area needs to be examined within its own context.

Zaria is one of the rapidly growing urban areas in northern Nigeria, not just because it houses the largest University in sub-Saharan Africa, but because for long it has served as an important commercial center linking most parts of the country. As expected of a typical Nigerian town, waste dumpsites are important features of this town. The farmers there are resorting to the use of the waste in soil fertility maintenance upon recognition of the positive effects of the site on crop yield and also because access to inorganic fertilisers is increasingly becoming difficult to them. Waste dump sites are now being invaded by scavengers who collect recyclable materials like plastics and metals and also by manure (composted waste) collectors who bag and offer the wastes for sale to prospective farmers in the area. While a 50kg bag of an inorganic fertiliser costs as much as N6, 000.00 (about USD 40) a similar bag of manure cost as cheap as N300.00 (about USD 4). Depending upon the richness of the composted waste, ten bags could be enough to cater for a 1ha farmland that would normally require up to 5 bags of 50kg inorganic fertiliser to fertilise in a year.

As economic hardships continue to affect the farmers, they are increasingly being left with little option than to resort to the use of composted urban waste is soil fertility maintenance in the area. However, even before economic situations of the country deteriorated to its present dismal level, small scale and resource poor farmers have traditionally been using soil as an important medium for municipal waste disposal from especially household sources. But now with organic fertilisers now becoming increasingly difficult for the farmers to afford, even where available, the use of such waste in soil fertility maintenance is now becoming more important in the area. Though such waste contributes to urban pollution and health risks, yet it has great potential because it can be exceedingly nutrient rich and can thus make it possible for the farmers to obtain a cheap supply of nutrients while alleviating the waste disposal problem at the same time. There is however every reason to be concerned about the public health implication of this practice since crops grown on soils amended with biosolids like urban wastes can typically immobilize heavy metals which eventually could find ways into human beings through the food chain processes (Silveira et al., 2003; Okoronkwo et al., 2005). Thus, the question of whether vegetables, fruits and food crops cultivated on soils to which such wastes are disposed are safe for human consumption is of great interest to public especially now that the environmental quality of food productions are of major concern in Nigeria. One way of ascertaining this is to evaluate the chemical condition of the wastes, and particularly their heavy metal contents since such metals are recognized as some of the most important attributes of municipal solid wastes. This implies that for the practice to become sustainable there is no doubt the need to monitor the quality of the waste in order to ensure that the farmers use only contaminants-free wastes as manure on their farms.

Previous research works on heavy metal pollution in soils receiving urban waste applications in Nigeria are limited in scope as they have concentrated mainly on examination of accumulation of the metals in soils and crops (see Amakhian et al., 2003; Ezeaku, 2003; Eddy et al., 2005; Okoronkwo et al., 2005; Pasquini, 2006 for instance). When someone considers that mobility of heavy metals in soils receiving biosolids applications tend to depend heavily upon the character of the waste applied (Silveira et al., 2003) studies are no doubt required that will as much as possible comprehensively look at the character of municipal solid waste being used in soil fertility maintenance.

Ugbaje and Agbenin (2012) conducted a pot experiment at the Institute of Agricultural Research, Zaria, Nigeria, to evaluate chemical condition of savannah soil amended with two urban wastes and planted with sorghum (Sorghum bicolor). They found out that waste application increased mobile Ni but decreased its residual form. The organically bound Pb was increased at the expense of residual Pb. With respect to Cr, waste application increased Cr form occluded in non-crystalline Fe oxides in the soil. They concluded that since a single application of urban wastes to this savannah soil significantly increased Pb uptake by sorghum, the consequences of long-term applications by local farmers should be of great concern; particularly with respect to children’s exposure to Pb through consumption of food and vegetables. A good way of addressing concerns such as this is to frequently be examining the quality of urban wastes that farmers do collect and use to amend the fertility of soils of their farmlands.

The objective of this paper therefore is to report the results of a study conducted to assess the quality of municipal solid waste being used in soil fertility maintenance in Zaria area, Nigeria.

2. Materials and methods

A reconnaissance survey was conducted during the end of dry season of 2006 (March to April) when the farmers were preparing for the commencement of the 2006 growing season. The survey was used to identify the major waste dumpsites in Zaria town from where wastes are bagged and sold to farmers. Six of major such sites were identified in the six major segments of the town (Muchiya, Sabon Gari, Gaskiya, Samaru, Tudun Wada, and Gyallesu). Samples of the wastes being collected from each of the six dumpsites were obtained in polythene bags and transported to the laboratory.

While in the laboratory, the various samples were digested using DTPA extraction procedures. This procedure was employed in order to obtain plant-available concentrations of some heavy metals (Cu, Zn, Mn, Fe, Cr, Cd, Ni and Pb) considered as the main ones with public health concerns. Concentrations of the metals in the digests were determined using atomic absorption spectrophotmetry.

To be able to evaluate the nutrient fertility status of the wastes, the samples were also anaylsed for some critical biochemical properties. The properties analysed were: CEC (using ammonium acetatate extraction method), carbon (using Walkey-Black chromic acid titration method), nitrogen (using Macro-Kjeldahl method), phosphorous (using Bray No. 1 method) and pH (using pH meter in 1:2.5 soil to water ratio). The amounts of exchangeable cations in the samples were also extracted using ammonium acetate extraction procedure and in the extracts obtained, concentrations of Ca and Mg were determined using flame emission photometry and those of K and Na using atomic absorption spectrophotmetry.

Mean value of every property determined was computed for each of the six waste sampling zones and bar graphs were used to display clearly the variations in these values over the zones. Analysis of variance (ANOVA) statistical test was then used to assess the significance of the difference in the mean values of every soil property between the six waste samples collection zones.

3. Results

Figures 1 to 4 display the mean values of the various properties determined in the waste samples collected from the six sampling zones across the study area. Table 1 presents the fertility rating used in characterizing the key fertility parameters determined in the waste samples while Table 2 gives a summary of the ANOVA statistical test conducted to assess the significance of the difference in mean values of every metal between the six different sampling zones in the area.

A close look at Figure 1 reveals that mean values of pH vary between about 8.2 and 9.8 (alkaline) in the various sampling zones, the only exception being at Gyallesu where it is about 4.8 (acidic). The difference between the various zones is not statistically significant (Table 2). Total nitrogen values are generally less than 0.5% and the difference between the sampling zones is not significant. The fertility of the element is low (Table 1). Values of organic carbon vary between about 2.2% at Tudun Wada and 4.6% at Muchiya and the difference between the sampling zones is not statistically significant. Sodium values vary between about 1.2Cmol/kg at Samaru to about 4 Cmol/kg at Gyallesu. The difference between the sampling zones is significant and the fertility rating of the element is low which implies that continuous addition of the waste to cultivated soils could result in sodicity problems resulting from high build up of Na in soils.

Mean values of phosphorous vary between about 22ppm at Tudun Wada to about 57ppm at Gyallesu (Figure 2) and the difference between the sampling zones is statistically significant (Table 2) and the fertility rating of the element is very high (Table 1). Potassium values vary between about 5 Cmol/kg at Samaru to about 10 Cmol/kg at Samaru and the difference between the sampling zones is statistically significant while the fertility rating of the element is also very high. Mean CEC values vary from about 22 Cmol/kg at Muchiya to about 60 Cmol/kg at Sabon Gari and the difference between the sampling locations is statistically significant. The fertility rating of the property is very high. Magnesium varies in mean values between about 2 Cmol/kg to about 13 Cmol/kg at Muchiya and Sabon Gari sampling zones respectively. The fertility rating of the element is medium to high and the difference between the sampling locations is statistically significant. Perhaps reflecting the trends of the base elements, percentage base saturating values of the waste samples are rated as very high but the difference between the sampling zones is not statistically significant as the mean values vary between about 82% to 90%.

The differences in mean values of all the heavy metals between the six sampling zones are all statistically significant (Table 2). The metals do not show any general trend of occurrence over the six zones. Highest concentration of Cu (about 8 mg/kg) was obtained at Muchiya and the lowest (about 1 mg/kg) at Samaru (Figure 3). For Cd, the highest value (about 7 mg/kg) was also recorded at Muchiya but the lowest (about 1.5 mg/kg) at Tudun Wada. Highest mean value of Ni (about 54 mg/kg) was recorded at Gyallesu and the lowest at Gaskiya (about 2 mg/kg). In the case of Pb, the lowest mean value (about 1 mg/kg) was recorded at Muchiya and the highest (about 20 mg/kg) at Samaru.

Highest mean Zn (about 15 mg/kg) value was recorded at Sabon Gari and the lowest (about 2 mg/kg) at Samaru (Figure 4). For Mn, highest value (about 250 mg/kg) was recorded at Gyallesu and the lowest (about 20 mg/kg) at Muchiya. In the case of Fe, the highest mean value (about 140 mg/kg) was recorded at Samaru and the lowest (about 40 mg/kg) at Muchiya. While each of Gaskiya, Samaru, Tudun Wada and Gyallesu sampling zones has a mean Cr value of about 25 mg/kg, a value of about 10 mg/kg was recorded at Sabon Gari and none was recorded in the waste samples collected from the Muchiya zone.

4. Discussion

On the basis of the analytical data obtained here on the analysed waste properties that influence soil fertility, it could be deduced that the fertility rating of the waste is generally high to very high. This confirms once again that compost waste is typically nutrient rich and can serve as a very good soil conditioner. However, the fact that the fertility rating of Na is low should be regarded as an issue of much concern. This is because, the high Na content of the waste may with time result in high build up of the element is soils of the area which could lead to sodicity problems.

In general, the heavy metals analysed exist in high to very amounts in the waste samples analysed. The occurrence of the metals across the six zones follows this trend: Fe>Mn>Cr>Zn>Ni>Pb>Cd>Cu. This trend indicates clearly that two of the most unwanted heavy metals (Pb and Cd) are concentrated in about the least amounts in the waste samples. Fe and Mn which depict highest concentrations are among the essential trace metals for plants growth but can be dangerous when concentrated in high amounts.

There is every reason to be concerned about the observed generally high levels of the various heavy metals analysed in the waste samples. This is because heavy metals contained in biosolids are easily immobilisable by plants, because of their strong association with organic matter in the biosolids (Silveira et al, 2003). Organic matter is quite effective in retaining metals. Metal-organic associations can occur both in solution and in the solid surfaces of either native soil constituents or any added material like biosolids. In a heavy metal-polluted forest soil, Kiikkila at al. (2002) studied the effect of biosolids as organic immobilizing agents and observed that exchangeable Cu concentration decreased as a result of immobilisation by the vegetation.

Schaecke et al. (2002) evaluated biosolid application rates (equivalent 82-330 t ha^{-1} dry matter) incorporated in 0-0.25 m depth of a Chernozem (1982-1985) with the aim of studying the fate of heavy metals Zn, Cd, Cu, Ni, Pb, and Cr, and to determine their concentration in the soil fractions. Eleven years after the last application, metals supplied with the sludge had moved as far as 50 cm in depth. Concentrations of Zn, Cd, Cu, Ni, and Cr in the saturation extract of the sampled soil layers were closely correlated to concentrations of dissolved organic carbon (DOC), that is, the heavy metal displacement was partly linked to the DOC movement in the soil. Mc Bride

(1989) has argued that the high degree of selectivity shown by organic matter for certain metals suggests that the metals coordinate directly, forming inner-sphere complexes with the acid functional groups.

The stability of organo-complexes is strongly influenced by the pH range. Generally at low pH, most metals are in the cationic form, but as pH increases, humate complexes are formed. For fulvic acids (FA), the complex stability increases from pH 3.5 to 5.0 (Kiekens, 1983). The stability constant of metal-FA complexes may decrease with increasing ionic strength in the solution. An anthropogenic FA, such as that extracted from a composted sewage, has macroscopic complexation properties (magnitude of the conditional stability constant and binding sites concentration) somewhat similar to the natural FA samples, but has some binding site structures containing nitrogen that probably play important role in the complexation, besides oxygen containing structures (Silva and Oliveira, 2002).

McBride (1989) suggested the following sequence of affinity of divalent metal ions for organic matter: Cu> Ni> Pb> Co> Ca> Zn> Mn> Mg. In general, the more electronegative the metal ion, the stronger the bond formed with organic matter. Copper is commonly found strongly complexed by organic matter. Evidences from electron paramagnetic resonance (ESR) studies suggested that Cu^{2+} is bonded rigidly as a inner-sphere complex, and that at high metal concentrations, the complex may be mobile (McBride, 1989). This metal may be bound by humic acids (HA), coordinating either with O atoms or with N atoms, and the first complex would be more accessible for plant uptake (Martin Neto et al., 1991). Most of the first-row transition metals (Mn^{2+}, Fe^{2+}, Co^{2+}) and alkaline earth metals (Ca^{2+}, Mg^{2+}) form outer-sphere complexes with organic matter. Desorption of heavy metals from organic matter requires a large activation energy to be overcome (McBride, 1989).

Even though some studies have shown that phytotoxicity only occurs when biosolids with high metal concentrations are applied at high rates, or when soils exhibit very low pH (below 5.0) (USEPA, 1993; 1994), the long term implication of metal availability to plants cultivated in biosolid-treated soil is uncertain. There is therefore the need for continuous monitoring to be made of the cultivated soils receiving application of urban waste being collected from different zones of the study area.

5. Conclusion

On the basis of the results obtained here, it could be concluded that even though the wastes being used by farmers in soil fertility maintenance in Zaria is nutrient rich and very high in fertility rating, there are valid reasons to be concerned about the possibility of occurrence of sodicity and heavy metal contamination problems. Thus, effective monitoring programme needs to be put in place in order to determine points in time when the two problems become real in farmers' fields in the area. It will however be worthwhile if screening programmes can be put in place to ensure that only treated wastes that are as much as possible free from the two problems are eventually used by the farmers.

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Figure 1: Mean Values of pH, N, C and Na in Waste Samples Collected from Different Sampling Locations in Zaria Urban Area

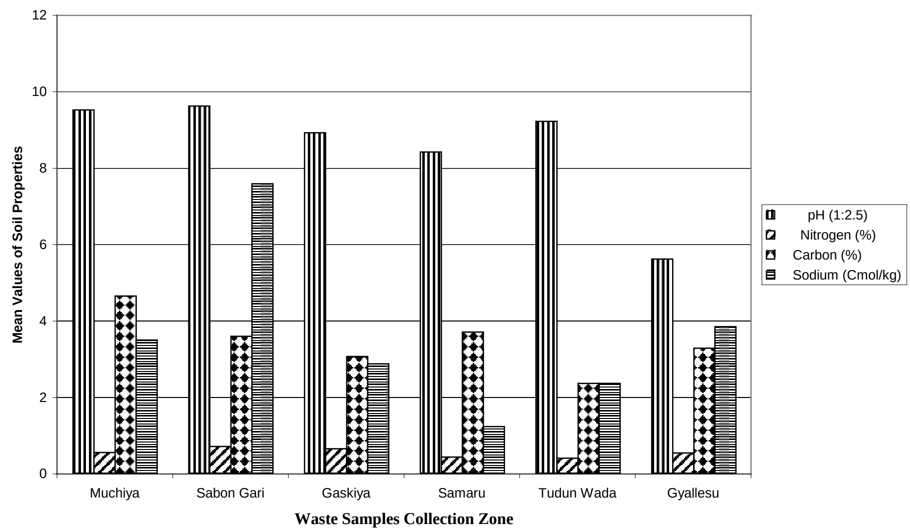

Figure 2: Mean Values of P, K, CEC, %BS and Mg in Waste Samples Collected from Different Sites in Zaria Utban Area

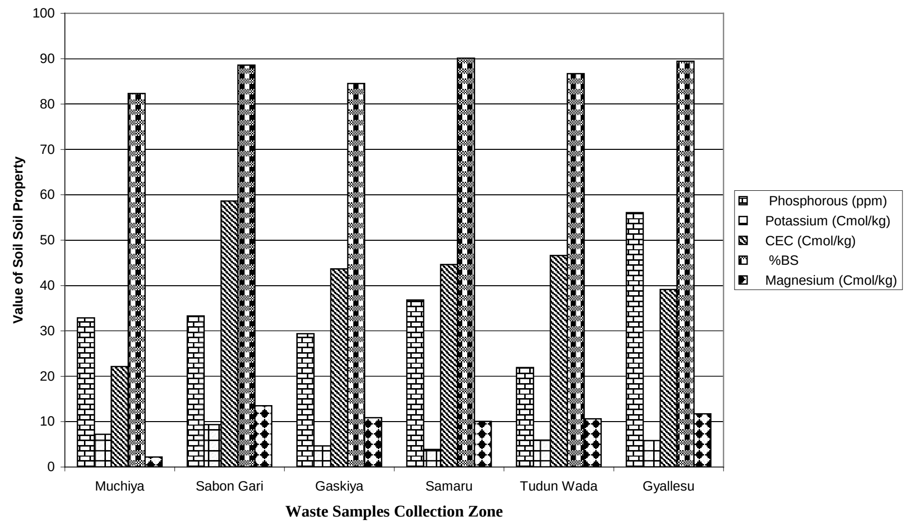

Figure 3: Mean Values of Cu, Cd, Ni and Pb in Waste Samples Collected from Different Sites in Zaria Urban Area

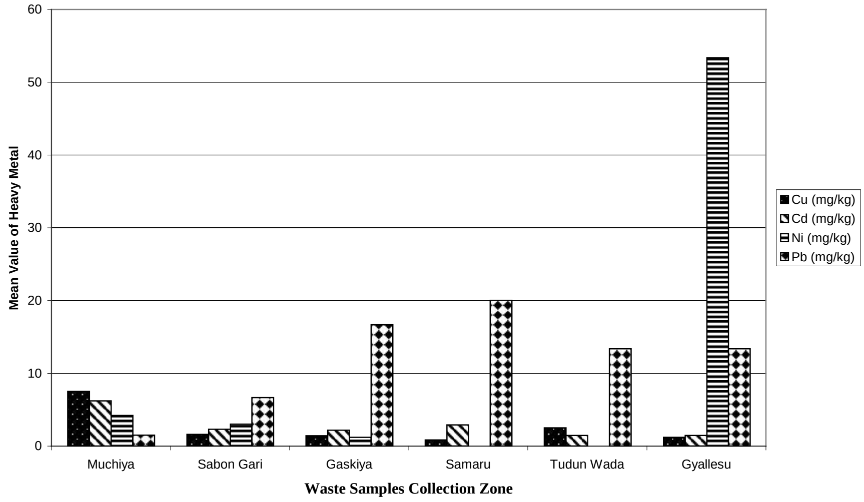

Figure 4: Mean Values of Zn, Mn, Fe and Cr in Waste Samples Collected from Different Sites in Zaria Urban Area

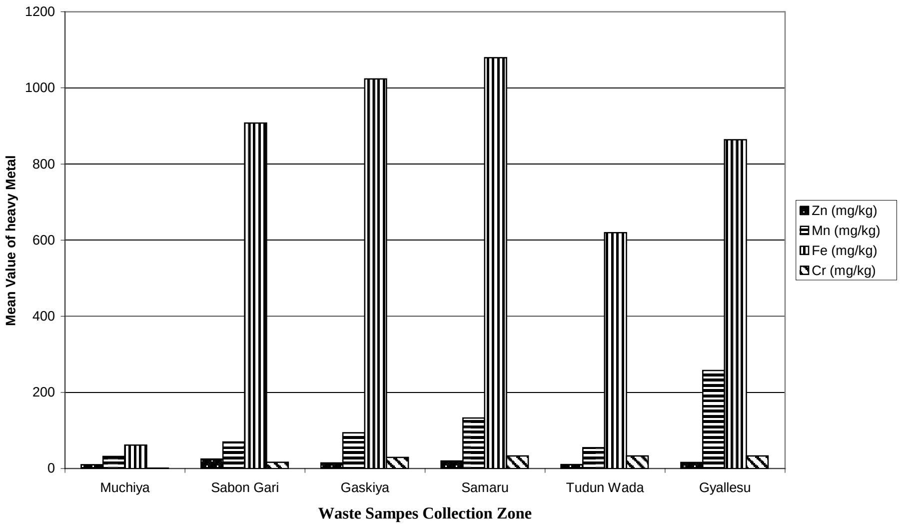

Table 1: Fertility Rating used in Chracterising the Fertility of Urban Waste Samples Analysed in Zaria Urban Area (based on Holland et al., 1989)

			Fertility Rating	
Property	**Low**	**Medium**	**High**	**Very High**
pH	4.1-5.2 [1]	5.3-6.5[2]	6.6-7.4[3]	7.5-8.3[4]
N	<0.10	0.10-0.45	>0.45	
P	5-15	15-30	30-50	>50
C	<1.5	1.5-4.5	>4.5	
Ca	2-5	5-10	10-20	>20
Mg	0.3-1.0	1-3	3-8	>8
K	0.2-0.3	0.3-0.6	3-8	>8
Na	0.1-0.3	0.3-0.7	0.7-2.0	>2.0
CEC	5-15	0.3-0.7	0.7-2.0	>2.0
%BS	20-24	40-60	60-80	80-100

Note: [1]pH strongly acidic; [2]pH acidic; [3]pH near neutral; [4]pH alkaline

Table 2: Summary of ANOVA Comparing Mean Values of the various Properties of the Waste Samples Analysed over the Six Sampling zones

Property	Calculated F-value	Critical F-value	Degree of Freedom	Significance of the difference
pH	0.39	2.26	44	NS
N	1.03	2.26	44	NS
P	2.45	2.26	44	S
C	0.76	2.26	44	NS
Ca	3.12	2.26	44	S
Mg	2.45	2.26	44	S
K	2.41	2.26	44	S
Na	2.33	2.26	44	S
CEC	4.12	2.26	44	S
%BS	1.56	2.26	44	NS
Cu	3.22	2.26	44	NS
Zn	2.67	2.26	44	S
Mn	16.33	2.26	44	S
Fe	23.16	2.26	44	S
Cr	5.34	2.26	44	S
Cd	2.36	2.26	44	S
Ni	3.31	2.26	44	S
Pb	5.47	2.26	44	S