February 2014- April 2014, Vol. 4, No. 2; 1609-1619. E- ISSN: 2249 –1929

Journal of Chemical, Biological and Physical Sciences

An International Peer Review E-3 Journal of Sciences

*Available online at*www.jcbsc.org

Section D: Environmental Sciences

CODEN (USA): JCBPAT Research article

Metal Content of Municipal Solid Waste Compost–Amended Arenic Kandidiult in Ihiagwa, Southeastern Nigeria

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Received: 20 December 2013**; Revised:** 28 January 2014**; Accepted:** 06 February 2014

Abstract: A 3^2 factorial experiment of MSWC (0, 6 and 12 Mg ha^{-1}) as factor A and lime (0, 2 and 4 Mg ha^{-1}) as factor B, arranged in RCBD setup with 3 replications was used for pumpkin (Telferia Occidentalis) production in an Arenic Kandidiult in Ihiagwa, Southeastern Nigeria. Soil and plant metal contents, metal accumulation index (Igeo), plant metal uptake, metal transfer ratio and the relationship between plant and soil metal contents were evaluated. Soil Zn, Cu, Co, Pb, Cd and Ni but Fe contents increased significantly (LSD 0.05) with MSWC rates only while contents of all metals decreased distinctly (LSD 0.05) with rates of lime and MSWC x lime. Impact of treatments on plant metal content was similar as the soil but with metal concentrations higher in the plants than the soil. Metal accumulation index showed that the soil was not polluted with Fe but slightly with Cu (20-50%), Pb (13-47%), and Co (27-47%) and heavily with Cd (73%). Soil metal contents were positively and significantly ($P < 0.01$) correlated with plant metal concentrations. Metal uptake significantly (LSD 0.05) increased with MSWC rates but distinctly (LSD 0.05) decreased with rates of lime and MSWC x lime. Metal transfer ratio differed and showed no relationship with soil metal content for most treatments. Plant Cd and Pb contents were above maximum permissible limits of various regulatory agencies, indicating that they could constitute serious health hazards with consumption of the crop. Though MSWC could be useful for soil fertility restoration, great caution is required for its use in the acidic soils of the tropics due to the high crop metal uptake.

Key words: Metal, MSWC, ArenicKandidiult, Ihiagwa, Southeastern, Nigeria.

INTRODUCTION

Composting as a strategy for the management of urban wastes has led to the production of a material, municipal solid waste compost (MSWC) with value for agriculture. Municipal solid waste compost refers to the product of the microbial decomposition of the organic fraction of municipal solid waste stream[1] and has been extensively used in countries like Canada, Spain, and USA etc, with much utilities being in land reclamation, landscaping, horticulture, forestry, agriculture and as substrate medium for nursery crop production[1].

Its use in the developing countries like Nigeria is however, at best currently gathering momentum. Land application of MSWC for crop production improves soil physical, chemical and biological properties[1-3]. It also promotes crop yields and quality [2-5]. Constraints often associated with its intensive use include; low and non-uniform nutrient content, bulkiness, presence of pathogenic organisms and high metal content [3, 4]. Probably, the high metal content and other toxic elements constitute the greatest limitation for its use in agriculture [3].As rates of MSWC application increases, soil metal concentration and accumulation also increases thereby discouraging its sustained use as soil amendment[6].

Metals often released from MSWC compost include Cd, Pb, and Hg, As, Ni, Cu, Fe and Zn, most of which are toxic and poisonous even at low concentrations to biological organisms [3, 7]. Metals are non-biodegradable and may constitute serious contaminants and pollutants to the environment [8, 9].Through root uptake, metals in the soil may enter into plants and become transferred up the food chain, posing serious hazards to animal and human health[6]. Some health problems associated with metals include cancer, anemia, impotency, sensory disturbance, hypo reflexia, tremor, gingivitis, night blindness, skin disorder and kidney dysfunction[9-11.] In the assessment of the environmental consequences of MSWC use, knowledge of the available metal content is more desirable than the total concentration, since most of the metals may be non-bioavailable. Research has indicated that the application of industrial compost to agricultural soils may increase the total concentrations of heavy metals and other toxic elements, without increasing their phytoavailability[3].

Therefore Knowledge of total metal content of a soil provides limited information about its potential behaviour and bioavailability [3, 12]. Metal availability is influenced by soil properties especially soil pH [6, 13]. It has been reported that metal solubility and availability increases with increase in soil acidity [4, 6,7,13]. This raises serious concern about the safety of MSWC as a soil amendment for crop production in the humid tropics and indeed Ihiagwa, where soil acidity is high due to high base leaching by the intense tropical rainfall [14]. Serious caution is therefore required in the use of MSWC in this region by making applications either at low rates or use of practices that reduce metal solubility and availability. This may involve the addition of materials such as phosphorus, organic matter, ammonium and lime to MSWC-amended soils [13, 15.]

Liming is used in agriculture to control soil acidity and reduce metal availability. This could be through increase in the soil pH and the precipitation of metals into insoluble compounds especially, the carbonates [6, 13, 16]. According to[7]lime increases soil pH thereby decreasing the solubility of metals. In Nigeria, few urban farmers use MSWC for dry season vegetable production but with none giving consideration to minimizing crop metal accumulation.

This could possibly be due to ignorance or dearth of information on the management practices to reduce plant metal accumulation of MSWC amendment. The objectives of this study were therefore to evaluate the impact of lime and MSWC on (1) soil and plant metal content (2) plant metal uptake and (3) the transfer factor of metals from soil to plants and (4) to determine the relationship between plant and soil metal contents.

MATERIALS AND METHODS

Study Site, Experimental layout and laboratory Analysis: The study location, experimental layout and characterization of selected soil and MSWC properties used in the study have been reported in another study elsewhere [17]. In this present study, the pH in 1:2.5 soil or MSWC/water ratios was reported and determined by inserting the glass electrode of the pH meter in the suspensions. Also values of the soil and compost organic carbon contents were converted to organic matter by multiplication with a value of 1.72 (Bemmelens factor).The soil, MSWC and tissue heavy metal (Fe, Zn, Cu, Co, Pb, Cd and Ni) contents were determined as follows: Five gram (5g) soil or MSWC sample was weighed into a 100 ml flask and 3 ml of 30% H_2O_2 solution added and allowed to stand for 1 hr. About 75 ml of 0.5 M HCL was then added and heated at low heat on a hot plate for 2 hrs. The suspension was decanted into a 50 ml flask and the Fe, Cu, Co, Pb, Cd and Ni contents determined using an Atomic Absorption Spectrophotometer (AAS) model AA 650. Similarly plant tissue metal content was determined by weighing about 0.5 g plant tissue sample into 100 ml flask and 5 ml conc. H_2SO_4 and 2 ml $HCCLO_4$ added. The flask was then digested at low heat on a hot plate till about 2 ml of the suspension was left. It was then allowed to cool and thereafter filtered into a 50 ml flask using 0.45 µm Millipore filter kit. The metal content of the clear supernatant was determined using AAS model AA 650 as in the soil sample.

Computations:

- Plant metal uptake: This was obtained by multiplying the plant metal content with plant dry matter yield.
- Transfer factor: Obtained as the ratio of the plant metal content to the soil metal content [18].
- Metal Geoaccumulation index, Igeo according to [23] was obtained as follows:

Igeo = In (Cn/1.5 x Bn), where
Cn = measured soil metal content of amended soil (mg kg-1),
Bn= Background metal content (mg kg-1) before soil amendment and
1.5 = Background matrix correction factor.

Statistical Analysis: Data generated for soil and plant metal contents plus the transfer ratio were subjected to the analysis of variance using Genstat statistical package[19]and correlation between plant and soil metal contents was conducted using the same statistical package.

RESULTS AND DISCUSSION

Characterization of pretreatment soil and MSWC Metal, Organic matter and pH (H_2O): Pretreatment soil and MSWC organic matter, pH and metal contents are presented in **Table 1.** The pH (H_2O) of the soil was acidic with the decree lower in the subsoil (15-30 cm) (pH = 4.36) than the topsoil (0-15 cm) (pH = 4.06) while that for MSWC was slightly alkaline (pH = 7.93). The high pH of MSWC indicates that its application as a soil amendment would improve soil pH and the condition for plant growth[1]. Soil organic matter was low, with the content higher in the topsoil (30.30 g kg^{-1}) than the subsoil (26.90 g kg^{-1}). Organic matter content of MSWC (363.40 g kg^{-1}) was more than ten times higher than that of the soil and its soil application would improve the low soil content. Iron content was higher than the other metals in the soil and MSWC. The high Fe content could be due to its large concentration on the earth crust and the dominance of oxides and hydrous oxides of Fe and Al as well as sequioxides in the clay mineralogy of tropical soils[13, 28]. Iron concentration of MSWC was more than six times higher than that of the soil attributable to the high content in the feedlot [5, 7] Also due to its high metal richness, MSWC had higher concentration of the other metals (Zn, Cu, Co, Pb, Cd and

Ni) than the soil. Except Zn and Cu, soil metal concentrations were higher in the subsoil than the topsoil probably due to their high mobility and leaching losses.

Table-1: Pretreatment soil and MSWC pH, Organic matter and metal contents

Parameters	Unit	Soil		MSWC
Depth (cm)		0-15	15-30	
pH (H_2O)		4.06	4.36	7.93
Organic matter	g kg-1	30.30	26.90	363.40
Fe	mg kg-1	171.34	232.05	705.9
Zn	,,	1.88	1.52	8.15
Cu	,,	0.51	0.03	6.40
Co	,,	0.28	0.32	2.60
Pb	,,	1.45	2.05	22.40
Cd	,,	trace	0.08	1.42
Ni	,,	trace	Trace	3.36

Soil Metal Content and Geoaccumulation: Content of most metals in the soil significantly (LSD 0.05) increased with rates of MSWC only exception being Fe that decreased distinctly (LSD 0.05) with application rates **(Table 2**). Increased soil metal content with MSWC rates has been reported and attributed to the high content in the compost feedlots[4, 6.] It could also be due to the high soil acidity since metal solubility and availability increases with soil acidity [7, 20]. It has been noted that the high pH of MSWC was depressed by an acidic loamy soil in China, and thus increased the soil metal content (Wong et al., 2001). Reduction in Fe content with compost rates has been indicated[3, 6] and associated with metal sorption, precipitation and complexation with the high OM content of the added compost[20]. Also soil Fe, Zn, Cu, Co, Pb, Cd and Ni contents decreased with lime rates and MSWC x lime for increased lime rate at various MSWC levels.

Table-2: Effect of MSWC and Lime on soil metal contents (mg kg^{-1})

MSWC (Mg ha^{-1})	Lime (Mg ha^{-1})	Fe	Zn	Cu	Co	Pb	Cd	Ni
0	0	100.02	1.36	0.14	0.07	1.08	0.05	Trace
0	2	60.71	0.22	0.12	0.05	1.06	0.03	Trace
0	4	40.11	0.18	0.08	0.03	1.03	0.02	Trace
Mean		**66.95**	**0.58**	**0.11**	**0.05**	**1.06**	**0.03**	**Trace**
6	0	73.32	6.31	3.16	1.61	21.61	1.05	1.65
6	2	42.12	3.47	2.15	1.06	8.22	1.00	1.35
6	4	23.31	4.63	2.73	1.13	8.16	1.01	1.34
Mean		**46.25**	**4.80**	**2.68**	**1.27**	**12.66**	**1.02**	**1.45**
12	0	84.01	6.35	3.63	1.67	21.86	1.08	1.76
12	2	23.41	4.50	2.77	1.07	8.34	1.03	1.45
12	4	23.10	3.49	2.03	1.05	8.23	1.00	1.41
Mean		**43.51**	**4.78**	**2.81**	**1.26**	**12.81**	**1.04**	**1.54**
LSDs (0.005)	Fact A	0.90	0.15	0.02	0.02	0.02	0.03	0.02
	Fact B	0.90	0.15	0.02	0.02	0.02	0.03	0.02
	Fact A x B	1.55	0.26	0.03	0.03	0.03	0.06	0.04
%CV		1.7	4.4	1.1	2.1	0.2	4.9	2.3

Other workers have reported reduced Cd[15]and heavy metal contents with lime [16]and with the integration of lime and bio solids application. Impacts of lime include an increase in soil pH and the reduction in metal solubility, availability and mobility through precipitation as insoluble hydroxides, carbonates or formation of insoluble organic complexes [6, 21]. Due to the high OM content of MSWC and tendency to increase soil pH and sorption, integration of MSWC with lime could decrease soil metal content through sorption by OM or reduced mobility and availability with low soil acidity. It has been indicated that due to the high OM content and tendency to increase soil pH, use of MSWC has been recommended to reduce the need for liming[3,22].Irrespective of treatment, Fe content was much higher than the other metals, probably due to the high content in the MSWC feedlots and on the earth crust. Cadmium had the least soil concentration except in the non-compost-amended treatments where the Ni content was the least. Concentrations of all metals were within normal ranges in the soil **(Table 3),** signifying that they may not be toxic to plants irrespective of the type and rates of soil amendments. Degree of metal pollution estimated using the geo-accumulation index[23] varied with treatments **(Table 4)**.

Table-3: Normal ranges and critical Metal concentrations (mg kg^{-1}) in soil and plants

Metal	Normal range in soil	Normal range in plants	Critical soil concentration	Critical limit for plants[c]
Fe[b]	5000-100,000	40-500	-	-
Zn[a]	1-900	1-400	100-400	60.0
Cu[a]	2-250	5.0-20.0	20-100	30.0
Co[a]	0.5-65	0.02-1.0	15-50	-
Pb[a]	2.0-300	0.2-20	30-300	5.00
Cd[a]	0.01-2.0	0.1-2.4	5.0-30.0	0.20
Ni[a]	2-750	0.02-5	10-100	-

a = Radojevic and Bashkin (2006), b = Stewart et al.(1974), c = WHO/FAO (2007)

In this estimation, metals with a geoaccumulation index (Igeo) greater than five (> 5) have a geoaccumulation class of six (6) and indicates a very strong intensity of contamination, those with Igeo> 4-5 have a Igeo class of 5, signifying strong to very strong intensity of contamination, Igeo> 3-4 have a Igeo class of 4 with a strong intensity, a Igeo Index >2-3 has a Igeo class of 3 indicating a moderate to strong intensity, Igeo index > 1-2 with a Igeo class of 2 and a moderate intensity, Igeo> 0-1 with a Igeo class of 1 and indicative of uncontaminated to moderate intensity while that with a Igeo< 0 has a Igeo class of zero (0) and signifying a practically uncontaminated intensity.

In this study, the soil degree of pollution for each metal include; practically no pollution for Fe, 73% moderately polluted and 27% practically unpolluted for Cd, 53% moderately, 20% unpolluted to moderately and 27% practically unpolluted for Cu, 13% moderately to strongly, 47% unpolluted to moderately polluted, 13% unpolluted to moderately and 27% practically unpolluted for Pb, 27% moderately polluted, 47% uncontaminated to moderate and 27% practically unpolluted for Co using the different treatments **(Table 4).** Due to none detection of Ni in the background soil, its level of pollution could not be established. In summary, the soil was not polluted with Fe despite its high content and as such posed no problem to plants and animals while Cd constituted the highest problem with respect to the soil pollution. Similar observation has been reported by others6,8.

Table-4: Effect of MSWC (A), Lime (B) and MSWC x Lime (C) on Metal Geoaccumulation Index and Classification

Treatments	Fe	Zn	Cu	Co	Pb	Cd	Ni
A			MSWC				
M_0	-1.35[a]	-1.86[a]	-1.94[a]	-2.13[a]	-0.72[a]	-1.61[a]	-
M_6	-1.72[a]	0.53[b]	1.25[c]	1.11[c]	1.76[c]	1.92[c]	-
M_{12}	-1.78[a]	0.53[b]	1.30[c]	1.10[c]	1.77[c]	1.94[c]	-
B			LIME				
L_0	-1.10[a]	0.50[b]	1.11[c]	0.98[b]	1.92[c]	1.58[c]	-
L_2	-0.81[a]	-0.03[a]	0.79[b]	0.55[b]	1.00[c]	1.53[c]	-
L_4	-2.19[a]	-0.02[a]	0.74[b]	0.57[b]	0.98[b]	1.51[c]	-
C			MSWC x Lime				
M_0L_0	-0.94[a]	-0.70[a]	-1.70[a]	-1.79[a]	-0.70[a]	-1.10[a]	-
M_0L_2	-1.44[a]	-2.55[a]	-1.85[a]	-2.13[a]	-0.72[a]	-1.60[a]	-
M_0L_4	-1.86[a]	-2.75[a]	-2.26[a]	-2.64[a]	-0.75[a]	-2.00[a]	-
M_6L_0	-1.25[a]	0.81[b]	1.42[c]	1.34[c]	2.30[d]	1.95[c]	-
M_6L_2	-1.81[a]	0.21[b]	1.03[c]	0.93[b]	1.33[c]	1.90[c]	-
M_6L_4	-2.40[a]	0.50[b]	1.27[c]	0.99[b]	1.32[c]	1.91[c]	-
$M_{12}L_0$	-1.12[a]	0.81[b]	1.56[c]	1.38[c]	2.30[d]	1.97[c]	-
$M_{12}L_2$	-2.40[a]	0.47[b]	1.29[c]	0.94[b]	0.90[b]	1.93[c]	-
$M_{12}L_4$	-2.41[a]	0.20[b]	0.98[b]	0.92[b]	1.33[c]	1.90[c]	-

M_0 = 0 Mg ha^{-1}MSWC, L_0 = 0 Mg ha^{-1} lime, M_0L_0 = 0 Mg ha^{-1} MSWC x 0 Mg ha^{-1} lime, a =practically unpolluted, b = Unpolluted to moderately polluted, c = moderately polluted and d = moderately to strongly polluted

Table-5: Effect of MSWC and Lime on Plant metal content (mg kg^{-1})

MSWC (Mg ha^{-1})	Lime (Mg ha^{-1})	Fe	Zn	Cu	Co	Pb	Cd	Ni
0	0	102.22	1.54	0.23	0.18	1.13	0.13	trace
0	2	63.74	0.42	0.41	0.08	1.15	0.08	trace
0	4	43.10	0.45	0.17	0.15	1.13	0.10	trace
Mean		**69.69**	**0.80**	**0.27**	**0.14**	**1.14**	**0.10**	**trace**
6	0	85.44	6.61	3.22	1.66	21.67	1.12	1.68
6	2	47.22	3.53	2.23	1.11	8.33	1.02	1.36
6	4	23.51	4.71	2.86	1.21	8.31	1.04	1.44
Mean		**52.06**	**4.95**	**2.77**	**1.33**	**12.77**	**1.06**	**1.49**
12	0	96.47	6.69	3.69	1.69	21.93	1.17	1.80
12	2	23.49	4.57	2.82	1.26	8.47	1.07	1.47
12	4	23.31	3.88	2.22	1.01	8.36	1.02	1.37
Mean		**47.76**	**5.07**	**2.91**	**1.32**	**12.92**	**1.09**	**1.57**
LSDS (0.05)	Fact A(MSWC)	1.37	0.02	0.01	0.01	0.01	0.01	0.03
	Fact B(Lime)	1.37	0.02	0.01	0.01	0.01	0.01	0.03
	Fact AxB	2.37	0.03	0.02	0.02	0.02	0.02	0.06
	% CV	2.40	0.50	0.70	1.50	0.20	1.20	3.40

Plant Metal content: Effects of treatments on plant metal content is presented in **Table 5.** Soil amendments had similar influence on plant metal content as it was for the soil content. This means that plant contents of Zn, Cu, Co, Pb, Cd and Ni increased distinctly (LSD 0.05) with rates of MSWC only while the reverse was the case for Fe. Conversely as rates of lime and integration of MSWC and lime increased, plant concentration of all metals decreased. As metal concentrations in the soil increased or decreased, metal concentrations in plant equally increased or decreased.

Similar observation has been reported by others 3,4,7,9, 24 [3, 4, 25, 6, 9]. The linear relationship between soil and plant metal contents was reflected in the positive and significant ($P < 0.001$) correlation between soil and plant Fe ($r = 0.99$), Zn ($r = 1.00$), Cu ($r = 1.00$), Co ($r = 0.99$), Pb ($r = 1.00$), Cd ($r = 1.00$) and Ni ($r = 1.00$) contents **(Table 6).**

Table-6: Simple correlation between soil and plant metal contents

	Plant metal content						
Soil metal content	Fe	Zn	Cu	Co	Pb	Cd	Ni
Fe	0.99*	0.013ns	-0.17s	-0.11ns	0.21ns	-0.31ns	-0.25ns
Zn	0.08ns	1.00**	0.97**	0.99**	0.92**	0.93**	0.95**
Cu	-0.07ns	0.98**	1.00**	0.99**	0.83**	0.97**	0.98**
Co	0.004ns	0.98**	0.98**	0.99**	0.88**	0.96**	0.98**
Pb	0.32ns	0.93**	0.88**	0.91**	1.00**	0.79*	0.83**
Cd	-0.27ns	0.90**	0.95**	0.95**	0.93**	1.00**	0.99**
Ni	-0.17ns	0.94**	0.98**	0.98**	0.71*	1.00**	1.00**

**** = significant at P < 0.01, * significant at P < 0.05 and ns = non-significant**

Similar relationship has been reported between soil and plant metal contents of crops grown on waste dumpsites in Uyo, Nigeria[13]. Also apart from Fe, there was a significant intercorrelationship between the various soil and plant metal (Zn, Cu, Co, Pb, Cd and Ni) contents. Irrespective of treatment, metal contents were higher in the plant than the soil. This means that as soil metal content increased with compost application, a large proportion was also absorbed by plant roots as have been indicated by [13]. The tendency of the crop to accumulate large amount of metals shows that its cultivation on contaminated soil or MSWC amended soil may have some metal implications on animal and human health. These include health problems as cancer, anemia, impotence, sensory disturbance, hyporeflexia, tremor, gingivitis, night blindness, and skin disorder and kidney dysfunction[9-11]. However, metal contents of the crop were within normal ranges for plants **(Table 3),** exception being Pb at rates equivalent to integration of 6 Mg ha^{-1} MSWC and zero lime (M_6L_0) and 12 Mg ha^{-1} MSWC and zero lime ($M_{12}L_0$) and Co at integration of 6 or 12 Mg ha^{-1} MSWC and the different lime rates (0, 2 and 4 Mg ha^{-1} lime). Compared to the WHO standard, plant metal contents fell within the critical limits of plants exception being Cd and Pb**(Table 3)**[25]. Also using the Chinese regulatory standard for vegetables and fruits, plant Cd and Pb contents of most treatments were above maximum regulatory limits of 0.2 and 9.0 mg ha^{-1} respectively [26]. Furthermore, using the Brazilian regulatory standards for fresh vegetables, metal content of the various amendments showed that plant Zn content was below the maximum permissible limit of 50 mg kg^{-1}, critical deficiency concentration of 15-20 mg kg^{-1} and critical toxicity range of 200-500 mg kg^{-1}, Cu content was below maximum permissible limit of 30 mg kg^{-1}, toxicity range of15-30 mg kg^{-1} and deficiency range of 1-3.5mg kg^{-1} exception being with integration of 12 Mg ha^{-1} MSWC and 0 and 2 Mg ha^{-1} lime rates. Plant Pb content was above maximum permissible limit of 0.50 mg kg^{-1} and the toxicity level of 8 mg kg^{-1} for all treatments exception being with zero MSWC only (control) and integration of zero MSWC and the different lime rates (0, 2 and 4Mg ha^{-1} lime). Plant Ni content was below maximum permissible limit of 5 mg kg^{-1} and toxicity level of 11 mg kg^{-1} for all treatments. The Cd content was above the permissible limits of 0.50 mg kg^{-1} except at zero MSWC only and integration of zero MSWC and the different lime rates (0, 2 and 4Mg ha^{-1} lime). This means that Cd and Pb may constitute serious health concerns on MSWC-amended soils with or without lime, though liming may lower the concentration.

Plant Metal Uptake and the Transfer Ratio: Effects of treatments on plant metal uptake and transfer ratios are shown in **Tables 7 and 8.**

Table-7: Effect of lime and MSWC on Plant metal Uptake (g ha^{-1})

MSWC(Mg ha^{-1})	Lime(Mg ha^{-1})	Fe	Zn	Cu	Co	Pb	Cd	Ni
0	0	14.40	0.22	0.03	0.03	0.16	0.02	trace
0	2	14.93	0.10	0.13	0.02	0.27	0.02	trace
0	4	10.21	0.11	0.04	0.04	0.27	0.02	trace
Mean		**13.18**	**0.14**	**0.07**	**0.03**	**0.23**	**0.02**	**trace**
6	0	23.78	1.84	0.90	0.46	6.03	0.31	0.47
6	2	12.63	0.94	0.60	0.30	2.24	0.27	0.36
6	4	5.51	1.10	0.68	0.28	1.95	0.21	0.37
Mean		**13.97**	**1.29**	**0.73**	**0.35**	**3.41**	**0.26**	**0.40**
12	0	29.02	2.01	1.11	0.51	6.60	0.35	0.54
12	2	8.81	1.71	1.06	0.47	3.18	0.40	0.55
12	4	4.83	0.80	0.46	0.21	1.78	0.21	0.28
Mean		**14.22**	**1.51**	**0.88**	**0.40**	**3.85**	**0.32**	**0.46**
LSDs (0.05)	Fact A (MSWC)	0.06	0.05	0.05	0.04	0.07	0.01	0.01
	Fact B (Lime)	0.06	0.05	0.05	0.04	0.07	0.01	0.01
	Fact A x B	0.11	0.09	0.10	0.06	0.12	0.17	0.02
% CV		0.50	5.40	9.70	14.20	2.70	4.80	4.60

Table-8: Effect of MSWC and Lime on metal transfer Ratio

MSWC (Mg ha^{-1})	Lime (Mg ha^{-1})	Fe	Zn	Cu	Co	Pb	Cd	Ni
0	0	1.02	1.13	1.64	2.57	1.05	2.60	trace
0	2	1.05	1.91	3.42	1.60	1.08	2.68	trace
0	4	1.07	2.50	2.15	5.00	1.20	3.33	trace
Mean		1.05	1.85	2.40	3.06	1.11	2.87	trace
6	0	1.17	1.05	1.02	1.57	1.00	1.07	0.47
6	2	1.12	1.02	1.04	1.05	1.01	1.02	0.36
6	4	1.01	1.02	1.04	1.07	1.02	0.98	0.37
Mean		1.10	1.03	1.03	1.23	1.01	1.02	0.40
12	0	1.15	1.05	1.02	1.01	1.00	1.08	0.54
12	2	0.73	1.02	1.02	1.18	1.02	1.04	0.55
12	4	1.01	1.11	1.09	0.96	1.02	1.02	0.28
Mean		0.96	1.06	1.04	1.05	1.01	1.05	0.46
LSDs (0.05)	Fact A	0.19	0.05	0.01	0.35	0.05	0.04	0.01
	Fact B	0.19	0.05	0.01	0.35	0.05	0.04	0.01
	Fact A x B	0.33	0.09	0.02	0.61	0.09	0.07	0.02
% CV		18.20	3.80	0.80	19.80	4.80	2.50	3.70

Metal uptake significantly (LSD 0.05) increased with increased rates of MSWC application but decreased with increased rates of lime only and integration of MSWC x lime. The increased metal uptake with MSWC rates could be due to the increased solubility and availability of metals resulting from the high soil acidity[6, 8] and the high metal content of the MSWC feedlots [4]. It could also be due to the improved root development as a result of the enhanced soil condition with compost addition and the tendency for more metal uptake [5]. The decreased metal uptake with lime addition could be attributable to the decreased metal availability due to the increased soil pH [7]. In general Fe uptake was higher than the other metals while Cd was the least for all treatments. Metal transfer ratio defined as the plant metal content per soil metal concentration[8, 13, 27] varied with treatments **(Table 8).** Irrespective of treatment, metal transfer ratio showed no definite pattern with plant and soil metal contents **(Table 8).** Except Ni with values less than unity, transfer ratios for all other metals were high and above unity. Highest metal transfer ratios occurred at zero MSWC and lime rates only and at zero MSWC and different lime rates for integration of MSWC x lime. At these rates which represent the background soil condition, soil acidity was high. Thus indicating that as soil pH decreased, metal solubility and availability and hence the transfer ratio increased probably due to the high soil acidity[8, 13, 27]. In addition, the high metal transfer ratio at these treatments with low soil metal concentrations indicates that factors other than soil metal content could be responsible for the metal transfer ratios[8, 13].

CONCLUSIONS

Municipal solid waste compost had higher OM, pH and metal contents than the soil and as such its soil application can improve soil concentrations. Soil Zn, Cu, Co, Pb, Cd and Ni but Fe increased with MSWC rates while contents of all metals (Fe, Zn, Cu, Co, Pd, Cd and Ni) decreased with lime only and MSWC x lime. Degree of metal pollution varied with treatments, but with soil practically unpolluted with Fe for all treatments and highly polluted with Cd in most treatments. Addition of MSWC and lime only and MSWC x lime had the same impact on the plant metal content as the soil but with plant concentration higher than the soil. Plant Cd and Pb contents were above critical regulatory limits and could constitute serious health risks. Plant metal uptake increased with rates of MSWC and lime and integration of MSWC x lime with Fe uptake higher than the other metals and Cd the least. Metal transfer ratio varied, with no definite pattern for treatments rates.

REFERENCES

1. J. C. Hargreaves, M. S. Adl and P. R. Warman, A review of the use of composted municipal solid waste in agriculture. *Agr. Ecosyt. Environ*.2008, **123 (**1-3): 1-14.
2. G. N Eriksen, E. J, Coale and G. A. Bollero, Soil nitrogen dynamics and maize production in municipal solid waste-amended soil, *Agon. J. 1999,* **91:1009**-1016.
3. V. D. Zheljazkov, and P. R. Warman, Source separated municipal solid waste compost application to Swiss chard and Bassil. *J. Environ. Qual.* 2004, **33**: 542-552.
4. R. R. Madrid, Lopez and C. Cabrera Metal accumulation in soil after application of municipal solid waste compost under intensive farming conditions. *Agri.Ecosyst. Environ, 2006,* 119 **(3-4):** 249-256.

5. J. C. Hargreaves, M. S. Adl and P. R. Warman, The effect of municipal solid waste compost and compost tea on mineral element uptake and fruit quality of strawberries. *Comp. Sci.Util.*2009, **17** (2); 85-94.
6. J.W.C. Wong, K.M. Lai, D.S. Su and M. Fang, Availability of heavy metals for Brassica Chinensis grown in an acidic loamy soil amended with domestic and industrial sewage sludge. *Water, Air, Soil Poll.2001,* 128: 339-353.
7. F. Ayari, H. Hamad, N. Jedidi, Gharbi and R. Kossai, Heavy metal distribution in soil and plant in municipal solid waste compost amended plots. *Int. J. Environ. Tech.* 2010, **7(3**): 465-472.
8. A. Agyarko, E. Darteh and B. Berlinger Metal levels in some refuse dump soils and plants in Ghana, *Plant Soil Environ*.2010, **56** (5): 244- 251.
9. G. F. Antonious, S. O. Dennis, J. M. Unrine and J. C. Snyder, Heavy metals uptake in plant parts of sweet potato grown in soil fertilized with municipal sewage sludge. *Int. J. Geol.* 2011, **1** (5): 14-20.
10. M. Girovich,'Biosolids" characteristics, treatment and use. An over view in biosolidstreatment, management and processes for beneficial use. M.Girovich Ed, Marccel Dekker, Inc, New York. 1996, Pp 1-45**.**
11. V. B. Omubo-Pepple, Tamunobereton-ari and E.D. Uko.Heavy Metal Speciation in contaminated soils of an Abandoned Hydrocarbon Exploration Field Camp and Workshop Site in Part of theNiger Delta, *NigeriaJ. Basic. Appl. Sci. Res*. 2011, **1(6)**456-463
12. C. Kabala, and B. R. Singh, Fractionation and mobility of copper lead and zinc in soil profiles in the vicinity ofa copper smelter. *J. Environ. Qual., 2001,* **30 (2**), 485-492.
13. G. A. Ebong, M. M. Akpan and V. N. Mkpenie. Heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by Carica papaya and Talinumtriangulare in Uyo, Nigeria. *E. J. Cem. 2008,* **5 (2):** 281-290.
14. FMANR (Federal ministry of Agriculture and natural resources), Literature review on soil fertiliy investigations in Nigeria (five volumes). 1990, Bobma Publ., Ibadan Nigeria.
15. C. D. Tsadilas, N. A. Karaivazoglou, N. C. Tsotsous, S. Stamatiades and V. Samaras. Cadmium uptake by tobacco as affected by liming, N forms and year of cultivation. Environment Pollution 2005, 134 **(2):** 239-246.
16. Z. S. Chen, and T. M. Lee, The effect of chemical remediation treatments on extractability of cadmium and lead in the soil and the uptake of cadmium and lead by wheat growing in contaminated soils. Proceedings of the 2nd International Conference on contaminants in the soil Environment in the Australasia-Pacific Region. 1999, Dec, 12-17, Delhi India (IN press).
17. B. U. Uzoho, G. E. Osuji, E. Ihem, I. I. Ibeawuchi, A. A. Ngwuta and A. C. Uzoho. Pumpkin (Telferiaoccidentalis) yields and nutrient use efficiency of limed municipal solid waste compost (MSWC)-amended Ultisol in Ihiagwa, Southeastern Nigeria. Inter. *Journ. Agric& Rural Dev.* 2012, **15 (1):** 854-860.
18. D. J. Oyedele, I. B. Obiah, J. A. Adejumo, A. F.Oluwole, P. O. Aina and O.I.Asubiojo, Lead contamination of soils and vegetation in the vicinity of a lead smelter in Nigeria. *Sci. Total Environ.1995,* 172:189-195.
19. W. Buysse, R. Stern and R. Coe. Genstat Discovery Edition for everyday use. ICRAF Nairobi, Kenya 2004, 114 pp.

20. Z.S Chen and D. Y. Lee. Evaluation of remediation techniques on two cadmium pollutedsoils in Taiwan. In: Remediation of soils contaminated with metals. A. Iskandar and D.C Adviano (Eds). Science *Reviews*, Northwood, UK. 1997, Pp 209-223.
21. S. R. Smith, Agricultural recycling of sewage sludge and the environment. CAB Inter. Wallingford. 1996, 382.
22. M. Mkhabela and P. R. Warman. The influences of municipal solid waste compost on yields, soil phosphorus availability, and uptake by two vegetable crops grown on a pug wash sandy loam soil in Nova Scotia. Agri. *Ecosyst. Environ*.2005, 106:57-67.
23. U. Forstner, W. Ahlf and W. Calmano, Sediment quality objectives and criteria development in Germany. *Water Science and Tech*.1993, 28: 307.
24. C. P. Jordao, C. C. Nascentes, R. L. F. Fontes, P. R. Cecon and J. L. Pereira. Effect of composted urban solid waste addition on yield and metal content of lettuce. *J. Brazillian Chem. Soc.* 2007, 18(1**)**:347-361.
25. WHO/FAO, Joint FAO/WHO food standard programme. Codex Alimentarices Commission, 13th Session Report of thirty session of Codex Committee on food hygiene, Houston, United States of America, 2007, ALINORM 07/30/13.
26. S. Khan, Q. Cao, Y. M. Zheng, Y. Z. Huang and Y. G. Zhu, Health risks of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing China. *Environmental Pollution* 2008, **152**: 686-692.
27. A. A. Amusan, D. V. Ige and R. Olawale. Characteristics of soils and crops uptake of metals in municipal waste dumpsites in Nigeria. J.Hum. *Ecol*.2005, 17:167-171.
28. A. N. Essoka, and I. E. Esu, Profile distribution of sesquioxides in the inland valley soils of central Cross River state, Nigeria. Proc. 26th Annual Conf. *Soil Sci. Soc. Nig*.2000, pp24-31.

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