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Remediation of trace metal Contaminated Auto-mechanic soils with Mineral Supplemented-organic Amendments

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Abstract:

Trace metal contamination of soil and surface waters arising from increased emissions from industries,traffic, auto-mechanic activities and agriculture raise concern on human health and environmental quality. The aim of this study was to find practical and cost-effective measures to reduce metal uptake in crops grown on metal contaminated soils. A laboratory batch experiment using 6 potential mineral–organic amendment combinations in the ratio 1: 2, (a)composted Farm yard manure (cFYM) + Gravel sludge (GrS), (b) Vemicompost (VC) + GrS, (c) composted sewage sludge (cSS)+ GrS , (d) Red mud (RM)+ cFYM), (e) RM + VC, (f) cSS+ RM, were used to treat trace metal contaminated soil in a completely randomized pot experiment using *Amaranthus viridis* as a test crop. Result showed that all the amendment combinations had varied potential to reduce metal uptake by *Amaranthus viridis* when compared to control. There was appreciable reduction in metal leachability across all the amendments: Cd (<51%), Cu (<67%), Zn (<34%) and Pb (<69%) on the average when compared to controls, with a concurrent reduction of uptake into *Amaranthus viridis* root and shoot tissues (Cd < 62%, Pb < 68%, Cu< 66% and Zn 56%) on the average. Dry matter yield in the amendments is in the order cFYM + GrS> cFYM +RM> cSS+GrS>cSS+RM>Control>VC+RM >VC+GrS.Acid extractable (DTPA) fractions of Cd, Pb, Cu and Zn were reduced by up to 76%, 79%, 65% and 49%, respectively in amended soils. Investigations on long term effects of metal mobility is recommended

Keywords: Amendment, bioavailability, metal-mobility, remediation and trace-metal

1.0 Introduction:

Many agricultural soils have concentrations of heavy metals, significantly exceeding the levels that are generally stated as environmentally acceptable and therefore form a potential health risk for humans, animals, and plants (De Sousa, 2003;Environment Agency, 2004).Heavy metals such as Cd and Pb have been shown to have carcinogenic effects (Trichopoulos, 1997). High concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastrointestinal cancer (Turkdogan et al., 2002). For most of the people, the main route of exposure to heavy metals is through the diet except occupational exposures at related industries. Regulations have been set up in many countries and for different industrial set up to control the emission of heavy metals.Nwachukwu, et al., (2010) reported high concentrations of heavy metals in soils of auto-mechanic villages in southeast Nigeria. Other anthropogenic sources include the use of agro chemicals and sewage sludge (Girisha, et al., 2009). The uptake and bioaccumulation of heavy metals in vegetables are influenced by a number of factors such as climate, atmospheric depositions, the concentrations of heavy metals in soil, the nature of soil on which the vegetables are grown and the degree of maturity of the plants at the time of harvest (Lake et al., 1984; Nwoko and Egunjobi 2002; Voutsa et al., 1996).

The threat of these metals to the environment can be reduced by fixation in the soil itself, thereby lowering the bioavailability and reducing further mobility. A considerable amount of research has been carried out amending soils with clay minerals, zeolites, and compost to immobilise metals through cation exchange (Simon, 2001), sorption, complexation and precipitation (Mule and Melis, 2000; Geebelen et al., 2002; Roman et al., 2003; Castaldi et al., 2005). Remediation of metal contaminated soils with immobilizing amendments represents one cheap and feasible option. Reviews of potential amendments are given by Knox et al. (2000) and Mench et al. (2003). Amendments can provide a large surface area for immobilizing reactivity, such as gravel sludge (Lothenbach et al., 1996) and organic matter (Vacha et al., 2002), and/or can change soil pH, such as red mud (Friesl et al., 2004), lime (Chlopecka and Adriano, 1996), and phosphates (Hettiarachchi and Pierzynski, 2002). Another option to reduce metal transfer from food crops to the food chain is to identify and cultivate metal-inefficient cultivars of major crop and forage plants (Puschenreiter et al., 2005).Brown et al. (2004) in his experiment reduced plant uptake of Pb, Cd, and Zn by adding H_3PO_4, and also reduced the resorption of Pb in weanling rats. Krebs et al. (1999) also found that soil application of gravel sludge reduced both the $NaNO_3$-extractable pool of Zn and Cd as well as reducing uptake of both elements by Lettuce. Vangronsveld et al. (1995) achieved a closed vegetation cover on a Zn-contaminated site by adding 5% beringite combined with metal-tolerant plants. Vangronsveld et al. (2000) concluded, in a short review of several field studies, that amendments decreased the soluble and exchangeable metal fraction, but uptake in plants was not significant in these cases.

The contamination of soils by heavy metals due to agricultural activities became a preoccupying problem in recent years (Jordao et al., 2006). Since heavy metals do not exhibit the same behaviour in different types of soils, the determination of their total content only provides little information. The mobility and availability of metallic elements in amended soils is indeed influenced by several factors such as the pH, the redox potential, the type and the quality of soil, the concentration and the type of ions competing for adsorption, and mainly the presence of organic or inorganic ligands (Narwal et al., 1999; Illera et al., 2000; Kabala and Singh, 2001). Naturally occurring minerals such as clays and red mud interact with metals to form a matrix in which the bioavailability of the metals is decreased (Ouki and Kavannagh, 1999; Simon, 2001). Red mud and other natural minerals may not be recommended alone as agricultural soil amendment (Reha´kova´ et al., 2004) it can also have an adverse effect on the soil structure and the amount to be added to the soil should therefore be limited (Geebelen et al., 2002).Enrichment of organic matter with gravel sludge and red mud could provide long-term immobilisation of the metals because these minerals will not be degraded and so will bind the metals for much longer. Altogether an improved biological quality of the soil will be obtained by improved nutrient levels though the organic matter as well as a reduced toxicity of the soil through immobilisation of the metals. The method whereby composted materials and inexpensive minerals (gravel sludge and red mud) may offer a low cost, sustainable solution for the remediation of permanently heavy metal contaminated automobile mechanic soils. This paper reported the results of a short term experiment undertaken to assess the viability of mineral supplemented compost-organic materials for the remediation of predominantly heavy metal contaminated soils.

2.0 Materials and Methods

2.1 Experimental design

A heavy metal contaminated sandy loam soil from auto-mechanic village in the southeast region of Nigeria, classified as Ultisol was used in this study. Nwachukwu et al., (2010) observed high level of heavy metals in Orji, Okigwe and Nekede auto-mechanic villages in Imo State, Southeast Nigeria. The soil was collected from the upper 0–20 cm of the soil, air dried and sieved to 2 mm. The sampling area is a humid tropical climate, with mean annual precipitation of 2200 mm and average annual temperature of 30°C. Initial soil characterization showed low carbon content<10 g kg^{-1}; N content 0.9 g kg^{-1}; pH 5.4; electrical conductivity 2102.4 µS $cm-^{1}$; bulk density 2.3 g $cm-^{3}$, calcium carbonate content 460 g $kg-^{1}$ and the total content of Fe, Cu, Zn, Pb and Cd is high; 70, 454 mg/kg Fe, 1004 mg/kg Cu, 1086 mg/kg Zn, 1087mg/kg Pb and 43 mg/kg Cd, respectively.

The experiment was carried out using three different organic amendments viz: composted farmyard manure (cFYM), vemicompost (Vc) and composted sewage sludge (cSS) and mineral amendments: gravel sludge (GrS) and red mud (RM). The organic and mineral amendments were mixed at the ratio of 2:1 to achieve six different combinations as follows: FYMc + GrS, VC + RM, cSS+ GrS, VC + GrS, cSS + RM and cFYM +RM. The composts were obtained by composting in aerobic conditions, after thermophilic and mesophilic phases, to eliminate pathogens and stabilize organic matter (OM). The main characteristics of the amendments are given in Table 1. Before application to soil, the amendment combinations were air-dried and applied to the heavy metal contaminated soil at the ratio of 1:3 to give 10kg(soil + amendment) and were placed in pots. Soil without amendment served as control. Each treatment was replicated three times in a randomized complete block. The moisture content of the soils was adjusted to 60% of the water-holding capacity(WHC) by adding distilled water and left to settle for 2 weeks before planting.

2.3 Pot experiment

Amaranthus viridis seeds obtained from National seed bank were sown into pot containing 10 kg soil mixture. The vegetable was grown in a screen house located at the school of Agricultural Technology, Federal University of Technology, Owerri, from 9 April to 10 June 2012 at a minimum night temperature of 12 °C and day temperature varying between 25 and 45 °C. During the growing period, the water content of the soil in all pots was maintained between 0.35 and 0.5 $m^3 m^{-3}$ by manual watering with tap water.The *Amaranthus viridis* grown on the compost amended soil was left to grow till maturity. Matured plant was up rooted washed, air- dried and divided into shoots and roots for analysis.

Transfer coefficients (TC_{metal}) were calculated on a dry weight basis by dividing the metal concentration in the plant (mg kg^{-1}) by the metal concentration in the soil (mg kg^{-1}).

2.2. Batch leaching experiments:

Batch leaching tests were performed according to Herwijnen et al., (2007) for materials with a particle size <4 mm. One-hundred gram samples of each soil mixture and a control of pure soil were mixed with 1 litre of carbonated de-iosnised water at a pH of approximately 5.6. The carbonated water was prepared by flushing the water with CO_2 until a pH of 5.6 was achieved. Each water-soil mixture was put in a 1-litre polypropylene bottle and rotated on a bottle roller for 24 ±1 h. After rotation, the mixture was stood for 7 days at room temperature after which the supernatant (leachate) was filtered over a 0.45 µm nitrocellulose membrane filter (VWR international Ltd, Poole, UK) for chemical analysis.

Table 1.0: Characteristics of the amendment materials applied to soil. Mean values ± standard deviation, (n = 3)

Parameters	cFYM	VC	cSS	GrS	RM
pH ($CaCl_2$)	7.2± 0.02	5.6±0.01	7.8±0.02	8.4±0.12	9.8±0.12
EC (µS cm^{-1}) ($CaCl_2$)	2435±213.1	2354±342.1	2010±213.1	1232±245.1	2354±435
Texture: (sand) (g/kg)	Na	4.5±0.21	na	52±23.3	na
Silt (g/kg)	Na	2.5±0.21	na	89±2.3	na
Clay (g/kg)	Na	5.6±3.2	na	64±4.6	na
$CaCO_3$ (g/kg)	23.3±14.5	32.5±23.4	45.3±23.4	253±34.7	94±23.1
OC (g/100g)	30.2±21.3	14.2±4.3	24.5±4.55.3	6.4±0.33	1.4±0.21
Pb (mg/kg)	10.2±2.4	11.3±3.6	16.7±6.7	37.2±2.6	154.2±23.6
Cu(mg/kg)	45.4±23.1	121.3±34.5	232.3±3.4	64.3±23.4	182.4±21.2
Cd (mg/kg)	0.21± 1.3	0.023±1.02	0.52±2.3	0.32±3.4	1.32±1.2
Zn(mg/kg)	142.2± 23.4	231.4±3.4	214.3±43.2	335±23.4	254±32.2

cFYM= composted farm yard manure, VC= vemicompost, cSS= composted sewage sludge, GrS= gravel sludge, RM= red mud.

2.4 Chemical analysis:

At the end of the experiment, amended soils were characterized using standard procedures (Baker and Amacher, 1982). Soil texture was determined using a combined sieving and pipette method after pre-treatment with 0.1 M $Na_4P_2O_7.10H_2O$. The content of $CaCO_3$ was determined with the Scheibler apparatus. Organic carbon concentrations of the soils and amendments were determined with a Thermo Finnigan Flash 1112 elemental analyzer (Franklin, MA, USA), after the elimination of carbonates with hydrochloric acid.The pH was determined using 0.01 M $CaCl_2$ with an ORION combined electrode. Electrical conductivity (EC) was measured in double distilled water(soil solution ratio 1:10) with a WTW Microprocessor Conductivity Meter LF 196. Extractable metal fractions were determined by using diethylen-triamine pent acetic acid (DTPA) buffered at pH 7.3.Ailquots of amended soil (3 g) were digested in 20 ml hot aqua regia according to

O¨ NORM M 6290, (1988). Plant materials (2 g) were digested (open system) using a mixture of concentrated 20 ml HNO_3 and 4 ml $HClO_4$. Soil samples were digested in aqua regia (Baker and Amacher, 1982). The metal concentrations in the extractable fractions were determined by inductively coupled plasma massspectrometry (ICP-MS PERKIN ELMER ELAN 6100). All digested samples were analyzed for Cd, Pb, Zn and Cu.

2.5 Statistical analysis:

Data were analyzed by Minitab software version 16. ANOVA was used for the statistical analysis of treatments effects and multiple range test based on Tukey's high significant difference (HSD) method was applied to establish differences between treatments.

3.0 Results and Discussion:

3.1 Leaching experiment: All the amendment combinations had profound effects on the concentration of metals leached from the heavy metal contaminated soil.The concentration of metals in the leachate is presented in Fig 1.0. VC + GrS amendment combination enhanced the leachability of Pb, Cu, Zn and Cd more than cFYM + GrS, RM + cFYM and cSS+ RM amendments. Pb and Cd concentrations in leachates of soil amended with cSS + GrS were significantly ($P<0.001$) higher than concentrations obtained in the leachate of soil amended with RM + cFYM and cFYM + GrS. There was significant reduction in metal leachability in the amended pot when compared to control. RM + cFYM amendment combination best reduced leachability of Pb (80%) and Cu (78%) compared to control. Also, cSS + GrS best reduced leachability of Zn (80%) and cFYM + GrS combination had the highest reduction in Cd (93%).The ranking of the amendment combinations in terms of effectiveness in reducing leachability of metal species is in the order: cSS + GrS >VC +GrS > cFYM + GrS> Rm+ VC> cSS+RM > RM+cFYM for Pb. VC+GrS> cFYM+ GrS> cSS+GrS> cSS+RM >RM+VC > RM+cFYM for Cu. VC + GrS> RM + VC> cSS + RM >RM + cFYM >cFYM + GrS > cSS + GrS for Zn. RM+VC > cSS + RM > Rm + cFYM > cSS +GrS > VC+ GrS > cFYM + GrS for Cd.

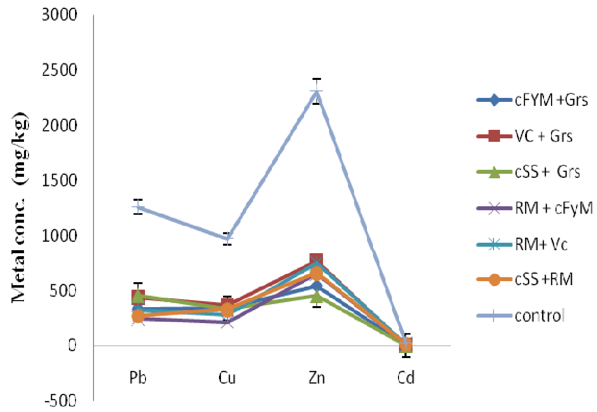

Fig 1.0 Effect of amendment on metal leaching. Bars represent standard deviation.

3.2. Dry weight of *Amaranthus viridis*as influenced by the amendment

Amaranthus sp recorded appreciable growth in all the amendment combinations (Fig. 2). cFYM + GrS produced the highest dry matter yield and significantly ($P<0.001$) differed from other amendment combinations. cSS + GrS, cSS + RM and control did not differ ($P<0.05$) in their dry matter production. *Amaranthus sp* grown on cFYM + GrS produced 2 fold more dry matter than when grown in VC + GrS, 1.7 fold when grown in cSS +GrS and 2.2 fold in RM +VC.

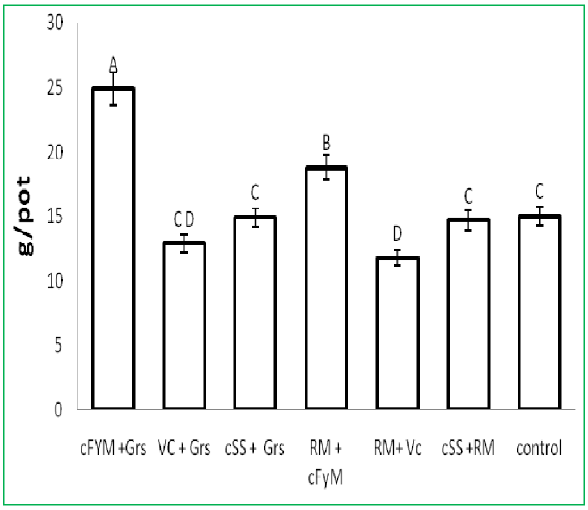

Fig. 2. Dry matter yield of *Amaranthus viridis* as influenced by amendment combinations. Error bars represent standard error of the mean. Bars with similar letters are not significantly difference

The addition of composted organic materials enhanced growth of *Amaranthus sp* irrespective of the heavy metal concentration of the soil. cFYM combination with mineral supplement produced more dry matter than other composted organic materials.

3.3 Effect of amendment on shoot metal concentration.

Soil amended with RM + VC caused upto 72% reduction of Pb concentration of shoot and Cd (92%) compared to the control (Fig.3.0).Also, cSS + RM amendment recorded (45.3± 2.52 mg/kg) 71% reduction of Pb in the shoot of *Amaranthus sp* compared to control. The least reduction (40%) in Pb shoot concentration occurred in the cSS+ GrS amendment combination. The amendment combinations did not significantly differ in their ability to reduce shoot metal concentration but significantly differed with control. VC+GrS was most impressive (74 %) followed by cFYM + GrS (70%) and cSS + RM (69%).The amendment combinations significantly reduced accumulation of Zn in the shoot of *Amaranthus viridis.*RM+ cFYM recorded the highest reduction (67%) compared to control. However, this did not differ between cSS + RM (65%) and cFYM +GrS(65%).

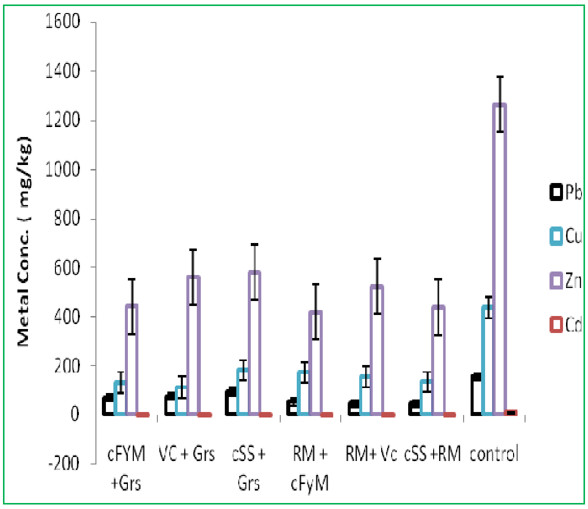

Fig. 3.0 Effect of amendments on shoot metal concentration of *Amaranthus sp*

The least of Zn reduction occurred in cSS +GrS (54%) and this did not vary significantly between VC + GrS (55.7%) and RM + Vc(58%). The reduction in shoot Zn concentration was strongly influenced by red mud mineral supplement. All the amendment combinations significantly affected shoot Cu concentration. VC +GrS gave the highest reduction (74%) of Cu compared to control and this differed with other amendment combinations. cFYM +GrS and cSS + RM significantly reduced shoot Cu concentration by 70.2% and 69%, respectively and did not differ significantly. Cadmium was poorly absorbed by *Amaranthus viridis* when compared with the control. The amendments probably may have played significant role. The highest reduction occurred in cSS +GrS with 0.436 ± 0.06 mg/kg Cd which represented (94.6%). This was closely followed by cFYM + GrS with shoot Cd concentration 0.447± 0.188 mg/kg (94.4%) . The least reduction ocurred in cSS + RM with 1.67 ± 0.12 mg/kg Cd concentration. The amendment significantly ($p<0.001$) affected Cd shoot concentration. The shoot Cd concentration of control significantly differed with other amendments. However, cFYM + GrS and cSS + GrS did not differ at ($p< 0.05$). The Cd shoot content of *Amaranthus viridis* as influenced by amendment combination is in the order of cSS + GrS > cFYM + GrS> RM +cFYM > RM +VC> VC +GrS> cSS+ RM.

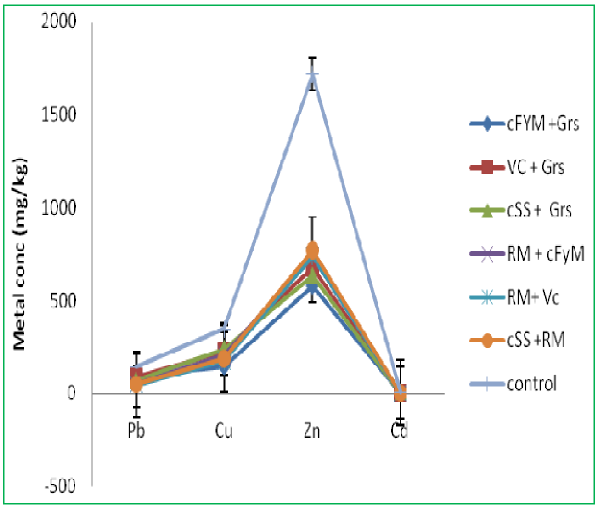

Fig. 4 Effect of amendment on metal root uptake by *Amaranthus viridis.* Bars represent standard deviation.

3.4 Effect of amendment on metal root uptake by *Amaranthus viridis*:

The amendment combinations effectively affected metal root content of *Amaranthus sp.* (Fig. 4). RM + VC combination was most impressive in reducing root Pb content(47.86±0.5mg/kg) compared to control (141.3±62.2mg/kg). This was closely followed by RM + cFYM (48.0 ±0.75mg/kg) and cSS + RM (49.7±0.32mg/kg). The least root Pb reduction capability of the amendment was observed in cFYM +GrS (94.63±1.84 mg/kg) followed by VC + GrS (88.8 ±1.9 mg/kg).Also, Root Cu content of *Amaranthus sp* significantly (p<0.001) varied among all the amendment combinations. The highest percentage root Cu reduction occurred in cFYM + GrS (57.6%) of Cu root concentration of 147.3±24.8 mg/kg compared with the control of 346.3±27.8 mg/kg. cSS + GrS was the least effective in influencing root Cu content (239.7±3.2 mg/kg) of *Amaranthus sp*. There is significant (p<0.002) concentration of zinc in the root of *Amaranthus sp* in all the treatment combinations. However, cFYM + GrS was most effective in reducing root Zn concentration (579.33 ±5.51 mg/kg) when compared with other treatments. The cSS + RM combination was the least in influencing Zn root concentration. Cd was the least root metal absorbed by *Amaranthus sp*. All the amendment combinations showed varied degree of effectiveness of metal retention. The highest reduction in root Cd metal concentration was in RM + cFYM (1.47 ±0.37mg/kg) compared to control of (8.0 ± 1.31 mg/kg). Apart from cSS + GrS and RM + cFYM that differed in there influence on root Cd metal content, no significant difference exist in the other amendment combinations.

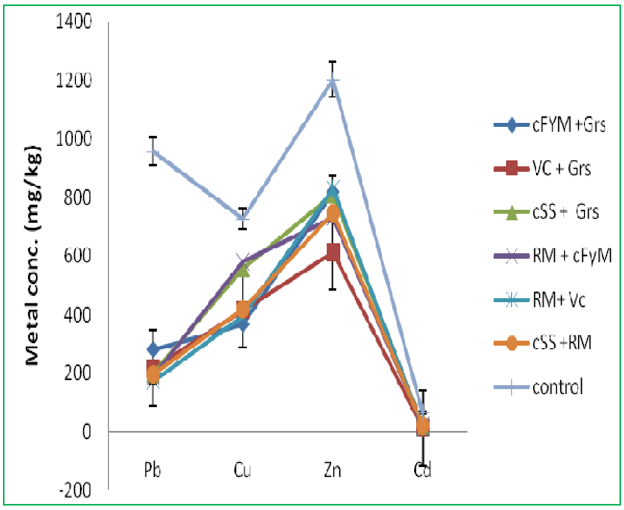

Fig. 5 Effect of Amendment on acid extractable metal. Bars represent standard deviation.

3.5 Effect of Amendment on acid extractable metal

The amendments significantly affected acid extractable metal fractions when compared to control(Fig 5). The highest reduction (82 %) in extractable Pb occurred in RM + VC and this was closely followed by RM + cFYM by 80%.Similarly, The lowest reduction (71%) of extractable Pb ocurred in cFYM+ GrS. Soil extractable Cd was significantly (p<0.002) affected by the amendments. VC + GrS was most effective in reducing extractable Cd (12.9 ± 1.04 mg/kg). and this did not differ from extractable Cd recorded in RM +VC (14.5 ± 0.2 mg/kg). cFYM + GrS extractable Cd of 22.8±0.34 mg/kg did not differ from that of cSS +GrS (22.26 ± 0.15 mg/kg).

The amendments significantly (p<0.003) reduced Zn acid exchangeable fraction. But the reduction did not differ among the amendment materials. The highest reduction of 49 % ocurred in VC + GrS, followed by RM + cFYM with 39%. The least influence of amendment on soil extractable Zn concentration was recorded in RM ± VC (31%). The amendments significantly affected exchangeable Cu concentration when compared to control. RM ± cFYM gave the least reduction (20%) of 581.1±63mg/kg . The highest reduction (50 %) of 366.4±0.7 mg/kg) ocurred in VC ± GrS. cSS ± RM, VC± GrS and cFYM

±GrS never differed in their contributions in the reduction of soil Zn extractable fraction in this experiment.

3.6. Metal transfer coefficient in *Amaranthus viridis* as influenced by the amendment:

The higher the value of the transfer coefficient, the more mobile/available the metal is. The transfer coefficient values as influenced by the different amendments varied across the metals (Table 2).
Transfer coefficients were generally high in Zn metal across the amendments especially in RM + FYM, RM + VC and cSS + RM. Cadmium was poorly absorbed to the plant tissue compared to other metals. RM + FYM, RM + VC and cSS + RM amendments exhibited low capacity to restrain metals to plant tissues. However, cFYM + GrS and VC + GrS amendment combinations were very effective in reducing metal absorption to plants.

Table 2. Metal transfer coefficient as influenced by organic amendments.

Metal	cFYM+GrS	VC+GrS	cSS+GrS	RM+FYM	RM+VC	cSS+RM
Pb	0.15	0.12	0.56	0.33	0.27	0.26
Cu	0.18	0.26	0.43	0.38	0.27	0.36
Zn	0.52	0.67	0.86	0.86	0.91	0.92
Cd	0.13	0.09	0.12	0.17	0.15	0.17

Table 3.0 Residual soil chemical characteristics as influenced by organic amendment

Parameter	cFYM+GrS	cSS+GrS	RM+Vc	cSS+RM	VC+ GrS	RM+FYM
Org. carbon (g/100g)	32.1	33.1	33.4	33.2	33.3	33.2
pH ($CaCl_2$)	6.3	6.4	5.2	6.4	6.5	5.4
EC ($\mu S\ cm^{-1}$) ($CaCl_2$)	2435	2435	2436	2436	2437	2437

Residual soil chemical properties shows moderate pH increase in cSS + GrS , cFYM+ GrS and VC+GrS amendments (Table 3.0). Electrical conductivity did not significantly vary across the different amendments units. Residual organic carbon considerably improved at the end of the experiment period.

The objective of this study was to investigate the potential for the remediation of metal contaminated soils by the addition of mineral-supplemented composts in an attempt to reduce metal leaching and bioavailability to plants. Other researchers have demonstrated the potential of compost for this purpose (Roman et al., 2003; Castaldi et al., 2005; Simon, 2005). The results from this study demonstrated similar effects but importantly showed that the leaching of the metals also could be affected. The affection of metal leaching is particularly true in the case of Zn, Pb and Cu where leachability increased in VC + GrS amendment combination.The increased leachability of Zn, Pb and Cu from the amended soil could be caused by the formation of complexes of Zn with organic matter compounds in the amendment, such as humic and fulvic acids (da Silva and Oliveira, 2002) or by changes in pH with the addition of VC. Effects for organic matter have been reported for Cu where a mixture of organic house hold waste compost and wood chips reduced the concentration of free Cu^{2+} in the soil water but increased the concentration of complexed Cu^{2+}(Kiikkila et al., 2001; Clemente et al.,2003). However, the final effect was a reduced toxicity to soil bacteria (Kiikkila et al., 2001). Apart from Cu and Zn it is also known that leaching of Pb can be increased by complexation with dissolved organic matter (Bradl, 2004; Menchet al., 2003) and these metals are therefore likely to have raised concentrations in the leachates of compost amended soils in our experiment.The best immobilization was achieved with cSS + GrS amendment combination (Fig.1.0). The main immobilization mechanism is probably chemisorptions onto Fe oxides/hydroxides (ferrihydrite). This was added as GrS and it provided an amorphous surface (Okazaki et al., 1986). The distance between the hydroxyl groups (OH-OH) in the Fe oxides matches well with the coordination polyhedra of many heavy metals (Knox et al., 2000). For Pb sorption onto ferrihydrite, Trivedi et al. (2003)demonstrated that edge-sharing bidentate complexes are mainly formed at pH > 5.0. A further potential immobilizing mechanism is the large surface provided by clay minerals added in RM (Lothenbach et al., 1996). Stipp et al. (1992)proposed that Cd sorbs onthe calcite surface and subsequently penetrates slowly intothe mineral.

Addition of the amendment appreciably improved the growth of *Amaranthus viridis* irrespective of trace metal presence in soil. No treatment combination potentially suppressed the release of essential nutrients. The improved plant growth could be due to immobilisation of the metals, but could also have been caused by either the addition of nutrients to the soil, or by dilution of the contaminants through compost and mineral amendment. The dilution of the contaminants was probably only a minor factor as can be seen from the leaching results where the effect of the amendments was more than what could be expected from dilution alone. The effect of nutrient can be observed from the improved growth after the addition of cFYM + GrS, VC+ GrS which did not immobilize the metals but had a very high dry matter yield (Fig .4.0). Shoot metal concentrations of *Amaranthus sp* was poorly influenced by the amendment combinations. The plant uptake of chemical species in soil solution is dependent on a number of plant factors. These include: physical processes such as root intrusion, water, and ion fluxes and their relationship to the kinetics of metal solubilization in soils; biological parameters, including kinetics of membrane transport, ion interactions, and metabolic fate of absorbed ions; and the ability of plants to adapt metabolically to changing metal stresses in the environment (Cataldo and Wildung, 1978). This study has indicated that: abiotic and biotic soil processes controlled the solubility and availability of metals for plant uptake; metals were taken up by plants at differing rates; and metals, once absorbed, varied as to their mobility within the plant, suggesting a second point of metabolic regulation. Essential nutrients e.g Cu and Zn exhibit two types of distribution in shoot tissues: relatively uniform distribution with leaves being the major site of deposition and transport within the plant through passive movement in the xylem and initial uniform shoot distribution, with remobilization of specific elements from leaves through phloem transport during senescence,to either developing leaves and/or seeds. Herwijnen et al, (2007) noted that The behaviour of metals (cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, lead and zinc) and metalloids (arsenic, boron and selenium) in contaminated soils depends to a large extent on the intrinsic charge, valence and speciation of the contaminant ion, and soil properties such as pH, redox status and contents of clay and/or organic matter. However, chemistry and behaviour of the contaminant in soil alone cannot predict soil-to-plant transfer. Root uptake, root selectivity, ion interactions, rhizosphere processes, leaf uptake from the atmosphere, and plantpartitioning are important processes that ultimately govern the accumulation of metals and metalloids in edible vegetable tissues.

All the amendment combinations significantly reduced DTPA-extractable metal species when compared to control.Organic matter is considered to play an important role in reducing plant uptake of Cd from soils due to its high CEC and complexing ability. Nevertheless, the results reported in the literature are not consistent. Many authors have found that high organic matter content or addition of organic matter by organic wastes decreased the Cd concentration in solution. This effect is explained by the high CEC of organic matter and its ability to form chelate complexes with Cd. Korcak and Fanning (1985) found a positive relationship between DTPA-extractable Cd and the amount of organic matter in soils. McGrath et al. (1988) found that the total Cu content was more dependent on the organic matter status, as soil and the proportion of Cu present in solution as Cu^{2+} increased and as pH decreased. They also implied that extractability of Cu, however, was affected by organic matter status, suggesting that the organic matter content of soils would have a great effect on the fate of Cu whether it was applied in fertilizers, sewage sludges or other organic wastes containing Cu.The amendment combinations provided sorption sites for the metal species. Reduction in metal sorption has been reported in Organic waste amended soils due to organic matter decomposition (Yuan and Lavkulich (1997) and Arnesenand Singh (1999). Transfer coefficient for the Zn metal was more profoundthan other metals in all the amendments. This finding may be attributed to the moresoluble Zn organic complexes found in soil pore water (Friesl et al., 2004).Shuman (1975)found that pH, the clay content, and organic matter content, and CEC influenced the adsorption of Zn by soils. Mandal and Hazra (1997) also found that organic matter application and low pH arrested a decreasing trend in Zn adsorption, and increasing levels of soil organic matter increased extractability of Zn.

5.0 Conclusion:

From this study we noted significant reduction in metal uptake and mobility with concomitant improvement in biomass yield in *Amaranthus viridis.* Composted sewage sludge and gravel sludge amendment combination was most effective in reducing leachability of metal species while composted farm yard manure with mineral supplements produced more dry matter than other composted organic materials. The addition of mineral-supplemented organic amendments did not influence tissue metal partitioning in this study but reduced uptake when compared to control.There is indication that the effect on amendment depends on the type of compost, the soil type, and related contaminant levels. It is therefore recommended that plant and leaching tests be performed before composts are applied on field scale for the reclamation or remediation of metal-contaminated soil. The metal leaching experienced in this study was ascribed to the formation of metal-organic complexes or chelating compounds from the organic matter, but changes in soil pH could also have an effect. More research into the formation of complexes between metals and organic matter, and into the occurrence of chelating compounds in composts is required to achieve a better understanding of the mechanisms involved with the use of compost for the remediation of metal-contaminated soils.

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