In-Situ Remediation of Heavy Metal Contaminated Soil Using Mexican Sunflower (Tithonia diversifolia) and Cassava Waste Composts

S.A. Adejumo, A.O. Togun, J.A. Adediran and M.B. Ogundiran

Abstract: The effectiveness of inorganic fertilizer (NPK) at 100kgN/ha, Cassava Wastes (CW) and Mexican Sunflower (MSW) comports each at 0, 20 and 40t ha$^{-1}$ were assessed on maize growth in the contaminated field in 2008 and 2009. Experimental design was Randomized Complete Block with four replications. 0t ha$^{-1}$ served as control. Lead (138,000 mg kg$^{-1}$) was most predominant with its concentration higher than the European Union maximum permissible limit for potentially Toxic Elements (Pb=300 mg kg$^{-1}$) at the study site. MSW at 40t ha$^{-1}$ increased (P<0.05) leaf area index (5.19); Crop Growth Rate (2.26 g/cm$^2$/week) and maize grain yield (4.4t ha$^{-1}$) more than the control. CW and MSW at 40t ha$^{-1}$ increased dry matter accumulation by 95% and plant height by 89 and 94%, respectively. Soil lead concentration was reduced by 72 and 69% in MSW and CW at 40t ha$^{-1}$, respectively. The relationships between soil lead and organic matter contents (r = -0.75); phosphorous (r = -0.59); magnesium (r = -0.47); and pH (r = -0.77) were negative. Total lead concentrations in maize plant from compost treated soils were the lowest. MSW and CW composts applied at 40t/ha would ecologically restore lead contaminated land.

Key words: Compost • Heavy metals • Contamination • Maize • Industrial wastes • Mexican sunflower • Cassava waste

INTRODUCTION

Lack of cultivable and productive land has been attributed to soil contamination from high rate of industrialization and urbanization [1, 2]. UNEP [3] calculated that 2 billion hectares of land that was once biologically productive has been irreversibly degraded in the past 100 years due to contamination and inaccessibility. Land contamination/degradation is a threat to sustainable agricultural development and food security in developing countries. Among all the degraded lands, those contaminated with heavy metals are largely irreversible and where reversibility is attempted, it is at high cost [4]. It has therefore become imperative that the environment and its resources should be managed judiciously to enhance sustainable national and socio-economic development.

Lead-Acid Battery production is one of the major sources of pollution which release toxic/hazardous substances to the environment at such a rate that is detrimental to the health of plants, animals, aquatic lives and humans [5, 6]. Of greater concern is the deterioration of farmlands resulting from indiscriminate discharge of the waste products from this process. Improper disposal of batteries generally results in the release of heavy metals into the environment-a situation that poses environmental and human health hazards. The effects of heavy metals most especially lead on the environment have been extensively reported [7, 8]. Their presence in food chain has been found to be detrimental to plant, animal and human health [9]. Lead is especially toxic to children and the young of other species [10-12]. Chronic lead exposure in children has revealed significant effects on intelligence and neuropsychological performance [13]. The presence of lead in soils has contributed greatly to poor soil fertility making the contaminated land unsuitable for agriculture [14, 15]. Excessive metal concentration in contaminated soils also resulted in decreased soil microbial activities and eventual yield loss [16]. Alterations of the physical landscape, destruction of natural habitat and biodiversity,

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soil degradation, air and water pollution are also some of the ecological consequences [17, 18].

Efforts made by different researchers to remediate contaminated soils are either costly or not environment-friendly. This explains the present promotion of compost-bioremediation for land reclamation by USEPA (United States Environmental Protection Agency). The benefits derived from utilization of organic materials for improvement of soil fertility, crop production and heavy metal binding have been well discussed by many authors. [16, 19-22].

However, there is dearth of information at the moment on the use of compost to enhance growth and yield of maize planted on heavy metal contaminated soil especially in Nigeria. This research work was therefore designed to test for the efficacy and optimum application rates of composts prepared from wild sunflower (*Tithonia diversifolia*) and Cassava waste as well as inorganic fertilizer as sources of remediation and on the performance of maize grown directly on the field contaminated with heavy metals.

**MATERIALS AND METHODS**

**Description of Experimental Site:** The dumpsite of the defunct Lead - Acid Battery Manufacturing Company in Ibadan, Nigeria was used for the trial. This is located at Ori-ile, Kumapayi village of Egbeda Local Government area (near Ibadan), Oyo State in Southwestern Nigeria. An unspecified amount of slag waste containing high level of lead reportedly dumped on this land has rendered it unproductive. Vegetation in and around the site has been degraded with *Imperata cylindrica* and *Gomphrena celosoides* being the only species of plants sparsely distributed on the site (Vegetation survey).

**Pre-Cropping Soil Analysis:** The soil was collected randomly at five points to ensure even representation of the site at 0-15cm deep using a standard auger and composite samples taken for pre-cropping physico-chemical analysis. This was analysed for the following heavy metals, Pb, Cu, Zn, Cd and Cr in mg/kg using model 210A of the Buck Scientific Atomic Absorption Spectrophotometer series with Air-Acetylene gas mixture as oxidant under different wavelengths after hot digestion with 2M HNO₃ [8]. Also, soil pH (using a pH meter-Electrometric Method), Organic Carbon (%) by dichromic oxidation, Total N (g/kg) by Kjeldahl method, Total P (mg/kg) by Vanado-molybdate yellow method and Exchangeable cations were determined using standard method by IITA [23].

**Preparation of Compost:** Composts were prepared separately from wild sunflower (*Tithonia diversifolia*), Cassava waste and poultry manure using surface heap method of composting [24]. The materials were laid out in ratio 3:1 of plant materials to poultry manure (on dry weight basis) after sorting and chopping. A layer consisted of 30kg of plant materials and 10kg poultry manure. Ventilation poles were inserted after the third layer and were arranged horizontally and vertically. At the base of each pole, small holes were created for efficient aeration of the heap during composting. The heap was left for the period of 12 weeks. Turning and watering were done fortnightly, after which the matured composts were evacuated from the heap, air-dried, shredded and samples taken for physico-chemical analysis using IITA, [23] procedure. The total N was determined by a semi-micro-kjeldahl digestion technique. The P and Fe were determined by colorimeter. K, Ca and Mg by flame photometry. Zn, Cu, Pb, Cr and Cd were determined using atomic absorption spectrophotometer.

**Experimental Procedure and Data Collection:** The total area used for the experiment was 45m x 17m (for the 2 types of compost and inorganic fertilizer) having 4 blocks with each block representing all the treatments. The spacing between each block was 1m apart and 0.5m between each plot. The size of each block was 45m x 3m. The treatments used include control (without compost or inorganic fertilizer), MSW₆₀ (Mexican sunflower compost at 20t/ha), MSW₉₀ (Mexican sunflower compost at 40t/ha), CW₆₀ (Cassava waste at 20t/ha), CW₉₀ (Cassava waste at 40t/ha) and F₁ [Inorganic fertilizer (NPK at 100KgN/ha)] using randomized complete block design (RCBD) and replicated four times. Composts were applied to the plots receiving compost at one month before planting of maize. The crop spacing was 75cm x 25cm between and within rows respectively. The experiment was repeated for residual trial the following year.

Data collection commenced 2 weeks after planting and continued fortnightly till final harvest. Data on plant height, number of leaves, stem-girth, number of tassels and ears and leaf area. Total grain yield, 100 seeds weight and dry matter yield were determined at maturity. LAI was determined by dividing the leaf area per plant by the unit of land area occupied by one plant while the CGR (g/m²/wk) was calculated as shown below.
CGR = \frac{W_2-W_1}{A(t_2-t_1)}

Where:
W_1 = Total plant dry weight at time t_1, W_2 = Total plant dry weight at time t_2, A =Land area per plant.

Plant Tissue Analysis: At final harvest, the roots and shoots of the maize plants were analyzed for Pb concentrations by ashing 1.0g of dried finely ground plant samples in a muffle furnace for 6 hrs at a temperature between 450-500°C [25]. The cooled residues were re-dissolved in 10ml of 2M HNO_3 and the solutions were filtered into 25ml volumetric flask for instrumental analysis. A buck scientific model 210A Atomic Absorption Spectrophotometer was used to analyze the plant total digests for Pb.

Post-cropping Soil Analysis: Soil samples from each treatment were taken after harvesting at the depth of 0-15cm and analysed separately to know the post-harvest concentrations of heavy metals using the method described in 2.2 for pre-cropping soil physico-chemical analysis.

Data Analysis: Data for the main and residual trials were pooled together and analyzed statistically using the analysis of variance and the mean of the treatments were separated by Duncan’s multiple range test of Statistical Analysis System package [26].

RESULTS AND DISCUSSION

Pre-cropping Soil Sample and Matured Compost Analyses: The results of pre-cropping soil analyses are presented in Table 1. It shows that the soil was acidic with pH of 4.2. Lead (Pb) and Cadmium (Cd) occurred in greater concentrations than does Zinc (Zn), Chromium (Cr), or Copper (Cu). The concentration of Pb was 146,000mg/kg, Cd-41.3 mg/kg, Zn-1510 mg/kg, Cr - 12.0mg/kg and Cu - 482mg/kg. These levels (lead and Cd) were extremely high when compared with the levels of these metals in uncontaminated soil. In the normal soil, the common ranges of Pb, Cd,Cr and Zn are 2-300, 0.01-2.7, 5-1500 and 1-900 mg/kg respectively [27-29]. The abnormally high level of Pb in this soil was probably due to the fact that the major constituents of lead-acid battery are lead and sulphuric acid and basically because the main operations of battery production are secondary smelting of Lead and the fabrication of Lead batteries [6]. Low pH of this soil might also be implicated in the high solubilization of these metals most especially Pb and Cd since heavy metals generally have been reported to become more mobile as acidity increases [8, 30]. The soil is low in all essential elements: Nitrogen, Phosphorous, Potassium and Magnesium were 0.12%, 125 mg/kg, 0.85 cmol/kg and 0.96 cmol/kg, respectively. The organic carbon was as low as 1.24%. This could be attributed to the fact that these waste piles consist basically of the slag wastes. Matured compost of MSW had the highest P (0.30%), Ca (3.71%), Mg (1.29%) and N (2.17%), while C (4.89%) was higher in the compost from CW (Table 2).

Development of Vegetative Characters in Maize: The vegetative growth of maize increased progressively from 3 to 12 weeks after planting except in control and inorganic fertilizer plants that got burnt off before reaching maturity. On the mean values of the growth characteristics in each treatment for the period of data collection, application of compost produced significantly taller plants, higher number of leaf and leaf area over control and inorganic fertilizer plants (Fig 1). Plant height was increased by 94, 92, 91 and 89% over control and inorganic fertilizer with the application of MSW, CW, MSW, CW, respectively. This was in agreement with the findings of Malama [31], Dale et al. [15],

<table>
<thead>
<tr>
<th>Properties</th>
<th>Pb</th>
<th>Cu</th>
<th>Zn</th>
<th>P</th>
<th>Cr</th>
<th>Cd</th>
<th>pH</th>
<th>OC(%)</th>
<th>N(%)</th>
<th>Ca (%)</th>
<th>Mg (%)</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>138,000</td>
<td>482</td>
<td>1510</td>
<td>125</td>
<td>12.3</td>
<td>41.3</td>
<td>4.2</td>
<td>1.24</td>
<td>0.12</td>
<td>4.28</td>
<td>0.96</td>
<td>0.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Properties</th>
<th>N (%)</th>
<th>P (%)</th>
<th>Ca (%)</th>
<th>Mg (%)</th>
<th>C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>1.93</td>
<td>0.01</td>
<td>3.63</td>
<td>0.53</td>
<td>4.89</td>
</tr>
<tr>
<td>MSW</td>
<td>2.17</td>
<td>0.30</td>
<td>3.71</td>
<td>1.29</td>
<td>3.94</td>
</tr>
</tbody>
</table>
Fig. 1: Effects of compost and inorganic fertilizer on plant height and stem girth (A), number of tassels and Ears (B), Leaf area (C) and number of leaves (D).

Bars carrying the same alphabet are not significantly different from each other at 5% level of significance by DMRT.

F1 = Inorganic fertilizer
MSW20 = Mexican Sunflower at 20t/ha
MSW40 = Mexican Sunflower at 40t/ha
CW20 = Cassava waste at 20t/ha
CW40 = Cassava waste at 40t/ha

Olabode et al. [32] and Rennevan et al. [22]. A significant increase (P<0.05) in the leaf area production was recorded in the maize plant treated with MSW20 followed by that of CW40. These results confirmed the findings of Dale et al. [15] and Rennevan et al. [22] that application of compost contributed greatly to the plant growth in the treated soils more than control. It could however, be due to the ability of compost to supply soil with all essential nutrients needed for the plant growth, thereby reducing the toxicity effects of these heavy metals on the crop [21, 33-35]. Another plausible reason could be due to the fact that metal-induced toxic effects might have been depressed as a result of dilution of toxic metal concentration in the plant tissue by the plant nutrients from the added compost [36]. Competition between these nutrients and toxic metals in plant tissue for binding sites in different apartments such
as cell walls, plasma membranes and inside the cells may influence the distribution of toxic metals negatively. This may in turn affect the rate of interference with sensitive metabolic reactions with resultant effects on plant growth [37].

**Dry Matter Accumulation, Total Grain Yield and 100 seeds Weight:** Effects of different application rates and compost types on 100 seeds weight, total grain yield and dry matter accumulation had significant (P<0.05) effect. Application of compost generally increased the dry matter production and grain yield but higher rates performed better than lower rate. Among the two types of compost applied at the rate of 40t/ha, maize plants grown on the plots amended with Mexican sunflower compost produced dry matter which was significantly higher than CW compost treatments (Fig 2). Similarly, of the two types of compost applied at the lower rate of 20t/ha, MSW compost performed better than CW compost. Higher dry matter yield was observed in compost treated plants could be the outcome of increased leaf area development and longer sustenance of growth more than control irrespective of Pb concentration in the soil [15]. The results were similar to what was observed by Akanbi, [38], Ojerenyi and Adejobi, [39] that application of manure treatments resulted in higher grain yield and dry matter accumulation. Similarly, on 100 seeds weight, harvested seeds from the maize plant grown on soil amended with MSW and CW at 40t ha⁻¹ had the highest weight. The total grain yield was significantly higher in maize plants that received MSW₄₀ (4.5t/ha) followed by CW₄₀ (2.6t/ha) and MSW₃₀ (1.09t/ha), while the lowest was obtained in maize plants grown on soil treated with CW₀₀ (0.73t/ha). (Figure 2). The variation observed in the effectiveness of each compost based on the type of plant materials used confirms the findings of Adediran et al. [40], that effectiveness of compost on growth parameters is a factor of source and types of organic materials, method of composting and compost maturity. Therefore production and stabilization of compost is highly important in agriculture (Saviozzi [41, 12]. The accumulation of dry matter in the root of maize plant treated with 40t/ha of MSW compost was higher than that of CW compost applied at the same rate due to the higher nutrient contents of MSW compost which was higher than that of CW compost (Table 2).
Leaf Area Index (LAI) and Crop Growth Rate (CGR) of Maize: Compost rates and types had significant effects on the leaf area index (LAI) in all the sampling periods. It increased progressively from 3WAP to 12WAP with MSWw (5.19) being superior at 12WAP followed by CWw (3.78), MSWw (3.17) and CWw (2.57). Provision of essential soil nutrients needed for plant growth by compost, enhanced leaf formation and development in the maize plant grown on compost amended soil. This probably was responsible for increase in LAI from compost treatments. The LAI in the control and maize plant treated with inorganic fertilizer were the lowest throughout the growth period except at 3WAP.

Effects of compost rates and types were also significant in crop growth rate (CGR) which increased between SWAP and 12WAP in all the treatments except control where the CGR was reduced. Application of MSW compost at 40t/ha (MSWw) increased the CGR during the growth period of 4-8SWAP while CW compost applied at the same rate (CWw) gave the highest CGR at the growth period of 8-12SWAP probably due to higher nutrient contents of MSW compost with resultant effects on maize growth. Moreover, maize growth/vegetative development is always faster at this stage (4-8 WAP) when anthesis, grain filling and general physiological development have not set in [24]. the reduction in the CGR at 8-12SWAP could be attributed to the diversion of food from vegetative development to flower formation and grain filling (Sink). There was no difference in the CGR of maize plants treated with 20t/ha of both Mexican sunflower and cassava waste composts (i.e CW20 and MSW20) at 4-8SWAP and 8-12SWAP. The lowest CGR was however recorded in the control plant and the plants that received inorganic fertilizer treatment due to decline in the maize growth on these treatments and eventual death.

Post-harvest Soil Pb Level: Soil Pb concentration was markedly reduced with the application of compost. Mexican sunflower compost at 40t ha⁻¹ reduced the level of Pb in the soil by 71.6% followed by that of cassava waste compost (67.33%) applied at the same rate. The lowest rate of 20t ha⁻¹ reduced by 66.06% (MSW) and 49.47% (CW). Soil treated with MSWw (39200mg/kg) had the lowest soil lead concentration compared to the soil treated with inorganic fertilizer (12500mg/kg) and control (137000mg/kg). Concentrations of other heavy metals such as Cd, Cr, Zn and Cu were also reduced with compost treatment. Chromium was not even detected in all the compost amended soil (Table 4). Addition of compost generally increased the concentration of macro elements such as Ca, P, K and Mg. The concentration of which were decreased in the soils treated with inorganic fertilizer and control except P which was significantly increased in soil treated with inorganic fertilizer than control. However, application of MSWw significantly increased the post-cropping soil Mg, Ca and P concentration more than other compost treatments. Soil organic matter content was also seven times higher in the soil treated with MSWw than control soil while soil pH was uniformly increased in all the compost amended soil. The concentrations of nitrogen, phosphorus, calcium and magnesium were higher in MSW-compost and was probably responsible for low lead level recorded in the soil treated with MSW-compost which was lower than that of CW-Compost as high calcium and phosphorous contents in the soil have been found to reduce lead concentration in the soil due to formation of calcium and phosphorous complexes with Pb thereby reducing its solubility [43]. High reactivity of humified fractions of compost has also been found to reduce the solubility and mobility of trace metals in the soil with appreciable content of organic matter [44]. The explanation for this is simply due to high affinity of humic acid in the organic matter for Pb [22] with resultant decrease in Pb concentrations in the soil (Pier et al. [45]). This probably explains the low level of Pb recorded in all the compost-treated soils. Low pH induces the solubility of Pb in the soil [46] thereby enhancing plant uptake. This was confirmed by the high lead level recorded in control and inorganic fertilizer treatments having pH of 4.0.

Lead (Pb) Concentration in Maize Tissue: Addition of compost to soil contaminated with lead did not totally restrict the uptake of lead by maize plants but the total level recorded in the plant tissues from all the compost treated plots were significantly lower than those treated with inorganic fertilizer and control. The distribution of Pb in the plant tissues from all the treatments followed the same trend and the highest concentration was found in the root followed by those of the leaves, stem and seeds in that order (Table 5). This result is consistent with other reports [47, 48] indicating that upper plant parts exhibit lower level of heavy metal accumulation than the root possibly due to the fact that the total amount of ions associated with root only a part is absorbed into cells [15, 49, 50]. It also confirmed the reports of previous experiments by Lombi et al. [51]; Sridhar et al. [52] and Dale et al. [15]. This could be attributed to the apoplastic (unregulated) movement of water and dissolved substances across the root cell membrane [53],
Table 3: Effects of different rates of sunflower, cassava waste compost and inorganic fertilizer on leaf area index (LAI) and crop growth rate (CGR) of maize planted on contaminated field

<table>
<thead>
<tr>
<th>Treatments</th>
<th>3WAP LAI</th>
<th>6WAP LAI</th>
<th>9WAP LAI</th>
<th>12WAP LAI</th>
<th>4-8WAP CGR g/m²/week</th>
<th>8-12WAP CGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.55 c</td>
<td>0.03 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.73 c</td>
<td>-0.12 c</td>
</tr>
<tr>
<td>F1</td>
<td>0.58 c</td>
<td>0.02 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.80 c</td>
<td>0.09 c</td>
</tr>
<tr>
<td>MSw20</td>
<td>0.52 b</td>
<td>2.40 b</td>
<td>3.35 b</td>
<td>3.17 b</td>
<td>0.78 b</td>
<td>1.68 b</td>
</tr>
<tr>
<td>MSw40</td>
<td>1.06 a</td>
<td>4.29 b</td>
<td>4.66 b</td>
<td>5.19 a</td>
<td>2.05 a</td>
<td>2.26 ab</td>
</tr>
<tr>
<td>Cw20</td>
<td>0.32 b</td>
<td>1.65 b</td>
<td>2.11 c</td>
<td>2.57 d</td>
<td>0.35 ac</td>
<td>1.63 b</td>
</tr>
<tr>
<td>Cw40</td>
<td>0.54 b</td>
<td>2.39 b</td>
<td>2.96 c</td>
<td>3.78 b</td>
<td>0.65 b</td>
<td>3.02 b</td>
</tr>
</tbody>
</table>

Means followed by the same letter in a column are not significantly different from each other at P<0.05 by DMRT.

MSW20= Mexican sunflower compost at 20t/ha
MSW40= Mexican sunflower compost at 40t/ha
CW20= Cassava waste compost at 20t/ha
CW40= Cassava waste compost at 40t/ha
F1=Inorganic fertilizer

Table 4: Effects of compost and inorganic fertilizer on post-harvest soil nutrient composition of contaminated soil

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cd(mg/kg)</th>
<th>Cr(mg/kg)</th>
<th>Cu(mg/kg)</th>
<th>Zn(mg/kg)</th>
<th>P(mg/kg)</th>
<th>Mg(mg/kg)</th>
<th>Ca(mg/kg)</th>
<th>Pb(mg/kg)</th>
<th>OM(%)</th>
<th>pH</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>33.4 a</td>
<td>14.3 a</td>
<td>492 a</td>
<td>437 a</td>
<td>228 a</td>
<td>65 a</td>
<td>58 a</td>
<td>137000 a</td>
<td>0.87 a</td>
<td>4.59 a</td>
<td>0.14 a</td>
</tr>
<tr>
<td>MSW20</td>
<td>18.9 a</td>
<td>0.00 a</td>
<td>187 a</td>
<td>267 b</td>
<td>1160 b</td>
<td>228 b</td>
<td>54 b</td>
<td>45800 a</td>
<td>2.83 a</td>
<td>6.76 a</td>
<td>0.25 a</td>
</tr>
<tr>
<td>MSW40</td>
<td>13.4 a</td>
<td>0.00 a</td>
<td>203 a</td>
<td>331 a</td>
<td>3630 a</td>
<td>3870 a</td>
<td>85 a</td>
<td>39200 a</td>
<td>6.14 a</td>
<td>6.90 a</td>
<td>0.57 a</td>
</tr>
<tr>
<td>CW20</td>
<td>20.4 a</td>
<td>0.00 a</td>
<td>243 a</td>
<td>274 a</td>
<td>1500 a</td>
<td>519 a</td>
<td>312 a</td>
<td>69700 a</td>
<td>2.43 a</td>
<td>6.44 a</td>
<td>0.17 a</td>
</tr>
<tr>
<td>CW40</td>
<td>20.1 a</td>
<td>0.00 a</td>
<td>244 a</td>
<td>286 a</td>
<td>1570 a</td>
<td>358 a</td>
<td>109 a</td>
<td>45100 a</td>
<td>4.11 a</td>
<td>5.99 a</td>
<td>0.28 a</td>
</tr>
<tr>
<td>F1</td>
<td>27.5 a</td>
<td>16.40 a</td>
<td>532 a</td>
<td>550 a</td>
<td>980 a</td>
<td>65 a</td>
<td>62 a</td>
<td>125000 a</td>
<td>1.25 a</td>
<td>4.91 a</td>
<td>0.12 a</td>
</tr>
</tbody>
</table>

Means followed by the same letter in a column are not significantly different from each other at P<0.05

MSW20= Mexican sunflower compost at 20t/ha
MSW40= Mexican sunflower compost at 40t/ha
CW20= Cassava waste compost at 20t/ha
CW40= Cassava waste compost at 20t/ha
F1=Inorganic fertilizer

Table 5: Effects of different rates of sunflower, cassava waste compost and inorganic fertilizer on the Pb(%) concentration in maize plant parts at maturity

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grains</th>
<th>Ear</th>
<th>Sheath</th>
<th>Leaf</th>
<th>Stem</th>
<th>Root</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.68 a</td>
<td>0.69 a</td>
<td>1.59 a</td>
<td>2.96 a</td>
</tr>
<tr>
<td>MSw20</td>
<td>0.02 b</td>
<td>0.01 b</td>
<td>0.01 c</td>
<td>0.02 c</td>
<td>0.02 c</td>
<td>1.12 b</td>
<td>1.25 b</td>
</tr>
<tr>
<td>MSw40</td>
<td>0.02 b</td>
<td>0.01 b</td>
<td>0.02 b</td>
<td>0.05 b</td>
<td>0.03 b</td>
<td>1.14 b</td>
<td>1.27 b</td>
</tr>
<tr>
<td>Cw20</td>
<td>0.03 a</td>
<td>0.00 b</td>
<td>0.03 b</td>
<td>0.02 a</td>
<td>0.04 a</td>
<td>1.14 b</td>
<td>1.27 b</td>
</tr>
<tr>
<td>Cw40</td>
<td>0.03 a</td>
<td>0.01 b</td>
<td>0.03 a</td>
<td>0.02 c</td>
<td>0.12 b</td>
<td>0.87 b</td>
<td>1.07 b</td>
</tr>
<tr>
<td>F1</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.62 a</td>
<td>0.79 a</td>
<td>1.59 a</td>
<td>3.00 a</td>
</tr>
</tbody>
</table>

Means followed by the same letter in a column are not significantly different from each other at P<0.05

MSW20= Mexican sunflower compost at 20t/ha
MSW40= Mexican sunflower compost at 40t/ha
CW20= Cassava waste compost at 20t/ha
CW40= Cassava waste compost at 20t/ha
F1=Inorganic fertilizer

Table 6: Pearson correlation between the heavy metals and other soil nutrients of post-cropping soil analysis on the field

<table>
<thead>
<tr>
<th>pH</th>
<th>Mg(mg/kg)</th>
<th>K(mmol/kg)</th>
<th>OM(%)</th>
<th>Ca(mg/kg)</th>
<th>P(mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb(mg/kg)</td>
<td>-0.77 ***</td>
<td>-0.47 *</td>
<td>-0.06 ns</td>
<td>-0.79 ***</td>
<td>-0.37 ns</td>
</tr>
<tr>
<td>Cd(mg/kg)</td>
<td>-0.69**</td>
<td>-0.48*</td>
<td>0.05 ns</td>
<td>-0.56**</td>
<td>-0.31 ns</td>
</tr>
<tr>
<td>Cr(mg/kg)</td>
<td>-0.81***</td>
<td>-0.40 ns</td>
<td>-0.14 ns</td>
<td>-0.69**</td>
<td>-0.33 ns</td>
</tr>
<tr>
<td>Zn(mg/kg)</td>
<td>-0.52*</td>
<td>-0.25 ns</td>
<td>0.051 ns</td>
<td>-0.43 ns</td>
<td>-0.26 ns</td>
</tr>
<tr>
<td>Cu(mg/kg)</td>
<td>-0.79***</td>
<td>-0.38 ns</td>
<td>-0.24 ns</td>
<td>-0.67**</td>
<td>-0.19 ns</td>
</tr>
</tbody>
</table>

* = Correlation was significant at 0.05 level of probability
*** = Correlation was significant at 0.01 level of probability
Ns = Not significant
while the slow movement of lead to the shoots and leaves of all the treatments including control was probably due to symplastic movement which is more regulated as a result of selectively permeable plasma membrane that controls access to symplast [54].

**Pearson Correlation Between Heavy Metals and Soil Nutrients:** The relationships between Pb and other soils nutrients (OM, Mg, Ca and Phosphorous) were inversely and significantly correlated. So also was soil pH. It was inversely and strongly correlated with all the heavy metals - Pb, Cd, Cr and Cu (p<0.01). Inverse correlation means that an increase in soil OM content, Ca, Mg and P concentrations from compost addition caused a reduction in the heavy metal concentrations of post harvesting soil sample as was also reported by Sposito et al. [55] and Pier et al. [45]. The same thing applies to soil pH, (increase in soil pH (alkalinity) results in lower concentration of heavy metals in the soil [56, 57].

The concentration of Mg in the post-harvest soil was also inversely correlated with the soil Cd concentrations but the correlation with Cr, Zn and Cu was not significant though negative. Except for Cu, the correlation between soil P and Pb, Cd, Cr and Zn was significant and inverse but there was strong correlation between the soil P and Pb while the correlation between soil Ca and the heavy metals was not significant. This simply means that high P concentration reduces the heavy metal concentration while Ca concentration had no significant effect. There was a correlation between the soil Mg and heavy metal concentrations but the correlation was highly significant with soil Pb and Cd concentrations while the correlations between Cr, Zn and Cu was not significant. Soil K concentration had no significant correlation with the soil heavy metal concentrations (Table 6).

**CONCLUSION**

It could be concluded that Mexican Sunflower compost at 40t/ha would ecologically restore lead contaminated soil more than Cassava waste compost and inorganic fertilizer.

**REFERENCES**


