Pollution Indices and Bioaccumulation Factors of Heavy Metals in Selected Fruits and Vegetables from a Derelict Mine and their Associated Health Implications

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Abstract

Concentration of heavy metals in the top and sub soils and in selected vegetables and fruits grown in Enyigba lead-zinc mine derelict was investigated using X-ray Fluorescence (XRF) spectrometric method. Samples of fruits and leaves of the plants collected from 2010 to 2012 were analyzed for arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), lead (Pb) and zinc (Zn) contents and their corresponding Pollution Indices (PI) and Bioaccumulation Factors (BAF) were evaluated. The mean pH of the soil was 6.5 and the mean concentrations (mg/Kg) of metals in the studied plants were of the range: Pb (0.22 – 6.72); As (0.10 – 10.6); Cd (0.10 – 12.4); Cu (12.6 – 82.1); Cr (0.01 – 1.02); Zn (34.2 – 162.1); Mn (412.1 – 42.6) and Ni (12.8 – 72.8). High PI of 22.4; 12.37; 8.67; 7.27 and 6.13 observed in Nauclea latifolia (African Peach); Sesamum indicum (Beni seed); Lactuca Sativa (Lettuce); Psidium Guajava (Guava) and C. Annum (Pepper) suggests that they are unfit for human consumption. Bioaccumulation Factors (BAF > 1) observed in some of the studied plants which suggested that the affected plants are good phytoremediation agents. Statistical analysis of variance (ANOVA) at p<0.05 showed variations in the heavy metal levels between and within groups.

Keywords: Fruits, Vegetables, Pollution Index, Bioaccumulation Factors, Lead-zinc Derelict, X-ray Fluorescence.

INTRODUCTION

Agricultural practices often result in some heavy metal deposition in soils and this includes non point sources of contamination inputs such as fertilizers, pesticides, sewage sludge, organic manures and composts (Singh, 2001). Unlike many other environmental pollutants, metals are non-biodegradable and they can undergo biomagnifications in living tissues (Clark, 1992). Elevated levels of heavy metals in the soils may lead to uptake by native and agronomic plants. According to Reilly (1980), some trace metals such as Fe, Zn, Cu, and Mn are known to be essential in plant nutrition; however many other metals do not play any significant role in the plants physiology. Plants growing in a polluted environment accumulate these toxic metals at high concentration which ultimately pose serious risk to human health when consumed. Plants absorb and adsorb these metals from the ground as well as from the parts exposed to air from polluted environment (Vousta et al., 1996). Metals of interest in this present study include As, Cd, Cr, Cu, Mn, Ni, Pb and Zn.

The major aim of this study is to examine and obtain the current data of heavy metal load in soil and edible fruits and vegetables from anthropogenically active areas of Enyigba lead-zinc derelict mine, using X-ray Resonance Fluorescence (XRF) spectrometric method and to mention their associated health implications. Other objectives of this work include obtaining pollution indices (PI) of studied metals and evaluating their bioaccumulation factors (BAF) which reveals the interactions between metals in soil and plants.

The pollution index (PI) is the ratio of metal concentration in a biotic or abiotic medium to that of the regulatory Standard of International bodies such as World Health Organisation (WHO), United States Environmental Protection Agency (USEPA), Federal Environmental Protection Agency (FEPA) of Nigeria etc (Jamali et al., 2007). Values of PI < 1 value
indicates that the soil or plant material is not yet contaminated whereas PI < 1 indicates pollution. On the other hand, PI = 1 reveals a critical state which makes the involved plant useful for environmental monitoring (Chukwuma, 1993). Mathematically, PI is expressed as

\[
PI = \frac{C_{\text{soil or plant}}}{C_{\text{USEPA-standard}}}
\]

Where PI is the individual pollution index of study metal; \( C_{\text{soil or plant}} \) is the Concentration of the metal in soil or plant. \( C_{\text{USEPA-standard}} \) is the value of the regulatory limit of the heavy metal by USEPA (Wong et al., 2002). The overall Pollution status of the investigated soil was determined with the formula:

\[
PI_{\text{Soil}} = \sqrt{\frac{(PI_{\text{ave}})^2 + (PI_{\text{max}})^2}{2}}
\]

Where \( PI_{\text{soil}} \) is the overall Pollution Index of the soil, \( PI_{\text{ave}} \) is the average Pollution indices of different soil samples analysed while \( PI_{\text{max}} \) is the maximum PI recorded (Jintao et al., 2011).

Bioaccumulation factor (BAF) also known as Bioconcentration factor (BCF) is defined as a ratio of metal concentration in plant shoot to extractable concentration of metal in the soil. It is the progressive increase in the amount of metal in a living plant because the rate of intake exceeds the plant's ability to remove the substance from the body (Branquinho et al., 2007). Mathematically, BAF is expressed as

\[
BAF = \frac{C_{\text{plant tissue}}}{C_{\text{soil}}}
\]

Where \( C_{\text{plant tissue}} \) is the concentration of metal in plant tissue and \( C_{\text{soil}} \) is the concentration of the metal in the soil. In this work \( C_{\text{soil}} \) was calculated by taking the average of the concentration of top and sub soil.

This present study aims at using PI to determine the toxic level of heavy metals and BAF to determine the phytoremediation potential of the studied plants.

**MATERIALS AND METHODS**

**Collection and Preparation of Soil Samples**

From each sampling site, composite soil samples were collected in labelled polythene bags, at 0-30 cm (n=6) and at 60-90 cm (n=6) depths which represents the top soil and the sub soil respectively (Danish EPA, 2000). The soil samples were air-dried, ground mechanically with stainless steel soil grinder and sieved to obtain < 2 mm fraction. 30g sub-sample was drawn from the bulk (< 2 mm fraction) and reground with laboratory mortar and pestle to obtain < 200 μm fraction. The sample was further dried in an open inert vessel in a muffle furnace at 105 °C for 2 hours so as to remove soil moisture, after which the samples were cooled in desiccators (FAO, 2009). The pH, percentage of Organic Matter and percentages of sand, silt, and clay of the soil were determined using Orion 920A pH meter; Walkley and Black method and Hydrometer method respectively (Brown, 2007; White, 2006).

**Collection, Authentication and Preparation of Plant Samples for XRF Analyses**

All the plant samples were collected between February 2008 and January 2010 depending on the seasons of the plant and were authenticated at Applied Biology Department of Ebonyi State University, Nigeria. The leaves and fruits of the plants were separated and cleaned to remove dust and other particles by putting them through a three step washing first with water, then with P-free detergent and followed by de-ionized water (Reuter et al., 1983). The moisture and water droplets were removed with the help of blotting papers. The samples were air dried, and placed in a dehydrator at approximately 80°C for 48 hours so as to stop enzymatic activity. This was followed by mechanical grinding with the aid of an agate mortar which results to the samples been pulverized into fine powdery form. The ground tissues were further dried at 65°C in an oven to obtain a constant weight upon which to base the analysis (Jones et al., 1991).

**XRF Analyses of Heavy Metal in Soil and Plant Samples**

The process begins with pelletization of the individual samples. A 13mm pellet of the sample was formed using CAVER model manual palletizing machine at a pressure of 6 - 8 torr. Standard Operating Procedure for XRF, using A voltage of 25KV and current of 50μA produced from X-ray tube was used to bombard the sample in XRF system for 18 minutes at 1000 counts. Si-Li detector was used to detect the characteristic X-ray of the metals and their corresponding concentrations were computed in the read out device Shefsky (1995).

**Statistical Analysis**

Composite samples of the investigated soils and plants were assayed and analyzed individually in triplicates. Data generated form XRF were reported as mean + Standard Error. One way analysis of variance (ANOVA) and Fisher’s Least Square Difference (LSD) were used to determine significant difference within and between groups, considering a level of significance of less than 5% (p<0.05) by using Minitab 2007 version 13.6 statistical software (Minitab Tip sheet 8, 2007). PI and BAF were calculated from the generated data.

**RESULTS**

The following tables 1, 2, 3, 4 and 5 present the results of XRF analyses and the generated PI and BAF data.
Table 1. XRF Mean Concentrations (mg/kg) of Heavy Metals in Soil and their Pollution Indices

<table>
<thead>
<tr>
<th>Metal</th>
<th>Topsoil</th>
<th>PI</th>
<th>Subsoil</th>
<th>PI</th>
<th>US-EPA</th>
<th>Overall PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>4.8 ± 1.8</td>
<td>0.06</td>
<td>2.12 ± 1.6</td>
<td>0.03</td>
<td>75*</td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>126.0 ± 42</td>
<td>1.5</td>
<td>28.8 ± 6.2</td>
<td>0.34</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>812.2 ± 141.2</td>
<td>0.19</td>
<td>322.2 ± 12.2</td>
<td>0.07</td>
<td>4300</td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>2.12 ± 0.2</td>
<td>–</td>
<td>1.02 ± 0.2</td>
<td>–</td>
<td></td>
<td>1.96</td>
</tr>
<tr>
<td>Mn</td>
<td>424.0 ± 50.4</td>
<td>–</td>
<td>120.0 ± 44.0</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>82.6 ± 22.0</td>
<td>1.1</td>
<td>34.8 ± 8.2</td>
<td>0.46</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>1116.8 ± 43.2</td>
<td>2.7</td>
<td>91.7 ± 16.7</td>
<td>0.22</td>
<td>420</td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>995.2 ± 82.4</td>
<td>0.13</td>
<td>322.0 ± 62.4</td>
<td>0.04</td>
<td>7500</td>
<td></td>
</tr>
</tbody>
</table>

* Values refer to metal concentration in typical soils (Miroslav and Vladimir, 1999).

Table 2. Properties of Soil from Enyigba Mine Derelict

<table>
<thead>
<tr>
<th>Properties</th>
<th>Enyigba Mine (n = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand (%)</td>
<td>61.28 ± 5.2</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>7.12 ± 0.8</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>31.60 ± 2.6</td>
</tr>
<tr>
<td>Organic Matter (%)</td>
<td>1.34 ± 0.5</td>
</tr>
<tr>
<td>Mean pH</td>
<td>6.5 ± 0.29</td>
</tr>
</tbody>
</table>

DISCUSSION

Heavy metal in the Soil Sample

Tables 1 and 2 show the mean concentration of heavy metals and the properties the soils from Enyigba derelict respectively. The results revealed that heavy metal concentration in the Enyigba mine decrease in the order Pb > Zn > Cu > Mn > Cd > Ni > As > Cr in topsoil and Zn > Cu > Mn > Pb > Ni > Cd > As > Cr in the subsoil. Analysis of variance shows that only Pb, Cu and Zn in the soil were significant at p < 0.05. The decreasing mean concentrations of the heavy metals from top to sub soil suggests anthropogenic source of contamination (Alloway, 1995). Consequently Pb, Ni and Cd from the Enyigba top soil exceeded the limits with their pollution index (PI) indicated in the order, Pb (2.7) > Cd (1.5) > Ni (1.1) respectively (USEPA, 1993). The overall pollution status of soils of Enyigba derelict was 1.96. High values of PI of Enyigba soils confirmed that the polluted status of soils of Enyigba in agreement with works by Chukwuma, (1994), and Nweke et al., (2008).

From Table 2, the percentage of organic matter content was 1.34 % and the mean pH was 6.5 and these two parameters determine the extent of heavy metal uptake. The obtained results were comparable to those of Nwoko and Egunobi, (2002). Organic matter and pH values have been reported to independently and associatively influence the concentrations of heavy metals in soils. Organic matter content increases with decrease in pH and an increase in metal concentrations (Adhikari et al., 2004). Metals such as Pb have low solubility at pH range of 5.5 – 7.5 which is normal for most mineral soils. Soils with pH around 7.0 have higher availability of nutrient elements such as Mg, Ca, K, N and S, while metals such as Pb, Cu, Mn and Zn are less soluble and therefore less available at about this pH (Assuncao, 2003). Table 2 showed that the soils from the derelict can support agricultural activities and this agrees with the findings of Anikwe and Nwobodo (2009) and Nnabo (2011).

Arsenic in Studied Plants

Table 3 shows the level of As decreased in the order Red sandal leaves > African Paudauk > guava > beni seed > African salad > mango / okro > lettuce / tomatoes. Table 4 reveals high PI of As, observed in Red Sandal wood (10.6), African paudauk (10), guava (7.2), beni seed (3.2) and African salad (2.8) and (PI >1) in water leaf, bitter leaf, red sandal wood, African salad, okro, beni seed, guava, mango, cassava makes the affected fruits and vegetables unfit for human consumption. Health implication for their consumption include kidney and liver damage, gastrointestinal effect, peripheral neuropathy, skin lesion, lung cancer and death (ATSDR, 2010).

Cadmium in Studied Plants

Very high PI of Cd was observed in in beniseed (124.0) followed by African salad (38.0) and red sandal wood
Table 3. XRF Levels of Heavy Metals in Fruits and Vegetables in Enyigba Mines (n=3)

<table>
<thead>
<tr>
<th>Botanical Name</th>
<th>Common Name</th>
<th>Plant Parts</th>
<th>Pb</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Cr</th>
<th>Zn</th>
<th>Mn</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. esoultum</td>
<td>Okro</td>
<td>Fruit</td>
<td>0.22</td>
<td>0.12</td>
<td>0.22</td>
<td>62.20</td>
<td>0.12</td>
<td>112.20</td>
<td>322.12</td>
<td>24.80</td>
</tr>
<tr>
<td>L. esculentum</td>
<td>Tomatoes</td>
<td>Fruit</td>
<td>1.40</td>
<td>0.10</td>
<td>0.12</td>
<td>48.12</td>
<td>0.02</td>
<td>100.12</td>
<td>192.22</td>
<td>22.20</td>
</tr>
<tr>
<td>C. annum</td>
<td>Pepper</td>
<td>Fruit</td>
<td>1.84</td>
<td>ND</td>
<td>0.21</td>
<td>34.22</td>
<td>0.01</td>
<td>68.22</td>
<td>82.88</td>
<td>46.14</td>
</tr>
<tr>
<td>Ptercarpus Soyauxi</td>
<td>African Paudauk</td>
<td>Leaves</td>
<td>0.82</td>
<td>1.00</td>
<td>0.10</td>
<td>42.21</td>
<td>0.04</td>
<td>34.20</td>
<td>42.60</td>
<td>18.02</td>
</tr>
<tr>
<td>Ptercarpus Santalinoides</td>
<td>Red sandal wood</td>
<td>Leaves</td>
<td>0.68</td>
<td>1.06</td>
<td>2.6</td>
<td>23.16</td>
<td>1.02</td>
<td>162.12</td>
<td>412.11</td>
<td>64.24</td>
</tr>
<tr>
<td>G. buchholzianum</td>
<td>African Salad</td>
<td>Leaves</td>
<td>1.42</td>
<td>0.28</td>
<td>3.80</td>
<td>72.88</td>
<td>0.24</td>
<td>72.84</td>
<td>56.12</td>
<td>12.84</td>
</tr>
<tr>
<td>Sesamum indicum</td>
<td>Beni Seed</td>
<td>Fruit</td>
<td>3.71</td>
<td>0.32</td>
<td>12.4</td>
<td>34.26</td>
<td>0.02</td>
<td>124.12</td>
<td>44.82</td>
<td>34.66</td>
</tr>
<tr>
<td>Nauclea latifolia</td>
<td>African Peach</td>
<td>Fruit</td>
<td>6.72</td>
<td>ND</td>
<td>0.32</td>
<td>20.28</td>
<td>0.67</td>
<td>89.5</td>
<td>124.60</td>
<td>42.69</td>
</tr>
<tr>
<td>Lactuca Sativa</td>
<td>Lettuce</td>
<td>Leaves</td>
<td>2.60</td>
<td>0.10</td>
<td>0.21</td>
<td>12.66</td>
<td>0.02</td>
<td>92.80</td>
<td>340.12</td>
<td>72.80</td>
</tr>
<tr>
<td>Psidium Guajava</td>
<td>Guava</td>
<td>Fruit</td>
<td>2.18</td>
<td>0.72</td>
<td>0.12</td>
<td>82.12</td>
<td>0.16</td>
<td>80.44</td>
<td>204.64</td>
<td>68.22</td>
</tr>
<tr>
<td>Mangifera Indica</td>
<td>Mango</td>
<td>Fruit</td>
<td>0.82</td>
<td>0.12</td>
<td>0.10</td>
<td>39.02</td>
<td>ND</td>
<td>78.12</td>
<td>124.46</td>
<td>12.8</td>
</tr>
</tbody>
</table>

WHO/FAO Maximum Limit
0.3   0.1   0.1   73   0.05  100   500   67

ND = Not detectable; WHO ML: World Health Organization Maximum Level

Table 4. Pollution Indices of Heavy Metals in the Selected Fruits and Vegetables

<table>
<thead>
<tr>
<th>Botanical Name</th>
<th>Common Name</th>
<th>Pb</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Cr</th>
<th>Zn</th>
<th>Mn</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. esoultum</td>
<td>Okro</td>
<td>0.73</td>
<td>1.2</td>
<td>2.2</td>
<td>0.85</td>
<td>2.4</td>
<td>1.12</td>
<td>0.64</td>
<td>0.37</td>
</tr>
<tr>
<td>L. esculentum</td>
<td>Tomatoes</td>
<td>4.67</td>
<td>1.0</td>
<td>1.2</td>
<td>0.06</td>
<td>0.4</td>
<td>1.0</td>
<td>0.38</td>
<td>0.33</td>
</tr>
<tr>
<td>C. annum</td>
<td>Pepper</td>
<td>6.13</td>
<td>-</td>
<td>2.1</td>
<td>0.47</td>
<td>0.2</td>
<td>0.68</td>
<td>0.17</td>
<td>0.69</td>
</tr>
<tr>
<td>Ptercarpus Soyauxi</td>
<td>African Paudauk</td>
<td>2.73</td>
<td>10</td>
<td>1.0</td>
<td>0.58</td>
<td>0.8</td>
<td>0.34</td>
<td>0.09</td>
<td>0.27</td>
</tr>
<tr>
<td>Ptercarpus Santalinoides</td>
<td>Red sandal wood</td>
<td>2.27</td>
<td>10.6</td>
<td>26.0</td>
<td>0.32</td>
<td>20.4</td>
<td>1.62</td>
<td>0.82</td>
<td>0.96</td>
</tr>
<tr>
<td>G. buchholzianum</td>
<td>African Salad</td>
<td>4.73</td>
<td>2.8</td>
<td>38.0</td>
<td>1.0</td>
<td>4.8</td>
<td>0.72</td>
<td>0.01</td>
<td>0.19</td>
</tr>
<tr>
<td>Sesamum indicum</td>
<td>Beni Seed</td>
<td>12.37</td>
<td>3.2</td>
<td>124</td>
<td>0.45</td>
<td>0.4</td>
<td>1.24</td>
<td>0.09</td>
<td>0.52</td>
</tr>
<tr>
<td>Nauclea latifolia</td>
<td>African Peach</td>
<td>22.4</td>
<td>-</td>
<td>3.2</td>
<td>0.28</td>
<td>13.4</td>
<td>0.89</td>
<td>0.25</td>
<td>0.64</td>
</tr>
<tr>
<td>Lactuca Sativa</td>
<td>Lettuce</td>
<td>8.67</td>
<td>1.0</td>
<td>2.1</td>
<td>0.17</td>
<td>0.4</td>
<td>0.92</td>
<td>0.68</td>
<td>1.09</td>
</tr>
<tr>
<td>Psidium Guajava</td>
<td>Guava</td>
<td>7.27</td>
<td>7.2</td>
<td>1.2</td>
<td>1.13</td>
<td>3.2</td>
<td>0.80</td>
<td>0.01</td>
<td>1.02</td>
</tr>
<tr>
<td>Mangifera Indica</td>
<td>Mango</td>
<td>2.67</td>
<td>1.2</td>
<td>1.0</td>
<td>0.54</td>
<td>-</td>
<td>0.78</td>
<td>0.25</td>
<td>0.19</td>
</tr>
</tbody>
</table>

(26.0) from Enyigba mine (Table 4). High accumulation of Cd in these affected plants makes them unfit for human consumption. Food substances containing excess Cd are known to result to bone fracture, cancer, diarrhea, stomach pains, severe vomiting, reproductive failure and damage of central nervous system (ATSDR, 1997; Assuncao et al., 2003; Roosens et al., 2003).

Lead in Studied Plants

Lead is the main cause for concern in terms of contamination of plants in Enyigba mine by heavy metals. Lead was detected in all the investigated fruits and vegetables from and their Pollution Indices were found to decrease in the order African peach > beni seed >
leek > guava > pepper > African salad > tomatoes >
African Paudauk > mango > Red sandal leaves > okro.
High values PI of Pb were observed in African peach (22.4),
beni seed (12.37), lettuce (8.67) and guava (7.27) which
makes the affected plants unfit for consumption. These
values are lower than those observed by Rose (2000) and Ross (1994).
Mobilized Pb in the soft tissues of the body can cause
musculoskeletal, renal, ocular, immunological, neurological, reproductive, and
developmental effects (ATSDR, 1999 and Aral, 2002).

Chromium in Studied Plants

High PI of Cr was observed in Red sandal wood (20.4),
African peach (13.4), African salad (4.8) and guava
(3.2) and they decrease in the order: red sandal wood >
African peach > African salad > guava > okro >
African paudauk > tomatoes / beniseed / lettuce >
pepper (Table 4). Chromium at low concentration is not
toxic to the body but at high concentration such as in
Red sandal wood accumulated chromium more than 20
times higher than the WHO-ML is lethal to the body.
Acute toxicity of chromium (VI) is due to its strong
oxidational properties. After it reaches the blood stream,
it damages the kidneys, the liver and blood cells through
oxidation reactions. Haemolysis, renal and liver failure
are the results of these damages. (Fordham, 1996).

Zinc in Studied Plants

High PI of Zn was observed in red sandal wood > beni
seed > okro from and their mean concentration exceeded
WHO ML (Table 3). Zinc is the least toxic of all the studied metals, and it is an essential element in the
human diet as it is required to maintain the proper
functions of the immune system, normal brain activity
and is fundamental in the growth and development of
the foetus (Prasad, 2003). Zinc deficiency in the diet may be
more detrimental to human health than excess Zinc in
the diet (Nair et al., 1997). Zinc is known to interfere with
Cu metabolism. High concentration of Zinc in vegetables
decreases the sense of smell and taste, slows down
healing process of wound (ATSDR, 1994). Pollution
index of one observed for Zn in tomatoes suggests that
the plant is in a critical state.

Nickel in Studied Plants

Low PI of Ni was observed in the studied fruits and
vegetables except in lettuce (1.09) and (1.02) guava from
Enyigba mine. Nickel at this level is not deemed toxic
to human health. Excess and deficiency of Ni in
vegetables and fruits are detrimental to human health
(MacNicol and Beckett, 1985). Deficiency of Nickel
have been linked with hyperglycemia, hypertension,
depression, sinus congestion, fatigue, reproductive
failures and growth problems in humans, while excess
intake of Ni leads to hypoglycemia, asthma, nausea,
headache, and epidemiological symptoms like cancer of
nasal cavity and lungs. The prescribed safety limit of
Nickel is 3 to 7 mg/day in humans (ATSDR 1999). On
the other hand bioaccumulation factor greater than one
was observed in red sandal wood, guava and lettuce
(Table 5). BAF > 1 suggest that plant could be a
hyperaccumulator which can be useful in cleaning up
polluted environment as phytoremediation agents.

Copper in Studied Plants

Low PI of Cu was observed in investigated fruits and
vegetables except in African salad (1.0) and guava
(1.13) from Enyigba mine (Table 4). Pollution Index of
Cu in African salad is at a critical point hence it can be
used for environmental monitoring. These results are
comparable to those reported by Yang et al., (2002) and

Manganese in Studied Plants

Very Low PI of Mn was observed in all the investigated
fruits and vegetables in this research (Table 4). At low
concentration, Mn is not known to be toxic rather it is
required by the body for proper enzyme functioning,
nutrient absorption, wound healing, and bone
development. Manganese deficiency is rare and can
been seen expressed in poor bone health, joint pain, and
Bioaccumulation factor was greater than one in okra and
red sandal wood (Table 5). This suggests that they can
be used as phytoremediation purposes since they have
tendency to be hyperaccumulators.

CONCLUSIONS

The decreasing mean concentrations of the heavy
metals from topsoil to subsoil suggests anthropogenic
source of contamination. Factors that affected high
level of heavy metals in the soil included soil pH,
solubility of the metal in soil solution and the organic
matter content. Of all the studied heavy metals in
soil, only Pb, Ni and Cd were found at elevated
concentrations above the US-EPA guideline limits. From
this work, Pb exceeded the WHO ML in all the selected
vegetables and fruits except okro. Arsenic levels in red
sandal wood, African salad, okro, beni seed, guava and
mango, also exceeded WHO ML. Cadmium levels in
pepper, lettuce, and beni seed significantly exceeded
WHO ML. Chromium in okro, African peach and guava
likewise exceeded WHO ML. Hence all the affected
plants are unfit for human consumption. BAF > 1 of Mg
and Ni were observed in okra and red sandal wood and in red sandal wood, guava and lettuce respectively. BAF > 1 suggest that plant could be a hyperaccumulator which can be useful in cleaning up polluted environment as phytoremediation agents.

**RECOMMENDATIONS**

Based on the findings of this work, the Government at all levels should discourage farmers from cultivating the lands around Enyigba mine. There is need for regular monitoring of heavy metal loads in our environment particularly within and around mining sites. This is to enable Federal and State Governments to be able to provide quick intervention in the event of emerging negative environmental pollution. Some of the plants such as tomatoes and African Paudak whose elemental composition reflects that of the soil can be used for environmental monitoring. Phytoremediation offers viable solution to pollution problems.

**REFERENCES**


Danish Environmental Protection Agency (2000). Guidance Regarding Advice of Inhabitants of Slightly Contaminated Soil (in Danish). Danish EPA, Office of Soil Contamination: Copenhagen, (75) pp.132-

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**Table 5. Bioaccumulation Factors of Heavy Metals in Fruits and Vegetables of Enyigba Derelict**

<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
<th>Plant parts</th>
<th>Pb</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Cr</th>
<th>Zn</th>
<th>Mn</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. esouletum</td>
<td>Okro</td>
<td>Fruit</td>
<td>0.00</td>
<td>0.04</td>
<td>0.00</td>
<td>0.12</td>
<td>0.08</td>
<td>0.17</td>
<td>1.18</td>
<td>0.42</td>
</tr>
<tr>
<td>L. esouletum</td>
<td>Tomatoes</td>
<td>Fruit</td>
<td>0.00</td>
<td>0.03</td>
<td>0.00</td>
<td>0.09</td>
<td>0.01</td>
<td>0.15</td>
<td>0.71</td>
<td>0.38</td>
</tr>
<tr>
<td>C. annum</td>
<td>Pepper</td>
<td>Fruit</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.06</td>
<td>0.01</td>
<td>0.10</td>
<td>0.31</td>
<td>0.79</td>
</tr>
<tr>
<td>Ptercarpus Soyauxii</td>
<td>African Paudak</td>
<td>Leaves</td>
<td>0.00</td>
<td>0.29</td>
<td>0.00</td>
<td>0.08</td>
<td>0.03</td>
<td>0.05</td>
<td>0.16</td>
<td>0.31</td>
</tr>
<tr>
<td>Ptercarpus Santalinoides</td>
<td>Red sandal wood</td>
<td>Leaves</td>
<td>0.00</td>
<td>0.31</td>
<td>0.03</td>
<td>0.04</td>
<td>0.65</td>
<td>0.25</td>
<td>1.52</td>
<td>1.09</td>
</tr>
<tr>
<td>G. buchholzianum</td>
<td>African Salad</td>
<td>Leaves</td>
<td>0.00</td>
<td>0.06</td>
<td>0.04</td>
<td>0.13</td>
<td>0.15</td>
<td>0.11</td>
<td>0.21</td>
<td>0.22</td>
</tr>
<tr>
<td>Sesamum indicum</td>
<td>Beni Seed</td>
<td>Fruit</td>
<td>0.01</td>
<td>0.09</td>
<td>0.16</td>
<td>0.06</td>
<td>0.01</td>
<td>0.19</td>
<td>0.16</td>
<td>0.59</td>
</tr>
<tr>
<td>Nauclea latifolia</td>
<td>African Peach</td>
<td>Fruit</td>
<td>0.01</td>
<td>0.00</td>
<td>0.04</td>
<td>0.43</td>
<td>0.14</td>
<td>0.46</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>Lactuca Sativa</td>
<td>Lettuce</td>
<td>Leaves</td>
<td>0.00</td>
<td>0.03</td>
<td>0.00</td>
<td>0.02</td>
<td>0.02</td>
<td>0.14</td>
<td>1.25</td>
<td>1.24</td>
</tr>
<tr>
<td>Psidium Guajava</td>
<td>Guava</td>
<td>Fruit</td>
<td>0.00</td>
<td>0.21</td>
<td>0.00</td>
<td>0.15</td>
<td>0.10</td>
<td>0.12</td>
<td>0.75</td>
<td>1.16</td>
</tr>
<tr>
<td>Mangifera Indica</td>
<td>Mango</td>
<td>Fruit</td>
<td>0.00</td>
<td>0.04</td>
<td>0.00</td>
<td>0.07</td>
<td>0.11</td>
<td>0.46</td>
<td>0.22</td>
<td></td>
</tr>
</tbody>
</table>


Minitab Tip Sheet 8 (2007). Department of Mathematics and Statistics University of Reading, (On-line: http://www.reading.ac.uk/statistics/tipsheets)


