ASSESSMENT OF HEAVY METAL CONTAMINATION IN SOILS AROUND AUTO MECHANIC WORKSHOP CLUSTERS IN CENTRAL AGRICULTURAL STATION, KUMASI-GHANA


a Soil Chemistry and Mineralogy Division, Council for Scientific and Industrial Research-Soil Research Institute, PMB, Kumasi, Ghana
b Environmental and Natural Resources Management, Presbyterian University College, Akuapem Campus, Ghana
c Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
d Soil Genesis, Survey and Evaluation Division, CSIR-Soil Research Institute, PMB, Kumasi, Ghana.
e Directorate, CSIR-Soil Research Institute, PMB, Kumasi, Ghana
f Corresponding Author: a.sadick@csir-soilresearch.org

Article received on January 25, 2015 Accepted on June 05, 2015

ABSTRACT

The study assessed the level of heavy metals in soils around auto mechanic shops and its effect on soil fertility at Kwadaso central agricultural station in the Ashanti Region of Ghana. Ten soil samples from the study area and two controls were collected at the depth of 0-15 cm for laboratory analysis. Heavy metals, soil texture, pH, organic matter content, cation exchange capacity and total nitrogen were analysed. The results showed that most of the heavy metals studied had concentrations above the background level (control). The heavy metal concentration showed an increased pattern of Pb>Fe>Cu>Mn>Cd>Zn. Also the pH, organic matter, nitrogen and cation exchange capacity varied from 6.15, 0.88%, 0.10% and 4.01 cmol (+)/kg to 7.30, 9.09%, 0.57% and 25.01 cmol (+)/kg. This showed a relative reduction in the nutrient levels in the experimental soils compared to the background level (control). The auto mechanic shops have been contributing to the heavy metal contamination of the soil at the Kwadaso Central Agricultural Station in Kumasi.

Key words: Heavy metal, pollution, nutrient status, Soil fertility, Soil properties

1. INTRODUCTION

Soils may become contaminated by heavy metals through various anthropogenic activities. Wuana and Okieimen (2011) identified mine tailings, disposal of high metal wastes, leaded gasoline and paints, application of fertilizers, pesticides, wastewater irrigation, spillage of petrochemicals, etc. as some of such activities. Heavy metal is a general term used to describe a group of metals and metalloids with an atomic density greater than 5.0 g/cm³ (Duffus, 2002). These elements occur naturally in soils and rocks at various ranges of concentrations; they are also found in ground and surface water bodies and sediments (Hutton and Symon, 1986). Unchecked industrial and human activities have contributed significantly to elevated (pollutional) levels of these metals, in surface and subsurface soils when compared to those contributed from geogenic or natural processes (Dasaram et al., 2011). Their pollution of the environment even at low levels and the resulting long-term cumulative health effects are among the leading health concerns all over the world (Huton & Symon, 1986). The concern is heightened by
their persistence in the soil and their tendency to bioaccumulate, move along the food chain and also poison soil microorganisms (Udousoro et al., 2010).

Soil being one of the repositories for anthropogenic waste, biochemical processes can mobilize the chemical substances contained in it to pollute water supplies and impact food chains thereby causing great harm to man. The high toxic and persistent natures of heavy metals in the environment have made them priority pollutants (Abechi et al., 2010). Top soils are the first locus of input of metals where they tend to accumulate on a relatively long term basis (Abenchi et al., 2010). These pollutants normally contaminate the upper layer of the soil at a depth (0 - 40) cm (Krishna & Grovil, 2007). This implies that, high concentration of these pollutants could be present at this depth if assessed (Pam et al., 2013). Many studies have shown that areas with heavy vehicular traffic and higher tempo of anthropogenic activities of urban settlements have high soils contaminants than those with low vehicular traffic (Adelekan & Alawode, 2011).

In Kumasi, prominent auto mechanic workshops are located in areas such as Suame (Magazine), Tafo, Asafo, Asuoyeboah and Kwadaso. These places are officially designated by Kumasi Metropolitan Assembly (KMA) for repairs and servicing of motor vehicles and other machineries. The sources and mechanism of release of heavy metals into the soil and water resource of automobile mechanic site include engine oil and lubricating oil, engine and gear box overhaul, battery charging, welding and soldering, automobile body work and spraying painting and combustion processes (Pam et al., 2013). These activities generates wastes such as spent lubricants, hydraulic fluids, worn-out parts, packaging materials, metal scraps, used batteries, discarded cans and stripped oil sludge (Pam et al., 2013). The heavy metals most frequently encountered in these waste include copper (Cu), lead (Pb), cadmium (Cd), zinc (Zn), manganese (Mn) and nickel (Ni), all of which pose risks to human health and the environment especially soil fertility levels (Adelekan & Alawode, 2011). Kwadaso Central Agricultural Station which is an experimental field for agricultural research has a number of cluster auto mechanic shops around it. It is therefore possible that these shops will contribute heavy metal contaminants to the experimental site thereby polluting the soil. It has therefore become imperative to monitor the levels of these heavy metals and nutrient status of soil at Kwadaso Central Agricultural Station.

2. MATERIALS AND METHODS

Study Area Description

The study area is located in Edwenase-Kwadaso, a suburb of Kumasi in the Ashanti region of Ghana (Figure1). This used to be trial grounds for agricultural research activities. The geographical location of Kwadaso lies in Latitude 6.42°N and Longitude 1.34°W with an altitude of 284m above mean sea level.
The topography of the area is partly flat plane and undulating surface, and lies within tropical rain forest. The soil type is made up of Cutanic Lixisol (WRB, 2006). The presence of the Agricultural College and two research institutes in the town attract a large population of people and presence of many automobile vehicles, which in turn gives a boost to automobile workshop activities.

### Sample collection and treatment

Soil samples were collected from four selected automobile workshops within the study area using soil auger, at the depth of 0-15cm representing the top soil. At each location, the soil samples were taken from two different points. The control samples were collected from the Soil research’s management farm, which was about 100m away from the influence of any auto mechanic activities. The location of the control sample was at the same geology (granite) with the study area. The samples were placed in labeled polythene bags and transported to the CSIR-Soil Research Institute laboratory for analysis. All soil Samples were subsequently air-dried to constant weight to avoid microbial degradation (Kakulu, 1993). They were homogenized, made lump free by gently crushing repeatedly using a pulverizing machine and passed through a 2 mm plastic sieve prior to analysis. Thus, a total of 10 top soil samples were collected from the study area and two (2) were taken from the control site.

### Determination of physiochemical properties of the soils

The physiochemical properties of the soil samples were determined using routine methods as described by Allison (1960) and Ibitoye (2006). The physiochemical parameters used for this study were pH, organic matter (OM), cation exchange capacity, total nitrogen and particle size distribution which influence the interactions and dynamics of metals within the soil matrix.
Determination of heavy metals as soil contaminant

One gram of the dried fine soil sample was weighed into an acid washed, round bottom flask containing 10 cm³ concentrated nitric acid (HNO₃). The mixture was slowly evaporated over a period of one hour (1) on a hot plate. Each of the solid residues obtained was digested with a 3:1 concentrated HNO₃ and HClO₄ mixture for 10 minutes at room temperature before heating on a hot plate. The digested mixture was placed on a hot plate and heated occasionally to ensure a steady temperature of 150°C over 5 hours until the fumes of HClO₄ were completely evaporated (Jacob et al., 2009). The mixture was allowed to cool to room temperature and then filtered using Whitman No.1 filter paper into a 50 cm³ volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels, to recover any residual metal. The filtrate was then stored in pre-cleaned polyethylene storage bottles ready for analysis. Heavy metal concentrations were determined using an Atomic Absorption Spectrophotometer (AAS) at the CSIR-Soil Research Institute, Ghana. The settings of the instrument and operational conditions were in accordance with the manufacturer’s specifications.

3. RESULTS AND DISCUSSION

Soil properties

Table 1: Summary of physicochemical properties of soils in each of the workshops

<table>
<thead>
<tr>
<th>Location</th>
<th>pH</th>
<th>OM</th>
<th>Total N</th>
<th>CEC</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1:1 H₂O</td>
<td>%</td>
<td>%</td>
<td>cmol(+) /kg</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>7.30</td>
<td>3.53</td>
<td>0.27</td>
<td>16.16</td>
<td>61.78</td>
<td>30.06</td>
<td>8.16</td>
<td>sandy loam</td>
</tr>
<tr>
<td>AB 1</td>
<td>7.40</td>
<td>1.21</td>
<td>0.20</td>
<td>20.79</td>
<td>49.62</td>
<td>34.14</td>
<td>16.24</td>
<td>loam</td>
</tr>
<tr>
<td>AM</td>
<td>7.12</td>
<td>5.72</td>
<td>0.34</td>
<td>10.48</td>
<td>69.10</td>
<td>24.42</td>
<td>6.48</td>
<td>sandy loam</td>
</tr>
<tr>
<td>AM 1</td>
<td>7.27</td>
<td>9.09</td>
<td>0.57</td>
<td>13.81</td>
<td>75.84</td>
<td>18.02</td>
<td>6.14</td>
<td>loamy sandy</td>
</tr>
<tr>
<td>AE</td>
<td>6.15</td>
<td>1.41</td>
<td>0.23</td>
<td>4.01</td>
<td>33.56</td>
<td>44.42</td>
<td>22.02</td>
<td>loam</td>
</tr>
<tr>
<td>AE 1</td>
<td>6.74</td>
<td>5.02</td>
<td>0.31</td>
<td>16.38</td>
<td>49.04</td>
<td>36.60</td>
<td>14.36</td>
<td>loam</td>
</tr>
<tr>
<td>AS</td>
<td>7.18</td>
<td>0.88</td>
<td>0.10</td>
<td>25.01</td>
<td>40.10</td>
<td>49.70</td>
<td>10.20</td>
<td>silty loam</td>
</tr>
<tr>
<td>AS 1</td>
<td>7.37</td>
<td>2.90</td>
<td>0.24</td>
<td>23.66</td>
<td>38.60</td>
<td>53.00</td>
<td>8.40</td>
<td>silty loam</td>
</tr>
<tr>
<td>MF</td>
<td>6.96</td>
<td>2.05</td>
<td>0.23</td>
<td>11.30</td>
<td>30.33</td>
<td>61.41</td>
<td>8.26</td>
<td>silty loam</td>
</tr>
<tr>
<td>MF 1</td>
<td>6.05</td>
<td>4.17</td>
<td>0.29</td>
<td>8.04</td>
<td>30.00</td>
<td>57.40</td>
<td>12.60</td>
<td>silty loam</td>
</tr>
<tr>
<td>Mean</td>
<td>6.95</td>
<td>3.60</td>
<td>0.28</td>
<td>14.96</td>
<td>47.80</td>
<td>40.92</td>
<td>11.29</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>0.49</td>
<td>2.53</td>
<td>0.12</td>
<td>6.81</td>
<td>16.36</td>
<td>14.55</td>
<td>5.04</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>1.35</td>
<td>8.21</td>
<td>0.47</td>
<td>21.00</td>
<td>45.84</td>
<td>43.39</td>
<td>15.88</td>
<td></td>
</tr>
</tbody>
</table>

AB: Auto body, AM: Auto mechanic, AE: Auto electrician, AS: Auto spraying, MF: Management farm (Control)

The results of the physicochemical characteristics of the soils analyzed are summarized in Table 1. The values of the pH of soils in the vicinity of auto mechanic workshop clusters ranged from 6.05 to 7.40 in deionized water. This means that the pH of the soil was slightly basic except the auto electrician shops which showed moderately acidic, in situ. This could be explained by the fact that at the auto electrician shop there is spillage of acids from the car batteries into the soil which would cause pH of soil to decrease. Therefore the movement of these cations from the surface to the underlying soil layer will be acidic and can affect plant growth within the vicinity of the auto mechanic shops. Gambrell (1994) indicated that pH is a major factor influencing metal chemistry of the soil and therefore this can influence the level of heavy metals in the study area.

The organic matter was in the range of 1.21 to 9.09 %. It plays an important role in metal binding (Akans et al., 2010). From the results, auto mechanic workshop was observed to have the highest organic matter (mean: 7.41%), while auto spraying shop had the least (mean: 1.89%). Organic matter of soils immobilizes heavy metals at strongly acidic conditions and mobilizes metals at weakly acidic to alkaline
reactions by forming insoluble or soluble organic metal complexes, respectively (Brümmer & Herms, 1982).

The cation exchange capacity (CEC) ranged between 4.01 to 25.01 cmol (+)/kg. The highest CEC was recorded at auto body workshop (mean: 18.48 cmol (+)/kg), and the least was auto electrician shop (mean: 10.20 cmol (+)/kg). The CEC of the soil can regulate the mobility of metals in soils and increase as pH increases. It is reported by Brummer and Herms (1982) that sandy soils have lower CEC than loamy soils, and below a pH of 6 high concentrations of Zn and Cd were measured for sandy samples and lower concentration for loamy, probably due to higher CEC of loam. The texture of the soils investigated in this study was generally loamy and could decrease the solution concentration of Zn, Cd.

The particle size distribution generally puts the soils in loamy on textural classification. These have high sorption capacity for metal ions due to their loamy texture. It is likely that the concentration of heavy metals of interest, Pb, Cu, Zn, Mn, and Cd may decrease with depth, possibly due to high pH and CEC levels from the surface.

Level of heavy metals in the soils

Table 2: Concentrations of Heavy metals (ppm) in the soils in auto mechanic workshop clusters in the study area

<table>
<thead>
<tr>
<th>Location</th>
<th>Fe ppm</th>
<th>Cu ppm</th>
<th>Zn ppm</th>
<th>Mn Ppm</th>
<th>Pb ppm</th>
<th>Cd ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>43.88</td>
<td>11.64</td>
<td>1.88</td>
<td>6.27</td>
<td>223.53</td>
<td>12.90</td>
</tr>
<tr>
<td>AB 1</td>
<td>90.56</td>
<td>7.89</td>
<td>2.91</td>
<td>4.84</td>
<td>225.96</td>
<td>13.50</td>
</tr>
<tr>
<td>AM</td>
<td>112.84</td>
<td>22.59</td>
<td>2.46</td>
<td>10.29</td>
<td>250.00</td>
<td>14.00</td>
</tr>
<tr>
<td>AM 1</td>
<td>59.96</td>
<td>20.36</td>
<td>2.93</td>
<td>18.49</td>
<td>260.43</td>
<td>17.80</td>
</tr>
<tr>
<td>AE</td>
<td>129.83</td>
<td>12.30</td>
<td>1.43</td>
<td>3.80</td>
<td>270.00</td>
<td>12.30</td>
</tr>
<tr>
<td>AE 1</td>
<td>120.38</td>
<td>33.06</td>
<td>2.84</td>
<td>10.36</td>
<td>265.33</td>
<td>10.22</td>
</tr>
<tr>
<td>AS</td>
<td>264.09</td>
<td>49.03</td>
<td>33.38</td>
<td>32.53</td>
<td>235.03</td>
<td>11.01</td>
</tr>
<tr>
<td>AS 1</td>
<td>125.34</td>
<td>26.91</td>
<td>33.00</td>
<td>19.97</td>
<td>230.10</td>
<td>10.90</td>
</tr>
<tr>
<td>MF</td>
<td>39.01</td>
<td>10.01</td>
<td>1.03</td>
<td>3.90</td>
<td>9.75</td>
<td>7.31</td>
</tr>
<tr>
<td>MF 1</td>
<td>36.89</td>
<td>12.33</td>
<td>1.90</td>
<td>4.80</td>
<td>9.22</td>
<td>7.01</td>
</tr>
<tr>
<td>Mean</td>
<td>102.28</td>
<td>20.61</td>
<td>8.38</td>
<td>11.52</td>
<td>197.94</td>
<td>11.70</td>
</tr>
<tr>
<td>SD</td>
<td>67.93</td>
<td>12.90</td>
<td>13.09</td>
<td>9.42</td>
<td>100.68</td>
<td>3.20</td>
</tr>
<tr>
<td>Range</td>
<td>227.20</td>
<td>41.14</td>
<td>32.35</td>
<td>28.73</td>
<td>260.78</td>
<td>10.79</td>
</tr>
</tbody>
</table>

From the concentrations of the heavy metals investigated were higher in the auto mechanic cluster soils than the at the control site (management farm) (Table 2). This result is corroborating with the statement by Adelekan and Alawode (2011) that areas with heavy vehicular traffic and higher tempo of anthropogenic activities of urban settlements have high soil contaminants than those with low vehicular traffic. Copper was present in all the soil samples investigated. These values were higher than the one that of the control site (mean: 11.17 ppm). The higher values of Cu than the one at the control site could be due to automobile wastes containing electrical and electronic parts, such as copper wires, electrodes and copper pipes and alloys from corroding vehicle scraps which have littered the vicinity of the study area for a long time, with metals released from the corrosion gradually leaching into the soil (Nwachukwu et al., 2011). There is wide range of distribution of Cu in the study area with mean values of 20.61 ppm. This value is below the maximum allowable limit (100 ppm) in Australia, Canada, Poland, Great Britain, Japan (125 ppm), and Germany (50 ppm) (Lacatusu, 2000).

The Zinc content in all the soils had a mean range of 8.38 ppm. These values are higher than those at the management farm (control) and suggest that, there is anthropogenic contribution. There is no industry exists in the vicinities of the study area, it is believed that the increase of Zn levels in the study area was from the auto mechanic shops, since this element is found as part of many additives to lubricating oils (Abenchi et al., 2010). The values of Zn obtained in the study area conform to the acceptable limit of 50 ppm (Lacatusu, 2000).

Manganese (Mn) is one of the elements found in abundant in the earth’s crusts and is widely distributed in soils, sediments, rocks and water (Shrivastava and Mishra, 2011). Mn analysis gave mean value of
11.52ppm. Although the levels found for Mn were above the control level, there was no soil quality criteria established for Mn for now (Kimberly & William, 1999; Karen, 2005). However, considering the year of establishment of the auto mechanic workshop clusters and mean concentration observed in this study as compared with the control results it appears that the level of Mn in the soils investigated is building up and need to be monitored to prevent any further increase.

The mean value of Pb in soils obtained in this study was 197.94ppm. This value is significantly higher than the control level. The high values in the study area attested to the overall high level of contamination of the environment with this metal and could easily be attributed largely to the activities in the auto mechanic shops. It is reported that Pb has the highest composition of heavy metals in waste oils (Oguntimehin et al., 2008). It is possible that high concentration of Pb in the study area was due to the amount of waste oil, presence of automobile emissions, and expired motor batteries indiscriminately dumped by battery chargers and auto mechanics in the surrounding areas. During the fieldwork campaign it was revealed that large amount of waste oil and expired motor batteries were seen at the auto mechanic and auto electrician shops and therefore it is attested to the fact that there was high level of Pb at auto mechanic and auto electrician shops (Table 2).

The mean concentration of Cd in the study area was 11.70ppm. The main source of environmental Cd pollution is the ferrous-steel industry (Onder et al., 2007); the accumulation of Cd in the area studied is likely to come from lubricating oils, vehicle wheels and metal alloys used for hardening of engine parts (Dabkowska - Naskret, 2004).

**Effect of the auto mechanic workshop clusters on the agricultural soil environment**

In order to have an idea about the levels of contamination of the soil which can be used for agricultural purposes, and now used as auto mechanic workshops, data obtained were compared with that from the control sample point. This implies that the operations of the mechanic shops around the agricultural sites are contributing to the increased concentration of heavy metals in the soil. The concentrations of all the heavy metals studied were above the background concentration level in the control soil indicating pollution. According to Puyate et al. (2007) the background value of an element is the maximum level of the element in an environment beyond which the environment is said to be polluted with the element. The average levels of these metals in the soil, in the auto-mechanic clusters indicate that they are not derived from the natural geology of the area as evident from the low level of metals in control samples. The heavy metals showed an increased distribution pattern of Pb>Fe>Cu>Mn>Cd>Zn as presented in Figure 2.

![Figure 2: Levels of metals in mechanic shops as compared with control site](image-url)
4. CONCLUSION

The investigation in this study indicated that even though the soil is polluted with heavy metals as compared with the background value in the control soil, the nutrient levels (pH, N, OM and CEC) needed for plant growth is relatively high. The heavy metal contamination of the experimental soils obviously comes from the activities of the auto mechanic shops sounding the site. The high organic matter content which favour heavy metal binding might have contributed to the high levels of the studied metals and hence the contamination of the soil. If the increasing trend continues it could deteriorate the soil when the contaminants exceed the maximum acceptable limits. Therefore the auto mechanic workshops have negative effect on the soil through heavy metal contamination. The mechanics should be taken through safe disposal of their waste from their operations so as to limit the discharges which contain these heavy metals. Examination of levels of heavy metals in the crops grown at the experimental site and the effect on the growth and the yield is recommended for further studies.

Acknowledgements

Our big gratitude goes to Soil Research Laboratory staff and auto electricians and mechanics who helped us during soil sampling and analysis

REFERENCE


