Contamination of the Content of Hazardous Heavy Metals in Soils and Plant Sample Grown around a Contaminated Area

Napattaorn Buachoon

Abstract—The content of copper, lead, cadmium and zinc in soils and plant grown around a contaminated area was determined by Inductively Coupled Plasma-Optical Emission Spectrometry. The area was divided into six sections, and each section was studied. Analyses were performed on sample rhizomes, stems, leaves, as well as the soil where the plant grew. Rhizomes showed a high content of the metals, followed by the leaves, the stems and finally the soil, which had the lowest content of the metals. Lead concentrations in rhizomes, stems, leaves and soil were 430 mg/Kg, 180 mg/Kg, 120 mg/Kg, 120 mg/Kg, respectively, while copper concentrations were 810 mg/Kg, 463 mg/Kg, and 48.5 mg/Kg respectively. In contrast, cadmium and zinc concentrations were lower and varied from 30 mg/Kg on rhizomes, 58 mg/Kg on leaves, and 46 mg/Kg on stems for cadmium, and the content of zinc found ranged from 31 mg/Kg on rhizomes, 35 mg/Kg on stems, and 42 mg/Kg on leaves. Soil concentrations were high in site 3 for lead and copper, 4,621 mg/Kg and 5,631 mg/Kg, respectively; lower concentrations were found for cadmium and zinc, 223 mg/Kg and 57 mg/Kg, respectively. The heavy metal content of the soils indicates the degree of pollution in the area. As expected, those sections which contained higher levels of heavy metals in the soil also showed to have higher heavy metal uptake by various parts of plant. These data demonstrate plant ability to uptake copper and lead, and to some extent cadmium and zinc, from heavy metal contaminated soils. Analyses of other heavy metals will also be examined.

Keywords—plant, soil, hazardous, heavy metals, Inductively Coupled Plasma-Optical Emission Spectrometry

I. INTRODUCTION

GLOBAL industrialization and human social and agricultural activities have an effect on environmental pollution and the global ecosystem. This corruption of the ecosystem has a negative effect on human health and on all living organisms. Growing industrialization and environmental pollution from technology have started to affect human health [1]. Soil pollution by heavy metals, such as cadmium, lead, chromium, and copper, etc. is a problem of concern. Although heavy metals are naturally present in soil, contamination and comes, from local sources: mostly industry (mainly non-ferrous industries, but also power plants and iron, steel and chemical industries), agriculture (irrigation with polluted waters, sewage sludge and fertilizer, especially phosphates, contaminated manure and pesticide containing heavy metals), waste incineration, combustion of fossil fuels and road traffic.

Long-range transport of atmospheric pollutants adds to the metals in the natural environment [2]. In recent years, it has been shown that lead levels in soil and vegetation have increased considerably due to traffic pollution, especially from usage of leaded petrol and exhaust combustion [3-6]. The problem worsens as daily traffic increases [7].

Heavy metal contamination of soil results from anthropogenic such as mining [8], smelting procedures [9] and agriculture [10] as well as natural activities. Chemical and metallurgical industries are the most important sources of heavy metals in the environment [11-13].

The industrial activity in the area has resulted in the accumulation of many heavy metals in the soil including copper, lead, cadmium, and zinc. The accumulation of these heavy metals in the soils, however, may have lessened over time as a result of the metals being up taken by creosote bushes. To date, no studies have been performed demonstrating creosote bushes as metal scavengers. Because creosote bushes are so prevalent throughout the southwest and because they are able to grow in such contaminated soil environments, they possess the qualities necessary for utilization as phytoremediation resources.[14-18].

The aim of the present study is to determined of the content of hazardous heavy metals present in the individual tissues including the rhizomes, stems, leaves and the soils from which the plants grew. Three replicate samples were collected from various locations on the Pathumtani Province. The samples were oven dried and then the tissues of rhizomes, stems, and leaves were separated. The soil and tissue samples were acid digested and analyzed by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) for the determination of the content of copper, lead, cadmium, and zinc.

II. MATERIALS AND METHODS

A. Collection of plant

For the present study, six locations were arbitrarily chosen to represent creosote bushes in various locations around the copper smelting industry. A six site, located 30 miles from sites 1-5, was chosen for control samples of the bushes. Three replicate samples of creosote bushes, approximately 3 ft. high and of the same stage of maturity, were collected using a shovel. A diameter of approximately 2 ft. was dug around each bush. The bushes were pulled up by the rhizomes and the residual soils from the rhizomes were shaken off the bushes and collected in plastic containers for later analysis. All three bushes were combined for representative sampling purposes.
**B. Collection of soil**

Soil (control) samples were taken at random at the location of plant sampling from uncontaminated agricultural lands. The other soil samples were taken at measurement points located near high-density traffic roads and near the textile plants in Pathumtani Province, Thailand.

**C. Reagents**

All reagents were of analytical reagent grade unless otherwise stated. Deionized water, HNO₃, H₂O₂ and HClO₄. The element standard solutions used for calibration were prepared by diluting a stock solution of 1000 ppm (Cu, Pb, Cd and Zn) supplied by Sigma.

**D. Preparation of plant and soils**

Samples of creosote bushes from each site were oven dried at a temperature of 90°C for four days. This mild temperature was chosen to avoid vapor loss of the metals or of their salts. After drying, the rhizomes, stems, leaves were separated and ground.

Soils were also sieved to -100 Tyler mesh to remove unwanted rock and sediment materials from the matrix. After the samples were obtained, three replicate one gram samples of each tissue were acid digested according to EPA method 3050. A fourth replicate sample was also prepared and digested but was spiked with either 1.0 or 5.0 ppm each of copper, lead, cadmium, and zinc, which were the metals of interest. A blank was also prepared to ensure the integrity of the analytical procedure. The EPA protocol that was adopted for the acid digestion of the soil and tissue samples here can be described as follows: A 1.00-2.00 gram homogenous representative sample was obtained and placed in conical beakers. Sample slurries were prepared by adding 10 ml of 1:1 nitric acid (HNO₃). The slurries were then covered with watch glasses, heated to near boiling, and refluxed for 15 min. After refluxing, the slurries were cooled and then 5 ml of concentrated HNO₃ were added and the solution was again allowed to reflux for an additional 30 min. This last step was repeated to ensure complete oxidation of the metals. After the third refluxing period, the sample was cooled to room temperature and 2 ml of deionized water and up to 10 ml of 30% hydrogen peroxide were added. The samples were then filtered to remove any particulates which might interfere with ICP-OES analysis. The filtrates were collected in 100 ml volumetric flasks and were diluted with deionized water to volume. The samples, which were approximately 5.0% (v/v) nitric acid, were now ready for ICP-OES analysis.

**E. Data Analysis**

The experiments were performed in triplicate, and the samples were analyzed in triplicate. For each set of given data, standard statistical methods were used to determine the mean values and standard deviations. Confidence intervals of 95% were calculated for each set of samples to determine the error margin.

**III. Results**

The range of linearity of concentration vs. absorbance curve is of great importance in determining the elemental concentration of the soil and plant samples. The calibration curves for Copper (Cu), Lead (Pb), Zinc (Zn) and Cadmium (Cd) are shown in Fig. 1.

![Fig 1. Concentration versus absorbance curves for Copper (Cu), Lead (Pb), Zinc (Zn) and Cadmium (Cd)](image)

The highest concentrations of heavy metals were found in samples from site 3. Site 3 Lead concentrations in rhizomes, stems, leaves were 430 mg/Kg, 180 mg/Kg, and 120 mg/Kg, respectively, while copper concentrations were 810 mg/Kg, 463 mg/Kg, and 250 mg/Kg, respectively. In contrast, cadmium and zinc concentrations were lower and varied from 30 mg/Kg on rhizomes, 58 mg/Kg on leaves, and 46 mg/Kg on stems for cadmium, and the content of zinc found ranged from 31 mg/Kg on rhizomes, 35 mg/Kg on stems, and 42 mg/Kg on leaves. Soil concentrations were high in site 3 for lead and copper, 4,621 mg/Kg and 5,631 mg/Kg, respectively; lower concentrations were found for cadmium and zinc, 223 mg/Kg and 57 mg/Kg, respectively. In all of the samples, copper concentrations were the highest, followed by lead. Cadmium and Zinc concentrations were extremely low.

![Fig 2. Lead, copper, cadmium and zinc contamination in rhizomes where plant. (every data point represents the mean value of three replicate samples)](image)

Heavy metal concentrations for the rhizomes from which Plant grew are shown in Fig 2. Plant tissue metal contents for stems, leaves and soil are reported in Fig 3, 4, and 5, respectively. The total metal concentrations in soils and plants from each site were all nearly 100-fold higher than in the control samples (site 6).

As expected, those sections which contained higher levels of heavy metals in the soil also showed to have higher heavy metal uptake by the various parts of Plant the highest levels of heavy metals found in various tissues of creosote were in conflict with the expected values. Particularly, because site 1 was located within the closest proximity to the suspected...
plants. Minimum values are consisted of control station. The remote areas which are not influenced by the traffic and textile samples near the plants. Control samples were taken from roadside were found to be higher than those of soil by acid. In general, heavy metal levels in the soil samples much higher at that site.

Heavy metal levels in the analysed samples are given in Table II. All metal concentrations were determined on digest by acid. In general, heavy metal levels in the soil samples taken from roadside were found to be higher than those of soil samples near the plants. Control samples were taken from remote areas which are not influenced by the traffic and textile plants. Minimum values are consisted of control station. The lead concentration in the samples increased with increasing traffic volume.

### Table I

**OBSERVED AND CERTIFIED VALUES (µG/G) OF ELEMENTAL CONCENTRATIONS IN SRM (GBW 08303 POLLUTED FARMLAND SOIL) AS AVERAGE±S.D.**

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>CERTIFIED VALUE</th>
<th>OBSERVED VALUE OF DIGESTION</th>
<th>RECOVERY (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>110±5.5</td>
<td>118±5.7</td>
<td>95</td>
</tr>
<tr>
<td>Pb</td>
<td>83±4.1</td>
<td>70±4.2</td>
<td>96</td>
</tr>
<tr>
<td>Zn</td>
<td>230±9.8</td>
<td>252±10</td>
<td>95</td>
</tr>
<tr>
<td>Cd</td>
<td>1.15±0.05</td>
<td>1.14±0.05</td>
<td>98</td>
</tr>
</tbody>
</table>

### Table II

**CONCENTRATION OF HEAVY METALS IN SOIL SAMPLES COLLECTED FROM PATHUMTANI PROVINCE, THAILAND**

<table>
<thead>
<tr>
<th>SITE</th>
<th>SOIL</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
<th>Cd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CONTROL</td>
<td>6.21±0.21</td>
<td>14.5±1.1</td>
<td>41.5±2.4</td>
<td>0.28±0.02</td>
</tr>
<tr>
<td>2</td>
<td>NEAR ROADSIDE 1</td>
<td>39.2±1.5</td>
<td>46.2±3.4</td>
<td>62.1±5.2</td>
<td>1.51±0.11</td>
</tr>
<tr>
<td>3</td>
<td>NEAR ROADSIDE 2</td>
<td>29.1±0.3</td>
<td>21.4±1.5</td>
<td>61.2±6.1</td>
<td>4.31±0.28</td>
</tr>
<tr>
<td>4</td>
<td>NEAR ROADSIDE 3</td>
<td>6.21±0.21</td>
<td>14.5±1.1</td>
<td>41.5±2.4</td>
<td>0.28±0.02</td>
</tr>
<tr>
<td>5</td>
<td>NEAR TEXTILE PLANTS 1</td>
<td>39.2±1.5</td>
<td>48.5±3.4</td>
<td>62.1±5.2</td>
<td>1.51±0.11</td>
</tr>
<tr>
<td>6</td>
<td>NEAR TEXTILE PLANTS 2</td>
<td>29.1±0.3</td>
<td>21.4±1.5</td>
<td>61.2±6.1</td>
<td>4.31±0.28</td>
</tr>
</tbody>
</table>

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Clearly, Plant takes up heavy metals from the soil. It is unclear though whether the plant has evolved to adapt to the high concentrations of heavy metals or if the bushes already possess the capability of being planted under these contaminated conditions and still grow to maturity. Plants are known to have at least two defense mechanisms whereby they are able to incorporate metals into their tissues and continue to survive. In response to the toxic elements, plants can synthesize metalchelating proteins called metallothioneins. Another mechanism which may account for the accumulation of heavy metals in plants is the synthesis of phytochelatins, as suggested by Rauser.

Various other mechanisms have also been suggested regarding where the heavy metals are compartmentalized. Plants can also tolerate heavy metal contaminates by excluding the metals from sensitive sites, changing the metabolic pathways to prevent damage, or by synthesizing enzymes that would detoxify the heavy metals. Detrimental effects of heavy metals on plants have also been found to prevent the uptake of valuable nutrients such as potassium and...
phosphorus. All of these parameters regarding the effects of heavy metals in relation to Plant will require further investigation.

The mean concentrations of metals in plant samples were generally similar to those found in other studies [19-23]. The fact that toxic metals are present in high concentrations in the fruiting bodies of fungi, from an area greatly favoured by plants, is of particular importance in relation to the FAO/WHO [24] Standards for Pb and Cd as toxic metals. The maximum permissible dose for an adult is 3 mg Pb and 0.5 mg Cd per week, but the recommended doses are only one-fifth of those quantities.

Further studies will involve utilizing appropriate analytical techniques to investigate the nature of the binding mechanism as well as the chemical functional groups responsible for the binding or uptake. For example, Environmental Scanning Electron Microscopy (ESEM) studies, in conjunction with X-ray Energy Dispersive Spectroscopy (EDS), will be undertaken to examine any noticeable morphological changes as a result of the incorporation of heavy metals in the tissues of the creosote bush. The future investigation of examining the molecular and structural characteristics which control the metal ion affinity and specificity in creosote bushes will ultimately aid in establishing our ability to selectively modify the metal binding properties. As a result, the biomaterials’ metal scavenging abilities can be substantially enhanced.

IV. CONCLUSIONS

Creosote bush plants have succeeded in demonstrating the ability to uptake heavy metals such as copper and lead from contaminated soils. The metal concentrations in the plant are dispersed throughout the rhizomes, leaves, and stems with the highest concentration found in the rhizomes. As expected, the higher the contaminant soil concentration, the higher the metal uptake by the various parts of Plant These data demonstrate the potential of phytoremediation via creosote bush as a low-cost, effective means of removing heavy metals from contaminated soils. The nature of the chemical groups that are responsible for the binding of the metals, however, is not fully understood and will be the purpose of further investigation.

REFERENCES


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2. Determination of the Content of Hazardous Heavy Metals on Curcuma longa Grown around a Contaminated Area
3. Determination of Heavy Metals in Thai Herbal Plants
4. Determination of Heavy Metals Concentrations in Soil and Plant Samples by Inductively Coupled Plasma-Optical Emission Spectrometry
5. Herbal Extract of Efficiency For Metal Reduced From Vegetables Washing Water
6. Contamination of Microbial in Thai Traditional Medicines