Heavy metal toxicity: Industrial Effluent Effect on Groundnut (Arachis hypogaea L.) Seedlings


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Abstract: Heavy metals are important environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, and environmental reasons. Arachis hypogaea was grown in pots for a period of 30 days where the soils were treated with different effluent concentrations (25, 50, 75 and 100%) collected near an industrial area and a control was carried out. The distribution of heavy metals in the soils and corresponding accumulations in the experimental crop was investigated on different experimental days 10, 15, 20, 25 and 30th day. The metals Cr, Cu, Mn, Fe, Co, Ni, Pb, Cd and Zn in plants and soil samples were analyzed by AAS technique. In Arachis hypogaea plants Fe was high in 100% effluent at 10, 15, 20, 25th days. It has been observed that at 25% effluent concentration, there is growth in the root length, an increase in shoot length, germination percentage, Chl a, chl b, total chlorophyll content in Arachis hypogaea L. chlorophyll content have increased upto the 20th day (2.929, 1.607, 4.536 mg/g.fw) and then decreased from 25th day (1.670, 0.832, 2.149 mg/g. fw) onwards.

Key words: AAS, chlorophyll, effluent, heavy metals, arachis hypogaea

INTRODUCTION

The problem of environmental pollution on account of essential industrial growth is, practical terms, the problem of disposal of industrial water, whether solid, liquid or gaseous. All three types of wastes have the potentially of ultimately polluting water. Polluted water, in addition to other effects, directly effects, soil not only in industrial areas but also in agricultural fields, as well as the beds of rivers, creating secondary sources of pollution

Use of industrial effluent and sewage sludge on agricultural land has become a common practice in India as a result of which these toxic metals can be transferred and concentrated into plant tissues from the soil. These metals have damaging effects on plants themselves and may become a health hazard to man and animals. Above certain concentrations and over a narrow range, the heavy metals turn into toxins.

In addition to providing large quantities of water, some effluents contain considerable amount of essential nutrients which may prove beneficial for plants. Although some work has been done on the performance of various crops irrigated with the effluent discharged from various sources, have suggested the recycling of alcohol, chemical industries and sago factory effluents for its fertilizer value.

MATERIALS AND METHODS

Study Site: A Rithwik energy systems (biomass power plant) is situated in Chittoor district at a distance of 35 Km from Tirupati, Andhra Pradesh, India. The climate is subtropical which seasonal rainfall during June to October. The plant capacity is 6 MW. About the site of Rithwik biomass power plant North longitude 13º 41’ 23.7”. East longitude is 79º 26 ’ 41.8”, altitude 80m, annual average temperature minimum 12º to 14º C , maximum 36º C and annual rainfall 935m.

Effluent Analysis: An effluent sample was collected during March, 2005 (peak hours) from outlets of (biomass power plant) Rithwik energy systems situated at Rachagunneri, Chittoor district, Andhra Pradesh. Effluent sample was collected in well cleaned polythene bottle. Before collection each bottle was washed with fresh water. Finally bottle was tightly closed. After filtering the pH, Electrical conductivity (EC) of the sample was immediately measured in the laboratory and afterwards the samples were stored at 4°C for physicochemical analysis, methodology of was followed.
Collection of Seeds: Sandy Clay Loam soil near Rithwik power plant collected and used for pot culture. The seeds of Arachis hypogaea were obtained from Agriculture College, Tirupati and treated with 0.2 N mercuric chloride for 2 minute and washed with running water to remove contamination of seed coat, prior to germination studies. This experiment carried out with Arachis hypogaea using different concentrations of effluent 25, 50, 75, 100% and distilled water which served as control. Each treatment including control was performed in triplicate and in every pot 10 seeds were used. The number of seeds germinated in each treatment was recorded on 10, 15, 20, 25 and 30th days of the experiment and the germination percentage was calculated.

Plant Growth and Estimation of Chlorophyll: Growth of the root and shoot length were measured with the help of meter scale and chlorophyll content estimated following the method of Arnon[5] using UV-UIS spectrophotometer 117 model.

Soil Analysis: Soil samples were dried at 70°C in the laboratory oven. To 1 gm sample, 8 ml conc. HCl and 2 ml conc.HNO3 were added and kept for over night at 35°C. Digestion was done according to the method of McGrath and Cunliffe[49]. After dilution and filtration the digested solution was analysed for determination of Cr, Cu, Mn, Fe, Co, Ni, Cd, Pb and Zn by AAS.

Plant Analysis: The total plants were carefully washed with deionized water and oven-dried at 70°C in the laboratory. Powdered plant samples (whole plant, 1 gm) were digested with 5ml diacid mixture, nitric acid (HNO3) : perchloric acid (HClO4) in the ratio of 3:2 at 110°C for 8 hours. Then distilled water was added to the digested samples to make up the volume to 50 ml and then filtered by Whatman-42 filter paper[43]. The samples were ready for elemental analysis by AAS.

Data Analysis: Data were expressed as Mean ±Standard error of mean (S.E.M.S). Results were statistically analyzed by student’s test[43].

RESULTS AND DISCUSSIONS

Results:
Physico-chemical Characters and Metals in Effluent: The physicochemical characteristics of effluent are presented in table 1. Effluent is colour is white and odorless. pH is 8.5, EC (Electrical Conductivity) 11.511µmos/cm these values are compared to ISI (Indian Standard Institution) standards recommended for disposal of effluent on land for not suitable to irrigation purpose. Total suspended solids, Total dissolved solids values are 611±11.79, 651.33±3.28. BOD (Biological Oxygen Demand) value is 53.6±0.28; COD (Chemical Oxygen Demand) value is 128.66±0.28. Chromium is 0.071±0.0.003, copper 0.014±0.0.002, manganese 0.035±0.002, Iron 0.050±0.001, cobalt 0.311±0.02, nickel 0.041±0.0.004, cadmium 0.028±0.002, lead 0.108±0.002, zinc 6.73±0.120. Copper, manganese, iron, nickel these are metal concentrations in effluent below limits compared to ISI standards. Remaining metals like chromium, cobalt, cadmium, lead and zinc these metals values are compared to ISI standards not suitable for irrigation.

Heavy Metals Effects on Growth and Chlorophyll: In Arachis hypogaea the percentage of seed germination on exposure of different concentrations and duration (120 and 192 hrs) was recorded in Table 2. The maximum seed germination was recorded at 25% and minimum at 100% of effluent concentrations, as compared to control. At 25% of effluent concentration, increase in root and shoot length at 30th day as compared to control. (Table 3, 3.1) Where as at 100% of effluent concentration decrease in length of root and shoot was recorded at 10, 15, 20, 25 and 30th days. Data of chlorophyll content at different duration of exposure and concentration of effluent represented in Table 4, 4.1, 4.2. At 25% of effluent concentration, increase in chlorophyll a, b and Total chlorophyll contents increased (2.929, 1.607, 4.536mg g-1 fwt) up to 20th day and decreased from 25th day (1.670, 0.832, 2.149mg g-1 fwt) onwards in Arachis hypogaea. At 100% effluent concentration over all decrease in chlorophyll content was recorded at all intervals as compared to control.

Heavy Metals in Soils: Metals in Arachis hypogaea soils (Fig 1-9) Co, Ni, Pb and Zn (8.123, 8.013, 4.868, 6.132 mg/g) were high in 100% effluent at 10th day, on 15th day Cu and Zn (4.816, 2.015) were high. 20th day Cr, Cu, Mn, Fe, Co, Ni, Cd and Pb (1.082, 3.141, 5.269, 31.031, 1.906, 2.011, 1.127, 2.994) mg/g were high in 50% effluent. Cr, Cu, Mn, and Zn (0.299, 2.827, 6.603, 0.192) mg/g were high in 50% effluent on 25th day. Cu, Mn, Fe, Co, Ni, Cd, Pb, and Zn (2.885, 8.239, 11.311, 1.030, 1.138, 1.099, 4.129, 2.020 mg/g) in 100% effluent.

Heavy Metals in Plants: Metals in Arachis hypogaea plants (Fig 1-9) Fe was high in 10 and 15th days in 100% effluent (937.32, 780.47), in 20th day Cr, Mn, Fe, and Pb (11.872, 99.601, 899.81, 110.36 mg/g) were high in 100% effluent. On 25th day all metals increased with 100% effluent. Cr and Pb were (56.241, 1071) high in 100% effluent at 30th day.
fauna. Inhibition of seed germination may be due to conditions for free metal availability to flora and properties of receiving water systems, which create Discussion: The higher EC alter the chelating properties of receiving water systems, which create conditions for free metal availability to flora and fauna. Inhibition of seed germination may be due to high level of dissolved solids. Which enrich the salinity and conductivity of the absorbed solute by seed before germination, Murkumar and Chauhan have reported that the higher concentration of effluent decrease
enzyme dehydrogenase activity that is considered as one of the biochemical change which may have disrupt germination and seedling growth. Studies on heavy metal tolerance in plants indicate that root growth is particularly sensitive to heavy metals\(^1\). Copper toxicity affected the growth of Alyssum montanum\(^43\) and Brassica juncea\(^43\).

Copper and Cd in combination have affected adversely the germination, seedling length, and number of lateral roots in Solanum melongena\(^41\). Reduction in root growth due to heavy metals has also been reported in wheat seedlings\(^43\). The number of leaves and branches, root and shoot length and biomass decreased as concentration of Cr increased in egg plant and tomato\(^40\) and in barley\(^41\).

Presence of Zn at higher concentrations retarded the growth and development of plants by interfering with certain important metabolic processes\(^2\). Heavy

### Table 2: Germination percentage of Arachis hypogaea in control and biomass power plant effluent at different time intervals

<table>
<thead>
<tr>
<th></th>
<th>120hrs</th>
<th>192hrs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.66±0.333</td>
<td>2.66±0.333</td>
<td>8.33±0.333</td>
</tr>
<tr>
<td>25%</td>
<td>6.33±0.333*** (11.752)</td>
<td>3.33±0.333*** (24.971)</td>
<td>9.66±0.333*** (16.008)</td>
</tr>
<tr>
<td>50%</td>
<td>5.33±0.333*** (-5.893)</td>
<td>2.33±0.333*** (-12.523)</td>
<td>7.66±0.333*** (-7.992)</td>
</tr>
<tr>
<td>75%</td>
<td>4.33±0.333*** (-23.539)</td>
<td>2.33±0.333*** (-12.523)</td>
<td>6.66±0.333*** (-19.992)</td>
</tr>
<tr>
<td>100%</td>
<td>3.0±1.0*** (-52.629)</td>
<td>2.33±0.333*** (-41.619)</td>
<td>5.33±1.667*** (-36.001)</td>
</tr>
</tbody>
</table>

Values are arithmetic mean ± SEM of three replicates

*p<0.01, **p<0.001, ***p<0.0001, ns- non significant

Values in parentheses are representing % change from control

### Table 3: Root length of Arachis hypogaea at different time intervals exposed to biomass power plant effluent (mg g⁻¹ fwt)

<table>
<thead>
<tr>
<th></th>
<th>10th day</th>
<th>15th day</th>
<th>20th day</th>
<th>25th day</th>
<th>30th day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.8±0.17</td>
<td>5.5±0.20</td>
<td>6.4±0.20</td>
<td>7.6±0.08</td>
<td>8.7±0.27</td>
</tr>
<tr>
<td>25%</td>
<td>5.5±0.17** (13.683)</td>
<td>6.3±0.12* (13.153)</td>
<td>7.1±0.11** (10.937)</td>
<td>8.1±0.14** (6.550)</td>
<td>9.3±0.06** (6.870)</td>
</tr>
<tr>
<td>50%</td>
<td>4.5±0.20* (-6.862)</td>
<td>5.2±0.20** (-5.454)</td>
<td>6.1±0.14** (-3.640)</td>
<td>6.8±0.34** (-10.913)</td>
<td>7.8±0.14** (-9.916)</td>
</tr>
<tr>
<td>75%</td>
<td>3.8±0.17* (-21.245)</td>
<td>4.6±0.21** (-15.763)</td>
<td>5.2±0.17** (-23.076)</td>
<td>6.3±0.26* (-16.585)</td>
<td>6.8±0.23** (-21.756)</td>
</tr>
<tr>
<td>100%</td>
<td>2.8±0.20* (-41.093)</td>
<td>3.9±0.08* (-28.490)</td>
<td>4.8±0.05* (-24.846)</td>
<td>5.7±0.28* (-20.527)</td>
<td>6.0±0.08* (-18.946)</td>
</tr>
</tbody>
</table>

Values are arithmetic mean ± SEM of three replicates

*p<0.01, **p<0.001, ***p<0.0001, ns- non significant

Values in parentheses are representing % change from control

### Table 3.1: Shoot length of Arachis hypogaea at different time intervals exposed to biomass power plant effluent (mg g⁻¹ fwt)

<table>
<thead>
<tr>
<th></th>
<th>10th day</th>
<th>15th day</th>
<th>20th day</th>
<th>25th day</th>
<th>30th day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.5±0.17</td>
<td>10.3±0.3</td>
<td>13.7±0.26</td>
<td>18.6±0.6</td>
<td>20.9±0.52</td>
</tr>
<tr>
<td>25%</td>
<td>4.1±0.11** (16.04)</td>
<td>10.9±0.26** (5.141)</td>
<td>15.8±0.17** (15.328)</td>
<td>20.2±0.24** (8.586)</td>
<td>21.7±0.35** (3.984)</td>
</tr>
<tr>
<td>50%</td>
<td>2.8±0.05** (-20.742)</td>
<td>7.9±0.38* (22.899)</td>
<td>13.0±0.11** (-5.109)</td>
<td>16.3±0.26* (-12.52)</td>
<td>18.5±0.20** (-11.465)</td>
</tr>
<tr>
<td>75%</td>
<td>2.0±0.05** (-43.39)</td>
<td>6.3±0.25* (-39.23)</td>
<td>12.1±0.25* (-11.678)</td>
<td>14.9±0.12* (-19.674)</td>
<td>16.9±0.12* (-18.946)</td>
</tr>
<tr>
<td>100%</td>
<td>1.5±0.14* (56.609)</td>
<td>5.7±0.20** (44.371)</td>
<td>10.6±0.20* (-29.245)</td>
<td>13.5±0.3*** (-37.685)</td>
<td>14.8±0.55* (-29.298)</td>
</tr>
</tbody>
</table>

Values are arithmetic mean ± SEM of three replicates

*p<0.01, **p<0.001, ***p<0.0001, ns- non significant

Values in parentheses are representing % change from control
Fig. 1: Chromium concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.

Fig. 2: Copper concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.

Fig. 3: Manganese concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.
Fig. 4: Iron concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.

Fig. 5: Cobalt concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.

Fig. 6: Nickel concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.
Fig. 7: Cadmium concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.

Fig. 8: Lead concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.

Fig. 9: Zinc concentrations in soil and Arachis hypogaea at different concentrations and time intervals. Values are arithmetic mean of three replicates.
**Table 4.1:** Change in Chlorophyll b content of Arachis hypogaea at different time intervals exposed to biomass power plant effluent (mg g⁻¹ fw).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>10th day</th>
<th>15th day</th>
<th>20th day</th>
<th>25th day</th>
<th>30th day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.825±0.054</td>
<td>1.183±0.047</td>
<td>1.194±0.015</td>
<td>0.607±0.086</td>
<td>0.589±0.044</td>
</tr>
<tr>
<td>25%</td>
<td>1.012±0.018** (22.666)</td>
<td>1.237±0.003** (83.564)</td>
<td>1.607±0.042** (34.589)</td>
<td>0.837±0.025* (37.891)</td>
<td>0.815±0.001* (38.370)</td>
</tr>
<tr>
<td>50%</td>
<td>0.552±0.039* (-33.090)</td>
<td>0.791±0.022* (-33.116)</td>
<td>0.926±0.0017** (-22.445)</td>
<td>0.371±0.034* (-38.269)</td>
<td>0.270±0.014* (-54.159)</td>
</tr>
<tr>
<td>75%</td>
<td>0.547±0.009* (-35.092)</td>
<td>0.532±0.030* (-53.092)</td>
<td>0.560±0.022** (35.092)</td>
<td>0.229±0.0046* (-54.269)</td>
<td>0.223±0.034* (-54.411)</td>
</tr>
<tr>
<td>100%</td>
<td>0.437±0.005* (-47.030)</td>
<td>0.439±0.045** (-62.890)</td>
<td>0.454±0.020** (-66.976)</td>
<td>0.099±0.023* (-85.690)</td>
<td>0.071±0.019** (-87.945)</td>
</tr>
</tbody>
</table>

Values are arithmetic mean ± SEM of three replicates

*p<0.01, **p<0.001, ***p<0.0001, ns- non significant

Values in parentheses are representing % change from control

**Table 4.2:** Change in Total chlorophyll content of Arachis hypogaea at different time intervals exposed to biomass power plant effluent (mg g⁻¹ fw).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>10th day</th>
<th>15th day</th>
<th>20th day</th>
<th>25th day</th>
<th>30th day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.052±0.079</td>
<td>3.583±0.032</td>
<td>4.017±0.082</td>
<td>1.811±0.111</td>
<td>1.514±0.023</td>
</tr>
<tr>
<td>25%</td>
<td>2.456±0.063** (19.688)</td>
<td>4.221±0.037** (17.806)</td>
<td>4.536±0.049** (12.920)</td>
<td>2.447±0.043* (35.118)</td>
<td>2.149±0.017*** (41.941)</td>
</tr>
<tr>
<td>50%</td>
<td>1.646±0.064* (-19.785)</td>
<td>2.804±0.030** (-21.741)</td>
<td>3.266±0.056* (-18.695)</td>
<td>1.384±0.064* (-23.578)</td>
<td>1.246±0.030* (-17.701)</td>
</tr>
<tr>
<td>75%</td>
<td>1.540±0.046* (-24.951)</td>
<td>2.356±0.051*** (-34.245)</td>
<td>2.804±0.057* (-30.196)</td>
<td>1.053±0.064* (-41.855)</td>
<td>0.865±0.064** (-42.866)</td>
</tr>
<tr>
<td>100%</td>
<td>1.410±0.048* (-31.286)</td>
<td>1.959±0.094** (-44.320)</td>
<td>2.586±0.059** (-35.623)</td>
<td>0.898±0.050* (-50.414)</td>
<td>0.612±0.052** (-59.577)</td>
</tr>
</tbody>
</table>

Values are arithmetic mean ± SEM of three replicates

*p<0.01, **p<0.001, ***p<0.0001, ns- non significant

Values in parentheses are representing % change from control

Metal induced reduction in total chlorophyll has been reported in pigeon pea due to Cd and Ni stress[43], and in Brassica juncea due to Cd stress[43]. Reduction in chlorophyll content due to its degradation and unfavorable effect on photosynthetic electron transport have been reported due to copper toxicity in sensitive species of Silene compacta and Thalpsi ochrulucum[44]. Nickel also reduced the total chlorophyll content leaves of plants that grow in presence of its inorganic forms in Phaseolus vulgaris[39] and organic form in cabbage leaves[36]. Nickel reduces photosynthetic activity of plants[33,30]. Zn and Cd both inhibited photosynthetic CO₂ fixation and Hill reaction activity of isolated spinach chloroplasts[12]. Cr toxicity is known...
to affect seed germination, seedling growth, senescence, pigment status and nutrient contents of crop plants\footnote{13}.

Accumulation of metals in root from soil and subsequent translocation to other parts of plants like stem, leaves and fruits is important for the selection of plant specially crops and vegetables. Plant accumulating least quantity of metals in edible parts, with the concentration within the permissible limit than the verity of species can be selected for the cultivation on the field having high level of metal contamination\footnote{19}.

In Arachis hypogaea soil metal concentration on 10\textsuperscript{th} day Co, Ni, Pb, and Zn were high in 100\% effluent, Cu is high in 50\%, Co is high in 75\%, and Cd is high in 25\% effluent concentrations.Cu and Zn were high in 100\%, Mn, Ni, Cd, and Pb were high in 25\% and Co is high in 50\% effluent concentrations on 15\textsuperscript{th} day. On 20\textsuperscript{th} day all metals increased with 50\% effluent. Cr, Cu, Mn, Fe, and Zn were high in 50\% effluent, Co and Cd high in 75\% effluent on 25\textsuperscript{th} day. Cu, Fe, Co, Ni, Cd, Pb, and Zn were high in 100\%, Mn is high in 25\% effluent concentrations on 30\textsuperscript{th} day.

In Arachis hypogaea plants Fe was high in 100\% effluent at 10, 15, 20, 25\textsuperscript{th} days except 30\textsuperscript{th} day. Cr, Cu, Co, Ni, Cd, and Pb were high in 50\% effluent. Mn, and Zn were high in 75\% effluent concentrations at 10\textsuperscript{th} day. Cr, Cu, Mn, Co, Ni, Cd, and Pb were high in 75\% effluent concentration Zn is high in 50\% effluent concentration on 15\textsuperscript{th} day. On 20\textsuperscript{th} day Cr, Mn, and Fe were in 100\% effluent, Cu, Cd, Co, Ni, Pb, and Zn were high in 75\% effluent concentration. Metal accumulation (Cr, Cu, Mn, Fe, Co, Ni, Cd, Pb, and Zn) increasing 100\% effluent concentration at 25\textsuperscript{th} day. Cr and Pb in 100\% effluent Cu, Co, Ni, and Zn were high in 50\% effluent Mn is high in 75\% effluent concentrations on 30\textsuperscript{th} day.

In contrast, plants accumulating high concentration of heavy metals from contaminated soil can be used for detoxification phytoremediation of metals from soil or growing medium. The accumulation of heavy metal from soil to plant parts did not follow any particular pattern and varied with respect to metals, species and plant parts.

The metal content in the cultivated soil irrigated with contaminated water was found to be either below or with in the typical back ground values as suggested by Bowen\footnote{14} except for Cd, Pb and Ni.

The concentration of metals especially Cd, Pb, Cr and Ni are much higher in heat and mustard and may exceed the average normal concentration reported by others and are beyond human consumption level. This may create health problems in the long run. The average normal concentration of Cd is 0.05\mu g/g\footnote{19} Pb is 0.01 to 1.0 \mu g/g\footnote{60}. Cr and Ni are 60 and 250 \mu g/g respectively\footnote{61}.

In excess concentration, the ill effects of Co on plants indirectly lower the concentration of essential nutrients, decrease photosynthesis, reduce intercellular spaces, and disturb the structural integrity of chloroplasts and carbohydrate metabolism\footnote{31}. The activity of several enzymes, including Fe-containing enzymes, is disturbed by excessive amounts of Co within the plants\footnote{16}.

Cadmium is one of the most dangerous heavy metals due to its high mobility and the small concentration at which its effects on plants begin to show\footnote{9}. Jarvis\footnote{24} found that the roots of lettuce released much more of their absorbed Cd for translocation to the shoots than other crops (ryegrass and orchard grass). Overnell\footnote{25} reported that (0.01 to 0.1 mg liter \textsuperscript{-1}). Cadmium reduced the concentration of ATP and chlorophyll in many species, and decreased oxygen production.

Lead has been shown to accumulate in plants from several sources including soil but the reports on accumulations of the metal with in plants are variable\footnote{17,22}. Holl and Hampp\footnote{21} have concluded that Pb is partially deposited on the surface and partially in incorporated into the tissue because the total Pb content showed a correlation with the leaf area. Large differences in Pb deposition have been reported in different plant species\footnote{17}.

Zn is an essential nutrient for plant growth, although elevated concentrations resulted in growth inhibition and toxicity symptoms. It does not affect seed germination but helps in plume and radicle development. Baker\footnote{3} reported that the seeds silene maritima were germinated better and rapidly on calcium nitrate solutions containing different concentration of zinc, at higher concentrations inhibiting root growth.

A number of studies have reported that oxidative stresses of increasing (Copper) affect mitotic activity and cell division of roots, with a subsequent decrease in growth or cellular death by necrosis\footnote{91}. Copper toxicity induces leaf chlorosis through degradation of photosynthetic components\footnote{78}.

Manganese is an essential microelement for most living organisms, and plays an important role in oxygen photosynthesis\footnote{33}. The tolerance to excess of this component varies characteristically with plant species and with cultivars with in these species\footnote{20}.

Nickel is considered an essential micronutrient for plants\footnote{3}, but is strongly phytotoxic at higher concentrations and has a destructive effect on growth, mineral nutrition, photosynthesis and membrane function\footnote{32}.

Chromium is essential for normal carbohydrate and lipid metabolism and improves insulin function. Furthermore Cr levels higher than 5.0 mg/g in plant.
species are considered excessive or toxic on a dry weight basis[28]. However, excessive concentrations of Fe have also been reported to be toxic to the plants[52].

The concentrations of nine metals in soils were the similar in plants, this result meant the concentrations of heavy metal in soils should have effect on the concentrations in plants. The reason maybe due to the fact that total concentrations of nine heavy metals in soils were affected by many factors, and influenced the concentrations in plant indirectly. Selecting different extract solution to get different part concentrations of heavy metals necessary, which could find direct factor that affect the concentration of plant[51, 13].

Plants maintain metals at relatively low concentrations with in plants by avoiding excessive metal uptake and transport[15, 46]. The mechanisms include chelation, compartmentalization, biotransformation, and cellular repair mechanisms[12, 21].

Accumulation and exclusion were two basic strategies by which plants respond to elevated concentration of heavy metals[39]. Hyper accumulators respond to heavy metals by employing the strategy of accumulation and sequestration of metals. Plants have an extremely high capacity to take up metals by roots and translocate and store them in the shoot[8, 35, 46].

Conclusions: This is an important work for phytoremediation of soil polluted by heavy metals. However, this work is complex and interdisciplinary, study on soil characteristic, the mechanism of plants to accumulate heavy metals, interaction between plant and soil, hence it may be suggested that nutrients available in 25% in biomass power plant effluent and it may be used as a suitable liquid fertilizer. It will reduce the quantity of water required for irrigation and help in water conservation and provide nutrients to the field and plants. Proper care should be taken in disposal of biomass power plant effluent to avoid soil pollution.

REFERENCES

Communications of soil science and Plant analysis, 35: 255-265.


