DISPERSION PATTERN OF TRACE METALS FROM SOIL TO LEAVES IN TEA GARDENS OF ASSAM, INDIA

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ABSTRACT
In the present study, five tea gardens located along National Highway-37, Assam were selected for collection of soil (0-15cm) and leaf samples. Four samples were collected from each tea garden at different distances from the road to examine possible contamination from vehicular traffic. Present study has been aimed at determining the level of heavy metals in the tea garden soils and the dissipation pattern of metals from soil to leaves. Results obtained revealed the decrease of metal concentration in soil with the increase of distances from the road, which indicates contamination of soil from vehicular traffic. Contamination Factor (Cf) was calculated using background values as baseline to assess the contamination level of soil with trace metal, which indicates moderate contamination in most of the cases and considerable contamination in few cases. Transfer Factor (TF) was calculated to investigate the dissipation pattern of metals from soil to leaves. Calculated Transfer Factor (TF) indicates the higher dissipation for Cu, Zn and Mn and lower dissipation for the toxic Pb, Cr and Ni. Comparison was also attempted with the background samples and some international maximum permissible limits.

Key Words: Contamination factor, Heavy metal, Tea garden soil, Tea leaves, Transfer factor

ABBREVIATIONS
WHO- World Health Organization
EU- European Union
ICRCL- Inter Departmental Committee for the Redevelopment of Contaminated Land

INTRODUCTION
Soil and water are two vital functions for human civilization. For food production, we have to rely on these two elements. So, protection of these two elements is the need of the hour. To meet the growing demand of food items with the explosion of population, we have to depend on inorganic fertilizer and pest control. In addition, irrigation, monoculture and plant genome modification are also unavoidable techniques in both modern and conventional agriculture. Increasing rely on these elements has increased the production upto many times but simultaneously degradation of both soil and water takes place1. Rapid urbanization, industrialization and automobile traffic also contribute to soil degradation. Once the soil is contaminated by heavy metal it persists for long time because it is not easily biodegradable.

Importance of agricultural soil quality assessment especially with respect to heavy metal is increasing globally now-a-days. Deterioration of soil has toxic effect on food quality, due to uptake of metals by plants. Ultimately toxicity is transmitted to human and other living organism through food chain. Toxic effect of heavy metal in human body is well known. Heavy metal can accumulate in human body and impair some important biochemical functions and also responsible for some lethal disease like kidney failure, liver failure, leukemia, reproductive disorders etc.2 Assam is renowned worldwide for tea, which is one of the major industries in Assam, India. The specific taste and aroma make tea (Camellia sinensis) as the most popular non alcoholic beverage in the world. Anticarcinogenic, antioxidative and antimutagenic activi-
ties of tea make it a healthy and beneficial drink for human. Drinking tea is the source of some essential nutritional elements. It also prevents cardiovascular disease. But the presence of some non essential toxic heavy metals in tea becomes a matter of concern. The most probable source of these heavy metals is the uptake from soil through root.

Though tea grows in entire Assam, most of the tea gardens are located in Upper Assam. The pH of Assam soil is mainly acidic (4.0-5.5) which is suitable for tea production. To increase the production, large amounts of inorganic fertilizers are applied in the tea garden soil. Now-a-days some tea gardens are introducing the use of organic fertilizer, but still now most of the tea gardens are relying on inorganic manure which contains sufficient amount of heavy metals.

In the roadside tea gardens, automobile traffic is the another source for soil contamination with trace metals. Specially, the dangerous Cd and Pb are the major metal contaminants for the roadside soil which are released due to the burning of fossil fuel, wearing of tyres, brake linings, leakage of lubricants, corrosion of batteries and metallic parts etc.

In the present study, it has been investigated any possible inputs of heavy metal from automobile pollution as the tea gardens are positioned along National Highway-37. Usually, crops uptake heavy metals in acidic soil. Since tea plant grows in acidic soil and soil becomes more acidic after its plantation, accumulation of heavy metal is obvious in tea leaves. So, soil quality management of tea garden is utmost necessary.

AIMS AND OBJECTIVES

The determination of heavy metal concentration in tea garden soil and assessment of the dissipation of metals from soil to tea leaves.

MATERIAL AND METHODS

Study area

Five roadside tea gardens located in Golaghat and Jorhat district of Assam, India were selected as the study area. All the five tea gardens viz. Borchapori T.E. (T1), Badulipara T.E.(T2), Rangamatty T.E.(T3), Negheriting T.E.(T4) and Socklatinga T.E.(T5) are situated along National highway-37. The study area is located from 26°38′32″ to 26°43′49″ N Latitude and 93°41′20″ to 94°42′27″ E Longitude (Fig. 1). The study area is on the South of the Brahmaputra river. The climate of the region is sub tropical monsoon type with mild winter and warm summer with high humidity.

Fig. 1 : Map showing the study area
Available nitrogen in tea garden soil was determined by Kelpus- Classic DXVA automatic nitrogen analyzer. The total potassium content was determined by using a flame photometer (ESICO, Model-1385).

For leaf samples, total nitrogen content was analyzed by using CHN analyzer (Model NO-LECO CHN 628). Crude protein content in leaf samples was determined by multiplying the total nitrogen value by a factor 6.25.\footnote{14}

For analysis of metal, the soil samples were digested with 3:1 (v/v) nitric acid: perchloric acid mixture.\footnote{15} After digestion, the samples were filtered through Whatman-42 filter paper to obtain a clear solution. The volume of the filtrate was made up to 50 ml in a volumetric flask. The filtrate was stored in a polypropylene bottle prior to total metal analysis by Atomic Absorption Spectroscopy (SHIMADZU AA-7000).

For analysis of metal content, leaf samples were first rinsed with distilled water and dried completely in air. After that leaf samples were burned in muffle furnace at 450\(^{\circ}\)C and finally digested with 2N HNO\(_3\) and analyzed for metal content in Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

Variation of physico-chemical parameters of tea garden soil and biochemical parameters of leaf samples

Table 1 contains physico-chemical properties of tea garden soil i.e. pH, redox potential, electrical conductivity, available nitrogen and potassium. All the values presented in the table are average of five samples from five tea gardens (T1, T2, T3, T4, T5) along with the maximum and minimum values. Distance from the road is used as variable. All the soil samples were found acidic (pH= 4.0-4.93), which is favorable for tea production and also agrees with the findings of Nath\footnote{16} and Chand et al.\footnote{4}, working on tea garden soil. Range of electrical conductivity is from 62.2 \(\mu\)S/cm upto 190.2 \(\mu\)S/cm. Range of 156.05-196.03 \(\mu\)S/cm electrical conductivity was reported by Baishya et al.\footnote{1}, in agricultural soil, which is similar to the present findings. Available nitrogen and potassium, both are the essential micronutrients for plants, are also presented in Table 1. Total organic carbon ranged from 0.96 to 2.25(\%).
Table 1: Physico-chemical properties of tea garden soil

<table>
<thead>
<tr>
<th>Sampling location</th>
<th>pH</th>
<th>Redox Potential (mV)</th>
<th>Electrical Conductivity (µS/cm)</th>
<th>Available Nitrogen (kg/hac)</th>
<th>Potassium (mg/kg)</th>
<th>Total Organic Carbon (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road edge</td>
<td>4.37*</td>
<td>129.9*</td>
<td>132.1*</td>
<td>165.9*</td>
<td>140.0*</td>
<td>1.11*</td>
</tr>
<tr>
<td>05 meter</td>
<td>4.27*</td>
<td>145.22*</td>
<td>144.3*</td>
<td>141.7*</td>
<td>127.1*</td>
<td>1.33*</td>
</tr>
<tr>
<td>10 meter</td>
<td>4.19*</td>
<td>153.2*</td>
<td>143.6*</td>
<td>134.9*</td>
<td>120.7*</td>
<td>1.24*</td>
</tr>
<tr>
<td>01 km</td>
<td>4.25*</td>
<td>155.2*</td>
<td>129.9*</td>
<td>151.1*</td>
<td>128.8*</td>
<td>1.19*</td>
</tr>
</tbody>
</table>

*Mean (n=5)

Some biochemical parameters of leaf samples i.e. moisture content, total inorganic content, nitrogen content and crude protein are presented in Table 2. Tea contains 4 to 9% of inorganic matter, which is similar to our findings.

Table 2: Biochemical parameters of leaf samples

<table>
<thead>
<tr>
<th>Sampling location</th>
<th>Moisture content (%)</th>
<th>Total inorganic content (%)</th>
<th>Nitrogen content (%)</th>
<th>Crude protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road edge</td>
<td>68.2*</td>
<td>5.57*</td>
<td>4.09*</td>
<td>25.54*</td>
</tr>
<tr>
<td>05 meter</td>
<td>67.5*</td>
<td>5.54*</td>
<td>3.99*</td>
<td>24.92*</td>
</tr>
<tr>
<td>10 meter</td>
<td>66.44*</td>
<td>5.92*</td>
<td>4.11*</td>
<td>25.69*</td>
</tr>
<tr>
<td>01 km</td>
<td>69.9*</td>
<td>4.96*</td>
<td>3.83*</td>
<td>23.94*</td>
</tr>
</tbody>
</table>

*Mean (n=5)

Distribution of heavy metals in tea garden soil and leaf samples

Heavy metal concentrations in tea garden soil and leaf samples are presented in Table 3. Values are presented at different distances from the highway i.e. at the road edge, at 05 meter, at 10 meter and at 01 km from the road. Values of five tea gardens including control samples are presented with minimum and maximum concentration. From Table 3, it has been found that the highest concentration of Cu measured at road edge is 26.12 mg/kg to 36.12 mg/kg with an average of 30.4 mg/kg and constantly decreasing when the distance from the road increases. At 05 meter from road, Cu ranges from 16.8 to 30.22 mg/kg with an average of 24.3 mg/kg. At 10 meter from the road, Cu has a concentration range 14.6-28.46 mg/kg with an average of 21.04 mg/kg. At 01 km from the road, Cu has the lowest range of concentration, which is 14.2-25.18 mg/kg with an average of 18.98 mg/kg. Other metals Zn, Ni, Pb, Cd, Co and Cr also follow the same trend i.e. decreasing trend as the
distance from the road increases. Nath has reported a similar trend for Cd, Cr, Ni, Pb on roadside tea garden soil. Swaileh et al., has also reported a similar trend for Pb, Cu and Zn on roadside soil and vegetation from the West Bank.

Table 3: Heavy metal concentration in tea garden soil and tea leaf samples

<table>
<thead>
<tr>
<th>Sample location</th>
<th>Cu (mg/kg)</th>
<th>Zn (mg/kg)</th>
<th>Ni (mg/kg)</th>
<th>Pb (mg/kg)</th>
<th>Cd (mg/kg)</th>
<th>Co (mg/kg)</th>
<th>Cr (mg/kg)</th>
<th>Mn (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road edge (soil)</td>
<td>(26.12-36.12)</td>
<td>(59.26-88.26)</td>
<td>(46.90-61.18)</td>
<td>(16.42-32.26)</td>
<td>(0.60-0.88)</td>
<td>(1.1-2.1)</td>
<td>(18.43-22.36)</td>
<td>(292.1-408.2)</td>
</tr>
<tr>
<td>05 meter (soil)</td>
<td>(16.8-30.22)</td>
<td>(50.0-68.5)</td>
<td>(35.4-47.72)</td>
<td>(15.21-30.52)</td>
<td>(0.4-0.7)</td>
<td>(0.95-2.0)</td>
<td>(18.43-19.25)</td>
<td>(215.6-290.1)</td>
</tr>
<tr>
<td>10 meter (soil)</td>
<td>(14.6-28.46)</td>
<td>(50.5-68.23)</td>
<td>(32.1-40.6)</td>
<td>(13.82-28.56)</td>
<td>(0.4-0.66)</td>
<td>(0.9-1.9)</td>
<td>(17.44-19.09)</td>
<td>(182.2-248.6)</td>
</tr>
<tr>
<td>01 km (soil)</td>
<td>(14.2-25.18)</td>
<td>(50.2-58.1)</td>
<td>(23.4-40.8)</td>
<td>(13.62-24.68)</td>
<td>(0.4-0.66)</td>
<td>(0.55-1.1)</td>
<td>(16.29-18.59)</td>
<td>(156.8-198.8)</td>
</tr>
<tr>
<td>Control (soil)</td>
<td>(6.72-10.81)</td>
<td>(41.82-46.37)</td>
<td>(8.68-15.94)</td>
<td>(1.1-10.95)</td>
<td>BDL</td>
<td>BDL</td>
<td>(1.26-2.2)</td>
<td>(654.5-720.3)</td>
</tr>
<tr>
<td>Road edge (Leaf)</td>
<td>(17.5-24.8)</td>
<td>(27.05-39.26)</td>
<td>(7.27-9.2)</td>
<td>(1.0-2.0)</td>
<td>(0.16-0.30)</td>
<td>BDL</td>
<td>(1.26-2.2)</td>
<td>(654.5-720.3)</td>
</tr>
<tr>
<td>05 meter (Leaf)</td>
<td>0.66(TF)</td>
<td>0.44(TF)</td>
<td>0.15(TF)</td>
<td>0.07(TF)</td>
<td>0.33(TF)</td>
<td>0.0(TF)</td>
<td>0.079(TF)</td>
<td>2.09(TF)</td>
</tr>
<tr>
<td>10 meter (Leaf)</td>
<td>0.70(TF)</td>
<td>0.43(TF)</td>
<td>0.18(TF)</td>
<td>0.04(TF)</td>
<td>0.31(TF)</td>
<td>0.0(TF)</td>
<td>0.078(TF)</td>
<td>2.57(TF)</td>
</tr>
<tr>
<td>01 km (Leaf)</td>
<td>0.58(TF)</td>
<td>0.43(TF)</td>
<td>0.16(TF)</td>
<td>0.024(TF)</td>
<td>0.28(TF)</td>
<td>0.0(TF)</td>
<td>0.073(TF)</td>
<td>3.11(TF)</td>
</tr>
<tr>
<td>05 meter (Leaf)</td>
<td>(10.1-18.2)</td>
<td>(20.5-30.2)</td>
<td>(2.12-7.4)</td>
<td>BDL</td>
<td>(0.04-0.13)</td>
<td>BDL</td>
<td>(1.0-1.7)</td>
<td>(135.3-708.3)</td>
</tr>
<tr>
<td>10 meter (Leaf)</td>
<td>0.75(TF)</td>
<td>0.47(TF)</td>
<td>0.13(TF)</td>
<td>0.0 (TF)</td>
<td>0.16(TF)</td>
<td>0.0(TF)</td>
<td>0.067(TF)</td>
<td>2.99(TF)</td>
</tr>
<tr>
<td>01 km (Leaf)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TF: Transfer Factor

At the road edge Pb has a range of 16.42 to 32.26 mg/kg, at 05 meter from road, it decreases up to 15.21 to 30.52 mg/kg. It further decreases to 13.82-28.56 mg/kg at 10 meter from road and at 01 km from road, it is 13.62-24.68 mg/kg. Oztas et al., reported 2 to 6 times higher concentration of Pb within 40 meter from the highway than the background level. Higher concentration of lead in the roadside soil is associated with the burning of leaded gasoline. Though leaded gasoline has been already phased out, but the retention time of lead in the environment is very high, which is almost 150 years. Corrosion of metallic parts, wear and tear of car engine and bearing metals are the causes for higher concentration of Cu in roadside soil. The source of Ni in roadside soil is combustion of diesel fuel. Zn comes to roadside soil from vehicle tyre because Zn is used as a vulcanization agent in tyres. Lube oil also contains Zn as an additive like Zinc diithophosphate. Sources of Cd in roadside soil are much less well defined than those of Pb. Lubricating oil and old tyres are the most probable source. Mn also originates from diesel exhaust. In addition to this, injudicious application of chemical fertilizer and pesticide has increased the burden of heavy metal...
in tea garden soils. From Table 3, it has been observed that heavy metal concentrations in tea garden soil are higher than the background values. When compared with some international standards, it has been observed that the tea garden soils are still below the permissible limit with respect to metal contaminants. WHO set a Maximum Permissible Limit (MPL) for Zn in agricultural soil as 200mg/kg; European Union set 140 mg/kg for Cu, 75 mg/kg for Ni, 3 mg/kg for Cd. A limit of 50 mg/kg of Pb has been set by ICRCL(1997) for agricultural soil. From our investigation, it has been observed that the studied metals are below MPL. Variation of average metal concentration in soil with respect to distance from the road is presented in Fig. 2 to Fig. 4 respectively. Variation of average metal concentration in tea leaves with respect to distance from the road is presented in Fig. 5 to Fig. 7 respectively.

Fig. 2 : Variation of Cu, Zn, Ni in tea garden soil

Fig. 3 : Variation of Co, Cd in tea garden soil
Fig. 4: Variation of Pb, Cr and Mn in tea garden soil

Fig. 5: Variation of Cu, Zn, Ni in leaves

Fig. 6: Variation of Cd, Pb, Cr in leaves
Metal content in tea leaves are also presented in Table 3. Cu has a concentration range from 6.79 to 19.98 mg/kg, which is in well agreement with 9.68-18.82 mg/kg\textsuperscript{26} and 9.4-13.8 mg/kg\textsuperscript{27} reported in China. However, present findings are much below than those reported in South Indian tea leaves as 66-127 mg/kg.\textsuperscript{28} Zn has a range of concentration 20.5-39.26 mg/kg. 25.39 mg/kg of Zn has been reported in tea leaves of South India.\textsuperscript{29} Co is present at below detectable level in the tea leaves of the present study. Pb has a range of Below detectable limit up to 2.0 mg/kg, which is lower than 0.31 - 3.42 mg/kg\textsuperscript{27} and 0.59-4.49 mg/kg\textsuperscript{30} reported in tea leaves of China. In tea leaves from South India, 3.1-14.5 mg/kg of lead was reported\textsuperscript{27}, which is much higher than the present findings. In case of Ni in tea leaves, present findings are lower than the reports from Turkey which is 6.6-11.7 mg/kg\textsuperscript{30}. Cd has been reported as 0.1-0.25 mg/kg in South Indian tea leaves\textsuperscript{27}, which is similar to the present findings. Cr has been reported in South Indian tea leaves as 1.0-2.0 mg/kg\textsuperscript{27}, which is similar to the present findings. Findings of heavy metals in agricultural soil at different regions of the world are presented in Table 4, most of which are similar to the present findings.

Table 4 : Comparison of the heavy metals in tea garden soil with different regions of the world

<table>
<thead>
<tr>
<th>City/Country</th>
<th>Cr</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
<th>Ni</th>
<th>Cd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>75.74</td>
<td>28.05</td>
<td>18.48</td>
<td>81.1</td>
<td>-</td>
<td>0.18</td>
</tr>
<tr>
<td>Yangzhou</td>
<td>77.2</td>
<td>33.9</td>
<td>35.7</td>
<td>98.1</td>
<td>38.5</td>
<td>0.3</td>
</tr>
<tr>
<td>USA</td>
<td>48.5</td>
<td>48</td>
<td>55</td>
<td>88.5</td>
<td>29</td>
<td>13.5</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>64.65</td>
<td>24</td>
<td>58</td>
<td>162.6</td>
<td>-</td>
<td>0.28</td>
</tr>
<tr>
<td>Spain</td>
<td>63.48</td>
<td>107.65</td>
<td>213.93</td>
<td>427.8</td>
<td>34.75</td>
<td>1.42</td>
</tr>
<tr>
<td>Present study (Min-Max)</td>
<td>17.36 - 21.24</td>
<td>18.98 - 30.4</td>
<td>18.43 - 24.5</td>
<td>52.6 - 72.94</td>
<td>31.82 - 53.9</td>
<td>0.49 - 0.70</td>
</tr>
</tbody>
</table>

Contamination factor and correlation study of soil heavy metals
The assessment of soil contamination was carried out using the Contamination factor (C\textsubscript{f}) and degree of contamination. Contamination factor is the ratio obtained by dividing the average measured concentration of each metal in the soil by the background or control value.\textsuperscript{31-35} Contamination factor (C\textsubscript{f}) is classified into four categories: \textsuperscript{37}
I. C_f <1, Low contamination factor
II. 1< C_f <3, Moderate contamination factor
III. 3< C_f <6, Considerable contamination factor
IV. C_f >6, Very high contamination factor

Modified degree of contamination is calculated as, mC_d = ∑_{i=1}^{n} C_f. Abrahim and Parker proposed the following gradations of modified degree of contamination in soil and sediments.

mC_d < 1.5 Nil very low degree of contamination.
1.5 ≤ mC_d < 2 low degree of contamination.
2 ≤ mC_d < 4 Moderate degree of contamination
4 ≤ mC_d < 8 High degree of contamination
8 ≤ mC_d <16 Very high degree of contamination
16 ≤ mC_d <32 Extremely high degree of contamination
mC_d ≥ 32 Ultra high degree of contamination

From the value of C_f in Table 5, we have observed that soils are considerably contaminated with Pb at all the four sites i.e at road edge, 05 meters, 10 meters and 01 kilometer. Considerable contamination with Cu was observed at the road edge but at the other three sites, soils are moderately contaminated with Cu. With respect to Ni, considerable contamination was noticed at the road edge, 05 meters and at 10 meters. But at 01 km from the road, contamination was moderate. Moderate contamination was detected with Zn, Co, Cr and Mn at all the four sites. With respect to the modified degree of contamination, all the four sites of the studied soils fall under moderate contamination.

Significant correlations have been observed between the metal pairs (Table 6). The significant relationship between the metal pairs indicates that, they originate from similar anthropogenic sources. In the absence of any mining and smelting industry near the study area, the anthropogenic sources of the metals could be attributed to the vehicular traffic. Use of chemical fertilizers and pesticides in the tea garden soil could be another source of heavy metals.

**Table 5 : Contamination factors(C_f) and modified degree of contamination(mC_d) using background values for heavy metal in soils from the study area**

<table>
<thead>
<tr>
<th>Sampling location</th>
<th>Cu</th>
<th>Zn</th>
<th>Ni</th>
<th>Pb</th>
<th>Co</th>
<th>Cr</th>
<th>Mn</th>
<th>Sum</th>
<th>mC_d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road edge</td>
<td>3.67</td>
<td>1.68</td>
<td>4.94</td>
<td>5.69</td>
<td>1.57</td>
<td>1.76</td>
<td>2.92</td>
<td>22.23</td>
<td>3.17</td>
</tr>
<tr>
<td>05 meter</td>
<td>2.93</td>
<td>1.48</td>
<td>3.7</td>
<td>5.26</td>
<td>1.16</td>
<td>1.56</td>
<td>2.25</td>
<td>18.34</td>
<td>2.84</td>
</tr>
<tr>
<td>10 meter</td>
<td>2.54</td>
<td>1.37</td>
<td>3.38</td>
<td>4.93</td>
<td>1.02</td>
<td>1.51</td>
<td>1.82</td>
<td>16.57</td>
<td>2.37</td>
</tr>
<tr>
<td>01 km</td>
<td>2.29</td>
<td>1.21</td>
<td>2.92</td>
<td>4.28</td>
<td>0.76</td>
<td>1.44</td>
<td>1.66</td>
<td>14.56</td>
<td>2.08</td>
</tr>
</tbody>
</table>

**Table 6 : Inter species correlation of tea garden soil**

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>Zn</th>
<th>Ni</th>
<th>Pb</th>
<th>Co</th>
<th>Cd</th>
<th>Cr</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>1</td>
<td>0.75**</td>
<td>0.74**</td>
<td>0.031</td>
<td>0.74**</td>
<td>0.70**</td>
<td>0.62*</td>
<td>0.76**</td>
</tr>
<tr>
<td>Zn</td>
<td>1</td>
<td>0.55*</td>
<td>0.34</td>
<td>0.72**</td>
<td>0.46*</td>
<td>0.68**</td>
<td>0.72**</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>1</td>
<td>0.29</td>
<td>0.70**</td>
<td>0.61*</td>
<td>0.79**</td>
<td>0.77**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>1</td>
<td>-0.01</td>
<td>-0.06</td>
<td>0.22</td>
<td>0.08</td>
<td>0.38</td>
<td>0.62*</td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>1</td>
<td>0.38</td>
<td>0.62*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>1</td>
<td>0.76**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**significant at p<0.001, * significant at p<0.05**

**Determination of transfer factor for tea leaves**

Since uptake of metal from soil to leaves is favorable in acidic soil and tea garden soils are acidic in nature, so uptake of metal from soil to leaves is a matter of concern. To investigate the uptake of metal from soil to leaves, Transfer Factor (TF) has been calculated. The Transfer Factor was calculated as : TF= C_{plant} / C_{soil} , where C_{plant} and C_{soil} represent heavy metals.
metal concentration in plants and soil respectively. The calculated Transfer Factors (TF) are presented in Table 3 along with the metal concentrations of tea leaves.

From Table 3, we have observed higher Transfer Factors for Cu (0.58-0.75), Zn (0.43-0.47), Mn (2.09-3.11) and very low Transfer Factors for Co (0.0), Cr (0.067-0.079), Pb (0.0-0.07) and Ni (0.13-0.18). The most probable reason for the higher uptake of Cu, Zn and Mn by plant is due to the requirement of these metals by plants for some biological functions, as these three metals are considered as micronutrients. Low uptake of Pb and Cr is a good sign. Cd (0.16-0.33) has a slightly higher transfer factor than Ni, Pb and Cr, which is a matter of concern. Jolly et al., reported Transfer Factors to access the level of uptake of metal from soil to vegetables as Zn (0.26-1.15), Cd (0.19-1.16), Pb (0.008-0.065), Cu (0.069-0.127), Ni (0.037-0.039) and Cr (0.008-0.029).

CONCLUSION

Heavy metals present in tea garden soils of our study are still far below than the maximum permissible limit prescribed by WHO, EU, ICRL, but higher levels are observed in comparison with the background values. The Contamination Factor (C) calculated using the background concentration as baseline, indicates moderate to considerable contamination of tea garden soil. The Transfer Factor (TF) calculated to investigate the level of metal uptake from soil to leaf indicates low uptake of toxic metals like Pb, Ni and Cr, which is a sign of relief for the people worldwide, who love this special beverage. In absence of any mining and smelting industry near the study area, vehicular traffic and application of chemical fertilizers, pesticides are the most probable anthropogenic sources of these metals. So, judicious application of chemical fertilizers and pesticides is strongly recommended. Introduction of organic fertilizers and organic pesticides is the need of the hour. The present study needs to be continued for constant monitoring of the trace metal levels specially Pb, Cd, Ni and Cr in tea garden soil and leaves as the concentration level of all metals are in increasing trend with respect to increasing number of vehicles day by day.

REFERENCES


