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HEAVY METAL UPTAKE CAPACITY OF SOME TREES FOR PHYTOREMEDIAL APPLICATION

Meha Bora*, Namita Joshi and Priya Chaudhary

Department of Environmental Science, Kanya Gurukula Campus, Gurukula Kangri Vishwavidyalaya, Haridwar, Uttarakhand, India

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ABSTRACT

The concentration of Pb, Mn, Ni, Cu and Cd were determined in leaf and bark sample of roadside trees (*Tectona grandis, Shorea robusta, Azadirachta indica, Ficus religiosa, Saraca indica* and *Eucalyptus citriodora*) as a means of assessing the potential of the trees to bioaccumulate heavy metal. The results concluded that the bioaccumulation of metals varied between the leaf and bark. The plant as indicator, accumulator and excluder depend on the concentration of metal present in different plant part with respect to their concentration in soil. All the studied tree species are accumulator, indicator and excluder for heavy metals and used in phytoremediation purpose especially with respect to Cu, Ni and Mn pollution in soil.

INTRODUCTION

Heavy metals are defined as those chemical elements with low concentrations in plant tissues (lower than 0.1%), independent of their toxicity or nutritional value (Bargagli, 1998). The responses of plants to a concentration gradient of trace elements in the soil solution can follow three main patterns (Baker, 1981; Baker *et al*. 2000). (1) ‘‘Excluders’’ have a low uptake of trace elements, by active exclusion in the roots, even at high external concentrations in the soil solution. (2) ‘‘Accumulators’’ are able to tolerate high concentrations of trace elements in their tissues, and this accumulation can be produced even at low external concentrations in the soil solution. (3) ‘‘Indicators’’ have a relatively constant root uptake over a wide gradient of trace elements in the soil. As a consequence they show a linear relationship between the concentrations in the plant tissues and in the soil.

Plants having the indicator or accumulator types of response could potentially be used as ‘‘biomonitors’’, defined as organisms that contain information on the quantitative aspects of the quality of the environment (Markert *et al*. 2003). There are several advantages of using the concentration of heavy metal in plant leaves, bark or stems, to monitor the level of soil pollution where they grow.

The accumulation of a heavy metal in plants confirms its availability in the soil; as distinct from having a high total metal concentration, which can be immobile in the soil complex (Baker *et al*. 2000). Thus, biomonitors can be used to detect low concentrations that are not always easy to measure directly using chemical extraction techniques; even if they are measurable as total levels, their ecological relevance is often difficult to determine from soil concentrations.

Higher plants not only intercept pollutants from atmospheric deposition but also accumulate aerial metals from the soil. Aerial heavy metal depositions are taken up from the soil by plants *via* their root system and translocated them to other parts of the plant. In industrial and urban areas, higher plants can give better quantifications for pollutant concentrations and atmospheric deposition than non-biological samples (Berlizov *et al*. 2007). Therefore, the aim of the study was to investigate the uptake capacity and bio-concentration factor of heavy metal using roadside trees as a biomonitor.

Corresponding author:* **Meha Bora
Department of Environmental Science, Kanya Gurukula Campus, Gurukula Kangri Vishwavidyalaya, Haridwar, Uttarakhand, India

MATERIALS AND METHODS

Study area

Haridwar, covering an area of about 2,360 km², is in the southwestern part of Uttarakhand state and is one of the important holy cities of India. It is extended from latitude 29°58′ in the North to longitude 78°13′ in the east with a subtropical climate.

Plant leaf and bark sampling

Fully matured leaves of *Shorea robusta*, *Tectona grandis*, *Azadirachta indica*, *Ficus religiosa*, *Saraca indica* and *Eucalyptus citriodora* were randomly collected during winter, summer and rainy season over a period of 24 months from July 2011 to June 2013. Bark was removed from target trees manually at chest height of 1-1.5 m from the ground. The leaf and bark samples were kept in paper envelopes and then placed in polythene bags for further analysis.

The leaves and bark samples were combusted in a furnace (50°C-80°C) for ash production. The samples were further digested by using dry ashing method (Behera, 2007). The content of heavy metal in (bark and leaves) digested samples was determined by using AAS/ICP-MS.

Concentration factor (CF): Concentration factor is the ratio of concentration of a particular heavy metal in the plant's part to that in the respective soil sample. It was calculated for leaf and bark sample (Chamberlain, 1983; Singh, 2005).

$$CF = \frac{\text{Concentration of respective metal in plant part}}{\text{Concentration of respective metal in soil sample}}$$

RESULTS AND DISCUSSION

Concentration of heavy metal in leaves and bark samples of different tree species

The concentrations of heavy metals are given in **(Table 1 - 6).** Average concentrations of all metals were found maximum during summer/winter season and minimum in rainy season. During summer season the atmospheric particulates loaded with heavy metals which readily deposited on the plant leaves and get translocated into the plant system through foliar absorption. Oluyemi *et al.* (2008) supported the fact and stated that due to the persistence of particulates on tree leaves and the total absence of washing of the leaves by rainfall contribute increasing metal concentration during summer/winter season. Due to the greater exposure of the foliage and coarse and rough bark surface they accumulate heavy loads of atmospheric pollutants from environment. The deposition of heavy metals on leaf surface depends upon the morphological characteristics of the leaf surface. The leaves having rough surface with emergent veins and prominent curvature, supports particulate deposition.

Flengen *et al.* (1980); Lebel *et al.* (1992) and Joshi *et al.* (1993) also stated that leaf morphology especially its surface characters and angle of adnation play an important role in dust and particulate deposition tendency of the plant. Bora and Joshi, 2014 also recommended *Azadirachta indica*, *Ficus religiosa*, *Saraca indica* and *Eucalyptus citriodora* for extensive plantation which can be used as bioindicators and mitigators of pollutants in an urban and industrial region Patel *et al.* (2012) also studied the concentration of heavy metal (Fe, Mn, Zn and Cu) in leaf tissues of *Ficus religiosa*, *Tectona grandis* and *Eucalyptus sp.* growing in polluted region. Verma *et al.* (2013) reported that *Azadirachta indica* and *Saraca indica* are good bioindicators and used in pollution monitoring for different areas. Naqvi *et al.* (2014) also worked on phytoremediation potential of *Saraca indica* from industrial region.

Concentration factor of heavy metal for different tree species

The mean values of CF for all tree species are given in **Table 7-12**.

During the present study it was observed that in case of *Shorea robusta* the leaves and bark are act as excluders (CF< 1) for Pb and Cu because the metal concentration in soil is greater than that present in plant part. For Ni and Mn the plant leaves accumulate more metal than in soil and act as accumulator (CF > 1) and bark act as excluder for Mn and accumulator for Ni whereas for Cd leaves are indicator (CF = 1) since the concentration of metal in leaves reflect the concentration in respect to soil and bark act as excluder with more concentration of metal present in soil.

The concentration of Pb, Cd, Ni and Mn in the leaves and bark of *Tectona grandis* were found less than that present in soil. Therefore, the plant acts as excluder in nature (CF < 1). The plant leaves are accumulator (CF > 1) for Cu with more metal concentration than soil whereas bark act as excluder (CF < 1) having less concentration of metal than present in soil. *Azadirachta indica* and *Saraca indica* follows the same trend both the species are excluder (CF < 1) for Pb, Cu, Cd, Ni and Mn. Their concentration in soil is greater than that present in plant part.

Table 1 Concentration of heavy metals in leaves and bark samples of *Shorea robusta* (2011-2013)
(All values are mean ± SE of 6 observation each)

Season / Metal	Rainy		Winter		Summer	
	Leaves	**Bark**	**Leaves**	**Bark**	**Leaves**	**Bark**
Pb (ppm)	1.376±0.195	1.737±0.219	2.284±0.251	2.561±0.266	1.469±0.202	2.216±0.248
Cu (ppm)	1.182±0.181	1.138±0.161	1.687±0.216	1.280±0.188	1.497±0.203	1.320±0.094
Cd (ppm)	1.288±0.189	1.078±0.146	1.159±0.166	1.091±0.150	1.201±0.174	1.105±0.154
Ni (ppm)	1.129±0.159	1.095±0.151	1.283±0.088	1.163±0.067	1.187±0.172	1.212±0.176
Mn (ppm)	1.522±0.205	1.353±0.193	2.801±0.278	1.851±0.226	2.399±0.258	1.767±0.221

Table 2 Concentration of heavy metals in leaves and bark samples of *Tectona grandis* (2011-2013)
(All values are mean ± SE of 6 observation each)

Season / Metal	Rainy		Winter		Summer	
	Leaves	**Bark**	**Leaves**	**Bark**	**Leaves**	**Bark**
Pb (ppm)	1.429±0.199	1.819±0.224	2.142±0.243	2.269±0.251	2.387±0.257	2.669±0.272
Cu (ppm)	1.287±0.189	1.132±0.160	1.630±0.132	1.178±0.070	1.386±0.103	1.255±0.184
Cd (ppm)	1.028±0.127	1.039±0.132	1.131±0.160	1.075±0.145	1.111±0.155	1.178±0.146
Ni (ppm)	1.185±0.171	1.159±0.128	1.521±0.221	1.131±0.156	1.589±0.218	1.153±0.270
Mn (ppm)	1.252±0.186	1.268±0.187	1.815±0.224	1.401±0.197	1.740±0.219	1.263±0.187

Table 3 Concentration of heavy metals in leaves and bark samples of *Azadirachta indica* (2011-2013)
(All values are mean ± SE of 6 observation each)

Season / Metal	Rainy		Winter		Summer	
	Leaves	**Bark**	**Leaves**	**Bark**	**Leaves**	**Bark**
Pb (ppm)	1.855±0.227	2.307±0.253	2.684±0.273	4.209±0.341	1.991±0.235	2.097±0.241
Cu (ppm)	1.393±0.104	1.414±0.107	1.815±0.150	1.585±0.127	1.624±0.131	1.427±0.108
Cd (ppm)	1.095±0.051	1.073±0.145	1.176±0.169	1.141±0.162	1.281±0.170	1.157±0.166
Ni (ppm)	1.192±0.173	1.140±0.164	1.343±0.197	2.308±0.192	1.329±0.195	1.267±0.186
Mn (ppm)	1.372±0.195	1.124±0.176	2.983±0.287	1.859±0.227	2.836±0.280	1.733±0.219

Table 4 Concentration of heavy metals in leaves and bark samples of *Ficus religiosa* (2011-2013)
(All values are mean ± SE of 6 observation each)

Season / Metal	Rainy		Winter		Summer	
	Leaves	**Bark**	**Leaves**	**Bark**	**Leaves**	**Bark**
Pb (ppm)	1.942±0.232	2.126±0.243	3.288±0.302	3.592±0.315	3.078±0.292	2.535±0.265
Cu (ppm)	1.138±0.061	1.203±0.175	2.305±0.192	1.436±0.110	1.293±0.190	1.334±0.196
Cd (ppm)	1.024±0.125	1.145±0.035	1.273±0.145	2.173±0.145	1.122±0.158	1.190±0.150
Ni (ppm)	1.275±0.187	1.152±0.165	1.387±0.103	1.266±0.186	1.289±0.189	1.274±0.187
Mn (ppm)	1.271±0.186	1.410±0.197	1.500±0.117	1.755±0.220	1.474±0.114	1.739±0.219

Table 5 Concentration of heavy metals in leaves and bark samples of *Saraca indica* (2011-2013)
(All values are mean ± SE of 6 observation each)

Season / Metal	Rainy		Winter		Summer	
	Leaves	**Bark**	**Leaves**	**Bark**	**Leaves**	**Bark**
Pb (ppm)	2.050±0.238	1.928±0.231	3.532±0.313	3.434±0.308	2.828±0.280	2.607±0.269
Cu (ppm)	1.307±0.190	1.412±0.106	2.377±0.256	1.272±0.186	2.092±0.241	1.365±0.100
Cd (ppm)	1.120±0.157	1.173±0.145	1.754±0.144	1.642±0.133	1.984±0.165	1.852±0.153
Ni (ppm)	1.186±0.171	1.237±0.181	1.484±0.115	1.341±0.197	1.273±0.087	1.346±0.198
Mn (ppm)	1.266±0.187	1.765±0.221	2.373±0.256	2.979±0.287	1.811±0.224	2.392±0.257

Table 6 Concentration of heavy metals in leaves and bark samples of *Eucalyptus citriodora* (2011-2013)
(All values are mean ± SE of 6 observation each)

Season / Metal	Rainy		Winter		Summer	
	Leaves	**Bark**	**Leaves**	**Bark**	**Leaves**	**Bark**
Pb (ppm)	2.114±0.242	1.735±0.219	3.280±0.301	4.041±0.335	2.759±0.276	2.631±0.270
Cu (ppm)	1.197±0.174	2.080±0.147	2.426±0.108	2.354±0.992	1.336±0.196	2.270±0.186
Cd (ppm)	2.278±0.146	1.107±0.154	1.421±0.158	1.266±0.186	1.133±0.160	1.217±0.177
Ni (ppm)	1.097±0.151	1.177±0.170	1.220±0.178	1.304±0.191	1.188±0.172	1.254±0.184
Mn (ppm)	1.216±0.183	1.681±0.216	1.763±0.221	2.179±0.246	1.785±0.222	2.096±0.241

Ficus religiosa act as excluder (CF < 1) for Pb, Cd and Mn. Because the metal concentration present in tree leaves and bark are less than soil. The leaves of the plant exhibit more concentration of Cu and Ni with respect to their soil thus act as accumulator (CF > 1). Whereas, bark contain less concentration of these metals with respect to soil and act as excluder (CF < 1) for these metals. In case of *Eucalyptus citriodora* the leaves and bark act as excluder (CF < 1) for Pb, Cd, Ni and Mn since the concentration of these metals are more in soil than the plant part.

Similarly, the leaves act as excluder (CF < 1) for Cu having more metal concentration in soil than leaves but the bark act as accumulator (CF > 1) containing more metal concentration than soil. Kumar *et al*. (1995) revealed that *Brassica juneca* and *Brassica nigra* had high metal accumulating ability. The binding of lead to soil and plant material explains relatively low mobility in soil and plants, the rate of lead uptake to roots decreased and the rate of translocation to the shoots increased as a function of exposure time. Jakhwal (2007) studied the concentration factor of *Ipomea fistula*, *Saccharum arboretum*, *Adhatoda asica* and *Tectona grandis* and observed that the above mentioned plants are act as excluder for Al, Fe, Mn and

Ni whereas accumulator for Cd, Cu and Zn and indicator for Ba, Sr and Te.

Table 7 Concentration factor of heavy metals in *Shorea robusta*

Element	Concentration factor *wrt* dry matter in leaves	Concentration factor *wrt* dry matter in bark
Pb	0.601	0.764
Cu	0.897	0.768
Cd	1.00	0.899
Ni	1.399	1.348
Mn	1.034	0.765

(Indicator: near unity; **Accumulator:** Cf >1; **Hyper accumulator:** Cf >>1; **Excluder:** Cf <1**)**

Table 8 Concentration factor of heavy metals in *Tectona grandis*

Element	Concentration factor *wrt* dry matter in leaves	Concentration factor *wrt* dry matter in bark
Pb	0.662	0.752
Cu	1.122	0.930
Cd	0.878	0.883
Ni	1.247	0.646
Mn	0.645	0.527

(Indicator: near unity; **Accumulator:** Cf >1; **Hyper accumulator:** Cf >>1; **Excluder:** Cf < 1**)**

Table 9 Concentration factor of heavy metals in *Azadirachta indica*

Element	Concentration factor *wrt* dry matter in leaves	Concentration factor *wrt* dry matter in bark
Pb	0.621	0.820
Cu	0.524	0.666
Cd	0.749	0.711
Ni	0.719	0.878
Mn	0.668	0.438

(Indicator: near unity; **Accumulator:** Cf >1; **Hyper accumulator:** Cf >>1; **Excluder:** Cf < 1**)**

Table 10 Concentration factor of heavy metals in *Ficus religiosa*

Element	Concentration factor *wrt* dry matter in leaves	Concentration factor *wrt* dry matter in bark
Pb	0.740	0.735
Cu	1.082	0.908
Cd	0.528	0.697
Ni	1.035	0.966
Mn	0.157	0.620

(Indicator: near unity; **Accumulator:** Cf >1; **Hyper accumulator:** Cf >>1; **Excluder:** Cf <1**)**

Table 11 Concentration factor of heavy metals in *Saraca indica*

Element	Concentration factor *wrt* dry matter in leaves	Concentration factor *wrt* dry matter in bark
Pb	0.744	0.705
Cu	0.840	0.589
Cd	0.960	0.922
Ni	0.961	0.957
Mn	0.374	0.490

(Indicator: near unity; **Accumulator:** Cf >1; **Hyper accumulator:** Cf >>1; **Excluder:** Cf <1**)**

Table 12 Concentration factor of heavy metals in *Eucalyptus citriodora*

Element	Concentration factor *wrt* dry matter in leaves	Concentration factor *wrt* dry matter in bark
Pb	0.594	0.613
Cu	0.954	1.289
Cd	0.925	0.538
Ni	0.810	0.863
Mn	0.584	0.730

(Indicator: near unity; **Accumulator:** Cf >1; **Hyper accumulator:** Cf >>1; **Excluder:** Cf <1**)**

CONCLUSION

The results concluded that the bioaccumulation of metals varied between the leaves and bark. The plant indicator, accumulator, hyperaccumulator and excluder depend on the concentration of metal present in different plant part with respect to their concentration in soil. All the studied plant species are accumulator, indicator and excluder for heavy metals and used in phytoremediation purpose especially with respect to Cu, Ni and Mn pollution in soil.

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