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Bioconcentration of heavy metals in selected medicinal plants of India

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Abstract: *This paper presents data on the bioconcentration of heavy metals found in 10 plant species that occur in mangroves and inland ecosystems of India. The average concentration of mercury in the mangrove plants (0.068 $\mu g\ g^{-1}$) was 11.3 times that of the inland plants (0.006 $\mu g\ g^{-1}$; $p<0.05$). The average concentration of lead in the mangrove plants (19.23 $\mu g\ g^{-1}$) was 1.7 times that of the inland plants (11.38 $\mu g\ g^{-1}$; $p<0.05$). The mean bioconcentration factors for lead in mangrove plants (2.40 ± 0.75) were higher than that the inland plants (1.42 ± 0.15). The factor analysis accounted for 21.55% of the total variance showed accumulation of mercury and lead confirming the polluted nature.*

Key words: *Mangroves, Medicinal plant, Heavy metal, Pollution, Environment, India*
PDF of full length paper is available with author ***(*pochuenshea@gmail.com)***

Introduction

India is one among the top 25 biological hotspots of the world and it harbors various species of endangered fauna and flora (Agoramoorthy and Hsu, 2002 a,b). Heavy metals are both toxic and common in the environment and they occur in soil, water and plants. The heavy metals are mobilized by human activities such as mining and discarding industrial waste in nature, and they pose a potential threat to organisms (Agoramoorthy, 2006; Hsu *et al*., 2006). However, data on the toxic levels of heavy metals found in India's plants that occur in mangroves and inland habitats are limited. Mangroves inhabit coastal areas while riverine forests occur inland. Mangrove forest is one of the highly endangered ecosystems of the world since the plants require specific conditions to survive.

Heavy metals are known to affect biological communities (Mountouris *et al*., 2002; Hsu *et al*., 2006; Ozdilek *et al.,* 2007; Sahu *et al.,* 2007). When the levels of heavy metals exceed in plants and animals, it can induce a variety of acute and chronic effects in wide range of organisms in various ecosystems. In USA for example, heavy metals have caused natural forest to decline (Gawel *et al.,* 1996). Due to rapid development, mangrove and inland habitats of most Asian countries including India, have been subjected to serious environmental stress due to the increasing intensity of domestic sewage, industrial waste, agricultural runoff, heavy metals and other toxic waste materials (Agoramoorthy, 2006; Agoramoorthy and Hsu, 2005; Hsu *et al*., 2006). Therefore, it is important to gather data on heavy metal levels in plants that inhabit mangroves and inland habitats and associated food webs in India.

In this study, we have investigated the bioconcentration of heavy metals in naturally occurring 5 inland plant species and 5 mangrove plant species in Cuddalore district of Tamilnadu state, India. These plant species are used in traditional medicine locally. We have analyzed the plants to determine the essential (Cu, Fe, Mg, Mn and Zn) and non-essential (environmentally toxic Hg, Pb and Sn) trace metals.

Materials and Methods

Mangrove plants were collected from the coastal forest areas located between Vellar and Coleroon estuaries (latitude 11° 22´ N to 11°30´ and longitude 79°45´ E to 79°52´) in Cuddalore district (Tamilnadu, India). Inland plants were collected along the Vellar and Coleroon rivers. Plant species were identified using field guides and confirmed at the Department of Botany, Annamalai University (Gamble, 1935). The climate of the study area is humid with an average rainfall of 1310 mm; rains occur during the northeast monsoon season (October-December) each year (Selvam *et al*., 2003). In order to study the bioconcentrations of heavy metals, 5 inland plants (*Acalypha indica, Eclipta alba, Hibiscus cannabinus, Sauropus androgynus* and *Tridax procumbens*) and 5 mangrove plants (*Avicennia officinalis, Bruguiera cylindrica, Rhizophora apiculata, Excoecaria agallocha* and *Acanthus ilicifolius*) were selected. Five leaves each from four different plants belonged to the same species were collected from dawn to dusk on a single day contributing to a total of 20 leaves for each species. Collected samples were stored separately in polythene bags and transported to the laboratory for processing.

Plant samples were digested for heavy metal analysis with a 90°C mixture of concentrated nitric acid and hydrogen peroxide (Krishnamurthy *et al*., 1976; MacFarlane *et al*., 2003) and made to 25 ml volume. Analysis for heavy metals was carried out on the resultant digests using air/acetylene atomic absorption spectroscopy. In order to ensure precision of atomic absorption spectroscopy results, three replicates of each sample were run to ensure measured absorbencies were consistent. Metal concentrations were calculated from each replicate absorbance value, which was then used to calculate an average sample metal concentration. Only eight metals

Table - 1: Spearman correlation matrix for heavy metals in 10 plant species of India

Metal	Copper	Iron	Magnesium	Manganese	Zinc	Mercury	Lead
Copper	-						
Iron	0.16						
Magnesium	0.49	0.25					
Manganese	-0.02	-0.68*	-0.22				
Zinc	0.27	0.61	0.27	-0.39	-		
Mercury	-0.24	-0.74*	-0.06	0.32	-0.74*		
Lead	-0.25	-0.55	-0.19	0.18	-0.56	0.78**	-

* = $p < 0.05$, ** = $p < 0.01$

Table - 2: Varimax rotated factor matrix for heavy metals in 10 plant species of India

Variable	Factor 1	Factor 2
Copper (Cu)	0.17	0.81
Iron (Fe)	-0.80	0.26
Magnesium (Mg)	-0.14	0.71
Manganese (Mn)	0.88	0.25
Zinc (Zn)	-0.70	0.45
Mercury (Hg)	0.59	-0.67
Lead (Pb)	0.41	-0.71
Eigen values	3.41	1.51
Percent variance	48.76	21.55

(copper, iron, mercury, magnesium, manganese, lead and zinc) were of interest in this study since arsenic and cadmium were not detectable in most plants. Elements such as copper, zinc and lead were given emphasis since they can be used as bio-indicators of exposure. All concentrations were expressed in $\mu g\ g^{-1}$ on a dry-weight basis using weights obtained from oven-dried specimens. All specimens were run in batches, which included known standards, method blanks, and spiked specimens. The absorbance of a blank sample was also conducted to allow background correction. Accepted recoveries ranged from 85 to 105%, and batches with recoveries less than 85% were rerun.

Two basic approaches were used to quantify the bioaccumulation of pollutants with the assumption that organisms achieve a chemical equilibrium with respect to a particular media or route of exposure (Mountoris *et al*., 2002). This approach used bioconcentration or bioaccumulation factors (BCFs or BAFs) to estimate chemical residues in plants from measured concentrations in the appropriate reference media. Soil, water and air were considered as reference media to calculate BCFs. Soil metal concentrations were normalized with metal values of Earth's Upper Continental Crust (Taylor and McLennan, 1985). The bioconcentration factor is defined as $BCF = C_{biota}/C_{soil}$, where C_{biota} and C_{soil} were the total metal concentrations in taxa and soil, respectively, in $\mu g\ g^{-1}$. The same formula was adopted to calculate BCF for all the collected samples of plants with the assumption that the distribution of heavy metals in the environment is controlled by a continuous exchange among phases such as air, water, soil/sediment and biota.

Statistical analysis system software (SAS institute Inc. 2000) was used for data analysis and all means are presented as the values ± 1 standard deviation. The averages of metal concentrations between mangrove and inland plants were tested using non-parametric Wilcoxon rank test. We calculated Spearman rank correlation coefficients among the eight heavy metal elements. In order to know the significant groupings of studied metals and delineate the dominant processes by which metals sourced in the studied plants, the metals data set was subjected to factor analysis extracted using Varimax rotation scheme.

Results and Discussion

The concentration of cadmium was not detectable with the exception of 2 species namely *Eclipta alba* (0.11 $\mu g\ g^{-1}$) and *Sauropus androgynus* (0.90 $\mu g\ g^{-1}$). Similar concentrations of cadmium were reported in Indian medicinal herbal drugs made from plants such as *Coleus forskohlii* and *Alpinia galangal* (Rai *et al*., 2001). Higher airborne cadmium can be inferred from its concentration between 0.2 and 1.0 $\mu g\ g^{-1}$ in plants (Braune *et al*., 1999). However, the cadmium concentrations were not detectable in most plants suggesting less airborne contamination in the mangrove and inland habitats of the study area.

The average concentration of mercury in the mangrove plants (0.068 $\mu g\ g^{-1}$) was 11.3 times that of the inland plants (0.006 $\mu g\ g^{-1}$ $p<0.05$; Fig. 1). This indicates that atmospheric pollutants through industrial sources from near by towns find their way into the natural mangrove ecosystem. Mercury is a severe environmental pollutant due to its toxicity even at low concentrations in biological systems and mangrove habitats are known to be vulnerable to mercury pollution (Horvat *et al*., 1999; Legret and Pagotto, 1999).

The concentration of iron was negatively correlated to the concentration of manganese ($p<0.01$). The concentration of lead was positively correlated to the concentration of mercury ($p<0.01$), while mercury was negatively correlated with iron and zinc ($p<0.005$; Table 1). The average concentration of iron in the inland plants was 451.8 ± 154.9 $\mu g\ g^{-1}$, which is significantly higher than the mangrove plants (207.6 ± 73.1 $\mu g\ g^{-1}$, $p<0.05$; Fig. 1). The average

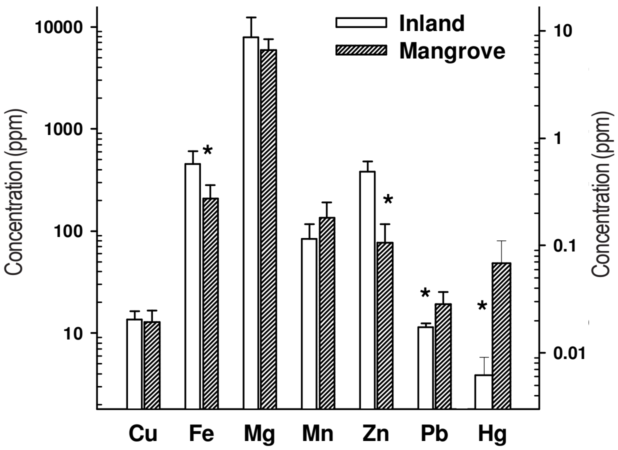

Fig. 1: Heavy metal concentrations (+SD) in 5 mangrove plants and 5 inland plants of India, * Significant level p < 0.05

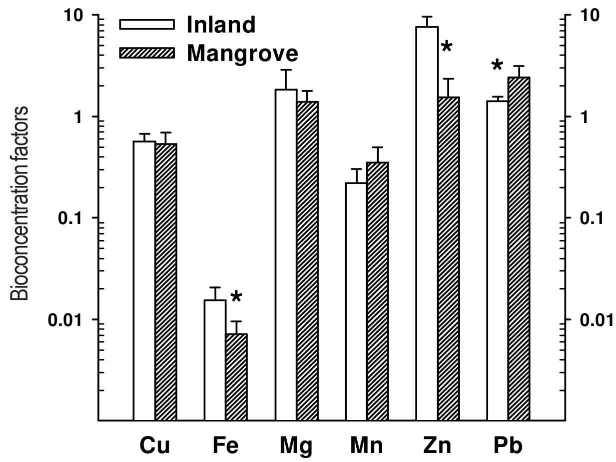

Fig. 2: Average bioconcentration factors (± SD) of 5 species of inland plants and 5 species of mangrove plants of India, * Significant level p < 0.05

concentration of zinc in the inland plants was 380.3 ± 98.5 $\mu g\ g^{-1}$, which is significantly higher than the mangrove plants (77.2 ± 39.6 $\mu g\ g^{-1}$, p<0.05; Fig. 1). The average concentration of lead in the mangrove plants (19.23 $\mu g\ g^{-1}$) was 1.7 times that of the inland plants (11.38 $\mu g\ g^{-1}$ p<0.05; Fig. 1). Lead accumulates in plants primarily from the atmosphere (Braune *et al*., 1999). With the exception of *Eclipta alba*, the concentrations of lead among the other 9 plant species investigated were higher than the normal range of lead concentration of plant materials (5.0-0.0 $\mu g\ g^{-1}$) reported by Alloway (1995) and Bowen (1979) showing apparent signs of environmental contamination.

The mean bioconcentration factors (BCF) for copper, iron and manganese were low while magnesium, zinc and lead were higher than 1.6 (Fig. 2). The BCF for zinc in mangrove plants (1.54 ± 0.79, n=5) was significantly lower than that in the inland plants (7.61 ± 1.97, n=5; Fig. 2). The BCF for iron in mangrove plants was 0.007, also significantly lower than that in the inland plants (0.016; Fig. 2). The BCF for lead in mangrove plants (2.40 ± 0.75) was significantly higher than that in the inland plants (1.42 ± 0.15; Fig. 2). The factor analysis indicated three factors describing 70.3% of total data variability in 10 different species of plants from mangroves and inland ecosystems (Table 2). The dominant factor accounted for 48.76% of the total variance that portrays accumulation of essential elements such as manganese, iron and zinc. The Factor 2 that accounted for 21.55% of the total variance and it showed accumulation of mercury and lead, confirming the polluted nature of the studied ecosystems. Thus the results indicate that the anthropogenic sources of metals pollute the biotic community in the mangrove and inland ecosystems of south India. Toxic heavy metals accumulate faster in the mangrove and riverine forest habitats due to their close proximities to development areas dominated by industrial wastes and garbage dumps (Stark, 1998). Metals such as copper, lead and zinc are of greatest eco-toxicological concern even in the less populated mangrove habitats of Australia (Irvine and Birch, 1998). The concentrations of heavy metals, especially lead, found in this study are several times higher than reported in the coastal forest areas of Australia and Panama (MacFarlane *et al*., 2003; Defew *et al*., 2005).

The plant species investigated in this study have been used in traditional medicine. For example, mangrove plants such as *Bruguiera cylindrica* and *Rhizophora apiculata* are rich in polyphenols and traditional healers in India use the plastered fruits of *Avicennia officinalis* onto boils and tumours while the poultice of unripe seeds are used to treat inflammations, abscesses, ulcers, and boils (Ravi and Kathiresan, 1990; Basu, 2000). *Excoecaria agallocha* has been used in traditional medicine to treat epilepsy, conjunctivitis, dermatitis, and leprosy (Bandaranayake, 1998). Some mangroves are used as tea (Kathiresan, 1995) while some inland plants (*Sauropus androgynus*) are used as vegetable (Padmavathi and Rao, 1990). Leaves of *Acanthus ilicifolius* have been used for treating rheumatism and neuralgia (Kirtikar and Basu, 1991). *Acalypha indica* has been used as an antidote for poisonous snake bites in rural India (Houghton and Osibogun, 1993). The plant *Eclipta alba* has been mentioned in the ancient texts in India as a nervine tonic (Vaidya, 1997). *Tridax procumbens* is a weed found throughout India, which is used to treat jaundice, bronchial catarrh, diarrhea, and dysentery (Ali *et al*., 2001). *Hibiscus cannabinus* (known as Kenaf) has long been used as a folk medicine in India and also in Africa for the treatment of blood/throat disorders and fever (Agbor *et al*., 2005). Due to the usage of the studied plants in traditional medicine to treat various ailments, there is significant health risk related to heavy metal toxicity. Our study indicates that heavy metal toxicity may be increasingly common among mangrove and riverine habitats in India. Our findings are similar to heavy metal toxicity reported in protected forests in Taiwan (Hsu *et al*., 2006). Recently, heavy metal pollution in marine organisms along the coastal areas of India has been reported (Kumar and Achyuthan, 2007). Therefore, the recognition of the occurrence and impacts of contaminants on food chains and ecosystems must lead to the development of strict environmental-monitoring research in India aimed at directly measuring the levels of contaminants in various organisms through systematic long-term research.

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