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Challenges in Biochemical Engineering and Biotechnology for Sustainable Environment

Phytoremediation of heavy metals using *Avicennia marina* and *Rhizophora mucronata* in the Uppanar River

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Abstract: Phytoremediation is an environmentally sound technology for pollution prevention, control and remediation of soil, water, or air. From January 2012 to April 2013, the concentration of Al, Co, Cr, Cu, Fe, Mg, Mn and Zn were examined in the mangrove sediment and plant species like *Avicennia marina* and *Rhizophora mucronata*. At the end of 16th month, the metal concentration in sediments, *Avicennia marina and Rhizophora mucronata* showed a decreasing order of Mg > Fe > Mn > (Co, Zn)> (Al, Cu)> Cr; Cu > Zn >(Al, Co, Fe) > (Cr, Mn) > Mg and Cu >(Fe, Mg) > Zn > (Al, Co) > (Mn, Cr) respectively. Among all the heavy metals, the concentration of Cu was maximum and fluctuated from 0.07 to 0.3 µg/g in *Avicennia marina* and 0.1 to 0.4 µg/g in *Rhizophora mucronata*. The bioaccumulation coefficient of *Avicennia marina* decreased consequently as Cu > Zn > Al > Co, Cr > Fe > Mn > Mg. Similarly, the bioaccumulation coefficient of *Rhizophora mucronata* decreased as Cu > Zn > Cr > Al > Co > Mg > Fe > Mn.
Keywords : Phytoremediation, *Avicennia marina, Rhizophora mucronata*, Uppanar River.

Introduction

Heavy metal pollution either industrial or domestic means is a major problem in many countries. Phytoremediation is a newly evolving field of science and technology that uses plants to clean-up polluted soil, water, or air[1,2]. This field is generating great excitement because phytoremediation techniques may offer the only effective means of restoring the hundreds of thousands of square miles of land and water that have been polluted by human activities. Pollutants can be remediated in plants through several natural biophysical and biochemical processes like adsorption, transport and translocation; hyperaccumulation; or transformation and mineralization.

Mangroves are very important to restore the marine ecosystems[3]. It helps in coastal water enrichment, commercial production, coastal preservation and increases fisheries production. At present, mangrove forests cover 20 million hectares of the land area of the world[3,4]. Mangroves are physiologically tolerant to high pollutant levels[5]. Heavy metals are persistent in the environment. Sediment acts as sink to these heavy metals and the constant exposure of the mangroves to the heavy metals makes mangroves metal tolerant. In some cases, it leads to loss of mangroves in recent decades[4,5]. So, it is important to study the capability of mangrove plants to take up heavy metals and to find out the suitable candidate for phytoremediation species as well as for the conservation of mangrove ecosystems.

Hence, the present study was dealt with the bioaccumulation capability of heavy metals by *Avicennia marina* and *Rhizophora mucronata* in the field conditions i.e., in the Uppanar River. In this work, the significance and novelty can be seen through the development of an artificial mangrove forests along the Uppanar River and to find out its phytoremediation potential in the field condition. No work has been carried out so far in this view.

Materials and Methods

Nursery Development

The mangrove propagules of *Avicennia marina* and *Rhizophora mucronata* were collected from Pichavaram mangrove forest, Tamil Nadu State, East coast of India during the month of July- August. The plot cultures were prepared with silt, clay and sand in the ratio of 2:4:94. The mangrove propagules were treated with seawater for every 24 h. The plants were grown in a green house, illuminated with natural light temperature of 27/25°C, 14/10 h light and dark period and the growth was monitored.

Study area

The study was conducted at Uppanar River of Sothikuppam, Cuddalore district, South East coast of India (Latitude of N 11º43'51.4" and Longitude of E 079º46'18.8").

Sampling and analysis

Avicennia marina and *Rhizophora mucronata* live plants and sediment samples were collected from the study area for every four months during January 2012 – April 2013. Plant samples were washed thoroughly to remove the attached contaminants and dried for 3 days. Three replicates of samples were oven-dried and digested with a mixture of conc. nitric acid and hydrofluoric acid in microwave assisted Kjeldhal digestion. The digested samples were diluted to 50 mL and subjected to analysis of the metals (Al, Co, Cr, Cu, Fe, Mg, Mn, Si and Zn) by atomic absorption spectrophotometer (ELICO SL176 double beam AAS, India). Results were expressed on dry weight basis of each component.

Bioaccumulation coefficient

The following formula was used for calculation of bioaccumulation coefficient (BAC) = metal concentration in plant (µg metal/g dry weight of plant) / metal concentration in sediment (µg metal/g dry weight of sediment). The experiments were repeated thrice.

Results and Discussion

During the study period, at the end of the 16th month, the growth of mangrove seedlings (*Rhizophora mucronata*) grown to an average height of 115 cm, each bearing 90 leaves with 8 branches to a length of 25 cm and bearing aerial roots to a length of 20 cm.

Heavy metal concentration in sediments

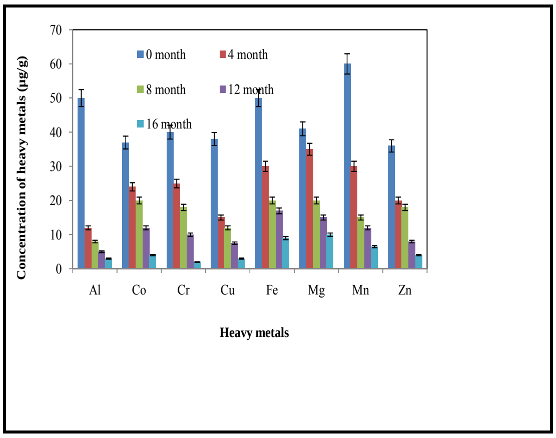

Fig. 1 Concentration of heavy metals in River Uppanar mangrove sediments

The study site contained elevated average concentrations of Mg (10 µg/g) followed by Fe (9 µg/g). As depicted in Fig. 1, the metal concentration in sediments showed a decreasing order of Mg > Fe > Mn > Co, Zn> Al, Cu > Cr at the end of 16th month of the study period. However, the concentration of the selected heavy metals in the sediments of River Uppanar was below the general soil concentration[6]. The concentration of heavy metals of the present study was comparable with the work of Cuong et al.[7] on heavy metal concentrations of mangrove habitants in Buloh River, Singapore and was lower than Nazli and Hashim[8] on phytoremediation of heavy metal contaminated water and sediments in Pariyej community reserve of Gujarat using macrophytes.

In addition, the lower concentration of Al, Co, Cr, Cu, Fe, Mg, Mn and Zn were might be due to the lower retention of heavy metals in sediments of River Uppanar. Also, it depicted that the origin of these heavy metals was natural[4]. Further, the enhanced values of some heavy metals attributed to elevated human activities near the surrounding areas. The results indicated that heavy metals (Al, Co, Cr, Cu, Fe, Mg, Mn and Zn) concentration revealed that River Uppanar was moderately polluted. The findings were in agreement with the study of Ayyamperumal et al.[9]. Therefore, further studies are needed to investigate these characteristics in order to understand the mobility, bioavailability and toxicity of the heavy metals in mangrove sediments.

Heavy metal concentration in *Avicennia marina* and *Rhizophora mucronata.*

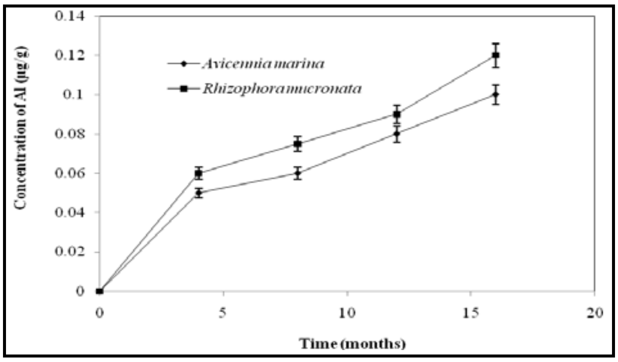

Fig. 2 Concentration of Al in *Avicennia marina* and *Rhizophora mucronata*

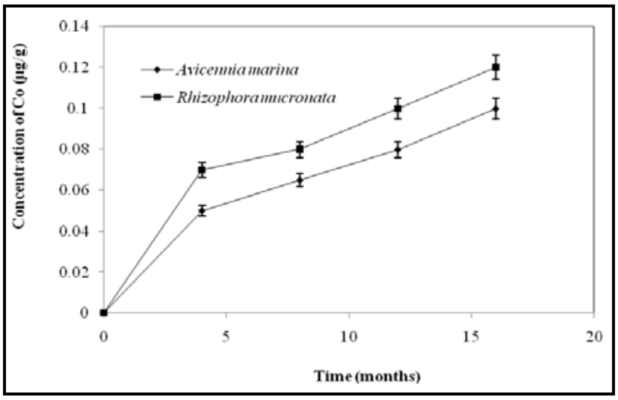

Fig. 3 Concentration of Co in *Avicennia marina* and *Rhizophora mucronata*

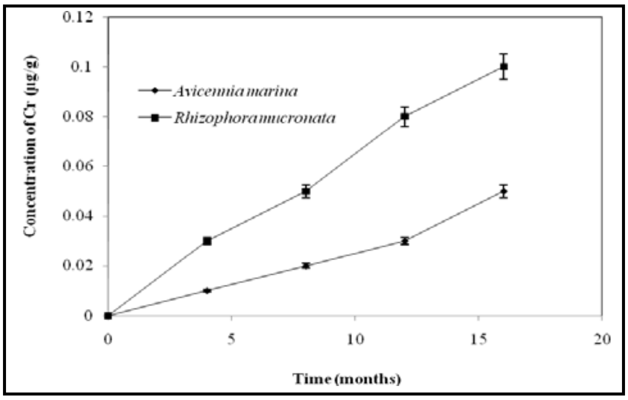

Fig. 4 Concentration of Cr in *Avicennia marina* and *Rhizophora mucronata*

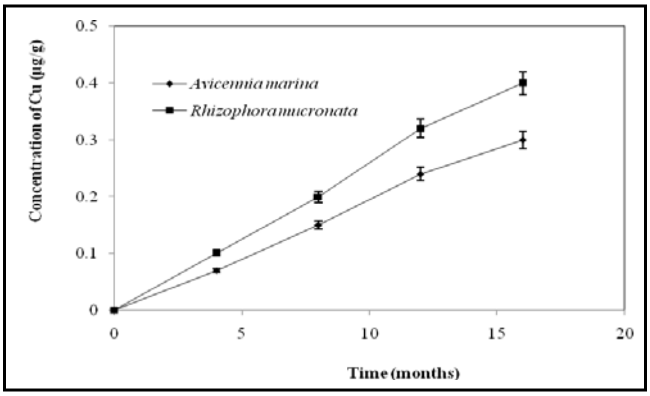

Fig. 5 Concentration of Cu in *Avicennia marina* and *Rhizophora mucronata*

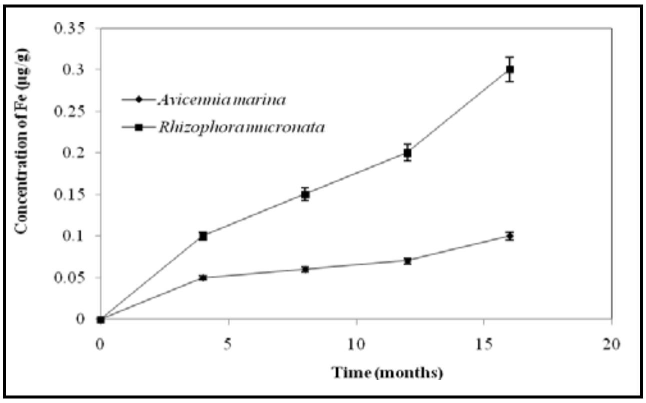

Fig. 6 Concentration of Fe in *Avicennia marina* and *Rhizophora mucronata*

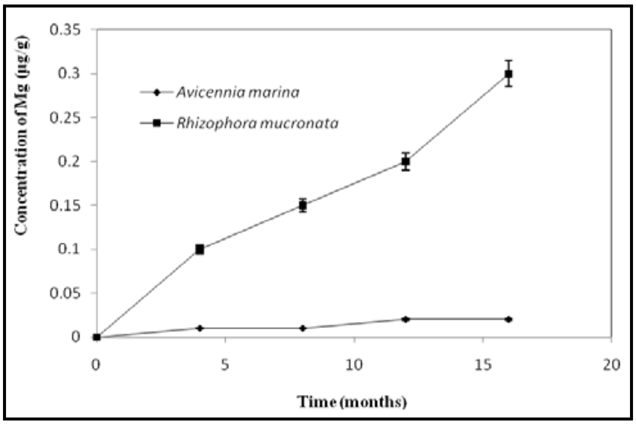

Fig. 7 Concentration of Mg in *Avicennia marina* and *Rhizophora mucronata*

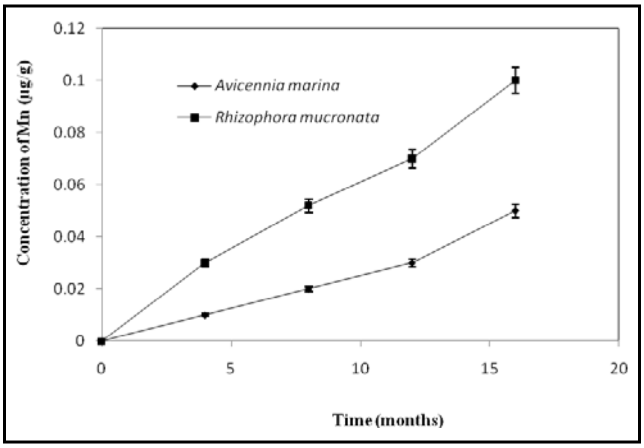

Fig. 8 Concentration of Mn in *Avicennia marina* and *Rhizophora mucronata*

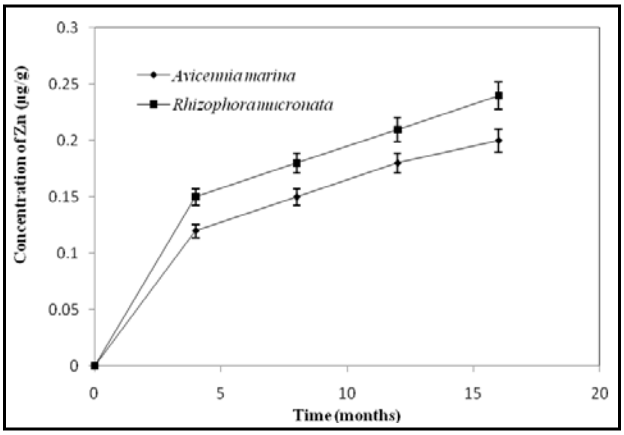

Fig. 9 Concentration of Zn in *Avicennia marina* and *Rhizophora mucronata*

Figs. 2-9 show the effect of time intervals on the concentration of Al, Co, Cr, Cu, Fe, Mg, Mn and Zn for *Avicennia marina* and *Rhizophora mucronata.* The accumulation of heavy metals in *Avicennia marina* and *Rhizophora mucronata* increased with increase in time.

The mean concentration of heavy metals in *Avicennia marina* decreased according to the sequence: Cu > Zn > Al, Co, Fe > Cr, Mn > Mg. Likewise, the mean concentration of heavy metals in *Rhizophora mucronata* decreased according to the sequence: Cu > Fe, Mg > Zn > Al, Co > Mn, Cr. Among all the heavy metals, the concentration of Cu was maximum and fluctuated from 0.07 to 0.3 µg/g in *Avicennia marina* and 0.1 - 0.4 µg/g in *Rhizophora mucronata*. On the other hand, minimum concentration of Mg was registered in *Avicennia marina* (0.01 µg/g) while comparatively higher amount of the same was observed in *Rhizophora mucronata* (0.3 µg/g). Besides, *Rhizophora mucronata* showed the lower amount of Mn (0.03 µg/g) and Cr (0.03 µg/g) while the greater amount of the Mn (0.05 µg/g) and Cr (0.05 µg/g) were recorded in *Avicennia marina.* The content of Al, Zn, Co and Fe were ranged from 0.05 – 1 µg/g, 0.12 – 2 µg/g, 0.05 – 0.1 µg/g, and 0.05 – 1 µg/g in *Avicennia marina.* The corresponding heavy metals content in *Rhizophora mucronata* were 0.06 - 0.12 µg/g, 0.15 – 0.2 µg/g, 0.07 – 0.12 µg/g and 0.1 – 0.3 µg/g. Nirmal Kumar et al.[10] carried out similar research work on phytoremediation of heavy metal contaminated water and sediments in Pariyej community reserve of Gujarat using macrophytes.

The maximum Cu concentration in the plants might be due to the industrial and anthropogenic activities that end up in sediments of the River Uppanar. Moreover, according to Buajan and Purmijumong[11], Cu does not travel far away after discharge, as it strongly attached to minerals and organic matter present in the sediment. The concentration of Cu in plants was lower than those measured in Saudi Arabia[12], Pakistan[13], China[14] and Iran[4]. However, the concentration of Zn was lower than those measured in China[15], Australia[16], Panama[17] and Iran[4]. The higher values of Zn and other metals like Cr, Mn in plants might be due to the electroplating industries, which are actively operating in the area adjoining the bank of River Uppanar. The results obtained in the present study were in accordance with the results of Yap et al.[18]; Buajan and Purmijumong[11].

Bioaccumulation coefficient (BAC)

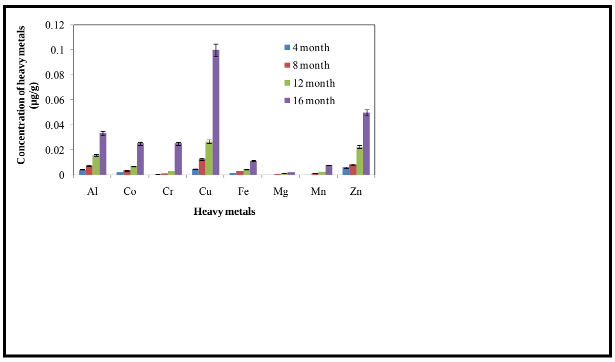

Fig. 10 Bioaccumulation coefficient of heavy metals in *Avicennia marina*

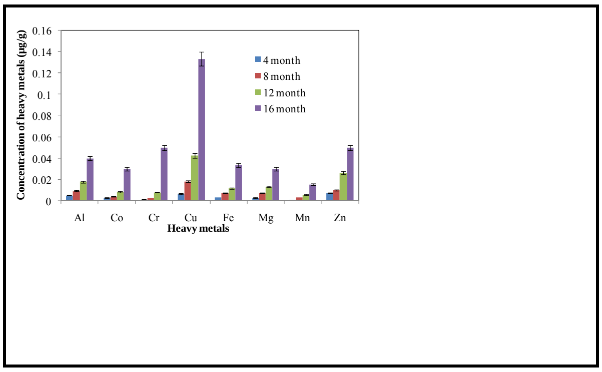

Fig. 11 Bioaccumulation coefficient of heavy metals in *Rhizophora mucronata*

A plant's ability to accumulate metals from sediments can be estimated using the bioaccumulation coefficient (BAC), which is defined as the ratio of metal concentration in the plants to that in sediment. The BAC of *Avicennia marina* decreased consequently as Cu > Zn > Al > Co, Cr > Fe > Mn > Mg (Fig. 10). Similarly, the BAC of *Rhizophora mucronata* decreased accordingly as Cu > Zn > Cr > Al > Co > Mg > Fe > Mn (Fig. 11). Among the eight metals tested, both the plants growing on the site were most efficient in taking up and translocating Cu. Since Zn and Cu are essential nutrients for plant systems, higher translocation from roots to shoots is understandable. The BAC of Cu content fluctuated from 0.004 - 0.1 in *Avicennia marina* and 0.007 - 0.13 in *Rhizophora mucronata*. On the other hand, minimum BAC was registered in *Avicennia marina* (0.002) for Mg while comparatively higher BAC was observed in *Rhizophora mucronata* (0.03).

BAC obtained in the present study for all heavy metals were lower than those found by Parvaresh et al.[4] in grey mangrove, Sirik Azini Creek, Iran and Nirmal Kumar et al.[10] in phytoremediation of heavy metal contaminated water and sediments in Pariyej community reserve of Gujarat using macrophytes. The research work was in accordance with the findings of Pahalawattaarachchi et al.[19] in metal phytoremediation potential of *Rhizophora mucronata* in Alibag, Maharastra, India. Similarly, Thomas and Eong[20] treated established *Rhizophora mucronata* Lam. and *Avicennia alba* Bl. seedlings in sediment with Pb and Zn. For these two species, root accumulation and reduced translocation from roots to shoots were observed for both metals.

Plants exhibiting BAC values less than one are unsuitable for phytoextraction[21]. According to Yoon et al.[22] few species growing at the site were capable of accumulating heavy metals in the roots, but most of them had low BAC values, which means limited ability of heavy metal accumulation and translocation by the plants. BAC of metals are rather low (< 0.05) for every metal studied except Cu. This is due to the fact that the BAC was calculated on the basis of total metal concentration in sediment rather than that of bioavailable fraction. Hence, it could be suggested that mangrove species are probably efficient biogeochemical barriers to the transport of metal contaminants in coastal areas. Also, the role of mangroves in phytoremediation depends upon plant age, growth and biomass production.

Conclusion

The research work revealed that phytoremediation capability of *Avicennia marina* and *Rhizophora mucronata* varies from metal to metal. BAC would be higher in future because the plant will be stabilised to the environment and grow to the greater extent when comparing now. Mangrove plays an important role in the purification of the eco-environment in river and estuary.

Acknowledgement

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