Ecological implications of trace metals in seaweeds: Bio-indication potential for metal contamination in Wandoor, South Andaman Island

P. Karthick a, R. Siva Sankar b,*, T. Kaviarasan b, R. Mohanraju a

a Department of Ocean Studies and Marine Biology, Pondicherry University, Brookshabad Campus, Port Blair, Andaman – 744 112, India
b Department of Ecology and Environmental Sciences, Pondicherry University – 605 014, India

Received 28 November 2012; accepted 23 December 2012
Available online 15 March 2013

Abstract Concentration levels of Mn, Pb, Zn, Cd, Cu and Cr in six seaweed samples (Acetabularia calyculus, Corallina sp., Galaxaura marginata, Sargassum duplicatum, Sargassum swartzi and Dictyota bartayresiana) were determined from Wandoor, south Andaman Island. Metals were extracted from sample homogenates and quantified by atomic absorption spectrometry. In the present investigation, heavy metal concentration levels in the following order: Mn > Pb > Cd. It is observed that Zn was only present in free floating brown seaweed S. swartzi. Cu and Cr did not show its presence in any of the seaweeds that was sampled. Metal pollution index (MPI) of six seaweed species were observed in the following decending order: A. calyculus > Corallina sp. > D. bartayresiana > G. marginata > S. duplicatum > S. swartzi. Results showed that chlorophyta, A. calyculus contained the highest concentration of heavy metals as compared to other algal species. One-way analysis of variance (ANOVA) showed that the concentration of metals was significantly different (p < 0.05) with respect to different species around the study area.

Introduction Contamination of heavy metals in the marine realm is posing a major problem which is directly related to anthropogenic actions. Assessment of heavy metal concentration in the coastal waters can be monitored with the help of indicator organisms, particularly algae (Ganesan et al., 1991; Rajendran et al., 1993) which accumulate pollutants proportionally to their environmental concentrations. Seaweeds or macroalgae have been widely used to monitor...
and to characterize the status of environmental pollution. They play an important role in the nutrient dynamics of coastal systems and reflect changes in water quality efficiently (Wilson, 2002). Hence, any change in the nature of the dynamics (like increased inputs of contaminants such as heavy metals) will likely to be reflected by these marine macroalgae. Metals, well known for their persistence in the environment and their ability of bioaccumulation and biomagnifications in the food chain (Gochfeld, 2003), are often responsible for irreparable damage to the marine environments even at low concentrations. Further, Higher concentrations of toxic metals such as Pb and Cd concentration on seaweeds will reduce the growth rate, chloroplast content and it leads to death of cells (Lamai et al., 2005). Generally macrophytes are the base of the aquatic chain and therefore can influence the chemical element content in higher trophic levels (Phillips, 1977; Netten et al., 2000). Studies pertaining to the metal pollution and bioaccumulation in macroalgae – seaweeds from Andaman waters are lacking and thus an attempt has been made to assess the differences in metal levels (Cd, Cu, Mn, Pb and Zn) between algal species collected from Wandoor, South Andaman Island, which will also serve as a baseline for future studies in this region.

Methodology

Study area

The Andaman and Nicobar islands, situated in the Bay of Bengal within 6–14°N latitudes and 92–94°E longitudes, are observed to be the most diverse with around 196 species of seaweeds (Muthuvelan et al., 2001). There are about 572 islands in the Andaman and Nicobar group, with a total land area of 8293 sq. km. The sampling site, Wandoor (Fig. 1) has been selected based on species diversity and dispersal.

Healthy seaweeds (Acetabularia calyculus, Corallina sp., Galaxaura marginata, Sargassum duplicatum, Sargassum swartzi and Dictyota bartayresiana) were collected from the intertidal regions. The collected samples were initially washed under a flow of tap water and washed again three times with double distilled deionized water to remove mineral particles, organisms and other external adherent. Samples were weighed into a pre weighed petri dish, and then dried at 80 °C until constant weight. The dried samples were weighed and placed in a cleaned dried mortar separately and grounded to fine particles and then sieved using a sieve of particle size 0.02 mm. Each sample of 0.5 g were transferred into clean dried beaker (100 mL), 5 mL of aqua regia HCl and HNO₃ (3:1) was then added to the sample for digestion. The samples were allowed to be evenly distributed in the acid by stirring with a glass rod and then the beaker was placed on the heater. The digested sample was filtered into a graduating cylinder and the filtrate was made up to 50 mL using distilled water. Perkin Elmer atomic absorption spectrophotometer model was used to analyse the concentration (µg/g) of heavy metals (Mn, Pb, Zn, Cd, Cu and Cr) in the different seaweeds samples. One-way analysis of variance (ANOVA) was employed to understand the variability between heavy metal and different species.

Figure 1  Map showing the location of the study area.
Dendrogram was drawn for studying the similarities between heavy metals in different seaweeds. The comparison of total heavy metal content in different classes of seaweeds was calculated by Metal Pollution Index (MPI) (Dadolahi et al., 2006; Giusti, 2001).

\[
\text{MPI} = \left( \frac{C_{f_1}}{C_2} \times \frac{C_{f_2}}{C_1} \times \ldots \times \frac{C_{f_n}}{C_1} \right)^{1/n}
\]

where \(C_{fi}\) = concentration for the metal \(i\) in the sample.

**Results**

The heavy metal concentrations such as Mn, Pb, Zn, Cd, Cu and Cr were determined in six seaweed species comprising *A. calyculus*, *Corallina* sp., *G. marginata*, *S. duplicatum*, *S. swartzi* and *D. bartayresiana*. It was found that among the concentration of heavy metals investigated, Mn showed the highest accumulation (0.543–3.615 \(\mu g/g\)) and Cd concentrations were the lowest (0.092–0.121 \(\mu g/g\)) (Fig. 2). Cd concentrations were found to be relatively uniform in all species of the seaweeds. Pb and Zn showed a range of 0.429–0.933 \(\mu g/g\) and 0.203 \(\mu g/g\) respectively. The concentration of Zn was observed only in *S. swartzi* and metals like Pb and Mn occurred at relative concentrations in *S. duplicatum* and *S. swartzi*. Metals like Cu and Cr were not detected in any of the samples. In the present investigation, the heavy metal accumulation of seaweeds was in the following order Mn > Pb > Cd (Table 1). One-way analysis of variance (ANOVA) revealed that the concentration of metals was significantly \((p < 0.05)\) varied with respect to different species around the study area.

The overall metal burden of *A. calyculus*, *Corallina* sp., *S. duplicatum*, *S. swartzi*, *G. marginata* and *D. bartayresiana* was calculated using Metal pollution index. MPI of six seaweed species were observed in the following descending order: *A. calyculus* > *Corallina* sp. > *D. bartayresiana* > *G. marginata* > *S. duplicatum* > *S. swartzi*. Among the different classes of seaweeds, the MPI were found to be highest for Chlorophyta and lowest for Phaeophyta (Fig. 3). Dendogram has delineated two major clusters, which were mainly segregated based on the accumulation of heavy metals (Fig. 4). The first group were *Corallina* sp. *G. marginata*, *D. bartayresiana*, *S. duplicatum*, *S. swartzi*; the second group consist of *A. calyculus*.

**Discussion**

Macro algae are known to be good indicators of heavy metals in the marine environment and they can be considered as good biomonitors of heavy metals (Philips, 1990). Six species of sea-
weeds from three different classes were examined for the accumulation of heavy metals and it was found that levels of zinc, cadmium, lead and manganese were lower in the limit in all the species. It has been reported that concentrations of chemical elements in seaweeds are generally low in the warmer months, i.e. the time of the highest algae metabolic activity resulting in dilution of the accumulated metals whereas in winter after slowing down of metabolic processes the element content is higher (Bojanowski, 1973; Brix and Lyngby, 1983; Malea, 1994; Hou and Yan, 1998; Villares et al., 2002). Moreover they have regulated the uptake of these metals and hence it does not accumulate them to such a great extent (Sudharsan et al., 2012). The concentration of manganese was higher in comparison to other elements in all the seaweeds. Occurrence of higher concentration of Mn in plants is a common feature for maintaining osmotic balance, ion regulation and for enzyme catalysis (Clarkson and Hanson, 1980). The earlier report Homaidan et al. (2011) also observed the high concentrations of manganese in seaweeds. Although they are essential micronutrients for plants it became more toxic at higher concentrations than the amount required for normal growth (Nies, 1999). It is worth noting that Zn was found only in brown algae, S. swartzi. The concentration of zinc may be attributed or controlled by activators of dehydrogenases and protein-synthesis enzymes in this species (Besada et al., 2009).

Heavy metals, such as Cd and Pb have unknown roles in living organisms, and are toxic even at lower concentrations (Nies, 1999; Ward, 1987) and the same has been recorded from the seaweed samples in the present study. Further, Cd concentrations were higher in red algae, Pterocladia capillacea (Topcuoglu et al., 2010), and brown algae, Undaria pinnatifida (Besada et al., 2009) but in our investigation the concentration of cadmium were relatively uniform in all classes of seaweeds. This ensures that the concentrations of cadmium in seaweeds may cause physiological disturbance and toxicity even at very low concentrations. The metal concentrations in the sampled seaweeds varied significantly from species to species, which gives an indication that different seaweed species are capable of accumulating metals differently from an environment. Green algae have more capacity to uptake of heavy metals as compare to red and brown algae in our study. Besada et al., 2009 concluded that there is a relationship between heavy metals and algae ‘classified’ by their colour (Chlorophyceae, green algae; Phaeophyceae, brown algae; and Rhodophyceae, red algae) and the ability to uptake of heavy metals based upon cell wall polysaccharides (Veroy et al., 1980).

**Conclusion**

The present study concludes that the variability of metal accumulation was probably the result of competition between the metals to bind with such polysaccharides at different levels and also based on their colour. Though the present investigation indicates that the sampling station showed lower limit of metal pollution, the results shows that the lesser concentrations has indirect effects of toxicants upon the distribution and abundance of closely associated fauna and also there is a possibility of bioaccumulation.

**Acknowledgements**

We are very thankful to Kada Narayana Murthy and Ramesh for their help during field collections and also thankful to
Pratheesh. C. Mammen, Ecology and Environmental Sciences, for the help rendered in completing statistical analyses. The authorities of the University are acknowledged for the support and facilities.

References


