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Heavy metal enrichment in seagrasses of Andaman Islands and its implication to the health of the coastal ecosystem

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Concentration of metals (Mn, Al, Fe, Cr, Cu, Zn, Pb, Cd, Co and Ni) in eight different seagrass species of Andaman Islands were analyzed using Inductively Coupled Plasma Optical Emission Spectrometer. The concentration of Mn was maximum in almost all the seagrasses, whereas Co recorded minimum concentration. The concentration of various metals are showed different concentration Mn (508-2224μgg^{-1}), Al (418.74-1064.8μgg^{-1}), Fe (525.6-1920.4μgg^{-1}), Cr (58.28-249.44μgg^{-1}), Cu (30.52-109.52μgg^{-1}), Zn (28.88-85.52μgg^{-1}), Pb (4.16-17.72μgg^{-1}), Cd (2.24-6.92μgg^{-1}), Ni (1.76-10.04μgg^{-1}) and Co (1-3.28μgg^{-1}). The results found that there where interspecific and intraspecific differences in the accumulation of different metals in seagrasses. However, there is no significant variation in metal concentration in seagrasses was obtained between stations. The study clearly indicates that the seagrasses can be used as a potential mean for monitoring the metal concentration in coastal environs.

[**Keywords:** Metal, Seagrass, Coastal environs, Andaman islands]

Introduction

Seagrass meadows play a significant role in the near shore dynamics, nutrient cycling, re-mineralization and sink for pollutants in coastal ecosystems. This ecosystem is well known for its high primary and secondary productivity, ability to stabilize sediments, production of vast quantity of detritus and support of diverse floral and faunal communities, they also represent as biotic heavy metal reservoirs[1]. Seagrass ecosystems are also considered to be one of the indicators of metal pollution in coastal waters[2,3].

Assessment of heavy metal concentration in the coastal waters can be made by using indicator organisms, particularly algae[4,5] and seagrasses[6,7] which accumulate pollutants proportionally to their environmental concentration[8,9]. Heavy metal pollution in the marine environment was investigated by several workers but such studies are limited[10,11,12,13] along the Andaman waters and it is also important to note that investigation on metal accumulation by the seagrasses was very much limited in the Indian waters[2,14].

The Andaman and Nicobar group of islands are reported for its higher biodiversity, pristine beaches and diverse coastal ecosystems[15,16,17]. Earlier studies on seagrasses were largely on the distribution of seagrasses of the Andaman islands in selected sites[18,19] and information on metal pollution and bioaccumulation by seagrasses are not available for the Andaman and Nicobar waters. Considering these facts, the present study was carried out to estimate the metal concentration in different seagrass species of the Andaman Islands.

Materials and Methods

Seagrass samples were collected from three different locations of the Andaman islands; Henry Lawrence island (Station 1: latitude; 12° 07' 50.7"N and longitude; 93° 05' 43.9"E), Neil island (Station 2: latitude; 11°50'31.1"N and longitude; 93°02'42.0"E) and Chidiyatapu (Station 3: latitude; 11°29'28.4"N and longitude; 92°42'32.4"E). These three sites were taken by considering the fact that they are very close to the active tourism sites of Andaman islands. Station I is close to Havelock island, known for its international tourism, station II itself is a good tourism area and station III is in close proximity to Mahatma Gandhi Marine National Park, Wandoor, another tourism area of Andaman and Nicobar.

Seagrass species were collected by skin diving method using snorkelers during November to December, 2007. Healthy matured green seagrass samples were collected from the shallow coastal waters of the sampling sites. Seagrass samples were washed by sea-water, cleaned to remove epiphytic organisms and are placed in separate polythene bags and transported to laboratory by keeping them in icebox. Seagrasses were washed under the tap water and finally rinsed in metal free glass double distilled water. Seagrass samples weighing 500 mg were dried at 105°C and ground to powder, they were made to ash with concentrated Nitric and Perchloric acid (4:1)[20] and then the metal concentrations [Manganese (Mn); Aluminium (Al); Iron (Fe); Chromium (Cr); Copper (Cu); Zinc (Zn); Lead (Pb) Cadmium (Cd); Nickel (Ni) and Cobalt (Co)] was determined by using Inductively Coupled Plasma Optical Emission Spectrometer (PerkinElmer, Optima 2100DV). The accuracy and precision of the analytical procedure were checked by analyzing standard reference materials of commercially available standards (Merck KGCA, 64271 Damstadt, Germany, ICP-Multielement standard solution IV, 23 elements in nitric acid). Triplicate samples were analyzed and standard deviations were worked out and expressed.

Oneway ANOVA and Pearson correlation (SPSS 11.5 package) were employed to understand the significance of metals with respect to seagrass and station and to get the correlation within the metals.

Results

Total of 8 seagrass species were recorded from the three sampling sites, of which Henry Lawrence recorded all the 8 species while Neil and Chidiyatapu were harboured with 5 species each (Table 1). The concentrations of heavy metals in the different seagrass species collected from three different locations of Andaman were analyzed. Metal concentration in the seagrasses of each station is represented graphically with standard deviation values [Mn, Al, Fe (Fig. 1 a-c); Cr, Cu, Zn (Fig. 2 a-c); Pb, Cd, Ni, Co (Fig. 3 a-c)].

Table 1—Seagrass distribution in the sampling sites

S.No	Seagrass species	St1	St2	St3
1	*Enhalus acoroides* (L.f.) Royle	+	-	-
2	*Halophila ovalis* (R.Br) Hook	+	+	+
3	*Halophila ovata* Gaud	+	-	+
4	*Thalassia hemprichii* (Ehrenb.) Asch	+	+	-
5	*Cymodocea rotundata* Ehrenb. and Hempr. Ex Asch	+	+	+
6	*Halodule uninervis* (Forsk.) Asch	+	+	+
7	*Halodule pinifolia* (Miki) Hartog	+	+	+
8	*Syringodium isoetifolium* (Asch.) Dandy	+	-	-

Among the 10 metals investigated, the concentrations of the Mn and Al were registered in higher concentration in the seagrasses of the Andaman Islands and their values varied with respect to different seagrass species. The minimum content of Mn (508µgg^{-1}) was recorded in *Enhalus acoroides* (L.f.) Royle collected from the Henry Lawrence island, where as Mn (2224µgg^{-1}) recorded higher concentration in *Syringodium isoetifolium* (Asch.) Dandy. Significant positive correlation was obtained between Manganese and Iron concentration in seagrasses (r= 0.728, P< 0.01). Aluminium is one of the major element found in seagrass samples which recorded the minimum concentration of 418.74µgg^{-1} in *Thalassia hemprichii* (Ehrenb.) Asch. collected from the Neil island and the maximum concentration of 1064.8µgg^{-1} in *Halodule uninervis* (Forsk.) Asch. collected from Henry Lawrence island. The

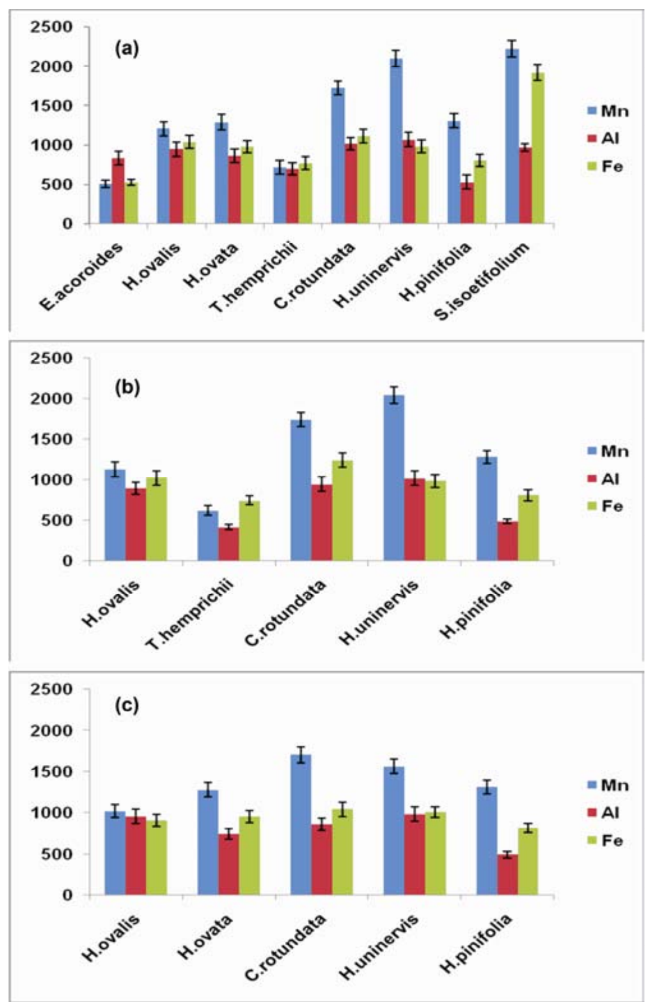

Fig. 1—Heavy metal concentration (Mn, Al and Fe in µgg^{-1}) recoreded in the seagrasses at Stations I (a), II (b) and III (c)

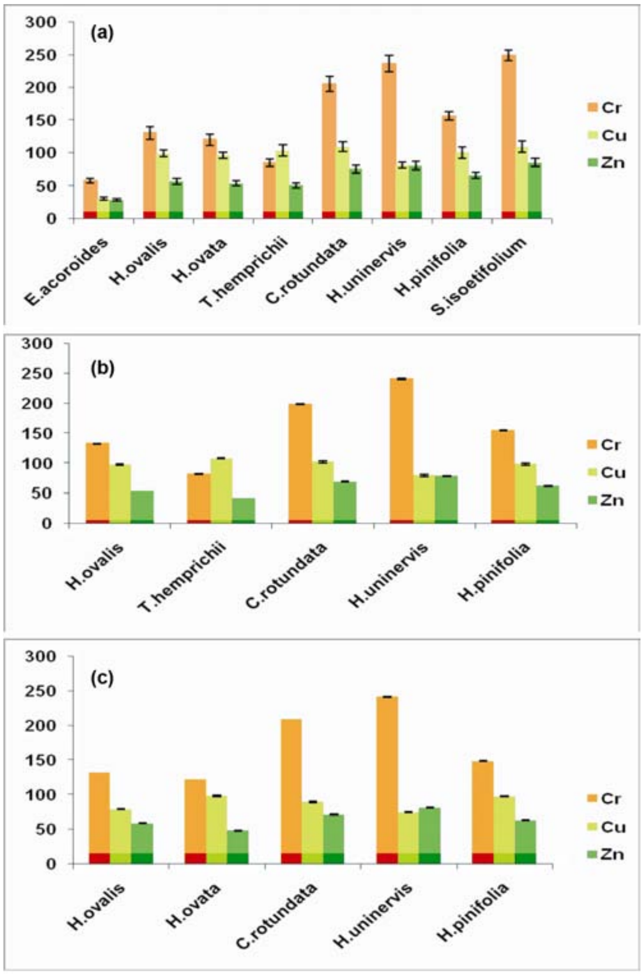

Fig. 2—Heavy metal concentration (Cr, Cu and Zn in µgg^{-1}) recoreded in the seagrasses at Stations I (a), II (b) and III (c)

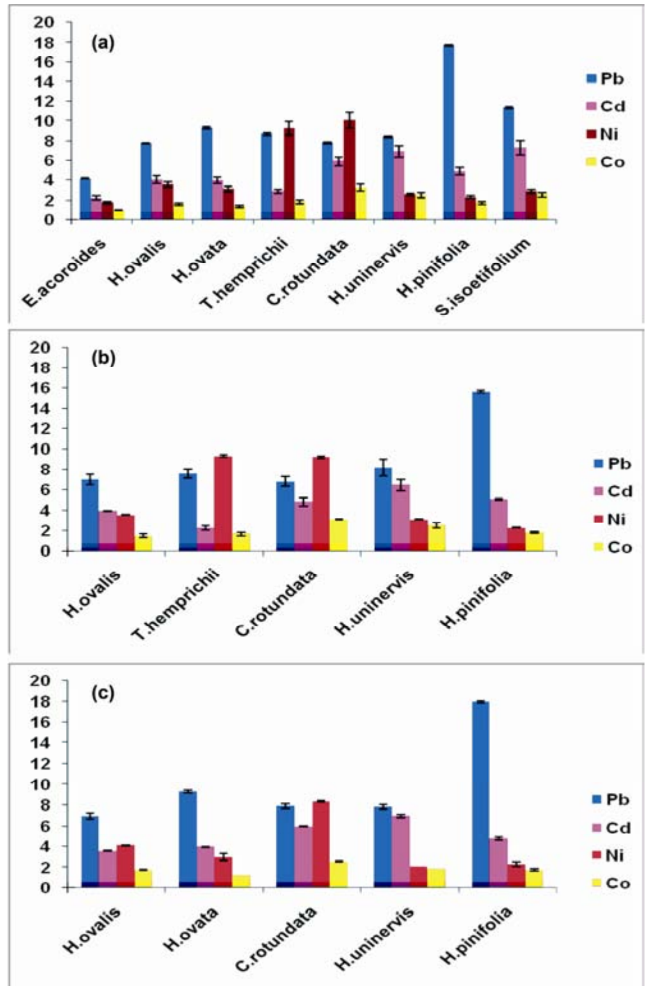

Fig. 3—Heavy metal concentration (Pb, Cd, Ni and Co in µgg^{-1}) recoreded in the seagrasses at Stations I (a), II (b) and III (c)

concentration of Iron also showed a similar trend like Al and all seagrass species investigated were showed meager variation in the concentration of Fe. Al showed significant positive correlation with Fe (r=0.483, *P*< 0.05). *E. acoroides* recorded the minimum concentration of Fe (525.6µgg^{-1}) whereas the maximum concentration (1920.4µgg^{-1}) was observed in *S. isoetifolium*. Chromium and Copper showed a similar trend of concentration registering minimum concentration of Cr (58.28µgg^{-1}) and Cu (30.52µgg^{-1}) in *E. acoroides,* while the maximum concentration of Cr (249.44µgg^{-1}) and Cu (109.52µgg^{-1}) in *S. isoetifolium.* The concentration of Zinc in different seagrass species varied between 28.88µgg^{-1} and 85.52µgg^{-1} registering the minimum in *E. acoroides* and maximum concentration in *S. isoetifolium*. Zn also showed a significant positive correlation with almost all the other metals [Cd (r=0.956), Co (r=0.761), Cr (r= 0.967), Fe (r=0.661) and Mn (r=0.981); *P*<0.01]. ANOVA test indicates significant variation in the concentration of Zn in different seagrass species (F=50.35, *P*<0.001) however there is no significant variation in the Zn concentration between the stations.

The concentration of Cadmium, Cobalt, Nickel and Lead was in lower limit in all the seagrass species. The concentration of Cd was lower (2.24µgg^{-1}) in *E. acoroides* and higher in (6.92µgg^{-1}) in *H. uninervis.* Whereas, in the case of Co the concentration varied between 1 and 3.28µgg^{-1} registering the lower concentration in *E. acoroides* and the higher concentration in *Cymodocea rotundata* Ehrenb. and Hempr. Ex Asch. Cadmium showed a significant positive correlation with Cobalt (r = 0.662, *P*< 0.01). The concentration of Ni was almost same in all the seagrass species tested. The minimum Ni concentration was registered in *E. acoroides* (1.76µgg^{-1}) and the maximum concentration was recorded in *C. rotundata* (10.04µgg^{-1}). The concentration of Pb varied between 4.16 and 17.72µgg^{-1} with the minimum concentration of Pb in *E. acoroides* and the maximum concentration in *Halodule pinifolia* (Miki) Hartog. Pb showed significant negative correlation with Al (r= -0.630, *P*< 0.01).

Discussion

Seagrasses and algae can be used as the indicators of heavy metals in the marine environment[21,22] and they can be considered as good biomonitors of heavy metals[23,24,25]. In some areas seagrasses represent as the greatest heavy metal reservoir, and this biotic compartment can remobilize metals by litter production and in food chains[26]. Concentration of metals in the 8 species of seagrasses varied considerably from species to species. This was evidenced by the ANOVA test, which indicates that there was significant variation in the metal concentrations in different seagrass species (*P*<0.001). This gives an indication that different seagrass species are capable of accumulating metals differently from the environment. The results also indicate that there is no significant variation in metal concentration in seagrass between the stations. This ensures that the seagrass species are reliable sources for metal pollution monitoring. Higher concentrations of Mn and Al were observed in all the seagrasses. Significant variations in the concentration Mn in different seagrasses was observed (F=28.52, *P*<0.001).

Approximately fifty three of the ninety naturally occurring elements are called heavy metals[27] and many of these, such as Cu, Mn, Fe, and Zn are essential micronutrients for plants, but can become toxic at concentrations higher than the amount required for normal growth[28]. Occurrence of higher concentration of Mn in plants is a common feature as Mn is used by plants for maintaining osmotic balance, ion regulation and for enzyme catalysis[29]. *H. uninervis* recorded maximum concentration of Cadmium in the stations Neil and Chidiyatapu while *S. isoetifolium* showed the maximum concentration of Cd in Henry Lawrence. Seagrasses, which are important contributors to primary production of the coastal areas, are also capable of taking up metals from both water through leaf surfaces, sediment and interstitial water through their roots[30,31,32]. Heavy metals, such as Cd, Hg, and Pb, have unknown roles in living organisms, and are toxic even at very low concentrations[28,33] were also recorded from the seagrass samples. A maximum (85.7µgg^{-1} d.w.) concentration of Cd content in seagrass was recorded by many researchers[34,35], but the concentration recorded in the present study are comparatively lower level (2.24-6.92µgg^{-1}). Cellular damage in leaf cells is reported due to Cd contamination in a concentration of 51.2± 15.3 µgg^{-1}d.w[36]. This ensures that the present concentrations of toxic heavy metals in the seagrasses of Andaman region are at lower side and not capable of causing any toxicity to the seagrasses.

T. hemprichii and *C. rotundata* in all the stations showed higher content of Ni whereas, all the other seagrass species reported to have the concentration less than 3µgg-1. Negative correlation was observed between Ni and almost all other metals analysed except that of Cobalt (r=0.512, *P*<0.05), this negative correlation shows the influence of other metals on Ni accumulation. Almost all the seagrasses recorded more concentration of Mn than Al and Fe. Whereas earlier studies conducted in Palk Bay reported higher concentrations of Fe than Mn, Cu and Zn in *E.acoroides*2. ANOVA test prove that like other metals, Al concentration in the seagrasses also varied significantly (F= 15.24, *P*<0.001) between all the species. Al showed significant negative correlation with Pb (r=-0.630, *P*<0.01), this negative relationship can be explained as that the increased amount of Al might have been decreasing the concentration of Pb in seagrasses. *S. isoetifolium* which is recorded only in the station 1 showed more Mn content than all other metals, whereas the metals like Cd, Co, Ni, Pb and Zn occurred in very less amount in this species. Pb recorded its maximum concentrations in *H. pinifolia* in all the three stations. Similar observations were made in Palk Bay where *H. pinifolia* recorded more concentrations of heavy metals than any other seagrass species[2].

Results indicate that concentrations of different metals in seagrasses showed clear interspecific and intraspecific differences in the accumulation of metals in seagrasses. However the intraspecies variation in different station is not significant and it showed that the environmental factors expcet the metal concentration of the ambient enviroment are not governing much on the metal accumulation of species. When compared to the metal concentration in the seagrasses of other parts of the country (Table 2), seagrasses in Andaman have accumulated lesser heavy metal concentration. However metal

Table 2—Heavy metal concentration (µgg^{-1}) recorded in the seagrasses of other parts of India

Seagrass	Study area	Fe	Mn	Zn	Cu	Ni	References
Halophila beccarii	Malvan	8650	500	--	6	4	14
Halophila ovalis	Palk Bay	795	2235	45	21.67	--	39
Syringodium isoetifolium	Palk Bay	708.33	553.33	53.33	56.67	--	
Enhalus acoroides	Palk Bay	909	304	35	36.5	--	
Thalassia hemprichii	Palk Bay	1085	220.5	35	37	--	2
Halodule pinifolia	Palk Bay	1886.67	491.67	69.17	60.83	--	

concentration in the environment may have a defined role in determining the metal concentration in the seagrasses. Metal concentration in the Andaman sea also registered with lower metal concentration (Mn: 286; Fe: 9810; Zn: 5129; Co: 466; Pb: 1899; Cd: 32µgg^{-1})[11] when compared to Indian mainland coast. This evidence that due to lesser concentration in the environment, seagrasses in this region also accumulating lesser concentration. Earlier reports favours that the seagrasses with large biomass may serve as heavy metal reservoirs[8,23,37]. However our results found that the interspecies variation in metal concentration was largely influenced by the plant physiological properties rather than the morphological characters. This is evidenced by the present results that the broad leaved seagrasses like *E. acoroides, T. hemprichii, C. rotundata* recorded lesser concentration of metals when compared to the seagrass species with small leaves. This evident that seagrass plant size is not playing a major role in metal accumulation and other factors might be playing a crucial role in determining the accumulation of metals.

Fe was always the most concentrated element followed by Mn, Zn and Cu in seagrasses[38]. But in the present study out of the 10 elements analyzed, Mn was found in higher concentration followed by Fe and Al. Higher concentrations of Mg and Mn are required for the seagrass growth[14]. During the present study, higher concentration of Zn was recorded in *S. isoetifolium* whereas the lower concentration was recorded in *E. acoroides*, similar results were also reported from seagrasses[39] from other parts of the Indian coast. The concentrations of metals observed in the seagrasses are in the ranges of other non-polluted marine areas of the world[7,40,41,42,43].

Even though the present study indicates that the marine environs of Andaman are still in pristine conditions and devoid of any metal pollution, the result warns the possibility of transfer of metals from seagrasses to higher tropic level consumers, including the green turtle and sea cow *Dugong dugon* of the Andaman waters. Sea cows (*Dugong dugon*) which solely feed on seagrasses[44] have been reported to have higher concentrations of metals[38] possibly linking the transfer of metals from seagrasses into higher trophic level consumers. These consumers have the ability to accumulate metals from leaf, root and detrital material, thereby posing threat to other coastal resources through bioaccumulation and subsequent effect on trophic relationships[45].

Table 3—Order of the mean metal concentration in the seagrasses of Andaman Islands

Seagrass species	Metal concentration
Enhalus acoroides	Al > Fe> Mn > Cr > Cu > Zn > Pb > Cd > Ni > Co
Halophila ovalis	Mn > Fe > Al > Cr > Cu > Zn > Pb > Cd > Ni > Co
Halophila ovata	Mn > Fe > Al > Cr > Cu > Zn > Pb > Cd > Ni > Co
Thalassia hemprichii	Fe > Mn > Al > Cu > Cr > Zn > Pb > Cd > Ni > Co
Cymodocea rotundata	Mn > Fe > Al > Cr > Cu > Zn > Ni > Pb > Cd > Co
Halodule uninervis	Mn > Al > Fe > Cr > Zn > Cu > Pb > Cd > Ni > Co
Halodule pinifolia	Mn > Fe > Al > Cr > Cu > Zn > Pb > Cd > Ni > Co
Syringodium isoetifolium	Mn > Fe > Al > Cr > Cu > Zn > Pb > Cd > Ni > Co

The mean concentration of metals in seagrasses of the three stations where given in the descending order in Table 3. Marine plants are considered to be reservoirs of heavy metals[1], all the three stations showed similar fluctuations in the concentrations of heavy metals, whereas each and every species in all the three sites accumulated metals in different concentrations. Though industrial and urban development can increase the quantity of metals available to seagrasses by diffuse and point source influences[45], the present study demonstrated that the land run off due to rain, sewage, boating operation and boat maintenance activities and paints in the vicinity might be the source for the metal supply to these sites. Statistical analysis using ANOVA revealed that there is no significant variation in metal concentration in seagrass species between the stations. But it also revealed that there is a clear inter species variation in metal concentration. These variations in the heavy metal concentrations of the seagrasses could be attributed to the local environmental conditions, different phenological stages of the seagrasses and the differential bioaccumulation abilities of different species.

Conclusion

The present study clearly showed the ability of different seagrass species in accumulation of metals in different concentrations. ANOVA test showed that there is no significant variation in the metal concentration between the stations in all the seagrass species. This study indicated that the seagrasses may be used as a potential mean of measuring the metal concentration in coastal environs. The metal concentration in the seagrasses of the three stations are within the limit and comparable with the other non-polluted marine environments of the world.

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