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Arsenic content in certain marine brown algae and mangroves from Goa coast

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Arsenic has been estimated in 7 species each of brown algae and mangroves, including different parts of *Sargassum cinereum*. Arsenic is more concentrated in brown algae [concentration /factor(CF) range 1.5 - 7 $\times 10^3$] as compared to mangroves (CF < 1). In brown algae organic As is accounted for about 75-90% of total, but in *S. cinereum* and *Sphacelaria furcigera* about 50-60% inorganic As is noted. Basal thallus and reproductive organs of *S. cinereum* have higher concentration of total and organic As than active photosynthetic portions. However, holdfast accumulates lesser As but its organic As is high (80 %). Arsenic in younger leaves of mangroves is marginally more (0.23 mg.kg^{-1} dry wt.) than that of mature and yellow leaves (0.16 mg.kg^{-1}).

Utilisation of seaweeds in food industries has recently achieved a quantum leap due to rapid innovative technology to enhance the biomass production of highly nutritive species, and improvement in the quality of algal products. Among the several criteria to use seaweeds and their products for human consumption, content of toxic element like As which is fixed by its safe level[1] is important. Though the coastal areas are vulnerable to land drainage knowledge on As composition and its biogeochemical distribution in highly productive areas like estuarine/mangrove environment is limited[2-4].

Seaweeds are known to accumulate As from its surrounding medium[3]. Brown seaweeds are efficient in accumulating As than green and red seaweeds and are species specific[5,6]. Therefore, in the present study an attempt has been made to estimate As in 7 species each of brown seaweeds (inorganic and organic fractions) and mangroves respectively collected from Anjuna and Chorao island of Goa (lat. 14°49'-15°52'N; long. 73°38'-74°24'E) during Dec. 1989 (mangroves) and Feb. 1990 (seaweeds). Seawater was collected from the surroundings of algal beds whereas sediment was collected from the mangrove habitat.

Floral material was cleaned of extraneous material, dried, powdered, sieved and used for analysis. Sediment sample from the top 5 cm was collected from the surrounding of the mangrove stands for analysis. After filtration seawater was directly used for As analysis[7]. In algae, mangrove and sediment samples, total As was estimated after complete destruction of organic matter with magnesium oxide and magnesium nitrite slurry[8]. In algae and different portions of thalli of *Sargassum cinereum* inorganic As was estimated after extraction with $FeCl_2$ + HCl solution[9]. The difference between the total and inorganic fraction gave organic As fraction. All samples were analysed in triplicate and results expressed as mean of 3 analyses. Coefficient of variation of total As as a percentage of standard deviation was calculated in *S. cinereum* (for inorganic As also) and a mangrove *Rhizophora apiculata* which was 10% and 15% respectively.

In algae inorganic, organic and the total As content range from 0.68-12.53, 3.85-9.31 and 4.53-20.93 mg.kg^{-1} dry wt respectively (Table 1). Total As content was more in *S. cinereum* than the other algal species and is comparable with *Sargassum* spp (8.44-68.34 mg.kg^{-1} dry wt.) reported from Gujarat coast[6]. The concentration of As in algae in the present study shows variability within and among the species analysed, which indicates their species specificity and phenology[3,6,9].

The physiological significance of high As content in seaweeds is not known but most part of it is in the organic form[5,9] (60-95%). In the present study organic As is noted to be 75-90% except in *S. cinereum* and *Sphacelaria furcigera* in which 40% and 50% of organic As is reported respectively. It seems that most part of the inorganic fraction in latter

Table 1—Arsenic content in brown algae (mg.kg^{-1} dry wt) and ambient seawater (μg.kg^{-1})

	Fraction of As(%)			
	Total	Inorg.	Org.	*CF(× 10^3)
Seawater	3.0	—	—	—
Algae				
Sphacelaria furcigera Kuetz	5.81	50	50	1.94
Dictyota dichotoma (Huds.) Lamour	10.34	10	90	3.45
Padina tetrastromatica Hauck	4.53	15	85	1.51
P. gymnospora Kuetz	4.87	20	80	1.62
Spatoglossum asperum J. Ag.	4.87	15	85	1.62
Stoechospermum marginatum (Ag) Kuetz	5.35	25	75	1.78
Sargassum cinereum J. Ag.	20.93	60	40	6.98
Different parts of *S. cinereum*				
Apical thallus (top 5 cm)	15.62	60	40	5.21
Apical frond like portion	18.85	65	35	6.28
Middle thallus (above 5 cm from base and below 5 cm from top)	21.93	60	40	7.31
Middle frond like portion	17.74	65	35	5.91
Lower thallus	22.14	60	40	7.38
Receptacles	23.73	50	50	7.91
Holdfast	6.63	20	80	2.21

*CF (concentration factor) = As in seaweed/As in seawater

species is not biochemically metabolised[5,9]. Analysis of different parts of *S. cinereum* shows relatively higher concentration of total As in receptacles and basal portions. Similar trend is noted[3] in *Ascophyllum nodosum* and *Fucus vesiculosus*. Comparable to apical thallus and frond like portions, basal portions and receptacles accumulate high fraction of organic As. Although holdfast accumulates minimum of total As, its organic fraction is highest (80%, Table 1). It seems that particularly in the latter portions the translocated inorganic fraction might be metabolised to certain extent to organic As[3]. Since the contribution of these portions to the total biomass is less, compared to the other portions containing higher fraction of inorganic As, inorganic As content is more in the plants as a whole.

Whyte and Engler[9] quoted that since organic bound As is stable and resistant to degradation by human digestive system, species like *Sargassum* pose a problem for human and animal consumption because of its high content of inorganic As than the permissible limit. In India *Sargassum* species are not directly used for human nutrition and these are potential animal feed[10]. Therefore, in case any meaningful consumption for human and animal nutrition of this most abundant genus is envisaged, its inorganic As should be taken into consideration.

Total As in different stages of mangrove leaves (young, mature and yellow) is very less and ranges from < 0.1-0.4 mg.kg^{-1} dry wt (Table 2). Its concentration in younger leaves (0.23 mg.kg^{-1} dry wt) is marginally more than that of mature and yellow leaves (0.15 mg.kg^{-1} dry wt). It probably shows that the absorbed As in younger leaves is diluted with the age of the leaf.

Table 2—Total arsenic content in mangrove habitat (mg.kg^{-1} dry wt.)

Species	Young leaves	Mature leaves	Yellow leaves
Avicennia officinalis Lamk	0.2	0.15	0.1
A. marina (Forssk) Vierh	0.4	0.25	0.15
Excoecaria agallocha Linn.	0.15	<0.1	0.1
Kandelia rheedi W. *et* A.	0.3	0.2	0.2
Rhizophora apiculata Blume	0.25	0.2	0.25
R. mucronata Lamk	<0.1	<0.1	<0.1
Sonneratia alba J. Sm.	0.2	<0.1	0.15
Sediment	4.6	—	—

Arsenic content of estuarine sediments is higher than their overlying waters[4] and provide biologically available As form to the organisms[2]. In the present study the reported value of As in the sediment is 4.6 mg.kg^{-1} dry wt. and its concentration factor in the mangrove leaves is < 1. It shows that As is not accumulated preferentially by mangroves from the sediment.

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