Minerals and Heavy Metal Composition in Seaweeds of the Eastern Coast, Northern Bay of Bengal, Bangladesh

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ABSTRACT: This study aimed to analyze minerals (Ca, Mg, Fe, Zn, Mn and Cu) and heavy metals (Pb and Cd) content of seaweeds collected from coastal waters of Bangladesh using Atomic Absorption Spectrophotometer (AAS). Eight wild species in three phyla viz. Rhodophyta (*Hypnea* sp.), Chlorophyta (*Enteromorpha*sp.),and Phaeophyta (*Sargassum*sp.,*Hydroclathrusclathratus, Padinapavonica, Colpomeniasinuosa, Petalonia fascia* and *Dictyotaciliolata*)and one cultured Rhodophyta species viz. *Hypnea* sp. were collected from St. Martin's Island and Cox's Bazar, respectively. Results showed minerals and heavy metals concentrations were varied from species to species. Ca concentration was the highest in Phaeophyta (18565 mg/kg-dw) and it was 19 times higher than the value reported in Chlorophyta (950 mg/kg-dw). In contrast, Fe, Zn and Mn were the highest in Rhodophyta. This is because different groups of seaweeds affinity to absorb minerals depend on environmental parameters for example salinity, pH and light intensity, mineral accessibility in sea water and interactions between elements, growth and metabolic factors, etc. Ca content was the highest in *C. sinuosa* (30890 mg/kg-dw), whereas, it was the lowest in cultured *Hypnea* sp. (120 mg/kg-dw). *P.pavonica* showed the highest concentrations of Fe (15030 mg/kg-dw), Zn (33.46 mg/kg-dw) and Mn (443.79 mg/kg-dw). Mineral contents of cultured seaweeds were comparatively lower than the wild species. Results showed mineral concentrations in all seaweeds were relatively greater than heavy metals. However, wild *Hypnea*sp. contained slightly 2 times higher Cd (2.11 mg/kg-dw) than the cultured *Hypnea* sp. (0.98 mg/kg-dw) due to higher level of anthropogenic source of pollution in St. Martin's Island. Heavy metal contamination in seaweeds might raise health concerns among the consumers. Findings of this study might help to unleash minerals and heavy metals compositions of the studied seaweeds of Bangladesh. Policy makers can formulate and establish health safety guidelines for safe consumption of seaweeds.

Keywords: Macroalgae, Toxic metals, Health risk, functional food, Bangladesh

INTRODUCTION

Seaweeds or marine macro-algae are rich in natural vitamins, fibres, lipids, minerals and proteins and that is why direct consumption of seaweeds is widely growing because of its high nutritional values and health benefits (Rupérez, 2002; Chen et al., 2018). Seaweeds contain higher level of minerals in their cell walls than terrestrial plants (Rupérez, 2002) and in some cases, the percentage of minerals would be up to 40% (Kumar et al., 2011; Nwosu et al., 2011). Seaweeds also contained significant extent of bioactive substance that showed antifungal, antibacterial, and antiviral properties (Kumar et al.,

2008). Seaweeds are considered as nutritional or functional food for the coastal people. Overwhelming majority of coastal people of Bangladesh (13.8% of the total population) live in poverty line (World Bank, 2018) who cannot afford to fulfill the daily requirement of nutritional foods. In this case, to meet the demand of nutrient rich foods including proteins or minerals, the coastal poor people can get highly nutritive seaweeds at a low-cost which are naturally grown in intertidal, tidal and subtidal regions of coastal waters (Khandaker et al., 2021).

The coastal waters of Bangladesh are very suitable for growing diverse number of natural seaweeds. In total 193 (Sarkar et al., 2016) or 244 (Uddin, 2019) seaweed species including 17 (Rani et al., 2020) or 19 (Sarkar et al., 2016) commercially important species are found in coastal waters. Among them, a total of 140 to 155 species are naturally grown in coastal waters of St. Martin's Island and Cox's

Bazar. However, till now scientists of Bangladesh Fisheries Research Institute (BFRI) have confirmed that 116 species are present in coastal regions of Bangladesh (DoF, 2019). There are 14 potential candidates of culturable species where only five species viz. *Gracilariatenuistipitata*, *Hypneamusciformis, Ulvaintestinalis and U. lactuca* (Hossain et al., 2021) and *Enteromorpha*sp. (Feed the Future, 2021) are farmed in Cox's Bazar district, Bangladesh but in small amount.

Coastal and estuarine waters of Bangladesh particularly east coast of Cox's Bazar and St. Martin's Island are severely polluted due to anthropogenic activities such as dumping from chemical industries, surface runoff and agricultural activities, wastewater discharging, mining, etc. (Rani et al., 2021). As a consequence, health anxiety has been elevated regarding potential contamination of heavy metals in seaweeds since seaweeds could accumulate elevated contents of heavy metals in their body from the seawater (Chen et al., 2018). This is because some metals like Cd, Pb and Hg can be noxious at a minute concentration and biologically indispensable metals could result in lethal effects at higher concentrations.

Globally several studies were directed to analyze minerals and heavy metals contents in seaweeds (e.g., Rupérez, 2002; Rubio et al., 2017; Chen et al., 2018; Yoganandham et al., 2019; Khandaker et al., 2021; etc.). Despite having many naturally available seaweeds in coastal waters of Bangladesh, there has scarce studies (e.g., Khan et al., 2016) on estimating mineral concentrations from them. Therefore, the use of this nutritious seaweeds as a functional food is still underutilized as people are not yet aware of the details nutritional value of each seaweed. Types and contents of minerals in seaweeds are varied depending on diverse geographical origins, methods of mineralization, wave exposures, tidal fluctuations, pollution levels and seasonal differences, etc. (Carlson and Erlandsson, 1991; Topcuoğlu et al., 2003; Żbikowski et al., 2006; Astorga-España et al., 2015). At the same time, the potential health risk of seaweeds consumption is very obligatory to understand. However, there has no study to analyze potential heavy metals contamination in seaweeds from coastal waters of Bangladesh for health safety issues. That is why, the present study aimed to analyze minerals and heavy metals concentrations in seaweeds collected from coastal waters of the St. Martin's Island and

Cox's Bazar, Bangladesh, northern Bay of Bengal. The findings of this study might help to understand the minerals and heavy metals compositions of the studied seaweeds of Bangladesh. Based on the findings the policy makers can formulate and establish health management guidelines for safe consumption of seaweeds.

MATERIALS AND METHODS

Study sites

In this study, a total of eight (8) wild seaweed species in three phyla viz. Rhodophyta or red seaweed (*Hypnea*sp.), Chlorophyta or green seaweed (*Enteromorpha* sp.), and Phaeophyta or brown seaweed (*Sargassum* sp., *Hydroclathrusclathratus*, *Padinapavonica*, *Colpomeniasinuosa*, *Petalonia fascia* and *Dictyotaciliolata*)*,* and only one cultured red seaweed species of *Hypnea* sp. were collected from the western coast of St. Martin's Island (20°37' N and 92°19' E) and Nunairchhara, Cox's Bazar (21°28' N and 91°57' E) of the south-eastern part of Bangladesh, northern Bay of Bengal, respectively. All seaweed samples were carefully washed in running seawater and rinsed with tap water to eliminate all unwanted materials such as salt and foreign particles e.g., epiphytes, shells, sand, debris, etc. Finally, samples were preserved into plastic jars using 4-5% of alcohol.

Sample preparation

All seaweed samples were gently rinsed with deionized water at the laboratory of Dhaka University and air-dried for 3 days. Later samples were oven-dried at 105ºC for overnight and then the dried samples were grinded into powder using a mortar and pestle. All powdered seaweed samples were kept in the desiccators at room temperature until chemical analyses were done.

Biochemical analyses to estimate minerals and heavy metals

Microwave digestion

For the microwave digestion less than 0.50 g of powdered seaweed samples were taken into a clean and dry microwave Teflon vessel. Later, added 8 ml of HNO_3 to the samples. A seal forming device was applied to enlarge the lip-seals on all vessel's caps. The vessels were stored in a bomb jacket with attached lids and kept in the microwave to digest the

samples at 200°C for 10 minutes (FSSAI, 2015). Then the vessels were transferred in a fume hood from the microwave. The caps of all vessel were carefully unbolted to remove nitrogen oxides. Finally, the digested samples were moved into 50 ml volumetric flasks through filtration and diluted with distilled water. Then clear solutions were moved into falcon tube for Atomic Absorption Spectrophotometer (AAS) (Analyst 200, Perkin-Elmer and USA) analysis. Blank was prepared in similar process without adding any seaweed sample. Appropriate dilutions containing 0.4% lanthanum (w/v) to overcome ionic interferences were used to determine calcium (Ca) and magnesium (Mg).

Standard wave length, detection limit and curve for minerals and heavy metals

The contents of six minerals viz. Ca, Mg, Fe, Zn, Mn and Cu, and two heavy metals viz. Pb and Cd were determined by flame AAS after appropriate microwave digestion of the samples. Hollow cathode lamps of each element were used to analyze the wave length of all minerals and heavy metals (Table 1). The device was calibrated with standard solutions.

Table 1: List of Wave Length and Detection Limit of Minerals and Heavy Metals

	Hollow cathode lamps	Wave length (nm)	Minimum detection limit(mg/kg)
Minerals			
Ca	Calcium hollow cathode lamps	422.7	0.06
Mg	Magnesium hollow cathode lamps	279.5	0.01
Fe	Iron hollow cathode lamps	248.3	0.04
Zn	Zinc hollow cathode lamps	213.9	0.01
Mn	Manganese hollow cathode lamps	285.2	0.01
Cu	Copper hollow cathode lamps	324.8	0.03
Heavy metals			
Pb	Lead hollow cathode lamps	283.3	0.18
Cd	Cadmium hollow cathode lamps	228.8	0.01

Quality Assurance and Quality Control

In this study, all laboratory instruments including materials for sample preparation and analytical procedures were acid-cleaned to avoid contamination risk. All analytical devices were carefully calibrated before doing any analysis to certify that it was functioning properly within the accepted ranges. Moreover, the accuracy and precision of the minerals and heavy metal concentrations of seaweeds were evaluated by quality assurance and quality control (QA/QC) procedures, which also implied for the analysis of blank and samples (USEPA, 1995). The accuracy of minerals and heavy metals concentration in seaweed samples was verified by standard samples analysis. The calibration curves with coefficient values (r^2) > 0.998 were used to calculate minerals and heavy metals concentrations of seaweeds (Table 2) and the estimated concentrations were expressed as mg/kg, dry weight (dw) basis. Blank samples were also digested following the similar procedures that were used to measure minerals and heavy metal

contents in seaweed samples. The minimum detection limit for Ca, Mg, Fe, Zn, Mn, Cu, Pb and Cd were 0.06, 0.01, 0.04, 0.01, 0.01, 0.03, 0.18 and 0.01 mg/kg-dw, respectively (Table 1).

Table 2: Standard Solution for Calibration Curve of Minerals and Heavy Metals

	Amount of standard solution (mg/L)	Correlation coefficient
Minerals		
Ca	1.0, 2.0, 3.0, 4.0, 5.0	0.999024
Mg	0.2, 0.4, 0.6, 0.8, 1.0	0.998744
Fe	0.5, 1.0, 1.5, 2.0, 3.0	0.999811
Zn	0.2, 0.4, 0.6, 0.8, 1.0	0.998461
Mn	0.2, 0.4, 0.6, 0.8, 1.0	0.999641
Cu	0.2, 0.4, 0.6, 0.8, 1.0	0.999180
Heavy metals		
Pb	0.5, 1.0, 2.0, 3.0, 4.0	0.999537
Cd	0.2, 0.4, 0.5, 0.6, 1.0	0.998462

Statistical analysis

The amount of minerals (Ca, Mg, Fe, Zn, Mn and Cu) and heavy metals (Pb and Cd) in seaweeds were

calculated from the readings of AAS at specific wave length using specific hollow cathode lamp. In this study, the mineral and heavy metal concentration of cultured seaweed species was excluded while estimating the differences of mineral concentrations in wild seaweed algal groups. Descriptive statistics were used to analyze the data in Microsoft Excel (version-2013). Data were presented in tabular and graphical forms.

RESULTS AND DISCUSSION

Mineral and heavy metal concentrations in seaweeds

This study showed mineral concentrations in different seaweed species were varied from species to species. The highest concertation of Ca (30890 mg/kg-dw) was found in *C. sinuosa*, whereas, the lowest concentration was recorded in cultured *Hypnea* sp. (120 mg/kg-dw) (Table 3). The amount of estimated Ca concentration was also very low in *Enteromorpha* sp. of green seaweeds compared with *C. sinuosa*. The reported Ca concentrations of *C. sinuosa* (52269 mg/kg-dw) and *P. pavonica* (31878 mg/kg-dw) collected from Qheshm Island in the south of Iran (Tabarsa et al., 2012) were comparatively higher than the results of the present study. The differences might be occurred due to environmental changes such as geographical location, tidal fluctuations, minerals in seawater availability and wave exposure (Astorga-España et al., 2015). Khan et al. (2016) reported that the concentration of Ca was 1021 mg/kg-dw in *Hypnea* sp. collected from coastal water of eastern St. Martin's Island, Bangladesh that was lower than the estimated Ca concentration in wild *Hypnea* sp. (11170 mg/kg-dw)

of this study. However, Khan et al. (2016) showed a slightly higher Ca concentration in*Enteromorpha* sp. than the present study. This could be happened due to changes of mineralization methods, wave exposures and tidal fluctuations.

Among all seaweeds,Mg concentration was varied from 2160 mg/kg-dw to 17540 mg/kg-dw (Table 3). The maximum concentration of Mg was recorded in green seaweed *Enteromorpha*sp. (17540 mg/kg-dw) followed by brown seaweeds *D. ciliolata* (10810 mg/kg-dw) and *P. pavonica* (10780 mg/kg-dw), whereas, the lowest concentration was recorded in cultured red seaweed *Hypnea*sp. (2160 mg/kg-dw).*P.pavonica* also exhibited the maximum concentrations of Fe (15030 mg/kg-dw), Zn (33.46 mg/kg-dw) and Mn (443.79 mg/kg-dw). Tabarsa et al. (2012) reported the concentration of Fe and Mn in *P. pavonica*were 2498.7 mg/kg-dw and 103.3 mg/kg-dw respectively that were not in line with the present study. Khan et al. (2016) showed the reported concentration of Fe (125 mg/kg-dw) in wild *Hypnea* sp. was very low than the estimated concentration of Fe (11670 mg/kg-dw) in wild *Hypnea* sp. in this study. The concentration of Zn in different seaweeds was varied from 10.60-33.46 mg/kg-dw in this study. Results showed that all studied seaweeds contained the lowest amount of Cu than rest of the minerals and the range of Cu concentrations varied from 3.13-16.48 mg/kg-dw (Table 3) that was comparatively lower than the differences in other mineral concentrations in different seaweeds. This is because seaweeds usually comprise very small amount of Cu contents compared to other foods (Muñoz and Díaz, 2020).

Table 3: Concentration (mg/kg-dw) of Minerals and Heavy Metals Estimated from Wild (otherwise specified)Seaweed Species Collected from St. Martin Island

| Phyla | Species name | Concentration (mg/kg-dw) | | | | | | | |
| | | Minerals | | | | | | Heavy metals | |
		Ca	Mg	Fe	Zn	Mn	Cu	Pb	Cd
Red seaweed	*Hypnea*sp.[a]	120	2160	2640	10.60	143.38	3.13	BDL[b]	0.98
	*Hypnea*sp.	11170	6200	11670	25.87	304.14	7.30	9.33	2.11
Green seaweed	*Enteromorpha*sp.	950	17540	5560	15.13	209.78	8.09	9.29	2.56
Brown seaweed	*Sargassum*sp.	13000	4100	1140	11.36	33.40	5.75	BDL[b]	2.87
	Hydroclathrusclathratus	15680	3090	9350	16.72	197.16	10.00	8.00	1.11
	Padinapavonica	27620	10740	15030	33.46	443.79	12.91	20.55	3.55
	Colpomeniasinuosa	30890	4970	10120	24.84	309.49	16.48	16.99	2.05
	Petalonia fascia	10630	5430	5710	22.85	127.38	11.34	6.00	2.22
	Dictyotaciliolata	13570	10810	5110	11.09	136.13	7.01	6.13	1.52

[a]Cultured seaweed species collected from Cox's Bazar, [b]Below detection limit

The mineral concentrations in cultured seaweed species were comparatively much lower and, in case of Ca, Mg and Zn, it was the lowest than all wild seaweed species. Comparing wild *Hypnea* sp., all minerals' concentrations in cultured *Hypnea* sp. was very low. This might be because of culturing *Hypnea* sp. crowdedly in one place (e.g., rope method) than the wild counterparts. On other hand, wild *Hypnea* sp. showed higher mineral contents because of growing separately in wide places. However, the harvests from the wild are limited.

This study reported wild *Hypnea* sp. contained higher level of heavy metals than the cultured *Hypnea* sp. (Table 3). Results showed the concentration of Pb was 9.33 mg/kg-dw in wild *Hypnea* sp., whereas, Pb was not detected in cultured species. Wild *Hypnea* sp. contained slightly 2 times higher Cd concentration (2.11 mg/kg-dw) than the cultured *Hypnea* sp. (0.98 mg/kg-dw). This study concluded heavy/toxic metals contaminations in seaweeds were comparatively higher in wild species (St. Martin's Island) than farmed species (Cox's Bazar). This might be occurred because natural/wild species was found tangled with marine litter in the shallow coastal waters. Studies reported that the estuaries and coastal waters of the east coast of Bangladesh, northern Bay of Bengal faced serious contamination because of massive discharging of untreated effluent from a large number of factories (e.g., Rani et al., 2021) which might be one of the causes of seaweeds heavy metals contamination. Moreover, tourists are indiscriminately dump waste not only in the beach but also in sea water which was hazardous for marine environment. Most of the plastic or other wastes are non-biodegradable and mixed with the habitat of or attached to the marine algae which act as the vector for micro/nano-plastic transfer in the marine food web (Li et al., 2020). In contrast, in Cox's Bazar, seaweed species are cultured in a fixed area with proper management and care where anthropogenic sources of pollution particularly beach waste or plastic pollution are limited. This might be one of the reasons of lower heavy metal contamination in cultured seaweeds than wild species.

This study showed the concentration of heavy metals in seaweeds varied from species to species. This is because some seaweeds show strong attraction to absorb heavy metals, and the level of affinity to absorb heavy metals are significantly reliant on the environmental factors (salinity, temperature and pH fluctuations, photoperiods, nutrients availability and concentrations, etc. (Besada et al. 2009; Wells et al., 2017). Moreover, seaweeds are able to purposively accumulate minerals in their thalli from the seawater (Azmat et al., 2006) and that is why, seaweeds mineral concentrations are species and place specific. This study showed the maximum concentration of Pb was recorded in *P. pavonica* (20.55 mg/kg-dw) followed by *C. sinuosa* (16.99 mg/kg-dw) (Table 3). But Pb concentration was not detected in cultured *Hypnea* sp. and wild *Sargassum* sp. This study found that the concentration of Cd was the lowest in all seaweeds and it was varied from 0.98 mg/kg-dw to 3.55 mg/kg-dw. The peak Cd content was reported in *P. pavonica* (3.55 mg/kg-dw) and least was found in cultured *Hypnea* sp. (0.98 mg/kg-dw). The intensity and magnitude of heavy metals concentrations in seaweeds might depend on the level of pollution or the sources of contamination. Rizvi and Shameel (2005) reported the concentration of Pb (15.93 mg/kg-dw) and Cd (2.33 mg/kg-dw) in *C. sinuosa* was nearly in line with the present study.

Variation of mineral and heavy metal concentrations in algal groups

This study found that mineral concentrations were varied in different seaweed samples when they are grouped as red, green and brown (Figure 1). Results showed that Ca concentration was the highest in Phaeophyta group (18565 mg/kg-dw) and it was 19 times higher than the value reported in Chlorophyta (950 mg/kg-dw) which indicated brown seaweeds are a good source of Ca. In most of the brown seaweeds such as *Sargassum* sp., *H. clathratus*, *P. pavonica*, *C. sinuosa*, *P. fascia* and *D. ciliolata*, the concentration of Ca was comparatively very high than rest of the studied minerals (Table 3). This is because brown seaweeds demonstrate higher level of disparity in mineral contents depend on various environmental issues such as chemical composition (e.g., concentrations of different metals and their interactions in sea water), physicochemical parameters (e.g., salinity, pH and photoperiods intensity), growth and metabolic parameters like dilution or changes of metal's concentration because of seaweed growth (Carlson and Erlandsson, 1991; Topcuoğlu et al., 2003; Żbikowski et al., 2006). In contrast, mean concentration of Fe, Zn and Mn were the maximum in Rhodophyta. The mean concentration of Fe (11670

mg/kg-dw) in Rhodophyta was almost double than the estimated Fe concentration in Chlorophyta (5560 mg/kg-dw). This is because red seaweeds encompass significantly greater concentration of Fe than that of green and brown seaweeds (Rohani-Ghadikolaei et al., 2012). Among different phyla, mean concentrations of Zn and Mn were comparatively very lower than rest of the minerals.

Results showed that heavy metal concentration of Pb was the highest in Phaeophyta group and it was 11.53 mg/kg-dw (Figure 2). Pb is not a vital component for the human body, thus, extreme level of Pb intake may harm the circulatory, endocrine, nervous, skeletal, enzymatic and immune structures. Particularly children, pregnant women and elderly persons are sensitive to Pb exposure that has substantial adverse impacts on intelligence quotients and physical development (Zhang et al., 2012). The concentration of Cd was the lowest in Rhodophyta, Chlorophyta and Phaeophyta. However, mean Cd concentration was higher in green seaweed than red and brown seaweeds. Since Cd is a nonessential element for human health (Revitt et al., 2013), higher level of Cd ingestion may result in lung damage, renal damage and skeletal changes (Godt et al., 2006; Bernar, 2008).
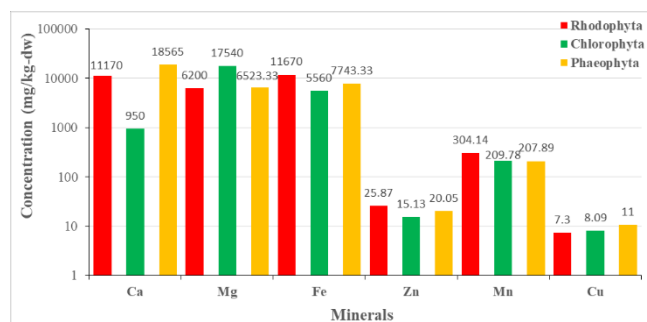
Figure 1: Variation of Mineral Concentrations (mg/kg-dw) in Different Wild Seaweeds Phyla Collected from South-eastern Part of Bangladesh, Northern Bay of Bengal

The mineral composition of seaweeds may be influenced by environmental conditions (Holdt and Kraan, 2011; Rubio et al., 2017; Siahaan et al., 2018), their age, and their capability to absorb inorganic elements from the surroundings due to the presence of polysaccharides-based cell walls. Brown seaweeds have higher absorption rates than green and red seaweeds owing to the existence of alginate, alginic acid salts and alginic acid (Siahaan et al., 2018). These polysaccharides have an affinity with Ca and

Mg salts. However, seaweeds accumulate not only desirable minerals but also undesirable metals from the surrounding environment to hazardous levels and migrate to the human body through the diet, resulting in negative health effects such as allergies, hyperpigmentation, and cancer caused (Holdt and Kraan, 2011; Rubio et al., 2017; Siahaan et al., 2018).
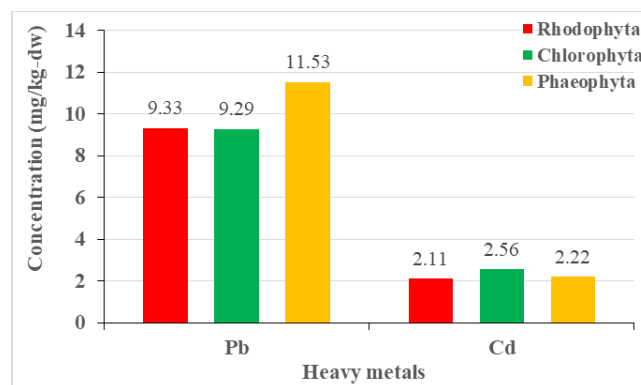
Figure 2: Variation of Heavy Metals Concentrations (mg/kg-dw) in Different Wild Seaweeds Phyla Collected from South-eastern part of Bangladesh, Northern Bay of Bengal

Seaweeds encompass greater amount of minerals than terrestrial plants and vegetations (Rupérez, 2002) and in some cases, the content would be as high as 40% (Kumar et al., 2011; Nwosu et al., 2011). This is because seaweeds absorb most of the minerals that are rich in macro- and trace elements from the seawater. The minerals in seaweeds are very essential for health maintenance. Globally around two billion people are suffered from Fe deficiency and majority of them are child and pregnant women (WHO, 2015). Findings of the current study suggested that seaweeds could be consumed as a potential source of Fe to fight against iron deficiency. Because Fe acts as an element of numerous metabolic functions such as oxygen carriage, electron transfer, and oxidase activities, while Mn is a cofactor of several metalloenzymes (e.g., superoxide dismutase, arginase, etc.) which is linked to amino acid, carbohydrate and lipid metabolism (Mišurcová et al., 2011). Similarly, Cu and Zn are fundamental elements of many enzymes that are connected with neurotransmitter synthesis, energy metabolism and collagen/elastin cross-linking (Osredkar and Sustar, 2011). Thus, seaweeds could be consumed as a functional food to fulfil the daily demand of recommended indispensable minerals and trace nutrients intake for the poor coastal people of Bangladesh.

This study found that the concentrations of minerals in all seaweeds showed moderately bigger values than potentially toxic metals (Table 3). However, heavy/toxic metals do not have beneficial effects in humans, in contrast, they have adverse effects on the body by impairing or over-stimulating an important chemical process (Balali-Mood et al., 2021). In Bangladesh, seaweeds consumption as a food is not widely accepted by the mass population. However, in recent years, its consumption is gradually increasing as public awareness is rising. At the same time, public health concern to consume seaweeds gets mass attention since seaweeds can absorb significant concentrations of heavy metals. As a result, a standard reference or maximum permissible level (MPL) is need to set to consume seaweeds. However, in Bangladesh, there has no specific regulation or standard reference on MPL of heavy metal contamination in seaweeds. France, the first European country, formulated a precise guideline regarding the consumption of seaweeds and French legislation has recommended a MPL for Cd in dehydrated seaweed of 0.5 mg/kg-dw (Besada et al., 2009). Bangladesh government can set a maximum acceptable limit of heavy metals contaminations in seaweeds for the safe consumption of the people.

CONCLUSIONS

This study estimated the concentrations of several minerals such as Ca, Mg, Fe, Zn, Mn and Cu, and heavy metals (Pb and Cd) from cultured and wild seaweeds species collected from coastal waters of Cox's Bazar and St. Martin's Island of Bangladesh, northern Bay of Bengal. Results showed that seaweeds are rich in valuable minerals that are very obligatory for the health maintenance. Seaweeds can fulfil the nutritional requirement of daily intake of minerals for the mass population at a low cost. Thus, seaweeds can be considered as a functional food for the coastal people particularly for the coastal vulnerable poor, women, elderly and tribal communities.

This study showed seaweeds are contaminated by few heavy metals such as Pb and Cd and this study is the first of its kind that provides evidence on heavy metal contamination in seaweeds from coastal waters of Bangladesh. The evidence of heavy metal contamination in seaweeds raises public health concerns to consume the seaweeds. However, the level of contamination in wild and cultured seaweeds is not same. Cultured seaweeds are comparatively less contaminated by heavy metals than the wild seaweeds which indicated careful management and less anthropogenic sources of pollution might influence the contamination level. This study suggests, the authority can establish a guideline or set a regulation for the maximum acceptable limit of heavy metals in seaweeds for safe consumption in future. Further studies can be conducted extensively to identify other minerals and potentially toxic heavy metals in seaweeds for health safety management.

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