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Estimation of trace elements in sediments by macroalgae: A case study in the northern coast of the Persian Gulf (Bushehr province)

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Abstract

Background: The present study was conducted to investigate the northern coast of the Persian Gulf (Bushehr province), which is exposed to industrial, agricultural, shipping, and oil pollution. This study aimed to determine the contamination of the northern coast of the Gulf using macroalgae and predict these elements in sediments.

Methods: Two items of sediment sampling and macroalgae were investigated. Linear regression was used to predict the amount of trace elements in sediments by macroalgae. In this study, aluminium (Al), calcium (Ca), cadmium (Cd), cerium (Ce), copper (Cu), lanthanum (La), lithium (Li), niobium (Nb), nickel (Ni), phosphorus (P), scandium (Sc), samarium (Sm), thorium (Th), and vanadium (V) were measured.

Results: The results showed that the highest amounts of Cd, La, Nb, Sc, and Th in sediment were recorded in Emam Hassan port. The highest mean amounts of Al, Li, and Sm in sediment were reported in Bushehr port. The mean of the highest amount of trace elements absorption was reported in *Sargassum glaucescens*, *Gracilaria corticate*, and *Rhizoclonium riparium*, respectively. The results of linear regression analysis showed that *S. glaucescens* had the highest efficiency in predicting the amounts of elements in sediments.

Conclusion: Predicting the amount of trace elements in sediments by macroalgae can be a great help in this field. In addition, by using the algal index, the amount of this pollution in sediments can be determined with the lowest cost.

Keywords: Trace elements, Seasons, *Gracilaria, Sargassum*

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Introduction

Trace elements played an important role in human health and disease in the past decades. Trace elements are minerals that form the weight of the mass of the organism in very minute quantities (less than 0.01%) (1,2). They are very useful for the growth, health, and recovery of organisms. Heavy metals in coastal environments are found in two forms, soluble in water column or stored in sediments, all of which depend on the chemical properties of species and physical and chemical factors such as pH, conductivity, and organic matter (3-5). Heavy metal pollution causes serious environmental degradation of the ecological and environmental conditions of that area (6-8). However, the level of environmental pollution cannot be predicted in marine environments by analyzing the total amount of metals in water and sediments. When these metals are found in high concentrations, they can accumulate in the tissues of organisms. Therefore, living organisms are used as biological to determine environmental contamination (9-11).

Due to Macroalgae's lifestyle, such as lack of mobility, having significant biomass, and easy identification, they can be used as a biodegradator. Macroscopic algae play an important role in ecosystems as food and shelter (12,13). Trace elements content in macroscopic algae is very little, but determining the amount of the elements in algae is of utmost importance when they are used as biodegradator. Macroalgae refers to a huge group of plants with a unique pattern. They are considered as main producers of this planet (not to be confused with seagrasses) (14). On the other hand, macroalgaes derive all their nutrients directly from the surroundings and are attached to the seafloor by their holdfast. Most macroalgae are classified into four basic groups: the blue-green algae (cyanophyta/cyanobacteria) that are often associated with blooms in rivers, the green algae, the brown algae, and the red algae (9). To live, macros algae need a region that can be easily connected to it; therefore, they can be found in certain areas of the coast. Several internal and external factors determine the absorption rate of these metals by these algae, which should be considered to get suitable qualitative information from the pollution level of metals in the environment (15). In India, the concentration of these elements in marine algae was used as an indicator for determining the pollution level in the environment (16). This study was conducted to determine the amount of these elements due to the importance of trace elements in the marine environment and human health and its high cost for determining the essential elements content in the sediments, so that in addition to reducing the cost, the time needed to the optimum use of macroalgae has become an effective biological indicator.

Materials and Methods

Bushehr province covers most of the coasts of the Persian Gulf. In this study, these beaches were divided into four areas for sampling (Figure 1). Emam Hassan Port was selected from the northern part of Bushehr province, and Bushehr Port, Ameri Port, and Nayband Bay were investigated from the central and southern parts of this province, respectively. Sampling was done for one year from September 2022. The sampling range from each region was about 5 km.

Sampling was done in the zone between the middle intertidal zone and the low intertidal zone. Sampling of algae was done seasonally. In this sampling, from each group of red, green, and brown algae, the most abundant algae in the sampling areas were taken. The largest number of algal species belonged to brown algae, and 45 samples of algae were taken at each sampling, with a total of 180 samples were taken during the four seasons. Sampling from sediments was done up to a depth of 5 cm from the depth of sediment in two middle intertidal zones and low intertidal zone. At each time, 50 samples were taken from four regions and a total of 200 specimens of sediment were taken during the four seasons. In each region, a species available in all seasons in all areas was selected, which includes *Rhizoclonium riparium* (green alga), *Gracilaria corticata* (red alga), and *Sargassum glaucescens* (brown alga).

After each sampling, algae samples in the same place were first washed with seawater, placed in plastic wrap, and transferred to the laboratory at 4 °C. The algae samples were placed at 85 °C for 24 hours in the oven, and then, powdered in a pestle. One gram of it was taken and 10 mL of 65% nitric acid was added to it for 24 hours at room temperature, and then, the samples were digested at a temperature of 140 °C for 5 hours. Then, they were filtered from Wattman filter paper No. 42, and a volume of 25 ml was made using double–distilled water. To normalize sediment grains, usually particles smaller than 63 microns are used. For this purpose, a 63-micron *sieve* was used. One gram of each sample was weighted and digested by 65% nitric acid and then 60% perchloric acid in a ratio of 1:4, firstly, at 40 °C for one hour, then, at 140 °C for 4 hours (17). Inductively coupled plasma mass spectrometry (ICP-MS) was used to determine TEs concentrations. The trace elements measured in this study

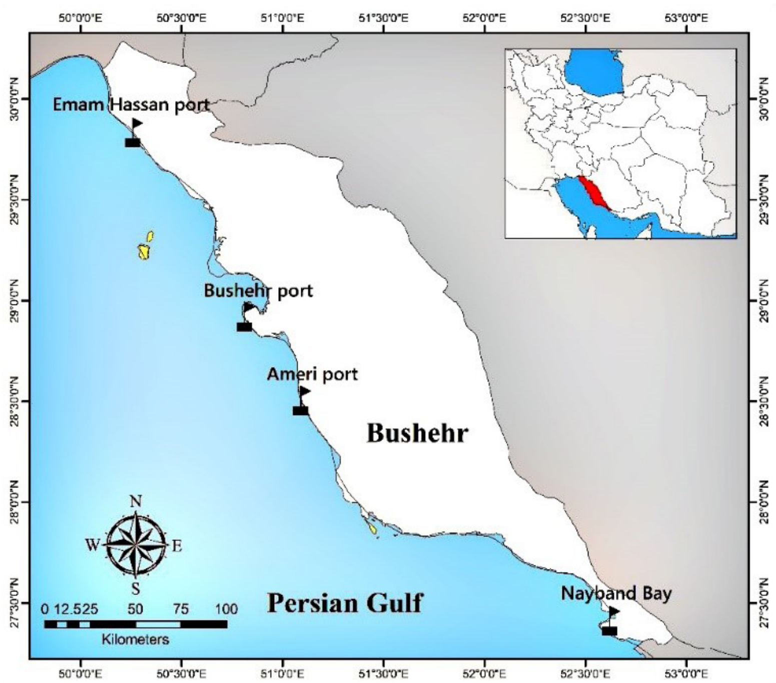

Figure 1. Sampling areas of sediment and macroalgae along the coast of the Persian Gulf (Bushehr province)

were as follows:

aluminium (Al), calcium (Ca), cadmium (Cd), cerium (Ce), copper (Cu), lanthanum (La), lithium (Li), niobium (Nb), nickel (Ni), phosphorus (P), scandium (Sc), samarium (Sm), thorium (Th), and vanadium (V).

Minitab 16 software was used to analyze the data. Linear regression was used to predict the amount of trace elements in sediments by macroalgae. Kolmogorov-Smirnov (K-S) test was used to determine the normality of the data and one-way ANOVA to examine the significance of differences between the variables ($P<0.05$).

Results

The amount of trace elements was measured in all the sampling points in the sediments. The mean trace elements and the highest and lowest values of the studied trace elements can be seen in Table 1. The results showed that the highest amounts of Cd, La, Nb, Sc, and Th were recorded in Emam Hassan port. The highest mean amounts of trace elements Al, Li, and Sm were reported in Bushehr port. The highest amounts of Ca, V, Cu, and P were recorded in Bandar Amari and Nayband Bay, respectively.

Investigating the amount of trace elements in the studied algal species was also evaluated. The mean amounts of trace elements and the minimum and maximum absorption of each metal by the studied species can be seen in Table 2.

Based on the results, it can be stated that the highest average absorption of Al, Ca, Cd, Ce, Cu, Li, La, Ni, Sm, and Th was recorded in *S. glaucescens*. The highest average metal absorption of Nb, P, and V was observed in *G. corticata*. In this study, only Sc metal in *R. riparium* had the highest average absorption compared to the other two types of algae. The rate of absorption of metals by macroalgae in different seasons was also investigated (Figure 2).

Therefore, the maximum absorption of metals by algae is as follows:

Sc in spring, Al, Th, V in summer, Ca, Cd, Cu, Li, Nb, Ni, P in autumn, and Ce, La, Sm in winter.

The amount of trace elements in sediments by algae was estimated by linear regression analysis. Table 3 shows that there is a significant relationship between the amount of trace elements in macroalgae and the amount of trace elements in sediments ($P<0.05$). In this study, the relationship between the amount of trace elements of all three groups of macroalgae and sediments was investigated. As shown in Table 3, the best macroalgal species for estimating the amount of metals Al, Ca, Cd, Ce, Cu, La, Li, Ni, Sm, and Th in sediments was *S. glaucescens*. For the estimation of Nb, P, and V metals in sediments, using *G. corticata* and for Sc, *R. riparium* showed the highest amount of R^2.

Pearson correlation analysis was done between trace elements in different algal species studied (Table 4). The results of this analysis showed that there was a strong correlation between the following trace elements in different algal species (significance level 0.01):

G. corticata: La-Ce (0.989), Sm-Li (0.910), V-Th (0.902).

S. glaucescens: La-Ce (0.984), Sm-Ni (0.922), V-Al (0.918), V-Cu (0.928), V-Ni (0.934), V-Sm (0.927).

R. riparium: Ni-Li (0.954), Ni-La (0.934), Li-Ce (0.927), La-Ce (0.998), Sm-Li (0.945), Sm-La (0.957), Sm-Ce (0.951).

Discussion

One of the most important steps to maintain

Table 1. Comparison of the amount of trace elements in the sediments of different sampling areas (mean ± SE)

Elements	Sediments							
	Emam Hassan Port		Bushehr Port		Ameri Port		Nayband Bay	
	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max
Al (mg/kg)	4088.3 ± 382.3	3342.5-4607.5	3611.6 ± 1407.4	1967.5-6412.5	4085.8 ± 225.4	3635-4315	1583.3 ± 891.1	572.5-3360
Ca (mg/kg)	1777625 ± 299.5	146750-235975	205966 ± 3336	201625-212525	199933.3 ± 38166.7	139850-270750	225433.3 ± 16443.5	197300-254250
Cd (µg/kg)	167.5 ± 65.5	77.5-295	200.8 ± 21.6	170-242.5	99.1 ± 37	40-17.5	63.3 ± 15.3	0.0001-190
Ce (µg/kg)	4952.5 ± 1187.9	3405-7287.5	6694.1 ± 1648.4	3515-9040	6254.1 ± 831.7	4882.5-7755	6239.1 ± 2778.9	2960-11765
Cu (µg/kg)	5840 ± 816.6	4310-7100	5871.6 ± 1259.8	4390-8377.5	5990 ± 167	5712.5-6290	1740.778.7	797.5-3285
La (µg/kg)	3045 ± 401.1	2285-3647.5	3193.3 ± 703.6	2452.5-4600	5990 ± 167	2792.5-3370	884.1 ± 366	412.5-1605
Li (µg/kg)	2964.1 ± 547	2195-4022.5	2958.3 ± 813.3	1765-4512.5	3239.1 ± 393.3	472.5-785	1692.5 ± 816.5	840-3325
Nb (µg/kg)	842.5 ± 328.1	415-1487.5	576.6 ± 95.4	455-765	621.6 ± 90.4	16657.5-19485	414.1 ± 158.5	215-727.5
Ni (µg/kg)	146.21 ± 3103.9	9522.5-20237.5	14292.5 ± 2718.7	8992.5-17995	17820.8 ± 853.7	86550-95675	9051.6 ± 1219.4	6670-10697.5
P (mg/kg)	93658.3 ± 8338.9	78225-106850	89966.6 ± 10683	71925-108900	90608.3 ± 2681.9	86550-95675	103366.6 ± 5856.1	97250-115075
Sc (µg/kg)	2188.3 ± 752.3	1400-3692.5	2816.6 ± 1190.4	1172.5-5130	2912.5 ± 802.6	1310-3795	1381.6 ± 220.8	1055-1802.5
Sm (µg/kg)	700 ± 91.88	522.5-830	949.1 ± 359	505-1660	721.6 ± 69.7	590-827.5	175 ± 78.8	90-332.5
Th (µg/kg)	1586.6 ± 429.3	1137.52445	1483.3 ± 39.7	1070-2200	1275.8 ± 131.4	1035-1487.5	596.6 ± 175.7	345-935
V (µg/kg)	10895 ± 1423.3	8365-13290	12081.6 ± 3266.1	8522.5 ± 18605	12989.1 ± 1865	9505-15885	3490.8 ± 1347.2	1922.5-6172.5

Table 2. Comparison of the amount of trace elements in the macroalgae (G. corticata, S. glaucescens, and R. riparium) of different sampling areas (mean ± SE)

Elements	Algae					
	G. corticata		***S. glaucescens***		***R. riparium***	
	Mean ± SE	**Min-Max**	**Mean ± SE**	**Min-Max**	**Mean ± SE**	**Min-Max**
Al (mg/kg)	2197 ± 400.15	547.9-4032.5	2700.23 ± 362.28	352.5-4147.5	2226 ± 538.7	217.5-6704.1
Ca (mg/kg)	55864.4 ± 14160.67	9500-156000	79461.3 ± 5953.6	57875-116275	70925.9 ± 14582.8	13300-149500
Cd (µg/kg)	797.43 ± 205.74	232.5-2310	809.3 ± 320.7	267.5-1520	246 ± 53.4	65-705
Ce (µg/kg)	1101.7 ± 225.8	208.9-2215	1991.3 ± 421.9	140-3917.5	1704.7 ± 511.6	107.5-5687.5
Cu (µg/kg)	5268.6 ± 740.84	1542.5-9262.5	5374 ± 664.1	2727.5-8412.5	4251.5 ± 625.1	1765-9866.6
La (µg/kg)	588.6 ± 113.8	130.1-1197.5	1075 ± 173.2	85-2040	899.6 ± 251.4	92.5-2770
Li (µg/kg)	3924.6 ± 923	770.5-10812.5	3582.9 ± 633.2	410-7417.5	2760.9 ± 572.4	390-6915
Nb (µg/kg)	744.1 ± 209.6	108.3-2472.5	464.7 ± 101.3	75-1297.5	391.7 ± 89.1	1062.5-4700.9
Ni (µg/kg)	9528.9 ± 1335.2	4920-17942.5	12213.8 ± 1859.8	3257.5-21397.5	9113.2 ± 1366.2	3222.5-19129.1
P (mg/kg)	592.5 ± 91.6	257.8-1225	413.8 ± 36.5	282.5-670	312.1 ± 53	94.7-700
Sc (µg/kg)	1473.07 ± 408.5	180-4916.6	1743.4 ± 282.5	580-3205	1832.7 ± 475.4	357.5-5237.5
Sm (µg/kg)	140.1 ± 26.1	13.7-277.5	281.7 ± 57	110-742.5	245.9 ± 71	12.5-740
Th (µg/kg)	515.5 ± 82.5	202.5-1140	769.7 ± 131.5	165-1497.5	675.1 ± 147.9	165-1800
V (µg/kg)	8601.4 ± 2814.2	2367.5-34680	7527.2 ± 1255.9	1257.5-13337.5	7364.6 ± 1507.2	1565-17882.5

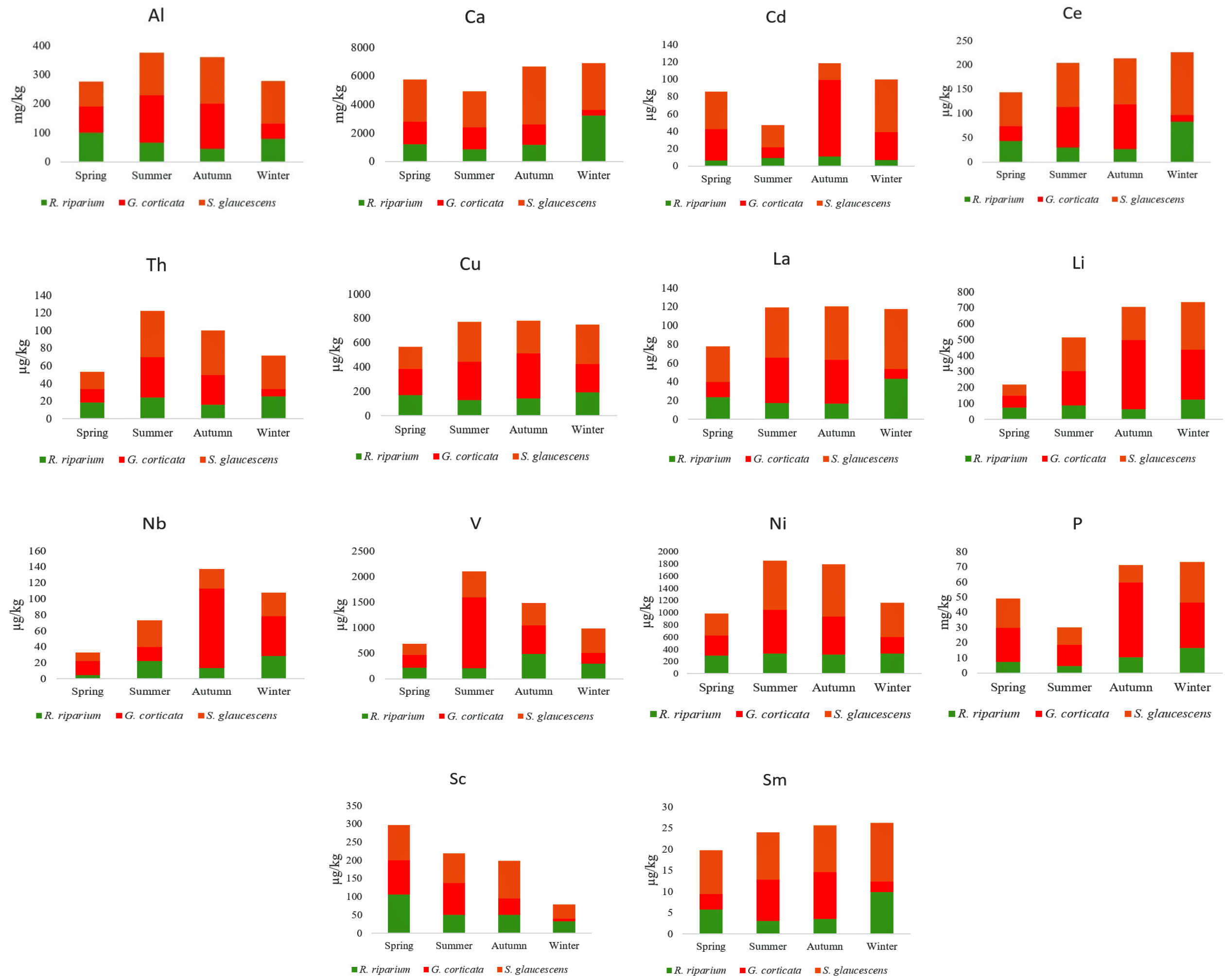

Figure 2. Comparison of absorption of trace elements by the studied macroalgae (*R. riparium*, *G. corticata*, and *S. glaucescens*) in different seasons

Table 3. The results of linear regression for the estimation of trace elements in sediments by the studied macroalgae

Trace elements	Predict	R^2
Al (mg/kg)	Sediment = 1.311 *S. glaucescens*	84.70
Ca (mg/kg)	Sediment = 2.836 *S. glaucescens*	83.32
Cd (µg/kg)	Sediment = 0.1279 *S. glaucescens*	82.26
Ce (µg/kg)	Sediment = 2.903 *S. glaucescens*	83.95
Cu (µg/kg)	Sediment = 1.241 *S. glaucescens*	81.87
La (µg/kg)	Sediment = 2.537 *S. glaucescens*	84
Li (µg/kg)	Sediment = 0.6415 *S. glaucescens*	85.06
Nb (µg/kg)	Sediment = 1.058 *G. corticata*	81.10
Ni (µg/kg)	Sediment = 1.380 *S. glaucescens*	82.35
P (mg/kg)	Sediment = 172.9 *G. corticata*	83.52
Sc (µg/kg)	Sediment = 1.596 *R. riparium*	81.98
Sm (µg/kg)	Sediment = 3.140 *S. glaucescens*	88.07
Th (µg/kg)	Sediment = 1.704 *S. glaucescens*	85.08
V (µg/kg)	Sediment = 1.132 *G. corticata*	82.54

environmental health is to identify potential problems, especially due to human activities. The high volume of contaminating material that enters the environment is transported to lower sediments. Deposition has attracted much attention due to the sudden changes that occur in the physical and chemical parameters (pH and salinity, etc), as well as intersections between continental and marine waters. Sediments are considered marine environments and it is possible to report what trace elements have entered into aquatic environments. It has been reported that the concentration of these elements in sediments is higher than in adjacent waters and interstitial waters (18). Sediment analysis provides good information for researchers such as identifying contaminated areas and evaluating their potential effects on organisms. The metals content in sediments indicates both natural and human activity-related factors. The weathering of soil and rocks and rocks is considered a natural factor in entering these elements. The entry of elements by humans is done in two ways: directly and indirectly. Indirectly, the elements are entered through sewage, petroleum, chemical, and transportation industries, and the elements are indirectly entered through the atmosphere and rivers, which are considered carriers for the transportation of these materials into the marine environments (19).

According to the definitions, trace elements in low minute quantities do not cause poisoning, but in large quantities are associated with poisoning. An example of the effects of the elements studied in the present study is as the following:

Cadmium is a transition metal that plays an important role in human biology and nutrition systems, but it is toxic even in moderate doses. Environmental contamination of cadmium is due to industrial and agricultural pollution. It has been reported that a disease causes bone fractures that occurred in Japan after World War II; this disease is due to contamination of the waters of that area with Cadmium. The effect of chronic cadmium exposure on liver-related outcomes in humans is reported, but it is found in very minute quantities in homeopathic drugs and several dietary supplements (20,21).

Nickel as a heavy metal and trace element is not an essential ingredient for human beings but is found in many tissues and has a significant relationship with metals, vitamins, and proteins. However, signs of nickel deficiency in humans are unclear, but it is toxic at high levels according to relevant signs (22).

Vanadium is considered a trace element that is absorbed very poorly, and no signs of disease due to vanadium deficiency in human beings have been reported. High doses of vanadium cause hepatotoxicity in animals and digestive problems in human beings (23).

There is no proven evidence to prove that aluminum plays a key role in the human body. The only main point is that large quantities of this element in the body cause neurological disorders and bone abnormalities, and also, cause Alzheimer's and Parkinson's diseases (24,25).

Lithium is commonly used for depression treatment, but if it increases more than the allowable limit, it can hurt the thyroid gland and cause unusual weight gain, but its essential function and states are still unknown.

The sediments were harvested from two parts of the intertidal zone and low tidal, and macroalgae were sampled from these areas. The alteration of algae species depends on climate change per season and the weather conditions of each season are suitable for each group of algae (brown, red, and green) (26). The important reason for algae growth is temperature especially for the macroalgae located in supratidal and intertidal but other macroalgae located in subtidal have more stability in their environment, they are underwater all the time and exposed to environmental stress in less time (27). Also, as the weather changes in various seasons and the temperature has a determinative and controller on other water physical and chemical factors and changing each of them is a function of physical and chemical characteristics, therefore, any change in temperature during various seasons will change physical and chemical characteristics of seawater, which can affect the alga's growth especially those which are in more lower areas (27,28). In the present study, in the sample area, temperature was recorded between 33-41 °C and between 17-22 °C in the winter. The hottest place of sampling in all seasons was Nayband Bay area. Since red macroalgae are subtidal, they are less affected by physical stresses, such as temperature and wind changes so they are more stable in the environment, on the other hand, the green algae are supratidal and intertidal and are more exposed to climate change (29).

Red algae can absorb light in deeper regions and this adaptation makes possible the presence of red algae in deeper regions. In contrast, two other algae groups have

Table 4. Spearman's correlation matrix between the levels of the trace elements in the macroalgae (*G. corticata*, *S. glaucescens*, and *R. riparium*)

R. riparium

	Al	Ca	Cd	Ce	Cu	La	Li	Nb	Ni	P	Sc	Th	Sm	V
Al	1													
Ca	0.294	1												
Cd	-0.191	0.150	1											
Ce	0.775**	0.609*	-0.413	1										
Cu	0.773**	0.326	0.329	0.489	1									
La	0.797**	0.593	-0.408	0.998**	0.520	1								
Li	0.855**	0.438	-0.404	0.927**	0.495	0.934**	1							
Nb	-0.279	-0.278	-0.017	-0.342	-0.322	-0.326	-0.242	1						
Ni	0.953**	0.337	-0.075	0.780**	0.812**	0.808**	0.858**	-0.255	1					
P	0.095	0.606*	0.759**	0.074	0.511	0.071	0.038	-0.314	0.181	1				
Sc	0.322	0.171	0.676*	-0.066	0.659*	-0.050	-0.054	-0.439	0.330	0.562	1			
Th	0.632*	0.611*	-0.314	0.852**	0.408	0.834**	0.730*	-0.686*	0.572	0.160	0.188	1		
Sm	0.839**	0.447	-0.366	0.951**	0.527	0.957**	0.945**	-0.178	0.857**	-0.022	-0.030	0.741**	1	
V	0.438	-0.018	0.086	0.348	0.572	0.365	0.331	-0.098	0.505	0.229	-0.015	0.069	0.374	1

G. corticata

	Al	Ca	Cd	Ce	Cu	La	Li	Nb	Ni	P	Sc	Th	Sm	V
Al	1													
Ca	-0.125	1												
Cd	0.483	0.111	1											
Ce	0.809**	0.118	0.452	1										
Cu	0.712*	-0.282	0.752**	0.526	1									
La	0.832**	0.119	0.466	0.989**	0.597	1								
Li	0.498	-0.287	0.488	0.499	0.557	0.504	1							
Nb	0.232	-0.478	0.451	0.330	0.422	0.279	0.767**	1						
Ni	0.851**	-0.019	0.520	0.746**	0.837**	0.810**	0.471	0.159	1					
P	0.580	-0.003	0.878**	0.441	0.648*	0.439	0.703*	0.554	0.463	1				
Sc	0.431	0.227	0.530	0.203	0.601	0.282	-0.244	-0.333	0.548	0.275	1			
Th	0.800**	-0.045	0.271	0.864**	0.630*	0.897**	0.368	0.146	0.904**	0.198	0.339	1		
Sm	0.703*	0.032	0.255	0.942**	0.345	0.910**	0.585	0.444	0.597	0.348	-0.115	0.777**	1	
V	0.704*	-0.138	0.123	0.658*	0.648*	0.736**	0.373	0.057	0.862**	0.075	0.344	0.902**	0.580	1

S. glaucescent

	Al	Ca	Cd	Ce	Cu	La	Li	Nb	Ni	P	Sc	Th	Sm	V
Al	1													
Ca	0.461	1												
Cd	-0.339	-0.482	1											
Ce	0.834**	0.572	-0.118	1										
Cu	0.787**	-0.120	0.123	0.585	1									
La	0.869**	0.510	-0.149	0.984**	0.654*	1								
Li	0.796**	0.265	-0.164	0.625*	0.761**	0.630*	1							
Nb	0.496	-0.054	0.012	0.523	0.695*	0.588	0.627*	1						
Ni	0.883**	0.142	-0.255	0.596	0.882**	0.698*	0.751**	0.632*	1					
P	-0.210	-0.071	0.782**	0.059	-0.033	-0.056	-0.060	-0.219	-0.410	1				
Sc	0.292	0.021	0.231	0.209	0.339	0.291	-0.132	-0.061	0.405	-0.032	1			
Th	0.360	0.495	0.128	0.608*	0.147	0.583	0.088	0.040	0.155	0.300	0.482	1		
Sm	0.877**	0.336	-0.311	0.740**	0.775**	0.815**	0.779**	0.711*	0.922**	-0.403	0.299	0.367	1	
V	0.918**	0.165	-0.108	0.771**	0.927**	0.832**	0.844**	0.694*	0.934**	-0.173	0.288	0.303	0.927**	1

less adaptation to live in deeper zones (30). Green, brown, and red algae occupy tidal areas from low to high depths, respectively, and have more stability against drought, especially in the summer (31), so the average amount of elements required from all three types was used to predict the amount of these elements in sediments.

Linear regression analysis in this study showed that the amount of metals in sediments can be predicted with the help of macroalgae. In this study, three types of macroalgae from all three groups (green, red, and brown algae) were evaluated. The results showed that the most efficient species was brown algae (*S. glaucescens*), followed by red algae (*G. corticata*), and green algae (*R. riparium*). The study in the field of predicting metals in sediments using algae has not been done specifically and this study can be called the first research. However, there are studies conducted in the field of investigating the amount of heavy metals in the coasts of the Persian Gulf, which can be referred to as the following studies:

There have been studies on the amount of heavy metals in sediments and algae in the Persian Gulf. For example, Bibak et al (10) investigated the amount of heavy metals in the sediments of the Persian Gulf. Another study conducted in 2020 by Bibak et al (9) investigated heavy metals in the Persian Gulf macroalgae using macroalgae as a measurement index to express the pollution level in the Persian Gulf coast. Another study by Bibak et al(12) investigated the absorption capacity of metals by macroalgae in the Persian Gulf, and the absorption capacity of each metal by different macroalgae. Ghaemi et al (32) investigated the characteristics of heavy metals and persistent organic pollutants in the sediments of marine protected areas: North of the Persian Gulf. The amount of metals in other marine organisms on the coast of the Persian Gulf has also been investigated by Emami et al (33). In this study, they investigated the bioaccumulation of heavy metals (Ni, V, and Hg) in the soft tissues of crustaceans, bivalves, and gastropods.

Conclusion

Due to the sensitivity of pollution, especially heavy metal pollution, it has always been important to introduce a way to monitor this pollution annually. Using laboratory methods as well as various pollution indicators can help researchers in this very important matter. Sediments as an archive of trace elements pollution can provide researchers with valuable information on the process of pollution. Predicting the amount of trace elements in sediments by macroalgae can be a great help in this field, in addition to using the algal index, it is possible to investigate the amount of this pollution in sediments with the lowest cost.

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Authors' contributions

Data curation: Mehdi Bibak.
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Competing interests

The authors declare that they have no conflict of interests.

Ethical issues

This study was approved by Vice Chancellor for Research, Bushehr University of Medical Sciences (Ethical code: IR.BPUMS.REC.1403.018).

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