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Assessment of Lead (Pb) Absorption in Selected Macroalgae and Seagrasses from the Red Sea, Jazan Region, Saudi Arabia

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Abstract. An assessment of lead (Pb) absorption by macroalgae and seagrasses of the Red Sea, Jazan region, Suadi Arabia, were evaluated. Samples were analyzed using inductively coupled plasma atomic emission spectroscopy ICP-AES (Method 3050B). Among all the species of macroalgae and seagrasses *Sargassum* spp. showed a high concentration of lead (Pb) and recorded the highest level (11.35 ppm) at a station near a sewage plant among the species in this study. In contrast, the least Pb- accumulated species was Cymodocea rotunda. Contamination of lead (Pb) for all macroalgae and seagrasses determined in this study were recorded in ascending order Cymodocea rotunda < *Cladophora* spp. < Halodule uninervis < *Sargassum* spp., collected close to the sewage plant. The results obtained from the study could be used for monitoring ecosystem lead pollution and the health of the shoreline.

Keywords: Lead (Pb), Macroalgae, Seagrass, Heavy metals, Pollution, Jazan, Bio-alarms.

1. Introduction

Environmental contamination has been exacerbated by the industrial revolution and anthropological activities. Significant pollutant discharges into the ocean have resulted in considerable hazards to the coastal environments (Zaynab *et al*., 2022). The volume of wastes as a result of the industrial activities that enter and contaminate water and sediments quickly rises in response to the fast expansion of the human population (Jessen *et al*., 2015; Tavakoly *et al*., 2014; Yantyana *et al*., 2018; Wurl *et al*., 2017; Nour & El-Sorogy, 2020; Hananingtyas, 2017). Mostly industrial and urban garbage increases with industrial growth have an augmentation effect on the volume of solids, liquids, and gases wastes. Some wastes contain toxic and dangerous chemical substances, such as heavy metals (Maurya *et al*., 2019). Companies frequently employ heavy metals in the industrial sector as raw materials, catalysts, and supporting materials (Nasir *et al*., 2016). Then, they release into nature as wastes after processing. At the same time, they are toxic and can accumulate in living organisms, causing long-term toxicity in living plants and animals through generations (Burakoy *et al*., 2018; Leong & Chang, 2020). Because they are substantially harmful to aquatic ecosystems, heavy metals require serious responses.

One of the most toxicant metals is Lead (Pb). Lead is emitted into nature by industries and transportation, and it is one of many sources of heavy metals in polluting marine and estuaries (Malar *et al*., 2016; Brennecke *et al*., 2016; Kong *et al*., 2015; Han *et al*., 2021; Nur and Karneli, 2015 & Setiawan, 2014). Lead (Pb) has a negative impact on human health (da Rocha Silva *et al*., 2018). The immune system, nervous system, senses, kidneys, reproductive system, and digestive tract are some areas that are intensively affected by lead contamination (Noviati & Brian, 2018; Rehman, 2018; Assi, 2016; Yuswir *et al*., 2015; Mason *et al*., 2014).

There were several attempts to reduce non-essential elements like Pb in waterways using various techniques, including biomass as biosorbents like algae (Ahmad *et al*., 2020; Marella *et al*., 2020; Yantyana *et al*., 2018). The use of biomass as a heavy metal adsorbent could be an appropriate alternative because, in addition to the simple process, it is also environmentally friendly and can be reused (Hananingtyas, 2017; Gautam *et al*., 2014; Ningsih *et al*., 2016; Rahmi & Sajidah, 2017). Compared to adsorption utilizing synthetic ion exchangers, biomass, which is abundant and simple to locate in nature, can lower the operational costs of activities (Zhang *et al*., 2017). Therefore, based on the treatment mentioned above techniques of marine ecosystems, it is confirmed that algae and seagrasses are effective bio-alarms of heavy metals marine pollution, which can be utilized to indicate and measure how polluted the sea water and shoreline are.

In the past decades, the Jazan region has been subjected to extensive industrial activities that may negatively affect marine resources and contaminate its coastal environments. Therefore, a study was carried out to detect the levels of lead contamination in selected macroalgae and seagrasses. The present study aims to determine the differences in lead (Pb) concentrations between macroalgae and seagrasses of Read sea by Jazan Region, Saudi Arabia. The detailed review of the literature showed that there were limited studies conducted in line with the contamination of heavy metals in marine vegetation of Jazan Region and also noted that, the present study was the first attempt to understand the lead contamination in macroalgae and seagrasses of the Red sea in Jazan Region.

2. Methodology

The samples of macroalgae (*Sargassum* spp., *Cladophora* spp.) and seagrasses (*Halodule uninervis, and Cymodocea rotunda*) were collected in March (2021). Samples were studied from the shoreline of the Red Sea, Jazan region, South Western Saudi Arabia. The sampling was launched in the vicinity of the sewage treatment plant, but different distances were considered (Fig. 1).

Both macroalgae and seagrasses were identified based on the taxonomic keys, and voucher specimens were deposited in Jazan University Herbarium(JAZUH).

Table 1 summarizes the traits of both plants.

The samples were taken to the lab and thoroughly washed with fresh water, and finally cleaned with distilled water and dried in the oven at 40 C^o until we had a stable weight. After that, 20 % of each sample was randomly taken for acid digestion. Then, the samples were ground to have them as powder. The grinder was cleaned well with alcohol wipes after each sample to avoid mixing and cross-contamination.

One to two grams were taken from the macroalgae and seagrasses into a tube, concentrated nitric acid HNO_3 (2.5 ml conc.) and 10 ml of concentrated hydrochloric acid HCL (7.5 ml conc) were added to the tube to digest the powder. The digestates were after that filtered through Filter Paper 40 Ashless Diameter of 125 mm. The filter for each sample was washed with 5 ml of hot HCl and 20 ml of reagent water. Three replicates per each sample were taken, and the averages were calculated.

The solution was put back in a tube with 5 ml of HCL.

Samples were analyzed using ICP-AES (US EPA 3050B, Acid Digestion of Sediments, Sludge, and Soils 1996). Blank samples were made of nitric acid, hydrochloric acid, and deionized water with the same concentrations above. The spectrometer software then automatically subtracts the blank from the concentrations detected in the samples. Duplicate QC digests were made using certified reference material (Apple leaves NIST 1515)

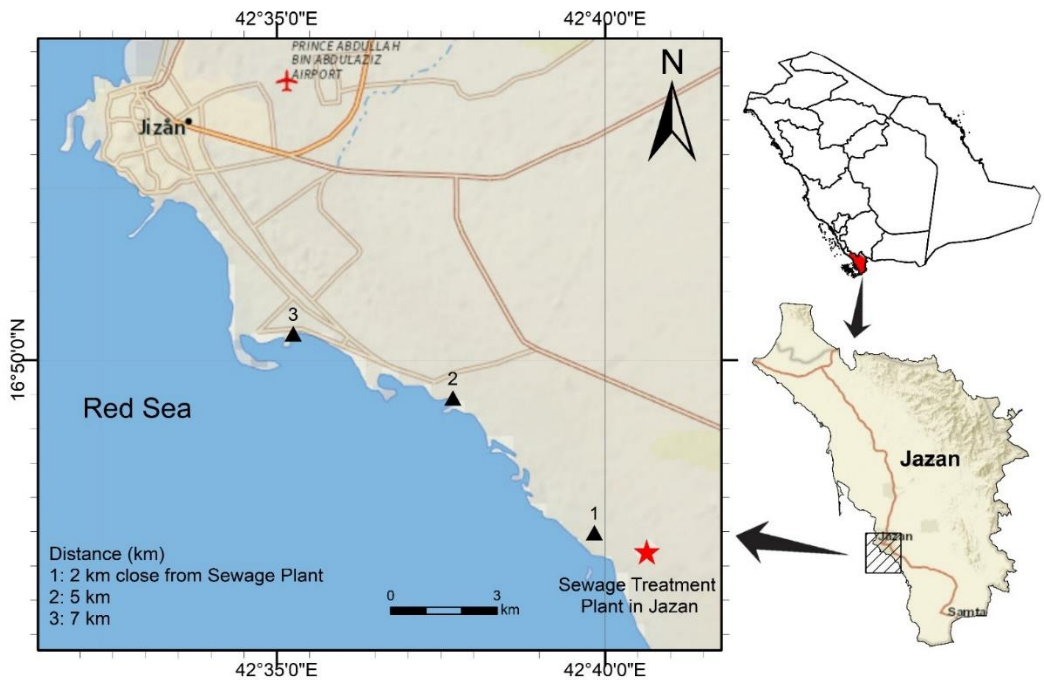


Fig. 1. Location of the study area in the Jazan Region.

Table 1. Shows the morphological and anatomical differences between macroalgae and seagrasses.

Macroalgae	Seagrasses
Not differentiated into root, stem, and leaves	Well-demarked root, stem, and leaves
Non-vascular plants	Vascular plants
Flowers are absent	Flowers present
Plant body is soft and delicate	Plants are strong

Retrieved from: https://myfwc.com/research/habitat/seagrasses/information/seagrass-vs-seaweed/#:~:text=Seagrass%20can%20easily%20be%20confused,little%20or%20no%20vascular%20tissues.

3. Results

It can be seen from (Table 2) that the average values of lead (Pb) concentrations were ranging in the algal species of *Cladophora* spp. and *Sargassum* spp. from 0.6 to 11.35 ppm. The results further show that the value of lead (Pb) reached its maximum in *Sargassum* spp., and its minimum in *Cladophora* spp. The results showed that *Sargassum* spp. accumulated more lead (Pb) than *Cladophora* spp. in general, regardless of the distance.

The ANOVA shows that (Table 3) the overall mean score for average Pb was 3.005 and the minimum and maximum values between 0.55 and 11.5. The findings showed the overall mean score of distance was 4.777 and ranged from 2 to 7. In addition, the calculated standard deviation for all the variables in this study ranged from 0.529 to 0.664.

Overall, Lead (Pb) concentrations decrease with increasing distance (km) from the station and increase near it. A high Lead concentration (Pb) in *Sargassum* spp. was found when it was close to a sewage treatment plant, around 2 km. On the other hand, the concentration of Lead (Pb) in *Sargassum* spp. decreased once it was sampled far away from the sewage plant, around 7 km, (Fig. 2.). The ANOVA analysis shows that there is no significant difference in Average Pb among Species categories as indicated by one-way ANOVA; $F(3,5) = 1.407$, $p = .344>0.05$ (the level of insignificance) Furthermore, there is no significant difference in distance between type (Macroalgae and Seagrasses) as indicated by one-way ANOVA; $F(3,5) = .096$, $p = .959$) (the level of insignificance) (Table 4).

The same condition happened with *Cladophora* spp. The analysis showed that the concentration of lead (Pb) was at its highest level, with a value of 1.54 ppm at a distance of 2 km from the plant. Low Pb-concentration in *Cladophora* spp. with a value of 0.6 ppm at a distance of 7 km from the sewage treatment plant (Fig. 3).

The two algae showed different percentages in the behavior of lead accumulation. Near the treatment plant, *Sargassum* spp. accumulated ten times lead than that was accumulated by *Cladophora* spp., 11.35 by *Sargassum* to 1.54 ppm by *Cladphora*.

Halodule uninervis and *Cymodocea rotunda*, seagrasses, showed a similar algal pattern in lead (Pb) accumulation depending on the distance from the sewage treatment plant. The species near the sewage treatment plant showed higher concentrations of lead (Pb) than those far from the treatment plant (Table 2). High concentration of lead (Pb) in *Halodule uninervis* with an average value of 3.23 ppm when it is close to the sewage plant (4 km), whereas it accumulated lower than that (0.55 ppm) when the distance increased to 7 km. At a distance of 5 km from the sewage center, *Halodule uninervis* showed an average Pb value of 0.765 ppm; and *Cymodocea rotunda* showed a higher capacity of lead accumulation than that of *Halodule uninervis*, almost a double Pb average value.

Table 2. The average levels of lead (Pb) ppm for macroalgae and seagrasses.

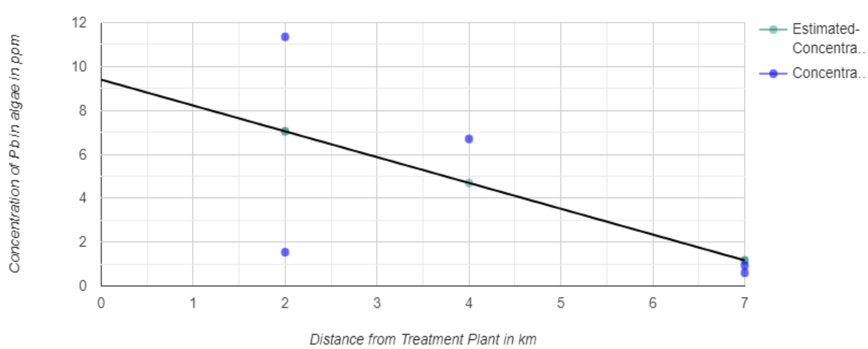
Spices	Type of plants	Average (Pb) in ppm	Standard deviation	Distance from the sewage treatment plant in (km)
Sargassum spp.	Macroalga	11.35	0.98	2
Sargassum spp.	Macroalga	6.7	0.3	4
Sargassum spp.	Macroalga	0.93	0.06	7
Cladophora spp.	Macroalga	1.54	0.12	2
Cladophora spp.	Macroalga	0.6	0.05	7
Halodule uninervis	Seagrass	3.23	0.2	4
Halodule uninervis	Seagrass	0.76	0.18	5
Halodule uninervis	Seagrass	0.55	0.2	7
Cymodocea rotunda	Seagrass	1.23	0.04	5

Table 3. ANOVA and Standard deviation.

Descriptive statistics										
						95% Confidence Interval for Mean				
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Average Pb	*Sargassum* spp.	3	6.3767	5.29241	3.05558	-6.7704	19.5237	.93	11.50
	Cladophora sp.	2	1.0700	.66468	.47000	-4.9019	7.0419	.60	1.54
	Halodule uninervis	3	1.5150	1.48912	.85974	-2.1842	5.2142	.55	3.23
	Cymodocea rotunda	1	1.2300	.	.	.	.	1.23	1.23
	Total	9	3.0050	3.74666	1.24889	.1251	5.8849	.55	11.50
Distance	*Sargassum* spp.	3	4.3333	2.51661	1.45297	-1.9183	10.5849	2.00	7.00
	Cladophora sp.	2	4.5000	3.53553	2.50000	-27.2655	36.2655	2.00	7.00
	Halodule uninervis	3	5.3333	1.52753	.88192	1.5388	9.1279	4.00	7.00
	Cymodocea rotunda	1	5.0000	.	.	.	.	5.00	5.00
	Total	9	4.7778	1.98606	.66202	3.2512	6.3044	2.00	7.00

Table 4. One way ANOVA.

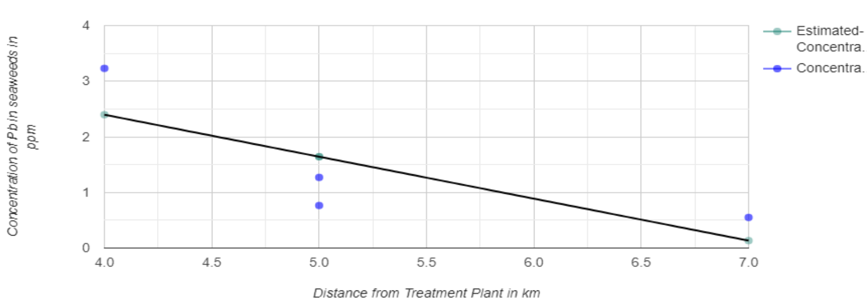
		Sum of Squares	df	Mean Square	F	Sig.
Average_Pb	Between Groups	51.404	3	17.135	1.407	.344
	Within Groups	60.896	5	12.179		
	Total	112.300	8			
Distance	Between Groups	1.722	3	.574	.096	.959
	Within Groups	29.833	5	5.967		
	Total	31.556	8			



Y = -1.176*X + 9.399

R^2 = 0.4

Fig. 2. Simple linear regression shows the relationship between Pb concentration in algae tissues and the distance from the treatment plant. The graph is designed using Statistics Kingdom. (https://www.statskingdom.com/linear-regression-calculator.htm/).



Y = -0.7521*X + 5.391

R^2 = 0.6

Fig. 3. Simple linear regression shows the relationship between Pb concentration in seagrass tissues and the distance from the treatment plant. The graph is designed using Statistics Kingdom. (https://www.statskingdom.com/linear-regression-calculator.htm/)

4. Discussion

The results summarized in (Table 2) indicated that macroalgae of *Sargassum* spp. and *Cadophora* spp. (11.35 and 1.54 ppm, respectively) showed relatively higher absorption performance of lead (Pb) than seagrass of *Halodule uninervis* and *Cymodocea rotunda*. *Sargassum* spp. (3.23 and 1.23 ppm, respectively) appeared actively collecting lead metals than the other species, either macroalgae or seagrasses. Sargassum is a brown macroalgae with a wide distribution in tropical waters, including the Red Sea, which might interpret the intensive absorption of lead. In addition, plants that thrive in a contaminated area and accumulate more toxic levels of heavy metals to the plants have detoxification systems that support and maintain the life of the plants and their flourishing in the contaminated areas (Deng *et al*., 2004).

The decrease of Pb- levels (0.6 ppm in macroalgae and 0.55 ppm in seagrass) alongside increasing distances from the treatment plant in the tissues of sea plants in this study confirms that the contaminations by lead come directly from the sewage plant, which urgently requires an intervention action by the responsible agency in the region.

A recent study by El Ashmawy *et al*. (2021) found metal pollution index and enrichment factor in *Avicennia marina* indicated contamination of sediment by Pb, Cu, and Mn on the Red Sea coast. Usman *et al*. (2013) indicated that heavy metal levels in sediments and mangrove plants of the investigated sites from the Farasan Islands, Saudi Arabia, could be considered low, moderate, or high pollution levels. A new study by Aljahdali & Alhassan (2020) reported that heavy metals at mangrove plants (*Avicennia marina*) in the Rabigh lagoon Red Sea were recorded as the highest (8939.38 ± 312.63 mg/kg), and these values can be attributed to a minimal circulation between the Rabigh lagoon and the sea. Therefore, the high concentrations of lead (Pb) in *Sargassum* spp. and the other sea plants in this study might indicate additional Pb- sources over the sewage treatment plant. Those sources could come from the mainland, where more inputs of lead could come to the seawaters transported by rainfall run-offs. A study by Alhababy (2016) observed high contents of lead (Pb) in sediments near Jazan city and indicated that the sources might be related to agricultural waste and rainwater floods from valleys bringing the organic matter to the coastal areas loaded with contaminants, including lead.

Heavy metals are toxic, and the level of danger increases if the assurance is that they are persistent in the environment where they accumulate in marine organisms (Brennecke *et al*., 2016); as a result, they move with food chain. Thus, it is crucial to invent environment-cleaning methods, specifically for the ecosystems, for their importance for human life and the environmental balance. Khatimah *et al*. (2020), Alim (2014), and Ihsan *et al*. (2015) suggested that macroalgae could be used as a bio-absorbent to reduce the concentration of heavy metals in water. As the analysis of this study ended with those results of lead in the tissues of sea algae and grasses, those plants might be utilized to supervise sea pollution. They could be indicators of pollution and cleaners of the ecosystems. The results of this study prove the helpfulness of Saragussum, at least as potential macroalgae with the highest value (11.35 ppm) for designing practical systems for removing lead (Pb) from the ecosystems. Other heavy metals from industrial effluents to the seawater may be removed by the same macroalgae, which needs more studies on that. The encouragement of algae and seagrass is a simple and low-cost way to examine sea plants in bioremediation and mitigate pollution.

In addition, the study recommended frequent monitoring of the coastal and marine environment to be safe for humans and marine organisms. Furthermore, the considerably high level of lead (Pb) 11.35 ppm in the study area could be related to wastewater treatment plants that runoff from heavy rain to the sea south of Jazan city.

5. Conclusions

Concentrations of lead (Pb) in macroalgae and seagrasses in the coastal Jazan region, Red Sea, indicate that, the area is affected by pollutants which have been released from the treatment plant with the highest value 11.35 ppm. Moreover, the results revealed that lead (Pb) was highly concentrated in the macroalgae and seagrasses (11.35 and 3.23 ppm) respectively. The present study suggests that *Sargassum* spp. can be indicated as a potential accumulator for lead (Pb) with the highest value 11.35 ppm.

This study can be used to monitor heavy metals, meanly lead (Pb), in the marine and coastal areas along the coast of Jazan to mitigate pollution and protect the marine environment. Future studies should be focused on the investigation of the concentration of lead (Pb) in sediments. Moreover, further work is required on the role of marine macroalgae and seagrasses in heavy metal contamination control via the cultivation of marine algae and investment in farming aquatic plants.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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تقييم امتصاص الرصاص (Pb) في طحالب كبيرة وأعشاب بحرية مختارة من البحر الأحمر، منطقة جازان، المملكة العربية السعودية

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المستخلص. تم تقييم امتصاص الرصاص (Pb) باستخدام الطحالب الكبيرة والأعشاب البحرية في البحر الأحمر، منطقة جازان، المملكة العربية السعودية. تم تحليل العينات باستخدام التحليل الطيفي للانبعاث الذري للبلازما المقترنة حثيًا ICP-AES (الطريقة B٣٠٥٠). من بين جميع أنواع الطحالب الكبيرة والأعشاب البحرية .*Sargassum* spp. وأظهرت تركيزًا عاليًا من الرصاص (Pb) وسجل أعلى مستوى (١١,٣٥ جزء في المليون) في محطة قريبة من محطة الصرف الصحي بين الأنواع في هذه الدراسة. في المقابل، كانت الأنواع الأقل تراكمًا للرصاص هي Cymodocea rotunda. وتم تسجيل التلوث بالرصاص (Pb) لجميع الطحالب الكبيرة والأعشاب البحرية المحددة في هذه الدراسة بترتيب تصاعدي Cymodocea rotunda < *Cladophora* spp. < Halodule uninervis < *Sargassum* spp.، وتم جمعها بالقرب من محطة الصرف الصحي. ويمكن استخدام النتائج التي تم الحصول عليها من الدراسة لرصد تلوث الرصاص في النظام البيئي وصحة الخط الساحلي.

الكلمات المفتاحية: الرصاص (Pb)، الطحالب الكبيرة، الأعشاب البحرية، المعادن الثقيلة، التلوث، جازان، الإنذارات الحيوية.