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Concentration of Heavy Metals in Sediment and Seagrasses Tissue of the Red Sea Coastal Water of the Sudan

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Abstract

The study investigated the concentration of Lead, Cadmium, Nickels and Chromium in sediment and seagrass tissues at six selected sites along the Sudanese Red Sea coast. The findings of the study added some important and necessary information about the status and condition of the coastal environment in the Sudanese Red Sea coast in terms of the extent of pollution with heavy metals. The study sites included: Marsa Bashayer, Marsa Dama Dama, Green Area, Shipyard, Marsa Halout and Dungonab Bay. The Atomic Absorption Spectrophotometer was used to measure Lead, Cadmium and Nickels. The colorimetric detection method was used for Chromium using the Spectrophotometer. Marsa Dama Dama site revealed high levels concentration of heavy metals in sediment for Lead (60.5) μg/g, Cadmium (0.22) μg/g and Chromium (146.65) μg/g. Marsa Halout showed the highest mean concentration of Nickel in sediment at 14 μg/g. The variation of concentration of metals in sediment between the sites was not significant. The mean concentration of metals in seagrass species tissues ranged from 3.9 to 26.25 μg/g for Lead, 0.1 to 0.90 μg/g for Cadmium, 0.38 to 5.96 μg/g for Nickel and 0.15 to 0.495 μg/g for Chromium. The differences of concentration of heavy metals in seagrass tissues among the sites were significant for Lead and not significant for Cadmium; Nickel and Chromium.

Keywords

Heavy Metals, Sediment, Seagrass, Contamination, Coastal Environment Condition

1. Introduction

Seagrasses take place mainly in shallow soft-bottom waters for instance muddy and sandy bays, estuaries, lagoons and mud flats [1] [2]. They have a probable to influence chemical and physical strictures in the sea water [3] and play significant functions in stabilizing the bed soil [4]. Seagrasses are widespread in the Red Sea commonly in shallow water areas with soft-bottom deposit. There are up to eleven species of seagrasses in the Red Sea and its two northern gulfs [5]. Ten species of seagrasses were reported in the Sudanese Red Sea coastal water [6] [7].

As seagrass beds are situated in the shallow coastal zone, they are affected directly or indirectly by land-based or other sources. Worldwide, seagrass habitats are declining due to both natural and environmental pollutions by human actions, including heavy metal effluence [8]. Seagrasses are increasingly exposed to human disturbances such as metal contamination, which is an important factor leading to seagrass losses [9]. Direct toxic oil spills directly damage seagrasses or affect the sediments in which they grow. Some species of seagrasses if destroyed are improbable to recover within decades [10] [11].

Heavy metal contamination in the marine environment is on the boost worldwide and the concentrations of heavy metals in natural aquatic ecosystems in the last decade have reached remarkable levels [12] [13]. Heavy metals are one of the main contaminants of anthropogenic sources in the Red Sea of Saudi Arabia [14].

The pollution with heavy metals may well be one of the most significant threats to seagrass environments [15]. Seagrass have ability to accumulate trace metals from the surroundings without demonstrating any impact on their productivity [16].

Only very few published researches have addressed the concentration and impact of heavy metals in sediments and seagrasses on the coastal waters of the Sudanese Red Sea, such as [17] who studied the levels of some heavy metals in the sediments of Port Sudan and Suakin Harbours. Most of the researches published in the Sudanese Red Sea coast focused on studying the concentration of heavy metals in fish. Study of the concentration and effect of heavy metals in the environment of seagrass bed and other coastal environments that abound in the Sudanese coast needs a lot of research and investigation in the future. The current study examined the concentration of Lead, Cadmium, Nickels and Chromium in sediment and seagrass tissues at six selected sites along the Sudanese Red Sea coast. The results of the present study will be a real addition to the basic information that may be needed in some administrative aspects of the coastal region in the Sudan.

2. Materials and Methods

2.1. Study Sites

Six sites were selected to conduct the study. Three of the six sites are located nearby Port Sudan town Area were chosen as special concern due to their locations because of stress by ships operations, previous dumping of solid wastes, morphological nature as a semi-enclosed inlet (Shipyard at latitude 19˚37'28''N, longitude 37˚13'21''E), new extension of Port Sudan Harbour (Green Area at longitude 19˚37'11''N, latitude 37˚14'24.4''E) and new oil export terminal (Marsa Dama Dama at latitude 19˚35'18.5''N, longitude 37˚14'30.4''E). One site was selected as an old fishermen marina and an oil terminal (Marsa Bashayer at latitude 19˚24'N, longitude 37˚16'E). Another site was chosen as a fishermen marina and delta of the seasonal *khor* of Arbaat (Marsa Halout at latitude 19˚47'N, longitude 37˚15'E). The last site was chosen as a big bay, a semi-enclosed, protected area, fishermen village, old oyster private farms and new modern oyster cultivation (Dungonab Bay at latitude 21˚06.292', longitude 37˚07.328').

2.2. Samples Treatment

The samples of sediment nearby seagrass bed at each site were collected randomly with clean PVC core and saved instantly in cleaned polythene containers and transferred to the laboratory. The samples were washed with free metal distilled water. Then, the samples were dried in an oven at 105˚C to constant weight, handled by Crusher, sieved in 0.2 mm. One mg of the each sample was transferred to a crucible. 10 ml of hydrofluoric acid (HF) was added, followed by five ml of $HClO_4$ and then two ml of Nitric acid (HNO_3). The samples were dry heated. The dried samples were diluted in 10 ml of hydrochloric acid (HCl) and warmed for five minutes. The samples were transferred to polyethylene flask and completed to 100 ml with metal free distilled water [18].

The samples of different seagrass species at each site were collected randomly from the substrate and swabbed with seawater to eradicate debris, sediment and attached fauna. After that, the samples were placed in cleaned polythene boxes and transferred to the laboratory. The samples were washed more than one time in free metal distilled water. 30 grams of seagrass tissue materials of each sample were dried in an oven at 105˚C to a constant weight. The samples were cooled to lower temperature, then to high temperature slowly till about 450˚C. The samples were cooled to room temperature and two ml of Nitric acid (HNO_3) were added. The samples were dried at lower temperature and then to 450˚C for about one hour and then to room temperature. Another two ml of Nitric acid (HNO_3) were added. Ten ml of hydrochloric acid (HCl) were added. The samples were diluted at lower temperature. Another 10 ml of hydrochloric acid (HCl) were added to 25 ml of the diluted sample and completed to 100 ml with free metal distilled water. The samples were transferred to read the heavy metals concentrations [18].

2.3. Heavy Metals Measurement and Data Analysis

Concentrations of Lead (Pb), Cadmium (Cd) and Nickel (Ni) in sediment and seagrass samples were measured using Atomic Absorption Spectrophotometer model 2380 (PERKIN-ELMER). Concentrations of Chromium (Cr^{6+}) in sediment and seagrass samples were measured with the colorimetric detection methods using HACH Direct Reading 2000 Spectro-photometer at wavelength 540 nm. The analysis of variance (ANOVA) was used to test the differences of heavy metals concentration between sites for sediment and seagrass data. The results were tabulated, illustrated in graphs and discussed.

3. Results

Port Sudan area sites (Marsa Dama Dama, Green area and Shipyard) demonstrated high content of heavy metals in sediment (Table 1). The highest mean concentration of Lead (Pb), Cadmium (Cd) and Chromium (Cr) in sediment were encountered at Marsa Dama Dama (60.5, 0.22 and 146.65 µg/g, respectively). Marsa Halout showed the highest mean concentration of Nickel (14 µg/g) in sediment at the study sites (Table 1).

The variations in concentration of heavy metals in sediments between sites were not significant ($f = 1.19$, $p = 0.414$, $df = 5$) for Lead, ($f = 0.85$, $p = 0.560$, $df = 5$) for Cadmium, ($f = 0.48$, $p = 0.779$, $df = 5$) for Nickel and ($f = 0.85$, $p = 0.560$, $df = 5$) for Chromium.

The mean concentration of heavy metals in seagrasses tissue ranged from 0.1 to 0.90, 3.9 to 26.25, 0.38 to 5.96 and 0.15 to 0.495 µg/g for Cadmium (Cd), Lead (Pb), Nickel (Ni) and Chromium (Cr) respectively (Figures 1-4). While the lowest mean concentration value at 0.1 µg/g for Cadmium in *Halodule uninervis* (Figure 1), the highest one at 26.25 µg/g for Lead in *Halophila stipulacea* (Figure 2), and the both values were encountered at Marsa Dama Dama site.

The differences in concentration of heavy metals in seagrass tissues between the sites were significant for Lead ($f = 2.61$, $p = 0.047$, $df = 5$) and not significant for Cadmium ($f = 1.91$, $p = 0.124$, $df = 5$); Nickel ($f = 0.87$, $p = 0.514$, $df = 5$) and Chromium ($f = 1.93$, $p = 0.122$, $df = 5$).

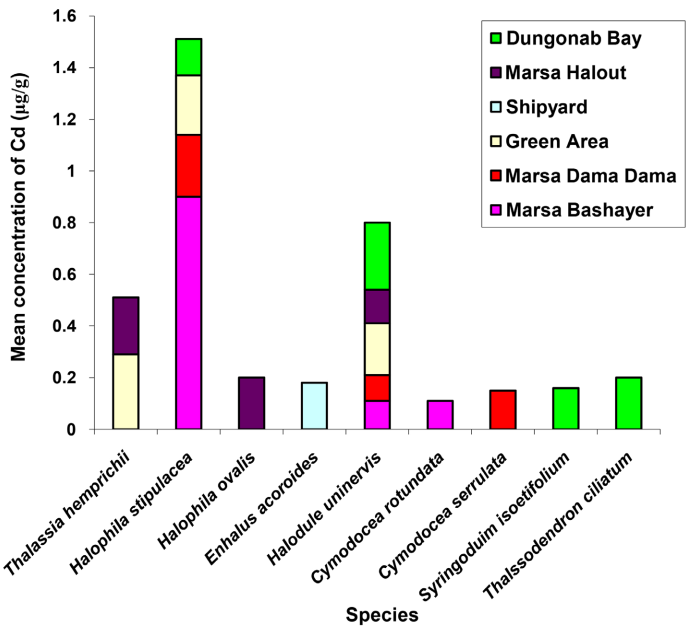

Figure 1. Mean concentration of Cd (µg/g) in seagrasses species at the study sites.

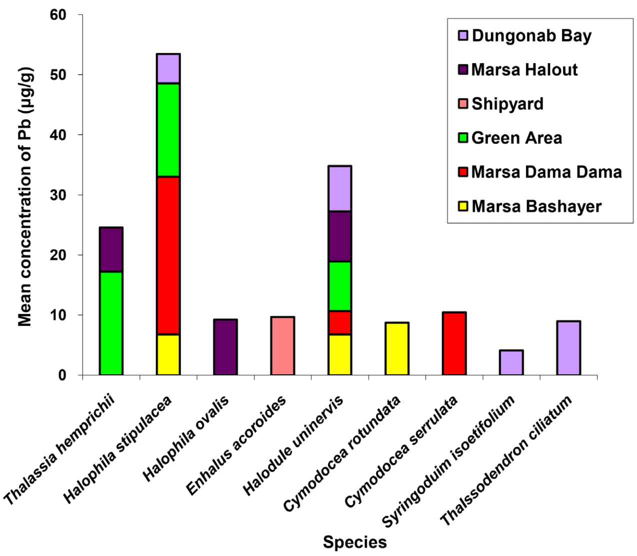

Figure 2. Mean concentration of Pb (μg/g) in seagrasses species at the study sites.

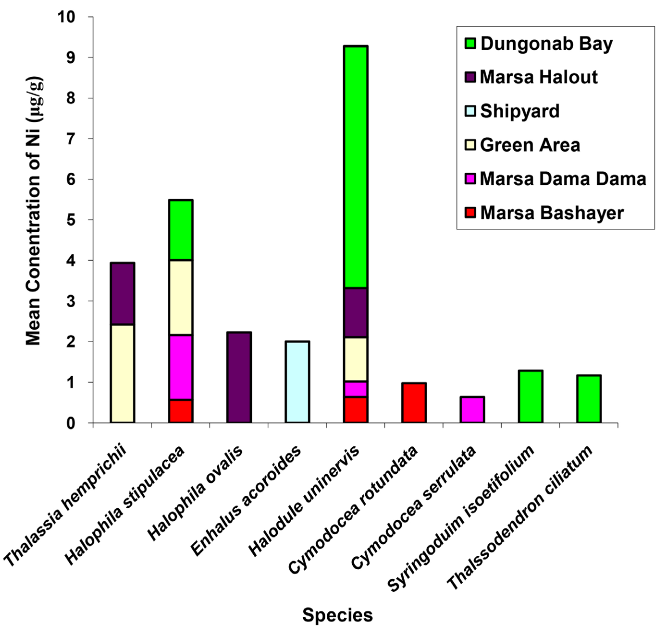

Figure 3. Mean concentration of Ni (μg/g) in seagrasses species at the study sites.

Table 1. Mean concentration of heavy metals (μg/g) in sediments at the study sites.

Site \ Metal	Lead (Pb)	Cadmium (Cd)	Nickel (Ni)	Chromium (Cr)
Marsa Bashayer	34.0	0.18	6.8	120.0
Marsa Dama Dama	60.5	0.22	6.4	146.65
Green Area	53.5	0.17	10.9	113.35
Shipyard	53.5	0.17	9.8	113.35
Marsa Halout	31.5	0.11	14.0	73.3
Dungonab Bay	53.5	0.15	6.8	100.0

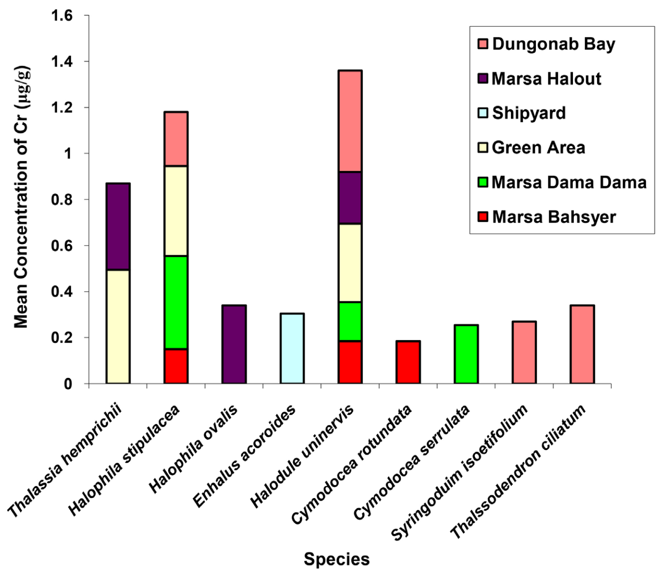

Figure 4. Mean concentration of Cr (μg/g) in seagrasses species at the study sites.

4. Discussion

The variations in concentration of heavy metals in sediment between sites in the current study they could be due to difference in sources. The relatively high mean concentration of heavy metals at Port Sudan Area sites (Marsa Dama Dama, Green Area and Shipyard) during the present study could be due to the high human activities that take place in this area, particularly Port Sudan Refinery south Marsa Dama Dama site. As well, the runoff from Port Sudan Town especially during the rainy season could constitute another source of heavy metals. It should be noted here that the distribution of heavy metals concentrations in coastal water can be explained by the proximity of river mouths and current patterns [19]. Throughout the study of [17] on the levels of some heavy metals in sediments of Port Sudan and Suakin harbours, they mentioned that the granulometric normalization exposed that some sites in Port Sudan harbour and one site in Suakin harbour have been exposed to dissimilar levels contamination of heavy metals, which maybe created from ships, industrial and household actions. The mean values recorded by [17] for Nickel (102 mg/kg) and Lead (17.1 mg/kg) in sediment are considered very high in the case of Nickel and low in the case of Lead compared to the current study. A range between 1.30 and 17.3 ppm was recorded by [20] at Port Sudan area for the concentration of lead in seawater during a study the assessment of industrial pollution, a study case in Port Sudan Town coast. This range is comparatively lower than the concentration in sediment in the present study. [21] in Ambon Island waters of Indonesia reported values in sediment ranging from 0.84 ± 0.06 to 2.090 ± 0.01 ppm for Pb and from 0.541 ± 0.02 to 1.195 ± 0.03 ppm for Cd, these values are very low in case of Pb and high in case of Cd in compared to the present study. [22] in Rabigh lagoon, Red Sea recorded in sediment mean values between 56.52 ± 6.04 and 113.44 ± 4.84 mg/kg for Ni and Pb, respectively, these values are very high compared to the values recorded during the current study. The values in sediment ranged from 10.72 to 28.23, 0.21 to 0.87, 19.03 to 51.43 and 8.32 to 28.68 μg/g for Pb, Cd, Cr and Ni, respectively were reported by [23] in the Gulf of Chabahar, Oman Sea, these values are low in the case of Pb and Cr and high in the case of Cd and Ni compared to the present study.

The moderately high concentration of heavy metals in sediment at Marsa Dama Dama site during the present study may be due to the human activities nearby the site. Resembling that at Green Area and Shipyard sites was probably due to the heavy boats traffic and operation at the two sites. Moreover, the previous dumping of solid wastes that was reported by [24] during the study of solid waste disposal on coastal zones, the case study of Port Sudan Harbour. Besides the morphological nature of the Shipyard site as a semi-enclosed inlet. Comparatively, the high concentration of Nickel (Ni) in the sediment at Marsa Halout site may be due to the sedimentation by the seasonal *Khor* of Arbaat.

The heavy metals concentration in seagrasses tissue in the present study ranged from 3.9 to 26.25, 0.1 to 0.90, 0.38 to 5.96 and 0.15 to 0.495 μg/g for Lead (Pb), Cadmium (Cd), Nickel (Ni) and Chromium (Cr) respectively. [25] reported mean concentration of heavy metals in seagrasses at 340, 19.6, 410 and 1160 μg/g for Lead, Cadmium, Nickel and Chromium, respectively. [21] encountered mean concentration values in seagrass *T. hemprichii* ranged between 1.036 ± 0.012 and 1.623 ± 0.231 ppm for Pb, and between 1.493 ± 0.598 and 1.593 ± 0.206 ppm for Cd, these values are low in the case of Pb and high in the case of Cd compared to the current study. In Denmark figures ranging between 35 and 3746 and between 9 - 292 μg/g for Lead and Cadmium concentration in seagrasses tissue, respectively were reported by [26]. These values are very high compared to the values in the current study. During the current study Marsa Dama Dama and Dungonab Bay sites have the highest mean concentrations of Pb and Ni in seagrass species, respectively. In the case of Dungonab Bay site may be due to the morphological nature of the bay as a semi-enclosed that may enhance the precipitation of metals. The concentration of heavy metals in leaves and roots of the seagrass were considerably higher in the contaminated location than in comparatively uncontaminated locations [27]. There are many factors known to influence the accumulation of heavy metals by seagrasses. These factors comprise the seagrass species, the type of tissue, the heavy metals, and the concentration of metals within the waters and sediments besides the sediment characteristics [28].

Contrary to the results of the current study, [21] reported at Ambon Island waters in Indonesia concentrations of Pb and Cd in seagrass species *T. hemprichii* higher than in sediments. As was stated in the current study, [19] in the seagrass beds of Guadeloupe Island encountered level of heavy metals contamination in plants lower than in sediments. Higher bioaccumulations of metals in *C. serrulata* more than *S. isoetifolium* were recorded by [29] in the Palk Strait, Bay of Bengal. This outcome is similar to the results of the present study in the case of Pb concentration, but it is not consistent with the other studied heavy metals.

5. Conclusion

Mean concentration of heavy metals in sediment during the study ranged from 31.5 to 60.5, 0.11 to 0.22, 6.4 to 14.0 and 73.3 to 146.65 μg/g for Lead (Pb), Cadmium (Cd), Nickel (Ni) and Chromium (Cr) respectively. Mean concentration of heavy metals in seagrasses tissue during the study ranged from 3.9 to 26.25, 0.1 to 0.90, 0.38 to 5.96 and 0.15 to 0.495 μg/g for Lead (Pb), Cadmium (Cd), Nickel (Ni) and Chromium (Cr) respectively. The variations in concentration of heavy metals in sediments between sites were not significant ($f = 1.19$, $p = 0.414$, $df = 5$) for Lead, ($f = 0.85$, $p = 0.560$, $df = 5$) for Cadmium, ($f = 0.48$, $p = 0.779$, $df = 5$) for Nickel and ($f = 0.85$, $p = 0.560$, $df = 5$) for Chromium. The differences in concentration of heavy metals in seagrass tissues between the sites were significant for Lead ($f = 2.61$, $p = 0.047$, $df = 5$) and not significant for Cadmium ($f = 1.91$, $p = 0.124$, $df = 5$); Nickel ($f = 0.87$, $p = 0.514$, $df = 5$) and Chromium ($f = 1.93$, $p = 0.122$, $df = 5$). Comparatively high mean concentration of heavy metals it was detected in sediment at Port Sudan Area sites (Marsa Dama Dama, Green Area and Shipyard) during the study. Marsa Dama Dama, Dungonab Bay, Green Area and Marsa Bashayer sites have the highest mean concentrations in the seagrasses species tissue. While Marsa Halout site showed high concentration of Nickel (Ni) in the sediment, Marsa Dama Dama and Dungonab Bay sites have the highest mean concentrations of Pb and Ni in seagrass species, respectively. The differences in heavy metal concentrations between sites during the current study may be due to differences in the amount and extent of heavy metal contamination and their sources. A proper assessment of the concentration and sources of heavy metals and their effects in the coastal habitats of the Sudanese Red Sea coast must be carried out.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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