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Risk assessment of heavy metals in mangrove trees (*Avicennia marina*) and associated sea water of Ras Mohammed Protectorate, Red Sea, Egypt

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ABSTRACT

The environmental condition of marine environment is rapidly deteriorating due to current population and development patterns. Marine protected areas (MPAs) are an approach to managing the oceans more sustainably. MPAs are places that have been legally recognized as being for the protection and conservation of valuable biodiversity, together with associated ecosystem services and cultural values. Seven sampling stations of sea water were selected as well as 62 mangrove samples were collected from these seven stations along the Ras Mohammed protectorate coast. The distribution of heavy metals as µg/L in water samples was in the following order Fe>Zn>Pb>Cu>Mn>Cd. The Enrichment Factor (EF) of Fe, Cd, Cu, Zn, Mn, and Pb in Ras Mohammed protectorate was slight, with values lower than 1 at all locations. In addition, the area of study was slightly affected by the metal pollution index (MPI) as it is located in class III (between 1-2 levels). Also, this study determined concentrations of these metals in three parts of *Avicennia marina* (leaves, stem, roots). The results showed that the concentrations of metals were ordered from high to low concentrations as follows roots>leaves>stem. Manganese was the highest concentration in bioconcentration factor among the elements examined in the roots, leaves, and stem of *Avicennia marina*.

INTRODUCTION

Current population and development trends are leading to an acute deterioration of the environmental state of the oceans **(Hassan *et al.*, 2022)**. One of the tools to manage the world's seas more sustainably is marine protected areas (MPAs). MPAs are legally designated areas to protect and conserve valuable marine and coastal biodiversity and associated ecosystem services and cultural values. There are rising calls to conserve 30% of the ocean by 2030, and MPAs provide a natural answer to support international efforts to adapt to and mitigate climate change. In 2019, there were 7.59% MPAs worldwide (**UNEP-WCMC and IUCN, 2022**).

Egypt established 29 protected areas that collectively accounted for 15% (150,000 km^2) of its total land area. Seven of these are marine; El-Salum, which was declared in the Egyptian Mediterranean costal water in 2010, and the remaining six, which together cover 46,400 km^2 of the Red Sea (17,915 square miles) **(UNEP-WCMC and IUCN, 2022)**.

The benefits of MPAs for fisheries, local economies, and the marine environment are wide-ranging and include: preservation of biodiversity and ecosystems; stopping and possibly reversing the global and local decline in fish populations and productivity by protecting crucial breeding, nursery, and feeding habits; enhancing the visibility of an area for marine tourism and broadening local economic options; providing opportunities for education, training, heritage, and culture; providing (**Marcos *et al.*, 2021; Younis, 2019)**

Synthetic compounds the introduced into MPA environments by anthropogenic activities, and many naturally occurring substances have seen an increase in concentration. These chemicals are considered contaminants when their concentrations exceed background levels **(Younis *et al.*, 2020; El-Naggar *et al.*, 2021; Younis *et al.*, 2022)**. Because of their ecological importance and the potential for their transfer to humans through food chains in quantities that can be dangerous, metals in the environment of MPAs have received a great deal of attention in research **(Hanafy *et al.*, 2021)**.

Ras Mohammed National Park exists at the southernmost tip of the Sinai Peninsula, on one side bordered by the Gulf of Suez and the other by the Gulf of Aqaba **(Frouda, 1984)**. The coastal plain is narrow with granitic mountains sloping down into the sea **(Shehata, 1998)**.

Mangrove forests are among the most threatened and undervalued ecosystems in the world, despite the crucial role they play for coastal people. As it is highly productive ecosystem, shelter, grazing and nursery ground for coral reef fishes, regulates sedimentation, supporting adjacent ecosystems, minimize coastal erosion. Over 30 tropical and subtropical countries are host to the world's mangroves, which occupy an area of about 99,300 square kilometers **(Singh, 2000)**.

According to the most recent estimates, Egypt's mangroves cover about 5 km^2. Egypt's sparse mangrove areas indicate that this ecosystem is vulnerable and requires proper management to ensure its long-term survival **(Saenger, 2002)**. There are just two species known from Egypt. *Avicennia marina* is the most popular (*Avicenniaceae*).

Because they offer crucial and unique ecosystem services and benefits to human society, coastal ecosystems, and marine ecosystems, mangrove forests are the most productive and ecologically significant ecosystems in the world **(Younis, 2020; Younis *et al.*, 2018)**.

A small stand of *Avicennia marina* occupies the narrow line at Ras Mohammed, extending for about a kilometre along the fault line, which has been covered with sand and has dense mangrove branches. The protected area is located at latitude 27.727439° N and longitude 34.247299° E. **(GabAlla *et al.*, 2010)**. The mangrove vegetation consists of the trunk, aerial roots, leaves, and the extensive shade provided by the trees. It is surrounded by associated lagoons and channels, as well as adjacent shallow subtidal sand and mud flats, sea grass beds, and fringing reefs. These habitats and adjacent biotopes are home to a variety of biota and fish species.

Heavy metal concentrations in the water and sediments of the study area have increased due to human activities that have introduced these metals into the marine environment **(Younis *et al.*, 2019; Soliman *et al.*, 2020)**.

The present work aimed to risk assessment of six heavy metals (Fe, Mn, Zn, Cu, Pb and Cd) in the sea water and compare it with their concentration in the mangrove trees (*Avicennia marina*) by, estimating the bio-concentration factor (BCF), to reflect the ability of plants to accumulate heavy metals at Ras Mohammed protectorate, Red Sea, Egypt.

MATERIALS AND METHODS

1. Study Area

The park was established in 1983 as Egypt's first national park, but it is generally recognized to have existed as a "paper park" until 1988 **(Shehata, 1998)**. In response to the area's rising popularity as a dive tourism destination, the Egyptian government gave the Egyptian Environmental Affairs Agency (EEAA) the responsibility of managing the park in that year. It was Egypt's first officially recognized national park.

The 480 km^2 Ras Mohammed National Park (RMNP) is divided into two parts, marine (part of the Gulf of Suez and part of the Gulf of Aqaba) which comprises 70% of the park's total area, and terrestrial (30%).

The park's remarkable geographic location has allowed for the evolution and continuous presence of numerous unique species and habitats, and it also has unique marine and terrestrial treasures.

As a result, the coral reef environment in the Ras Mohammed protectorate, which is ranked among the greatest in the world, has become famous globally. It is a major tourist attraction in the Sharm El-Sheikh region, especially for SCUBA divers. The enormous range of coral species found in RMNP's coral reef ecosystem considers it one of the best in the world.

Due to the 220 different species of coral present in this coral aggregation's very tiny area, the environment of this area is highly specific and is therefore considered to be unique. There are three different types of marine turtles that are endangered (Green, logger head and hawksbill turtles). It is considered the bottleneck for the endangered white storks and endangered mangrove species (*Avicenna marina*) as well.

2. Sampling and Analysis

Seven sampling stations for sea water were selected along Ras Mohammed protectorate coastal water as well as 62 mangrove samples were collected from these seven stations along the mangrove ecosystem of Ras Mohammed protectorate. The sampling locations were selected based on the properties of physicochemical parameters and the source of contaminations (Fig. 1).

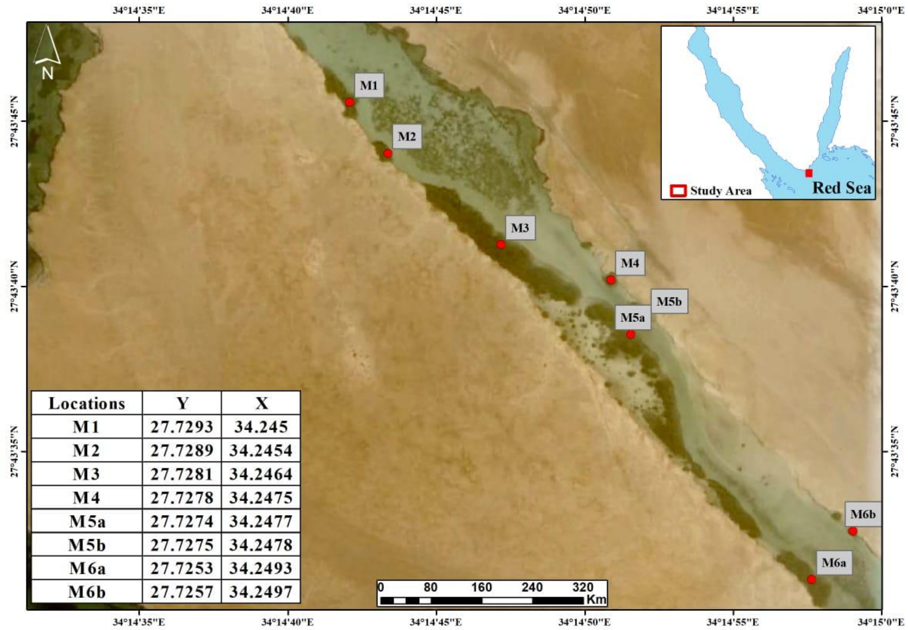

Fig. 1. Sampling locations in the area of study.

According to **Eaton (1976)**, each 750 ml filtered sample was put into a separating funnel where its pH was adjusted to the range from 4.8-5.2, using concentrated nitric acid. To each sample, 15 ml of 1 % APDC and 30 ml MIBK were added. The funnels were shaken for 15 minutes on an automatic shaker. Following separation of the phases, the aqueous layer was drawn off into clean separating funnel and another 30ml of MIBK were added, the upper MIBK layer with the extracted metals was retained in the corresponding small 100 ml separating funnel. The same procedure was repeated two additional times for another 15 minutes and then for 30 minutes. At least, 15 ml of 2N of HNO3 were added to MIBK extract in the 100 ml separating funnel, shacked and left 48 hours for phase separation. The extracted 15 ml aqueous layer of 2 N HNO3 containing the chelated metal from the 750 ml sample solution was kept in tightly stopper scintillation vials for storage until analysis.

All mangrove tissue were dried individually at room temperature until constant weight. Then 0.50 mg of the mangrove tissue was digested with 6 ml concentrated HNO3 as described by **Spalla *et al.* (2009)**.

The concentration of heavy metals (zinc, iron, copper, cadmium, lead and manganese) in the leaves, stem and roots of mangroves and seawater was measured by atomic absorption spectrophotometer (AAS Perkin Elmer analyst, Model100) and the results were expressed in µg/g; dry weight for mangrove samples and µg/L for sea water samples. Reagents of analytical grade were utilized for the blanks and calibration curves. Precision was checked against standard reference material and lied within the range of certified values with 90-97% recovery for all metals studied.

3. Ecological Risk Assessment

3.1. The enrichment factor (*EF*)

The enrichment factor (*EF*) was applied to assess the pollution degree of heavy metals in sea water that were impacted by anthropogenic activities. EF for each metal was determined by comparing the observed dissolved metal concentration over minimal risk concentration of metals reported for WQC.

3.2. Metal Pollution Index (MPI)

The MPI represents the sum of the ratio between the concentration of analyzed metal and their corresponding maximum allowable concentrations (MAC). The **WQC (1972)** is used in MAC calculations for the determined metals.

$$\mathbf{MPI} = \sum_{i=1}^{n} \frac{c_i}{(MAC)_i}$$

where concentration of i^{th} metal; MAC = Maximum allowable concentrations.

3.3. Bio concentration (BCF) and translocation factors (TFs)

In the present study bio concentration factor was conducted by dividing the concentration of test substance in/on specified tissues thereof (as mg/kg) by the concentration of the chemical substance in the surrounding medium (as mg/L or mg/Kg).

For the investigated heavy metals, the bio concentration factors were calculated based on the equation **(Cui *et al.*, 2007; Yoon *et al.*, 2006)** as the following.

BCF = Concentration of the substance (mg/kg)/Concentration of the substance in water (mg/L). While the translocation factor (TF) was calculated using the following equation

$$TF_{leaf} = \frac{C_{leaf}}{C_{root}},$$

where C_{leaf} and C_{root} are the heavy metal concentrations in the leaves and roots, respectively.

RESULTS AND DISCUSSION

1. Assessment of heavy metals in sea water

The physical and chemical characteristics of seawater, such as temperature, pH, turbidity, salinity, and levels of dissolved oxygen, may have an impact on the changes in the concentrations of heavy metals in sea water. Additionally, the redox conditions in the environment and the oxidation state of the element as well as the nature and quantity of organic ligands, all have a major role in determining the metal solubility.

In Ras Mohammed protectorate coastal water, we found that the highest Cu (1.795 µg/L) appeared in station 1 followed by Mn (1.034 µg/L).

Distribution of heavy metals as µg/L in water samples collected from Ras Mohammed protectorate is shown at Fig. 2. Our results showed that the maximum concentration of Fe (33.6 µg/L) found in water sample of station 6, while the highest values of Pb, Cd and Zn (3.156, 0.398, 12.97 µg/L) were found in station 2, this may be returned to wastewater discharges associated with shipyards disposals and antifouling paints and repairing rusts of the ship maintenances found in this station; Zinc, Copper and Cupric oxide released from the antifouling and anticorrosive paints that protect the hulls of marine vessels.

2. Risk assessment model

The level of metal contamination in seawater has been measured using a variety of techniques. To convert the calculated numerical results into broad descriptive bands of pollution, ranging from low to high intensity, scholars have proposed pollution impact ranges **(Hakanson, 1980; Tamasi and Cini, 2004)**. Two methods were used to investigate the level of contamination in the area under investigation.

2.1. Enrichment factor

The concentrations of metals at each site were compared with those recognized as minimal risk concentrations of metals reported for water quality criteria **(WQC, 1972; Udayakumar *et al.*, 1992)** to identify the risk assessment of metals in the study area. According to the WQC, EF values more than 1 show that the waters are enriched with metals **(Udayakumar *et al.*, 2011; Asa *et al.*, 2015)**.

Table 1 shows the EF values in different locations. Contamination of Fe, Cd, Cu, Zn, Mn and Pb in Ras Mohammed protectorate was slight, with all EF values lower than 1 in all locations. That means water of the protectorate is not much enriched with those metals and that investigated the flourish and high capacity of mangrove ecosystem and being compatible with all kinds of surrounding habitats of different organisms.

Table 1. Enrichment factor (EF) of the studied heavy metals in water samples collected from Ras Mohammed protectorate.

Locations	Cu	Fe	Pb	Cd	Zn	Mn
1	0.1795	0.5970	0.2115	0.0191	0.5885	0.0517
2	0.1246	0.5406	0.3156	0.0398	0.6485	0.0337
3	0.0990	0.5976	0.2386	0.0207	0.4792	0.0358
4	0.0715	0.4734	0.1575	0.0199	0.3107	0.0338
5	0.0763	0.4470	0.1499	0.0163	0.2683	0.0305
6	0.0951	0.6720	0.1895	0.0232	0.3232	0.0396
7	0.0688	0.3134	0.1368	0.0178	0.1901	0.0188
8	0.0733	0.3924	0.1114	0.0120	0.1838	0.0265

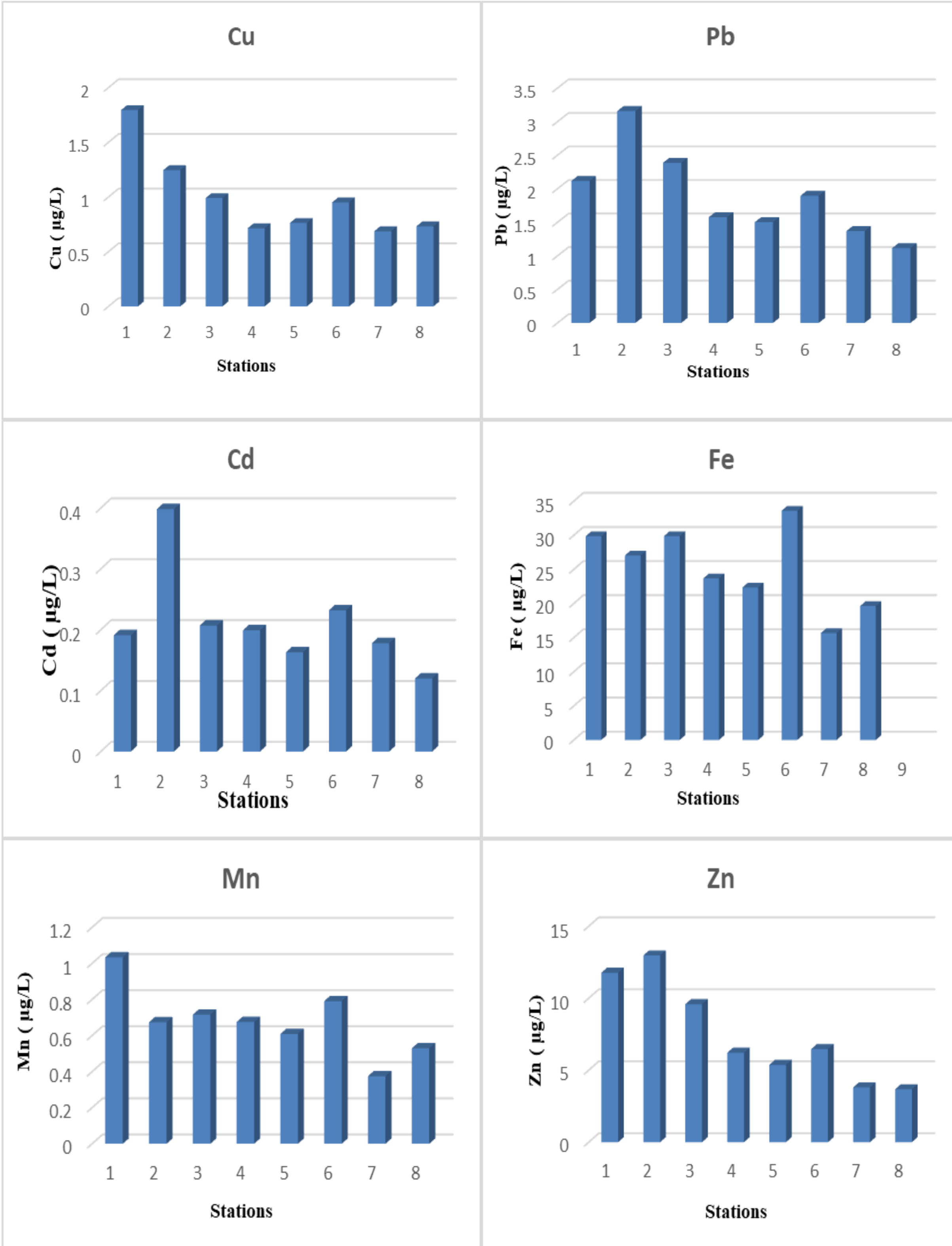

Fig. 2. Metal concentrations (µg/L) in water samples collected from Ras Mohammed protectorate.

2.2. Metal pollution index

The Metal Pollution Index (MPI) measures the overall impact of all metals on the quality of the water. Depending on the amount of anthropogenic metal input throughout various periods of monitoring, the water quality is divided into six separate classes. An MPI of < 0.3 represents very pure (Class I), 0.3–1.0 poor (Class II), 1.0–2.0 slightly affected (Class III), 2.0–4.0 moderately affected (Class IV), 4.0–6.0 strongly affected (Class V) and a MPI of >6.0 represents seriously affected (Class VI).

Contamination by metals in seawater samples was assessed by MPI and is presented in Fig. 3.

We can illustrate from the figure that all investigated locations of Ras Mohammed protectorate were slightly affected by metal pollution index as it located in class III because MPI of all locations in it between 1-2 level.

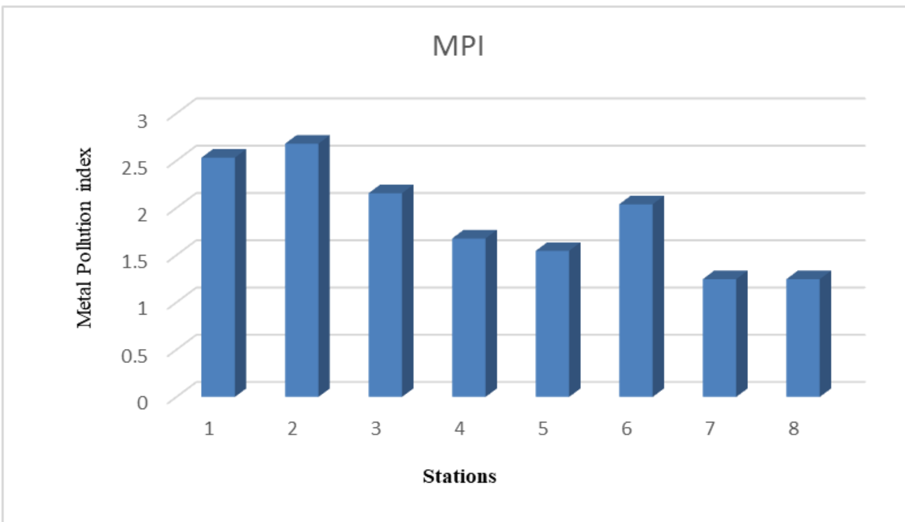

Fig. 3. Metal Pollution index (MPI) in water samples collected from Ras Mohammed protectorate.

3. Heavy metal accumulation in *Avicennia marina* tissue

Mangrove forests have the ability to capture suspended particles, with their load of heavy metals originating from upstream soils, rocks, or anthropogenic activities **(Wolanski, 1995; Furukawa *et al.*, 1997; Tam and Wong, 1999)**. Mangroves are therefore regarded as effective sea-to-land barriers because they act as sinks for toxic elements and protect coastal waters from contamination. However, the hydrology and sediments properties may affect its capacity **(Kaly *et al.*, 1997)**. Due to diverse biogeochemical processes occurring across the intertidal zone, metal dynamics in mangroves are complex **(McKee, 1993; Marchand *et al.*, 2011; Nol *et al.*, 2015)**.

Mangrove stand of Ras Mohammed which is about 0.9 hectares is continuously threatened with oil pollution leaked from shipping lines and old delivery lines lying on the Gulf of Suez at distances between 45-110 km northern to mangrove of Ras

Mohammed. Also due to the dominant wind direction and shoreline extension in the Old Quay and Mangrove channel is again make the site good receptor for different forms of floating pollutants and severely to oil pollution which is actually documented since more than forty years with its signs of impact to mangroves of Ras Mohammed **(El-Hussieny, 2012)**. This study examined the determination of six metals (Cu, Fe, Pb, Cd, Zn, Mn) in three parts of *Avicennia marina* (leaves, stem, and roots) in Ras Mohammed during 2018.

Table 2. Heavy metal content (µg/g) in mangrove roots in Ras Mohammed protectorate.

Locations	No. of samples	Cu	Fe	Pb	Cd	Zn	Mn
		µg/g					
M2	1	0.077	0.881	0.129	0.045	0.419	0.149
	2	0.085	1.045	0.094	0.131	0.709	0.175
	3	0.325	4.999	0.631	0.146	1.417	3.318
M3	4	0.092	0.901	0.131	0.052	0.465	0.134
	5	0.114	1.007	0.171	0.079	0.703	0.175
M4	6	0.100	0.876	0.211	0.061	0.577	0.165
	7	1.307	69.78	3.887	0.889	7.966	10.19
	8	0.103	1.457	0.354	0.084	0.916	0.272
M5a	9	0.093	1.186	0.194	0.096	0.847	0.172
	10	0.147	3.033	0.287	0.129	0.884	0.191
	11	0.132	1.022	0.277	0.091	1.407	0.148
M5b	12	0.079	0.752	0.196	0.067	0.585	0.099
	13	0.182	2.625	0.391	0.126	0.948	0.322
	14	0.172	3.026	0.42	0.113	0.863	0.239
M6a	15	0.229	3.088	0.204	0.121	1.144	0.335
	16	0.169	1.354	0.184	0.057	0.817	0.244
	17	0.051	1.386	0.204	0.064	0.442	0.11
M6b	18	0.111	0.535	0.182	0.07	0.429	0.17
	19	0.132	2.681	0.142	0.068	0.514	0.159
	20	0.102	1.739	0.099	0.059	0.506	0.174

Tables 2, 3 and 4 show that the concentrations of metals ordered from high to low concentrations as following roots>leaves>stem. This refers to the concentration of metals accumulated in different parts of the plant which is a measure of the efficiency of the capacity of each plant component for metal uptake **(MacFarlane *et al.*, 2007)**.

Our results also showed that Fe was the highest concentration in roots of location 4 (M4) in Ras Mohammed protectorate with 69.78 µg/g. Mn followed the iron in the same location in roots with 10.19 µg/g then Zn the following with 7.966 µg/g then Pb with 3.887 µg/g then Cu with 1.307 µg/g and finally Cd with 0.889 µg/g.

Table 3. Heavy metal content (µg/g) in mangrove leaves in Ras Mohammed protectorate area.

Locations	No. of samples	Cu	Fe	Pb	Cd	Zn	Mn
		µg/g					
M2	**1**	0.143	3.366	0.331	0.097	0.654	0.797
	2	0.147	5.877	0.402	0.12	0.685	0.995
	3	0.169	3.438	0.377	0.109	0.781	0.731
M3	**4**	0.215	7.79	1.216	0.192	2.047	2.537
	5	0.077	0.912	0.274	0.078	0.835	0.229
M4	**6**	0.078	0.929	0.129	0.074	1.056	0.19
	7	0.245	10.05	1.263	0.177	1.208	0.444
	8	0.157	3.964	0.398	0.132	1.032	0.73
M5a	**9**	0.194	3.017	0.331	0.109	1.438	0.589
	10	0.135	4.461	0.334	0.132	1.35	0.447
	11	0.079	1.376	0.321	0.115	0.553	0.302
M5b	**12**	0.079	4.859	0.259	0.098	0.8	0.561
	13	0.135	3.707	0.372	0.098	0.882	0.795
	14	0.081	2.62	0.267	0.095	0.748	0.55
M6a	**15**	0.141	7.346	0.574	0.111	0.831	1.508
	16	0.066	0.871	0.173	0.065	0.517	0.175
	17	0.086	2.02	0.354	0.085	0.463	0.362
M6b	**18**	0.133	3.697	0.631	0.218	1.501	0.273
	19	0.117	3.816	0.715	0.087	0.565	0.691
	20	0.168	5.21	0.211	0.085	0.702	0.979
	21	0.103	7.215	0.259	0.079	0.434	0.558

The results also showed that location 4 (M4) reach the high concentration in leaves of metals as following Fe> Zn> Pb> Mn> Cu> Cd. While location 4 has the highest concentrations in stem parts of the mangrove as following Fe> Mn> Zn> Pb> Cu> Cd.

Heavy metals that are released into the environment tend to be concentrated in the soil and sediments, which serve as a significant reservoir for plant roots and leaves that are extremely sensitive to changes in heavy metal concentrations. Therefore, high concentrations of metals were recorded in roots and leaves more than stem in location 4 of Ras Mohammed due to drainage influent in this area with high tourism sewage concentrated.These results are in agreement with **Nazli and Hashim (2010)**, They found that Cu and Pb are accumulated in *Sonneratia caseolaris* roots and leaves (concentrations of Pb and Cu for leaves were 35.5 µg/g and 26.8 µg/g, and for roots were 92.9 µg/g and 31.2 µg/g, respectively), and they came to the conclusion that this species' roots have a high capacity for absorbing heavy metals and could be a potential phytoremediation species for heavy metal treatment in Malaysian mangrove ecosystems.

Table 4. Heavy metal content (µg/g) in mangrove stem in Ras Mohammed protectorate area.

Locations	No. of samples	Cu	Fe	Pb	Cd	Zn	Mn
		µg/g					
M2	1	0.072	1.624	0.14	0.04	0.336	0.27
	2	0.076	2.762	0.226	0.067	0.461	0.404
	3	0.094	1.988	0.131	0.161	1.158	0.163
M3	4	0.135	2.095	0.405	0.208	1.151	0.166
	5	0.09	0.848	0.724	0.191	0.984	0.198
M4	6	0.37	1.716	0.827	0.139	1.85	1.864
	7	0.191	7.434	0.419	0.126	0.671	0.195
	8	0.157	9.393	0.254	0.124	1.299	0.364
M5a	9	0.116	1.665	0.358	0.177	1.07	0.346
	10	0.193	2.519	1.933	0.277	1.52	0.335
	11	0.073	4.342	0.376	0.169	0.613	0.165
M5b	12	0.278	3.122	0.611	0.223	1.399	0.294
	13	0.089	4.418	0.224	0.056	0.562	0.159
	14	0.073	3.2	0.165	0.071	0.865	0.132
M6a	15	0.076	0.712	0.126	0.064	0.758	0.167
	16	0.059	0.942	0.167	0.051	0.504	0.111
M6b	17	0.092	1.535	0.085	0.05	0.357	0.1
	18	0.064	2.972	0.163	0.081	0.524	0.098
	19	0.196	2.299	0.261	0.124	0.655	0.312
	20	0.215	2.628	0.251	0.105	0.656	0.326
	21	0.191	2.897	0.235	0.117	0.615	0.33

4. Bio concentration Factor for studied heavy metals

In the current investigation, relative metal uptake metrics were utilized to differentiate between the uptake of each heavy metal. To assess how sensitive various tissue types are to various environmental loadings, the biological concentration factor (BCF) of roots, stems, and leaves was estimated.

Table 5. Bio concentration factor of heavy metals in *Avicennia marina* roots of Ras Mohammed protectorate area.

Locations	No. of samples	Cu	Fe	Pb	Cd	Zn	Mn
		BCF					
M2	1	0.0618	0.03259	0.04087	0.11307	0.03231	0.22107
	2	0.06822	0.03866	0.02978	0.32915	0.05466	0.25964
	3	0.26083	0.12453	0.10488	0.24372	0.05042	1.18249
M3	**4**	0.09293	0.03015	0.0549	0.31902	0.04852	0.18715
	5	0.11515	0.0337	0.07167	0.48466	0.07335	0.24441
M4	**6**	1.82797	2.94804	2.46794	4.46734	1.28215	15.0963
	7	0.14406	0.06155	0.22476	0.42211	0.14743	0.40296
	8	0.13007	0.05011	0.12317	0.48241	0.13633	0.25481
M5a	**9**	0.19266	0.1357	0.19146	0.79141	0.16477	0.31363
	10	0.173	0.04573	0.18479	0.55828	0.26226	0.24302
	11	0.10354	0.03365	0.13075	0.41104	0.10904	0.16256
M5b	**12**	0.19138	0.07813	0.20633	0.5431	0.14666	0.40708
	13	0.18086	0.09006	0.22164	0.48707	0.13351	0.30215
	14	0.2408	0.0919	0.10765	0.52155	0.17698	0.42351
M6a	**15**	0.24564	0.08641	0.1345	0.32022	0.21489	0.65067
	16	0.07413	0.08845	0.14912	0.35955	0.11625	0.29333
	17	0.16134	0.03414	0.13304	0.39326	0.11284	0.45333
M6b	**18**	0.18008	0.13665	0.12747	0.56667	0.13983	0.30057
	19	0.13915	0.08863	0.08887	0.49167	0.13765	0.32892
	20	0.14461	0.07584	0.19838	0.69167	0.15751	0.46125

From Table 5 we found that high bio concentration factor of Mn element in M4 which reverse to main roots of mangrove tree with 15.0963 (BCF) which indicates high accumulation of Mn in this tree soil and absolute pollution in this location by these high calculations.

With the same area we discovered high concentration of Cd in the same main roots of mangrove tree with 4.46734 (BCF) and high concentration of Pb with 2.46794 (BCF) of the same roots in the same location that indicates highest pollution of this area.

This can be explained by the fact that the area is exposed to high pressures of domestic waste in the channel and that metals can accumulate in the roots because the roots might prevent the transfer of non-essential metals.

Aljahdali and Alhassan (2020) studied that Ecological risk assessment of heavy metal contamination in mangrove habitats, using biochemical markers and pollution indices: A case study of *Avicennia marina* L. in the Rabigh lagoon, Red Sea , and they proved that the non –positive correlation of some heavy metals with either Fe, Mn, Cu, Ni or Zn in there study may be due to their relationship to organic detritus, or to different transportation or distribution patterns and they also stated that some of the heavy metals determined in this study, such as Fe, Cu, and Mn, occur naturally and are essential for growth physiology if they do not exceed Nevertheless, some heavy metals like Pb, Cd, and Cr, are toxic to the plant.

Table 6 show that, the highest concentration of metals (Mn with 1.90645 BCF) in the leaves of mangrove trees on Ras Mohammed protectorate area was recorded at (M6a) from Mn with 1.90645 (BCF) and high concentration of Cd in the same area with 1.22472 (BCF) followed by Pb which arrived to 0.47753 (BCF).

The high concentration of Mn in leaves could be due to regional rock compositions or other natural production of this metal from the benthic region of the channel through natural weathering. But the exceeding value of Cd and Pb in leaves indicate absolute ecological risk of this area.

Table 7 shows that high concentration founded in stem part in M4 of Mn element with 2.76148 (BCF) followed by Cd in M5a with high concentration 1.69939 (BCF) and these concentrations ensure previous results in leaves and roots by definite high calculation of Mn in Ras Mohammed channel due to reasons that mentioned above.

After all calculations to the BCF of six metals in Ras Mohammed protectorate we can find out that the highest BCF element in all locations was Mn with 15.0963 (BCF) in M4 extracting from respiratory roots of the trees in this area and that illustrate significant stress facing the whole organisms associated surroundings. We can classify BCF from high to low concentrations according to elements Mn> Cd> Pb> Fe> Zn > Cu. All calculations founded show loadings of metals in the whole area presented in roots more than leaves and finally become the stem role.

5. Translocation Factor (TF) of heavy metal

Translocation factor (TF) Shows the efficiency of plants in transporting HMs from belowground to aboveground organs **(Usman *et al.*, 2012)**. TF was calculated using the following equation **(Mahdavian *et al.*, 2017)**. Furthermore, the translocation factor (TF) was calculated as the ratio between the concentrations of heavy metals in the leaves and the aerial roots. This parameter indicates the ability to transport heavy metals from the roots to the leaves.

Table 6. Bio concentration factor of heavy metals in *Avicennia marina* leaves of Ras Mohammed protectorate area.

Locations	**No. of samples**	**Cu**	**Fe**	**Pb**	**Cd**	**Zn**	**Mn**
		BCF					
M2	1	0.11477	0.12453	0.10488	0.24372	0.05042	1.18249
	2	0.11798	0.21743	0.12738	0.30151	0.05281	1.47626
	3	0.13563	0.12719	0.11946	0.27387	0.06022	1.08457
M3	**4**	0.10101	0.02932	0.08843	0.37423	0.0602	0.23045
	5	0.07778	0.03052	0.11484	0.47853	0.08712	0.31983
	6	0.07879	0.03109	0.05407	0.45399	0.11018	0.26536
M4	**7**	0.34266	0.42459	0.8019	0.88945	0.19443	0.65778
	8	0.21958	0.16747	0.2527	0.66332	0.1661	1.08148
	9	0.27133	0.12746	0.21016	0.54774	0.23145	0.87259
M5a	**10**	0.17693	0.1996	0.22282	0.80982	0.25163	0.73399
	11	0.10354	0.06157	0.21414	0.70552	0.10308	0.49589
	12	0.10354	0.2174	0.17278	0.60123	0.14911	0.92118
M5b	**13**	0.14196	0.11033	0.19631	0.42241	0.13645	1.00506
	14	0.08517	0.07798	0.1409	0.40948	0.11572	0.69532
	15	0.14826	0.21863	0.3029	0.47845	0.12856	1.90645
M6a	**16**	0.09593	0.05558	0.12646	0.36517	0.13598	0.46667
	17	0.125	0.12891	0.25877	0.47753	0.12178	0.96533
	18	0.19331	0.23593	0.46126	1.22472	0.39479	0.728
M6b	**19**	0.15962	0.1945	0.64183	0.725	0.1537	1.30624
	20	0.2292	0.26555	0.18941	0.70833	0.19097	1.85066
	21	0.14052	0.36774	0.2325	0.65833	0.11806	1.05482

Table 7. Bio concentration factor of heavy metals in *Avicennia marina* stem of Ras Mohammed protectorate area.

Locations	No. of samples	Cu	Fe	Pb	Cd	Zn	Mn
		BCF					
M2	1	0.05778	0.06008	0.04436	0.1005	0.02591	0.40059
	2	0.061	0.10218	0.07161	0.16834	0.03554	0.59941
	3	0.09495	0.06653	0.0549	0.98773	0.12083	0.22765
M3	**4**	0.13636	0.07011	0.16974	1.27607	0.1201	0.23184
	5	0.09	0.02838	0.30344	1.17178	0.10267	0.27654
	6	0.51748	0.0725	0.52508	0.69849	0.29776	2.76148
M4	**7**	0.26713	0.31407	0.26603	0.63317	0.108	0.28889
	8	0.21958	0.39683	0.16127	0.62312	0.20908	0.53926
	9	0.16224	0.07034	0.2273	0.88945	0.17222	0.51259
M5a	**10**	0.25295	0.11271	1.28953	1.69939	0.28332	0.55008
	11	0.09567	0.19427	0.25083	1.03681	0.11426	0.27094
	12	0.36435	0.13969	0.40761	1.3681	0.26076	0.48276
M5b	**13**	0.09359	0.13149	0.11821	0.24138	0.08694	0.20101
	14	0.07676	0.09524	0.08707	0.30603	0.13382	0.16688
	15	0.07992	0.02119	0.06649	0.27586	0.11726	0.21113
M6a	**16**	0.08576	0.06011	0.12208	0.28652	0.13256	0.296
	17	0.13372	0.09796	0.06213	0.2809	0.0939	0.26667
	18	0.09302	0.18966	0.11915	0.45506	0.13782	0.26133
M6b	**19**	0.26739	0.11718	0.23429	1.03333	0.17818	0.58979
	20	0.29332	0.13394	0.22531	0.875	0.17845	0.61626
	21	0.26057	0.14766	0.21095	0.975	0.1673	0.62382

Table 8. Translocation factors of heavy metals in mangrove trees of Ras Mohammed protectorate area.

Location	**Cu**	**Fe**	**Pb**	**Cd**	**Zn**	**Mn**
	TF					
M2	0.942505	1.831191	1.299766	1.012422	0.833006	0.692751
M3	1.431373	4.688578	4.356725	2.109375	2.477364	8.753165
M4	0.39654	0.23516	0.23516	0.449154	0.39102	0.165789
M5a	0.818436	2.225088	1.202632	1.202091	0.939847	2.990868
M5b	0.61235	1.564595	1.195074	0.844444	0.832826	3.184152
M6a	0.861027	2.011603	2.031579	1.926702	1.469787	1.545802
M6b	1.141176	2.748984	2.564935	1.195238	1.06379	3.861352

From the results of Table 8 we found that, the levels of measured heavy metals in mangrove tissues were considered to be relatively high when compared with respective global concentrations. This may be due to the presence of those metals in higher concentrations in the surrounding sediments.

Table 8 proved that the highest metal absorbed via aerial roots and founded in mangrove leaves after its translocation founded in M3 was Mn element with TF about 8.753165 followed after that Fe element with a TF of about 4.688578 then Pb with a TF of about 4.356725 and Zn with 2.477364 and finally Cd with TF 2.109375 concentrations. Mn toxicity is a relatively common problem compared to other micronutrient toxicity. It has two roles in the plant metabolic processes: as an essential micronutrient and as a toxic element when it is in excess. Normal manganese contents of leaves vary greatly between species 20 - 50µg/g.

The natural sources of Mn in mangrove environments within location 3 could be from weathering of rocks and soils, decaying vegetation. These records showed the highest bioavailability of the six elements found in leaves of the trees translocated from the sediment of those trees. Despite all of that, our study suggests that the mangrove ecosystems unpolluted by metals in the area of study.

CONCLUSION

Mangrove areas are subjected to extensive environmental stress as a result of human activities such as urbanization and industrialization, which have an impact on the ecosystem. This study provides information about the absorption and accumulation of essential and non-essential metals by the mangrove plant from the surrounding environment at different locations along the Ras Mohammed protectorate costal water. The Enrichment Factor (EF) and metal pollution index (MPI) of essential and non-essential metals in the seawater of Ras Mohammed protectorate were slight. Additionally, due to increased bioaccumulation and translocation factors evidenced, *Avicennia marina* tissues, particularly the leaves, roots, and stem, may be used as a biological indicator of mangrove environmental exposure of essential and non-essential metals such as Fe, Zn, Pb, Cu, Mn, and Cd.

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