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Geo-environmental study on mangrove swamps in some localities along the Red Sea coast of Egypt.

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ABSTRACT
Twenty one samples from the roots and leaves of *Avicenia marina* and the associated sediments were collected from two mangrove swamps along the Egyptian Red Sea coast for studying the heavy metals (Fe, Zn, Cu, Ni, Pb and Cd) accumulation and distribution. The results showed that the sediment samples have high concentration of heavy metals especially, the essential metals like Fe, than those recorded in roots and leaves of mangrove plants. Multi-statistical analyses Pearson's correlation coefficients, CF, Igeo, BCF and TF analyses are widely used to distinguish the correlations among metals and the sources of these elements. Strongly positive correlations were observed in mangrove sediments between Zn and each of Cu, Ni as well as between Cu, Ni, Cd and Fe, in both studied sites indicating a good proxy for terrigenous material. The recorded levels of Fe, Zn, Cu and Ni in mangrove sediments were higher than the Red Sea, Gulf of Aqaba and Tanaznia sediments, while Pb and Cd were lower than those recorded from background continental crust and sediment quality guidelines (ERL).

The EF values for heavy metals indicated weak enrichment and reflect the local mineralogy rather than contamination. In addition, the values of CF indicated that the mangrove sediments of studied samples are low contaminated with Fe, Zn, Cu, Ni and Pb, while Cd value indicateds moderately contamination. Therefore, the average values of I_{geo}in the two studied locations indicated unpolluted to moderately polluted sediments. The metal concentrations in these sites were either derived from similar sources of nearby Red Sea mountains or experienced analogous biogeochemical or accumulation processes. The obtained different correlations of heavy metals in the organs of mangrove plants may be attributed to the differences in the bioavailability of trace metals for the plants, the physicochemical properties of sediments or waters. BCFs and TFs values were basically less than one, except for TF of Ni and Pb as well as TF of Fe in two organs of mangrove at both studied sites, indicating that this mangrove species tend to restrict metal sediments-roots and roots-leaves transformations, guaranteeing the conduction of various important metabolic activities including photosynthesis in the above ground parts and confirmed that the *Avicennia marina* has the tendency to accumulate and translocate the heavy metals.

INTRODUCTION

Natural mangrove swamps of species *Avicennia marina*, covered many areas along the Egyptian Red Sea coast and play an important role in environmental balance in the coastal and marinehabitats. Heavy metals enter the environment naturally as a result of chemical and physical weathering of rocks, leaching of soils, vegetation, and volcanic activity (Al-Saad *et al.*, 1997), and may originate from both natural and anthropogenic processes, especially in the last decades (Markert and Friese, 1999; El-Sorogy *et al.*, 2012 and Alharbi *et al.*, 2017).

These pollutants are characterized by high toxicity, persistenceand bioaccumulative behaviors, and havenegative effects on mangrove swamps (Cosma *et al.*, 1979).

Numerous studies reported the occurrence and distribution of heavy metals in the sediments and plants at tidal flat zone (Marcovecchio,2000 and Ferrer *et al.*, 2006). Therefore, the tidal flat plays an important role in the biogeochemical cycling of pollutants through their active and positive circulation mechanisms (Weis and Weis, 2002). Marine plants (vegetation) can absorb the nutrients and metals from the sediments when their concentrations are relatively high (Weis *et al.*, 2003; Windham *et al.*, 2003; Almeida *et al.*, 2004; Reboreda and Cacador, 2007a; and Cacador *et al.*, 2009). The bioaccumulation process is dependingon the mobility and bioavailability of metals as well as thephysicochemical characteristics of the sediments such aspH, salinity, redox potential, organic matter content, grain size (Alloway *et al.*, 1990).

The main objectives of this study are to: (1) assess the current status and spatial distribution of heavy metals (Zn, Cu, Pb, Ni, Cd, and Fe) in the roots and leaves ofthe mangrove (*Avicenniamarina*) and the associated sediments from the tidal flat zone in the two mangrove swamps:17Km south Safaga and Quah sites along the Egyptian Red Sea coast; (2) comprehend the relationship between heavy metal concentrations in the plants and sediments and explore the role of *Avicenniamarina*on the biological concentration and translocation of heavy metals in the ecosystem of tidal flat; (3) compare our sediments with other worldwide ones.

The Study Area

Site 1: 17Km south Safaga

It is situated 17 km south ofSafaga cityon thewestern side of the Red Sea coastat the intersection oflatitude 26°36′53″–26°37′07″N and longitudes 34°00′46″–34°00′27″E, (Fig. 1). Generally, Safaga area is occupied by relatively low hill ofsedimentary rocks surrounded by mountains of igneous andmetamorphic rocks.

Fig. 1: Location map of the studied and sampling sites.

The south Safagamangrove swamp is very shallow, occupiesabout 5Km^2; its boundaries arefringing reef from the north, and beach from the west.The field survey revealed that the bottom is composed of dead coralline limestone covered with thin layer of sand, mud and biogenic sand. The tidal flat is very large and extents smoothly to seaward, while shoreline narrow occupied by coarse sands. The supratidal zone represents vegetated coastal dunes.This swamp belongs to the Ministry of Agriculture and Land Reclamation and represents a greenhouse for the cultivation of mangroves.

Site 2: El Quah

El Quah site lies at 44 km to south Safaga city along the main Safaga – Quseirroad between Lat. 26°23′46″–26°24′08″N and longitudes 34°07′25″–34°06′48″E, (Fig. 1). The coastal zone is crowded with many coastal sand dunes inhabited with two species of higher plants (Tamarax and Zigophylum). The beach is sandy in the northern part while the middle and southern part is rocky from grit stone. The tidal flat zone is shallow, wide extends to about 2Km and composed of biogenic sand inhabited with seagrass and algae. This zone followed by the coral edge which has high biodiversity of corals, shells and sponges. El Quah mangrove swamp is healthy and the density increases at the entrance of swamp and at the northern side.

MATERIALS AND METHODS

Field work

Twenty one sediment samples were collected from tidal flat zone of natural mangrove swamps at 17Km south Safaga city and El Quah area by pushing plastic box with a 10 cm deep in sediment, as well as 21 samples from both roots and leaves of species (*Avicennia marina*) of mangrove plant during November2017. Acomposite sample was taken from each station and placed immediately in polyethylene bags then transferred to the laboratory. Physicaland chemical parameters of seawater such as Dissolved Oxygen, Temperature, Total Dissolved Solids, Ion Hydrogen and Salinity were measured in situ using Hanna Instrument (Hi 9828) during the field works. Global Position System GPS (Magellan 1000) recorded the geographic positions.

Laboratory methods

In the laboratory, sediment samples were dried in temperature room for one week. Subsamples were sieved on 2 mm stainless sieves to remove pebbles or large particles, mangrove leaves and roots, and shell fragments. Grain size analysis with different particles was doneaccording to Folk(1974).

Portion of each sediment sample was dried in an oven at 50 ± 5 °C overnight to a constant weight and ground using electric agate mortar for 20 minutes, then passed through a 80-mesh size sieve. Half gram of each grinded sample was digested using 10 ml of mixed reagents (HF: $HCLO_4$: HNO_3 acids) with ratio 1:1:1 respectively, (Oregioni and Aston, 1984), then diluted to50 ml with deionized water.

Roots and leaves sample were completely dried in room temperature for one weeks, then dried in hot plate at 70C° for 24 hours. Half gram of each sample was digested using 10ml of HNO_3 by Hot plate till there was no brown fume, the ndilute it to 50 mL with deionized water (APHA, 2005).The analytical determination of Fe, Zn, Cu, Ni, Pb, and Cd in the dissolved phase was carried out by GBC atomic absorption reader (Model Savant AA AAS with GF 5000 Graphite Furnace) at NIOF.

Statistical analysis

Statistical analyses on the data were performed by a SPSS Windows release 18.0. Pearson’s correlation coefficients were used to verify the relationships among variables. Also, the enrichment factor (EF), geoaccumulationindex (Igeo), and contamination factor (CF) were calculated for the studied mangrove sediments (Muller, 1979a; Hökanson, 1980; Sinex and Helz, 1981; Leopold *et al.*, 2008).

For the roots and leaves of mangrove plants; the bioconcentration factor (BCF) is defined as BCF= ¼ C_{plant} /C soil, where C_{plant} and C soil were the metal concentration in plant and soil respectively, in mg/g (Mountouris *et al.*, 2002). Also,the translocations factors(TF = metal concentration in the leaves/metal concentration in roots) were also determined for each mangrove samples,according to (Hanna, 1992 and Wedepohl, 1995).

RESULTS AND DISCUSSION

Physical and chemical parameters of seawater

The average surface water temperature at 17 km south Safaga and El Quah is 28.57 ^{o}C and 28.13^{o}C respectively. The average salinity values of both sites are 40.04 and 39.95 ‰ respectively. The pH levels of the seawaters were neutral to mildly alkaline water, where the average concentration is 7.82at 17 km south Safaga and 8.15 mg/L at El Quah site. So, the average value of Do in seawater is 6.34 mg/L at 17 km south Safaga and 6.59 mg/L at El Quah site, because the most marine plants and animals have plenty of oxygen (Table 1).

The TDS of surface water showed similar spatial average concentrations are 42.05 and 42.16 g/L at the17km south Safaga and El Quah sites respectively (Table 1). The global average TDS is 34.5 g/L (Gaid and Treal, 2007). Higher TDS levels observed in the two studied locations is probably due to the dissolution and leaching of the coral debris. As the investigated areas are located in a desert belt, the atmospheric dust input from the surrounding arid region is considered as an important source of salts and trace metals to seawater.These physical properties could change the microenvironment and therefore affect the bioavailability of metals in the tidal flats (Windham and Lathrop 1999; Windham *et al.* 2003).

Table 1: Average values of physical and chemical parameters of seawater in the two studied sites.

Location	Temp. ^{o}C	Sal. ‰	pH	Do mg/L	TDS g/L
17 south Safaga	28.57	40.04	7.82	6.34	42.05
Quah	28.13	39.95	8.15	6.59	42.16

Characteristics of the sediments

The studied sediments are primarily composed of gravel, sandand silt with the average percentage being 16.30, 79.73, and 3.97% respectively at El Quah site, while at 17Km south Safaga city the average value of gravel, sand and silt are 6.88, 85.97, and 7.15% respectively. The highest proportion of sand is found in 17 Km south Safaga site (98.09%) along the beach, while the highest proportion of gravel is found in El Quah site (40.0%) on the beach. Meanwhile, the highest silt fraction value is 18.8% at 17 km south Safaga site and 17.08 % in El Quah site (Table2).

Concentration of Heavy Metals

Mangrove swamps play an important role in the biogeochemistry of trace metal contaminations in tropical coastal areas, either as sinks or as sources for these contaminants (Lacerda *et al.*, 1993). The Adsorption/mobilization of heavy metals in mangrove ecosystems is highly dependent on their physical, chemical and biological conditions like other wetland soils, (Lacerda *et al.*, 1992). Heavy metals are commonly retained within mangrove sediments (Badarudeen *et al.,* 1996). The concentrations of the heavy metals in sediments of mangrove illustrated in (Table 2).

Table 2: Coordinates, grain size characteristics and heavy metals concentrations (µg/g) in mangrove sediments from the two studied sites.

S. N.	Site	Lat.	Long.	Gravel	Sand	Silt	Fe	Zn	Cu	Ni	Pb	Cd
SF_1S_1	**17 km south Safaga**	26° 36 ' 54.00"	34° 00' 43.2"	0.57	98.09	1.35	10731	87.49	56.56	27.33	4.92	0.25
SF_1S_2		26° 36' 05.76"	34°00' 46.8"	1.00	97.44	1.56	7561	75.98	51.52	28.54	4.22	0.36
SF_1S_3		26° 37 01.20"	34° 00' 50.4"	5.71	93.26	1.04	6181	71.32	49.13	26.32	5.21	0.70
SF_2S_1		26° 36' 05.76"	34° 00' 36.0"	7.00	80.3	12.71	10352	53.89	33.82	19.74	7.15	0.17
SF_2S_2		26° 37' 01.20"	34° 00' 39.6"	2.17	94.14	3.69	8523	49.88	29.45	14.68	5.93	0.11
SF_2S_3		26° 37' 08.04"	34° 00' 43.2"	34.6	58.44	6.96	8652	39.48	19.74	22.17	6.14	0.13
SF_3S_1		26° 37' 04.08"	34° 00' 28.8"	0.22	80.98	18.79	10935	44.11	26.34	16.27	7.18	0.25
SF_3S_2		26° 37' 08.04"	34° 00' 32.4"	3.69	83.49	12.82	865	33.17	18.35	11.25	5.92	0.11
SF_3S_3		26° 37' 12.00"	34° 00' 36.0"	7.03	87.56	5.41	996	22.36	16.27	0.76	8.58	0.00
Min.				0.22	58.44	1.04	865	22.36	16.27	0.76	4.22	0.0
Max.				34.60	98.09	18.8	10935	87.49	56.56	28.54	8.58	0.7
Aver.				**6.88**	**85.97**	**7.15**	**7199.56**	**53.08**	**33.47**	**18.56**	**6.14**	**0.23**
S. N.	**Site**	**Lat.**	**Long.**	**Gravel**	**Sand**	**Silt**	**Fe**	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**
Q1S1	**El Quah**	26° 23' 45.6"	34° 07' 21.0"	34.57	65.19	0.24	5453	80.68	56.05	69.44	4.17	1.95
Q1S2		26° 32' 52.8"	34°07' 15.6"	11.55	81.25	7.19	4521	62.14	33.56	26.55	3.85	0.58
Q1S3		26° 23' 56.4"	34° 07' 19.2"	23.39	65.51	11.09	9056	52.32	19.61	19.39	4.93	0.70
Q2S1		26° 23' 49.2"	34° 07' 4.80"	1.0	96.31	2.69	6582	66.93	44.12	28.47	6.44	0.63
Q2S2		26° 23' 56.4"	34° 07' 8.4"	32.69	67.15	0.15	4879	52.37	39.85	33.75	5.31	0.35
Q2S3		26° 24' 03.6"	34° 07' 12.0"	40.0	59.57	0.43	5534	62.63	33.57	26.46	6.79	0.42
Q3S1		26° 23' 56.4"	34° 06' 57.6"	6.27	93.15	0.58	6826	82.67	31.80	48.75	6.75	0.25
Q3S2		26° 24' 03.6"	34° 07' 1.2"	7.3	91.11	1.69	6592	75.37	33.70	19.87	5.25	0.21
Q3S3		26° 24' 10.8"	34° 07' 4.8"	18.95	63.96	17.09	7606	78.63	38.88	11.12	5.18	0.20
Q4S1		26° 24' 03.6"	34° 06' 50.4"	10.11	87.47	2.42	6084	80.62	38.07	30.41	6.51	0.45
Q4S2		26° 24' 07.2"	34° 06' 50.4"	1.40	98.32	0.28	6582	65.81	33.68	27.85	4.69	0.52
Q4S3		26° 24' 14.4"	34° 06' 54.0"	8.39	87.82	3.79	6065	66.80	28.32	29.55	5.62	0.65
Min.				1.0	59.57	0.15	4521	52.32	19.61	11.12	3.85	0.20
Max.				40.0	98.32	17.09	9056.0	82.67	56.05	69.44	6.79	1.95
Aver.				**16.30**	**79.73**	**3.97**	**6315**	**68.91**	**35.93**	**30.97**	**5.46**	**0.58**

Heavy metals in sediments of mangrove

Iron exhibitsa similar distribution pattern in all beach samples of the two studied sites. In south Safaga site; Fe is the most abundant heavy metal (average 7199.56µg/g), followed by Zn (53.08 µg/g), Cu (33.47 µg/g), Ni (18.56 µg/g), Pb (6.14 µg/g), Cd (0.23 µg/g), while in El Quah site; Fe is the most dominant heavy metal (average 6315.0µg/g), followed by Zn (68.91 µg/g), Cu (35.93 µg/g), Ni (30.97 µg/g), Pb (5.46 µg/g), Cd (0.58 µg/g), (Table 2). The highest concentration of Zn (87.49 µg/g) is recorded in sample SF_1S_1, and the lowest one of Zn (22.36 µg/g) is recorded in sample SF_3S_3 at south Safaga site, while in El Quah site the highestcontent of Zn (82.67 µg/g) in sample $Q_3S_1$and lowest on (52.32 µg/g) with sample Q_1S_3 (Fig. 2-1 & Table 2).

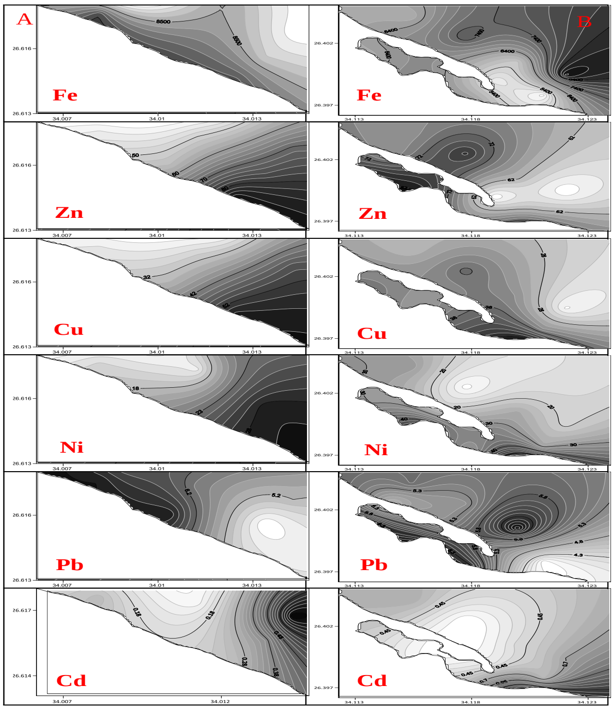

Fig. (2-1). Spatial distribution of heavy metals in studied mangrove sediments at: A) 17Km south Safaga site and B) El Quah site.

The average concentrations of Cu (33.47 µg/g) in south Safaga and El Quah (35.93µg/g) are lower than the Arabian Gulf (Alharbi and El-Sorogy, 2017), Gokcekaya, Turkey (Akin and Kırmızıgul,2017), background shale (Turekian and Wedepohl, 1961), background continental crust (Taylor, 1964), and its average value is higher than the one recorded from the Gulf of Aqaba (Shriadah, 1999 and Al-Taani *et al.*, 2014), the Red Sea coast (Nour *et al.*, 2006) and Salaam coast, Tanzania, (Rumisha *et al.*, 2012). The average value of Ni (18.56 and 30.97µg/g) in both two studied locations is higher than the Gulf of Aqaba (Al-Taani *et al.*, 2014), Sediment quality guidelines ERL (Long *et al.*, 1995), the Red Sea coast (*Nour et al., 2006*) and Salaam coast, Tanzania, (Rumisha *et al.*, 2012) as shown in Table (3).

Table 3: Ranges and average of heavy metals concentrations in surface sediments as reported from the studied area and other locations.

location	Reference	Fe	Zn	Cu	Ni	Pb	Cd
17 Km south Safaga	Present study	7199.56	53.08	33.47	18.56	6.14	0.23
El Quah site	Present study	6315.00	68.91	35.93	30.97	5.46	0.58
Arabian Gulf, Saudi Arabia	Alharbi and El-Sorogy (2017)	7552	52.68	182.97	75.01	5.358	0.23
Arabian Gulf, Emirates	*Shriadah (1999)*	--	11.3	7.21	36.4	28.1	4.82
Gokcekaya, Turkey	Akin and Kırmızıgul (2017)	15495	265.8	108.99	125.7	74.44	0.007
Gulf of Aqaba	Al-Taani *et al.* (2014)	1172-1437	7.0-7.7	7.6-10.8	--	3.7-6.8	0.06-0.07
Sediment quality guidelines (ERL)	Long *et al.* (1995)	--	--	34	21	47	1.2
Salaam coast, Tanzania	Rumisha *et al.* (2012)	461-5352	2.6-9.3	0.3-2.1	0.4-2.9	0.8-2.2	0.01-0.4
Red Sea, Egypt	Nour *et al.* (2006)	4942	7.66	0.38	3.16	2.56	0.09
Background shale	Turekian and Wedepohl (1961)	47200	95	45	68	20	0.3
Background continental crust	Taylor (1964)	56300	70	55	75	12.5	0.2

-- Not detect

Enrichment factor index (EF) was generally applied to predict the source of heavy metals (naturally or anthropogenic). Therefore, the total levels of heavy metals in all studied sediments were generally low and come from natural sources.As shown in Table (4), the EF average values of Fe, Zn, Cu, Ni, Pb and Cd were <1, indicating weak enrichment. Also, the average contamination factor (CF) values for Fe, Zn, Cu, Ni and Pb were less than 1.0 indicating that the bottom sediments of two studied sites are low contaminated, while The highest contamination (i.e., CF value) for Cd was found in both studied locations with average (1.16 in south Safaga) and (2.88El Quah)showing moderate contamination (Table 4).The bioaccumulation process is depended on the mobility and bioavailability of metals as well as the physicochemical characteristics of the sediments such as pH, salinity, redox potential, organic matter content, grain size (Alloway *et al.* 1990). According to the Muller's scale (1981), the average values of Igeoin two studied locations indicatedunpolluted to moderately polluted contaminated sediments with Fe, Cu, Zn, Ni, and Pb, while the average of Cd was (-0.197 and -0.267) exhibited that these sediments not contaminated (Table 4).

Table 4: Pollution indicators as anaverage (Enrichment factor (EF), contamination factor (CF)and geo-accumulation index (I_{geo}) used in the present study.

Factor	Location	Fe	Zn	Cu	Ni	Pb	Cd
EF	South Safaga	---	0.010	0.008	0.003	0.010	0.009
	El Quah	---	0.009	0.006	0.004	0.004	0.028
CF	South Safaga	0.119	0.76	0.61	0.25	0.49	1.16
	El Quah	0.112	0.98	0.65	0.41	0.44	2.88
I_{geo}	South Safaga	0.057	0.714	0.099	0.111	0.178	-0.197
	El Quah	0.056	0.086	0.097	0.096	0.183	-0.267

The correlation matrix (Table 5) exhibit that a strong significant positive correlation (r=0.88 and 0.82) was obtained between metal pairs Zn, Cu and Ni an as well as between Zn and Cu(r= 98) indicating a similarity in their geochemical source, and strong significant negative correlation between Pb and rest heavy metals in samples from south Safaga. While in El Quah sediment samples; there is negative correlation between Cu, Ni, Cd and Fe. The levels of Pb also negative correlated between Pb-Cu (r=-0.12), Pb-Ni (r= -0.08) and Pb-Cd (r= -0.45). There are goodcorrelations noticed between Ni and Cd (r= 0.74). This result revealed that these metals have the same source of contaminations.However, main possibility is that the roots of *Avicennia marina* will be submerged by water during high tides, while the leaves may additionally absorb metals from the water.

Table 5: The correlation coefficient among heavy metals in mangrove sediments of the studied sites.

	17 Km south Safaga							El Quah site					
	Fe	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**		**Fe**	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**
Fe	1						**Fe**	1					
Zn	0.56	1					**Zn**	0.021	1				
Cu	0.47	0.98**	1				**Cu**	-0.48	0.45	1			
Ni	0.64	0.88**	0.82**	1			**Ni**	-0.38	0.36	0.60	1		
Pb	-0.27	-0.79	-0.75	-0.83**	1		**Pb**	0.13	0.21	-0.12	-0.08	1	
Cd	0.22	0.66	0.70	0.69	-0.58	1	**Cd**	-0.18	0.12	0.57	0.74**	-0.45	1

**. Correlation is significant at the 0.01 level (2-tailed).

Heavy metals in the roots and leaves of *Avicennia marina*

Heavy metal concentrations in roots and leaves of *Avicennia marina* from two studied sites are given in (Table 6 and Figs. 2-2& 2-3). The average contents of Fe, Zn, Cu, Ni, Pb and Cd were (546.56 µg/g), (40.36 µg/g), (29.74 µg/g), (0.24µg/g), (0.20 µg/g) and (0.027µg/g) respectively in the roots of south Safaga site, while in El

Quah site they were (444.33 µg/g), (40.8µg/g), (24.28µg/g), (0.20µg/g), (0.199 µg/g) and (0.003µg/g) respectively. Allsamples exhibit higher concentrations of Fe with respect to other heavy metals, whereas Fe concentrations were relatively homogenous in two organs of *Avicennia marina* with slightly enrichment in the roots samples from south Safaga than those in El Quahsamples.

Table 6: Heavy metals concentrations (µg/g) in roots and leaves of mangrove from two studied sites.

S. N.	**Fe**	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**	**Fe**	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**
	Heavy metals concentrations (µg/g) in roots						Heavy metals concentrations (µg/g)in leaves					
SF_1S_1	583	63.66	49.07	0.19	0.26	0.0	135	25.81	12.42	0.34	0.14	0.0
SF_1S_2	552	52.39	33.69	0.18	0.17	0.0	233	25.37	17.36	0.21	0.13	0.0
SF_1S_3	517	43.78	34.89	0.14	0.23	0.0	689	26.72	22.36	0.19	0.27	0.0
SF_2S_1	633	33.69	29.87	0.32	0.14	0.11	536	22.36	13.62	0.32	0.15	0.0
SF_2S_2	428	31.18	27.63	0.18	0.20	0.1	555	21.36	17.40	0.25	0.15	0.01
SF_2S_3	379	30.13	26.13	0.28	0.18	0.02	487	22.78	16.35	0.19	0.14	0.0
SF_3S_1	863	32.39	25.51	0.28	0.11	0.0	545	28.56	22.50	0.21	0.22	0.0
SF_3S_2	425	44.37	19.36	0.36	0.27	0.01	514	27.36	18.37	0.14	0.24	0.0
SF_3S_3	539	31.69	21.47	0.25	0.25	0.0	439	25.33	22.35	0.36	0.34	0.01
Min.	379	30.13	19.36	0.18	0.11	0.0	135	21.36	12.41	0.14	0.125	0.0
Max.	863	63.66	49.07	0.36	0.27	0.11	689	28.56	22.50	0.36	0.34	0.01
Aver.	**546.56**	**40.36**	**29.74**	**0.24**	**0.200**	**0.027**	**459.22**	**25.07**	**18.08**	**0.25**	**0.20**	**0.002**
Q_1S_1	462	18.26	20.81	0.14	0.19	0.0	604	28.91	19.03	0.10	0.17	0.0
Q_1S_2	587	27.70	19.35	0.13	0.26	0.0	578	24.37	25.37	0.11	0.16	0.02
Q_1S_3	723	45.57	22.32	0.22	0.38	0.0	479	23.35	15.15	0.52	0.24	0.0
Q_2S_1	269	33.10	28.14	0	0.10	0.0	634	33.47	22.58	0.51	0.33	0.0
Q_2S_2	285	36.21	27.37	0.36	0.29	0.0	279	29.31	21.37	0.41	0.41	0.01
Q_2S_3	297	33.45	22.54	0.21	0.22	0.01	385	31.47	20.46	0.36	0.36	0.0
Q_3S_1	536	52.36	31.36	0.14	0.14	0.01	496	28.34	14.40	0.28	0.15	0.0
Q_3S_2	478	38.25	33.48	0.23	0.10	0.0	587	33.26	15.58	0.64	0.33	0.0
Q_3S_3	626	37.54	30.08	0.32	0.13	0.0	760	47.21	29.11	0.69	0.20	0.0
Q_4S_1	325	55.37	19.69	0.21	0.11	0.01	436	26.34	22.47	0.41	0.12	0.0
Q_4S_2	219	40.07	20.66	0.31	0.11	0.0	490	28.42	26.58	0.32	0.11	0.0
Q_4S_3	525	71.86	15.54	0.16	0.36	0.0	433	30.21	16.27	0.12	0.51	0.0
Min.	219	18.26	15.54	0.0	0.10	0.0	279.00	23.35	14.40	0.10	0.11	0.00
Max.	626	71.86	33.48	0.36	0.36	0.01	760.00	47.21	29.11	0.69	0.51	0.02
Aver.	444.33	40.08	24.28	0.20	0.199	0.003	**513.42**	**30.39**	**20.70**	**0.37**	**0.26**	**0.003**

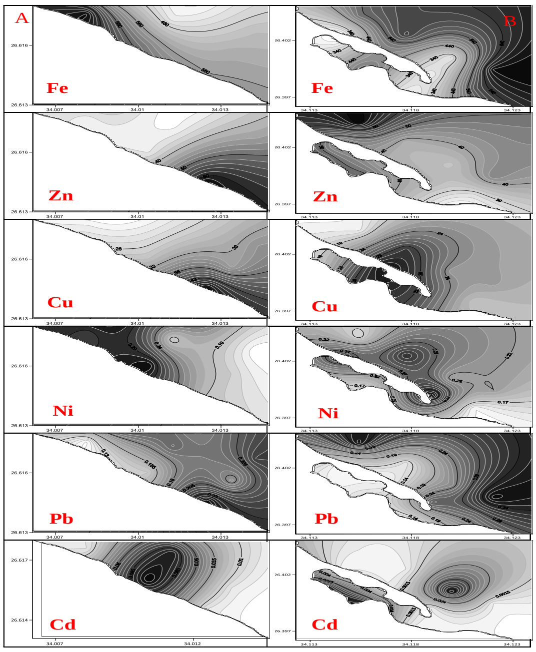

Fig. (2-2). Spatial distribution of heavy metals in roots of mangrove at: A) 17Km south Safaga site and B) El Quah site.

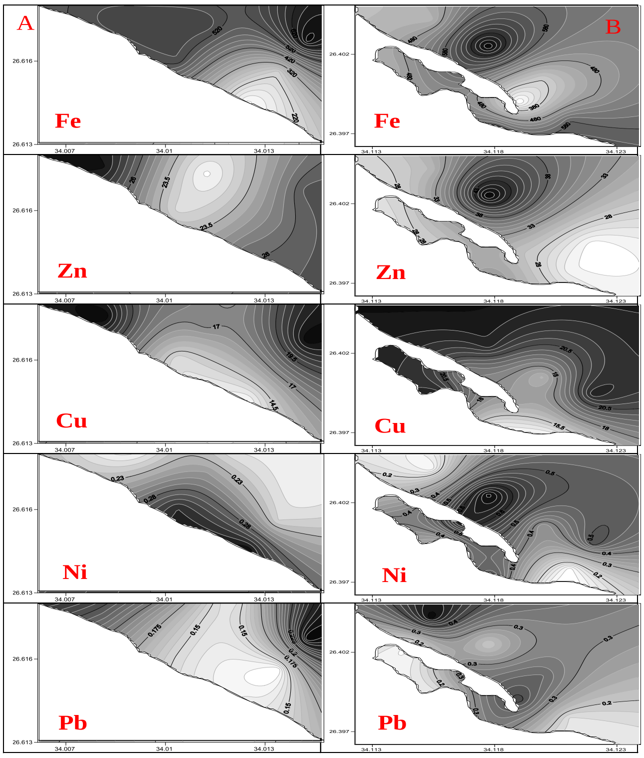

Fig. 2-3: Spatial distribution of heavy metals in leaves of mangrove at: A) 17Km south Safaga site and B) El Quah site.

Zn was mainly accumulated homogenously in the rootsin south Safaga and El Quah sites. Zn plays vital role in the nutrition and enzymatic activities of plants and it is the metal activator of enzymes, (Bonanno and Lo Giudice 2010). The Average contents of Zn in leaves were 25.07 and 30.39 µg/g in south Safaga and El Quah site respectively. Cu can be present in many oxidizing enzymes involving the redox processes of plants. Also, Cu concentrationsin the roots of mangrove is similar with an average values 29.74 and 24.28µg/g in south Safaga and El Quah site respectively, while in leaves; its average is 18.08 and 20.70µg/g in south Safaga and El Quah site respectively.

Ni was accumulated in both roots and leaves of mangrove with concentrations of less than 0.5µg/g in the two studied sites.Ni is a toxic element for plants.Pb is considered as more toxic than other metals (Kabata and Mukherjee, 2007). In addition, Pb accumulation in the leaves may be additionally affected by the exposure to the waste gas exhausted from automobiles (Schierup and Larsen, 1981; Djingova *et al.,* 2003; Bonanno and Lo Giudice, 2010). Pb was identical in the roots and leaves of samples in both sites with average less than (0.5 µg/g). So, Pb is an immobile element for its strong binding to organic matters and other components in plants (Aksoy *et al.*, 2005; Mazej and Germ, 2009).

The distribution of Cd was very similar in roots and leaves of mangrove in two investigated areas, Cd is a highly toxic and nonessential element, and it can hinder the growth and metabolism process of plants (Scholze *et al.*, 1988).Cd could also go into the root cells by competitive relationship with nutrients and then be transferred into the stems and leaves by leaf vacuoles (Almeida *et al.*, 2004; Reboreda and Cacador, 2007b; Vymazal *et al.*, 2007).

In the roots of south Safaga site; Fe was negatively correlated with Pb and Cd (r =-0.59 and -0.13) respectively, while Cd was negatively correlated with Zn (r =-

0.43), Cu (r =-0.12) and Pb (r=-0.33). Also, low negative correlation were found between Pb and Cd and Ni (r=-0.33 & =-0.14), (Table 7-1). The concentration of Fe in the studied roots of El Quah area was low negatively correlated to the concentration of Ni, and Cd (r < -0.22), also, Cu was negatively correlated with Zn and Pb (r=-0.22 & -0.5) respectively. The concentration of Cd was negatively correlated with Ni and Pb (r=-0.09 and -0.25) respectively, (Table 7-1).

Table 7-1: Pearson's correlation for heavy metals found in roots of mangrove plants of studied sites.

	17km south Safaga							El Quah					
	Fe	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**		**Fe**	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**
Fe	1						Fe	1					
Zn	0.01	1					Zn	0.15	1				
Cu	0.14	0.77	1				Cu	0.05	-0.22	1			
Ni	0.07	-0.37	-0.62	1			Ni	-0.05	0.05	0.11	1		
Pb	-0.59	0.44	0.12	-0.14	1		Pb	0.44	0.26	-0.5	0.09	1	
Cd	-0.13	-0.43	-0.12	0.16	-0.33	1	Cd	-0.22	0.27	0.03	-0.09	-0.25	1

The correlation matrix (Table 7.2) showed that a strong positive correlation (0.75 < r < 0.79) was obtained between metal pairs Cu, Ni and Pb in leaves of south Safaga samples. The levels of Ni negatively correlated with Cu (r=-0.31) and Zn (r=-0.30) and also, weak negative correlation between Fe and Zn & Ni (r=-0.04 & -0.40) respectively, while in El Quah site; astrong positive correlation (r=0.77) between Cu and Cd, as well as between Fe and Zn (r= 0.58), while negative correlation found between Fe and Pb (r=-0.37) & Cd (r-0.57), as well as between Cu and Pb (r=-0.36) and correlation very weak negative between Cd and Zn (r=-0.09).

Table 7-2: Pearson's correlation for heavy metals found in leaves of mangrove plants of studied sites.

	17km south Safaga							El Quah					
	Fe	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**		**Fe**	**Zn**	**Cu**	**Ni**	**Pb**	**Cd**
Fe	1						Fe	1					
Zn	-0.04	1					Zn	0.58	1				
Cu	0.55	0.53	1				Cu	0.35	0.43	1			
Ni	-0.40	-0.31	-0.30	1			Ni	0.29	0.57	0.14	1		
Pb	0.42	0.49	0.79	0.75	1		Pb	-0.37	0.15	-0.36	0.40	1	
Cd	0.13	-0.40	0.27	0.44	0.3	1	Cd	-0.57	-0.09	0.77	0.24	0.37	1

The correlation between metals in roots and leaves usually related to discharging of contaminants and their effect on partitioning of metals in aquatic system and may be influenced by differences in physical, chemical and biological processes in aquatic environment (Usman *et al.*, 2013). Generally, biological concentration factors (BCFs) and translocation factors (TFs) are widely used to estimate a plant's abilities in accumulating metals from sediments and transferring metals from roots to roots, respectively (Yoon, *et al.*, 2006). If plants exhibit BCFs or TFs more than one, they are suitable for phytoremediation (Fitz and Wenze, 2002).

In the present study, BCFs and TFs were basically less than one, except for TF of Ni and Pbin two organs of mangrove in both studied sites, as well as TF of Fe in El Quah samples, (Table 8). These results indicated that this mangrove species tend to restrict metal sediments-roots and roots-leaves transformations, guaranteeing the conduction of various important metabolic activities including photosynthesis in the aboveground parts. According to the BAF and TF values, it is evident that a tissue of *Avicenniamarina* has increased ability to accumulate and translocate the heavy metals (Gill *et al.* 2012). BCF for 5 metals were determined according to Wedepohl (1995), except Fe was detected according to (Hanna, 1992**).** The uptake and accumulation of heavy metals by plants follow two different paths: (1) by the root system and (2) by the foliar surface (Sawidis *et al.,* 2001).

Table 8: Average values of BCF and TF of roots and leaves of mangrove (*Avicennia marina*) in the studied locations.

Factor	Site	Fe	Zn	Cu	Ni	Pb	Cd
BCF	South Safaga	0.046	0.194	0.520	0.003	0.003	0.065
	El Quah	0.037	0.196	0.424	0.003	0.003	0.006
TF	South Safaga	0.90	0.66	0.70	1.11	1.03	0.00
	El Quah	1.28	0.83	0.90	1.45	1.48	0.00

CONCLUSION

The analyses of 6 heavy metals from 21 samples of roots and leaves of mangrove (*Avicennia marina*) and the associated sediments from the tidal flat zone in two mangrove swamps along the Egyptian Red Sea coast indicated the following order of averages: Fe >Zn > Cu>Ni >Pb>Cd.

Multi-statistical analyses Pearson's correlation coefficients, EF, CF, Igeo, BCF and TF analyses are widely used to distinguish the correlations among elements and the sources of these elements. Strongly positive correlations were observed in mangrove sediments in south Safaga site between Zn and each of Cu and Ni as well as between Ni and Cu, indicating a similarity in their geochemical source, whilein El Quah sediment samplesshow negative correlation between Cu, Ni, Cd and Fe, indicating a goodproxy for terrigenous material. The recorded levels of Fe, Zn, Cu and Ni in mangrove sediments were higher than the Red Sea, Gulf of Aqaba and Tanazniasediments, while Pb and Cd were lower than those recorded from background continental crust and sediment quality guidelines (ERL).

The EF values for Fe, Zn, Cu, Ni, Pb, andCd indicate weak enrichment and reflect the local mineralogy rather than contamination.The values of CF indicatethat the mangrove sediments of studied samples arelow contaminated with Fe, Zn, Cu, Ni and Pb, while Cd value indicates moderately contamination. The average values of I_{geo}in two studied locations indicatedunpolluted to moderately polluted contaminated sediments.The metal concentrations in thesesites were either derived from similar sources of nearby Red Sea Mountains or experienced analogous biogeochemical or accumulation processes.

In the roots and leaves *Avicennia marina*samples, however, only Fe was negatively correlated with Pb and Cd (r =-0.59 and -0.13) respectively, and also negatively correlated to the concentration of Ni, and Cd ($r < -0.22$) in roots of both studied sites. A strong positive correlation ($0.75 < r < 0.79$) was obtained between metal pairs Cu, Ni and Pb in leaves of south Safaga samples, as well as a strong positive correlation (r=0.77) between Cu and Cd, as well as between Fe and Zn (r=0.58) in El Quah leaves samples. The different correlations of heavy metals in the plants may be attributed to the differences in the bioavailability of trace metals for the plants, the physicochemical properties of sediments or waters.

In the present study, BCFs and TFs were basically less than one, except for TF of Ni and Pb in two organs of mangrove in both studied sites, as well as TF of Fe in El Quah samples, indicating that this mangrove species tend to restrict metal sediments-roots and roots-leaves transformations, guaranteeing the conduction of various important metabolic activities including photosynthesis in the above ground parts. The translocation and bioaccumulation factor of sediments, roots and leaves were lower than one, except for TF of Ni and Pb in two organs of mangrove in both studied sites, as well as TF of Fe in El Quah samples, thus confirmed that the *Avicennia marina* have the tendency to accumulate and translocate the heavy metals.

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