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Evaluation of some leachable heavy metals in the Seafloor sediments of the two navigation Harbours El Zaitiya and Adabiya, Gulf of Suez, Egypt

Ahmed R. Elgendy[1], Farouk Ahmed Soliman[2], Mahmoud Abdel-Radi Dar[1], Ahmed R. Hassan[1], Lamiaa I. Mohamedein[1] and Mohamed A. Hassaan[1*]

1- Environmental Division, National Institute of Oceanography and Fisheries, Egypt
2- Geology Department, Faculty of Science, Suez Canal University, Egypt.
[*] Corresponding author: Mhss95@mail.com ; ma.hassaan@niof.sci.eg

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ABSTRACT

The finest sediment group (FSG) including ($Ø_3$, $Ø_4$ and $<Ø_4$) and the bulk sediment samples were used to estimate the leachable forms of Fe, Mn, Zn, Cu, Ni, Pb, Co and Cd at Adabiya and El Zaitiya harbours in the Suez Bay at the northern tip of Suez Gulf using flame atomic absorption spectrophotometer (AAS). FSG was representing the essential constituents of the seafloor sediments with averages of 70.62% from the total sediments at El-Zaityia Harbour and 70.38% at Adabiya Harbour indicating the deposition under calm oceanographic conditions. Fe was the metal carrier for the different heavy metals, the average leachable forms of Fe and Zn in the FSG (50924.94; 377.61 µg/g) about two folds in the bulk sediment (27153.9; 180.47µg/g) at El Zaityia Harbour and about three folds in the FSG (43965.42; 456.94 µg/g) which more than the bulk sediments (17777.75; 134.62 µg/g) at Adabiya Harbour. In the same Matter, the averages of leachable forms of Mn, Cu, Ni and Pb in the FSG recorded about three folds (532.15; 195.38, 54.60, 145.94 µg/g) at El Zaitiya Harbour and (476.88; 109.42, 47.35, 67.11 µg/g) Adabiya Harbour than the recorded averages in the bulk sediment (182.43; 67.01, 19.01, 62.80 µg/g) at El Zaitiya Harbour (155.56, 35.14, 15.78, 20.27 µg/g) and Adabiya Harbour respectively.

INTRODUCTION

Maritime activities contribute to multiple changes in the seafloor sediments at the near shores and coastal areas. Concentrations of maritime transport and Harbour activities, combined with other socio-economic activities, resulted in hotspots of fine and particulate sediment accumulations. Harbours are important links between the hinterland and the coastal areas due to their vicinity to city and anthropogenic sources of fine and particulate sediments, (Paetzel, *et al.*, 2003; Schiff, *et al.*, 2004; Hassaan and Ali, 2017). Warnken, *et al.*, (2004) considered the heavy metals accumulation of sediments from harbours and marinas has been attributed to the application of antifouling paints on ship hulls. Toes *et al.*, (2008) documented that some of these harbours have to be dredged frequently for navigational purposes, meanwhile (Vanden Berg *et al.*, 2001) pointed out that the dredging operations can increase metals mobilization by whirling up fine sediment particles and allowing oxygen to come in contact with previously buried and reduced sediments (Caplat *et al.*, 2005).

They added, the extent of heavy metals release depends on local parameters such as sediment geochemistry, currents, grain size, pH, and salinity.

In the aquatic environment, the little quantities of some heavy metals, such as: Cu, Zn, Fe, Mn and Ni are essential for biological systems functions, but their excessive concentration can be toxic to living organisms (Sany *et al.*, 2013; Hassaan *et al.*, 2016 ; Hassaan *et al.*, 2017; El-Rayis *et al*., 2014). Other heavy metals such as Cd, mercury, arsenic and Pb are non-essential and therefore have toxic effects on living organisms. Many studies reported that the high concentration of heavy metals, especially Fe and Pb in the water and sediment in harbours is probably derived from transportation and navigation, land-based contaminants and industrial discharges (Everaart and Swennen 1987; Barka *et al.,* 2001; Sany *et al.,* 2013; Hassaan and El-Rayis 2018).

The Gulf of Suez is characterized by the existence of many harbours with a variety of activities including: Suez Bay harbours (Port Tawfiq, Tersana (cargo and passenger hunch), El Zaitiya (the reception of oil and gas tankers), Attaka (fishing), Adabiya (goods) and El Sukhna (goods) (GARSP, 2017). As in the maritime activities, most of heavy metal loads are transported by water either dissolved or particulate. Fine sediment discharges with the ballast water have great effects on the geological and geochemical characteristics of the sediments at these harbours. With increasing the maritime activities inside the Egyptian harbours due to growing up the different facilities and activities led to significant changes in nature of seafloor sediments with increasing the heavy metals load within these sediments. The impact of industrial wastes discharges into the sea depends on various factors, e.g., local meteorological conditions (the wind effect is important in controlling turbidity), hydrodynamic regime of water masses; and the amount and frequency of the discharges (Boughri *et al.,* 1994). The present work aims to evaluate the effects of maritime activities on the geological and geochemical characteristics of the seafloor sediments inside the navigation harbours of the two studied harbours through determination the concentrations of eight leachable heavy metals Fe, Mn, Zn, Cu, Ni, Pb, Co and Cd.

MATERIALS AND METHODS

El Zaitiya Harbour is located in the western part of the port of Suez near the southern entrance of the Suez Canal (29^o 57.2' N - 32^o 31.8' E), with maximum design capacity 4.14 million tons per year Casting liquid with floor area 11.6 million square meters. Adabiya Harbour is located on the southwestern shore of the Suez Bay (29^o 52' N - 32^o 29' E), with maximum design capacity 10.75 million tons per year, with Floor area 854,000 m^2 and a surface water area of about 158 km^2, which is a common area between port Tawfiq, Tersana, El Zaitiya and Attaka harbours.

Twenty samples were collected from Both El Zaitiya and Adabiya Harbours seafloor sediments (Fig. 1). After washing and dried the samples sieved using mechanical shaker every one Ø interval to estimate the main sediment constituents according to (Folk, 1974). The leachable forms of; Fe, Mn, Zn, Cu, Ni, Pb, Co and Cd were also measured using the flame AAS technique in both bulk and FSG samples according to (Chester *et al*., 1994 and Hassaan, 2010). Heavy metal concentrations (in ug/g) were measured by complete digestion. Before digestion to analyze heavy metals, each sample was dried at 65 ^{0}C for 48 h then, 0.5 gm of well grinded and dried samples (0.125, 0.063 and pan fractions) and ($Ø_3$, $Ø_4$ & <$Ø_4$) were immersed in 10 ml of $HNO_3/HCLO_4$ acid mixture (70 % purity), to investigate the effect of the maritime activities in the selected harbours, this approach were done according to (Chester *et al.,* 1994)**,** All treatments were performed in triplicate for each sample. The distribution patterns of heavy metal contents inside the Harbour were drawn by golden software surfer Ver. 13. The estimated correlation coefficient relationships were computed and figured using Excel 10, Graph Prism 6.0 and Wingraph 10.0.

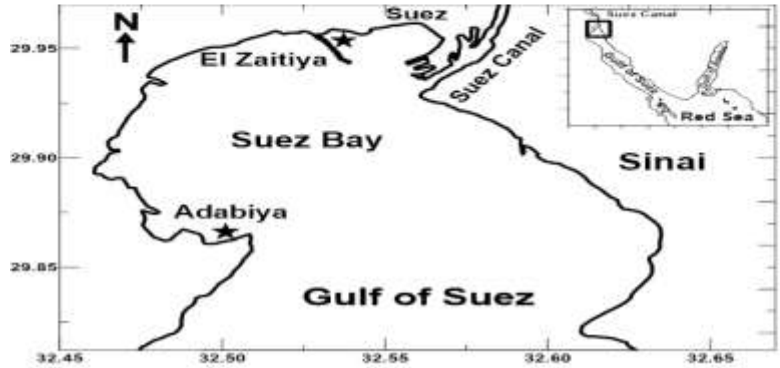

Fig. 1: A map of the two studied areas (El Zaitiya and Adabiya Harbours).

RESULTS

Adabiya Harbour:

The leachable Fe in the bulk sediments at Adabiya Harbour was fluctuated between 2607.62µg/g and 30005.62 µg/g with an average of 17777.75µg/g, in the meantime, the FSG, leachable Fe varied from 21986.95µg/g to 56413.97µg/g with an average of 43965.42µg/g. The leachable Mn in the bulk sediments was varied between 40.55µg/g to 266.01µg/g with an average of 155.56µg/g, while, in the FSG, Mn leachable was ranged between 240.46µg/g and 730.35µg/g with an average of476.88µg/g.

The leachable Zn in the bulk sediments was varied from 23.09 µg/g to 332.96 µg/g with an average of 134.62µg/g, however leachable Zn in the FSG, was fluctuated between 160.25µg/g and (965.15µg/g) with an average of456.94µg/g. the leachable Cu in the bulk sediments was ranged between 11.50µg/g and 98.46µg/g with an average of 35.15µg/g while in the FSG, leachable Cu showed the variation from 48.03µg/g to 221.43µg/g with an average of 109.42µg/g. leachable Ni in the bulk sediments was ranged from ND to 62.53µg/g with an average of 15.78µg/g, however in the FSG, leachable Ni was fluctuated between 21.26µg/g and 62.43µg/g with an average of47.35µg/g.

The leachable Pb in the bulk sediments was declined from 75.48µg/g to ND with an average of 20.27µg/g, meanwhile in the FSG, Pb was declined from 300.59µg/g to 29.95µg/g with an average of 67.12µg/g. In the bulk sediment the leachable Cd was insignificant, meanwhile in the FSG, Cd was ranged from 0.12µg/g to 3.50µg/g with an average of 1.01µg/g. Finally, the leachable Co in the bulk sediments was increased from 0.16 µg/g to 25.12µg/g with an average of 12.37µg/g, while in the FSG, was increased from1.02 µg/g to10.39 µg/g with an average of 5.65 µg/g, (Table 1).

El Zaitiya Harbour:

The Leachable Fe in the bulk sediments at El Zaitiya Harbor was ranged between 2009.41µg/g and 48.292.56µg/g with an average of 27153.91 µg/g, in the meantime, the FSG showed leachable Fe varied from 33363.28 µg/g to 78611.22µg/g with an average of 50924.94 µg/g. The leachable Mn in the bulk sediments was fluctuated between 18.59µg/g and 314.35 µg/g with an average of 182.43µg/g, however in the FSG, leachable Mn showed variation from 305.44 µg/g to 859.21 µg/g with an average of532.15µg/g.

The leachable Zn in the bulk sediments was fluctuated between 69.72 µg/g and 414.84 µg/g with an average of 180.47 µg/g, on the other hands, and in the FSG, the leachable Zn was ranged between 142.60 µg/g and 994.24 µg/g with an average of 377.61µg/g. The leachable Cu in the bulk sediments showed variation from 11.91 µg/g to 272.19 µg/g with an average of 67.02 µg/g, in the meantime, in the FSG, leachable Cu ranged from 66.36 µg/g to 467.12 µg/g with an average of 195.38 µg/g. The leachable Ni in the bulk sediment was changed between ND and 34.63 µg/g with an average of 19.01 µg/g, while in the FSG, leachable Ni was fluctuated between 29.33 µg/g and 77.45 µg/g with an average of 54.61 µg/g.

The leachable Pb in the bulk sediments was changed between 10.44 µg/g and 375.68 µg/g with an average of 62.81 µg/g and in the FSG, leachable Pb varied between 33.25 µg/g and 460.26 µg/g with an average of 145.95 µg/g. the leachable Cd in the bulk sediments was insignificant, meanwhile in the FSG, the leachable Cd was increased from ND to 2.11 µg/g with an average of 0.78 µg/g. finally, the leachable Co in the bulk sediment was declined from 14.59µg/g to ND, with an average of 6.91 µg/g, meanwhile in the FSG, the leachable Co was declined from 5.20 µg/g to11.68 µg/g with an average of 7.72 µg/g (Table 1).

Table 1: The average values of heavy metals in the bulk sediments and FSG at El Zaitiya and Adabiya harbours.

Bulk	**Fe**	**Mn**	**Zn**	**Cu**	**Ni**	**Pb**	**Co**	**Cd**
El Zaitiya	27153.91	182.43	180.47	67.02	19.01	62.81	6.91	0.02
Adabiya	17777.75	155.56	134.62	35.15	15.78	20.27	12.37	0.14
FSG	**Fe**	**Mn**	**Zn**	**Cu**	**Ni**	**Pb**	**Co**	**Cd**
El Zaitiya	50924.94	532.15	377.61	195.38	54.61	145.95	7.72	0.78
Adabiya	43965.42	476.88	456.94	109.42	47.35	67.12	5.65	1.01

DISCUSSION

The leachable Fe in the studied harbours showed significantly high concentrations in the FSG group than in the bulk sediment. In FSG group, The highly leachable Fe at El Zaitiya and Adabiya, was attributed to the anthropogenic effluents including Boats maintenance, corrosion of constructions and pipes beside the high organic matter that formed highly reducing conditions as well as the bad water mixing. The distribution pattern of leachable Fe contents at Adabiya harbours increased toward the offshore, (Fig. 2A). At El Zaitiya; the leachable Fe covers the whole harbours accompanied with the high FSG distribution (Fig. 3A). The heavy metals average in the bulk sediments and FSG at the studied harbours in comparison with the other studies in Egypt and worldwide were tabulated in (Table 2). At Adabiya and El Zaitiya harbours the leachable Mn recorded the averages of; 532.14 µg/g, 476.87µg/g, indicating the effect of the different anthropogenic sources same as Fe, in addition to the reducing conditions inside these harbours due to the high percentages of fine sediments and organic matter. Mn pattern at Adabiya harbour was increased beside the wharf due to the navigation activities (Fig. 2B), furthermore, El Zaitiya harbour showed hotspots inside and at the entrance of the harbour attributed to different anthropogenic sources (oil spills from boat engines and tankers) (Fig. 3B).

The leachable Zn showed considerably higher contents in the FSG group than in the bulk sediments at Adabiya and El Zaitiya. At Adabiya and El Zaitiya harbours, Zn increased below the navigation wharfs indicating to the essential source from the maritime activities such as antifouling paints and industrial wastes (Figs. 2C and 3C).

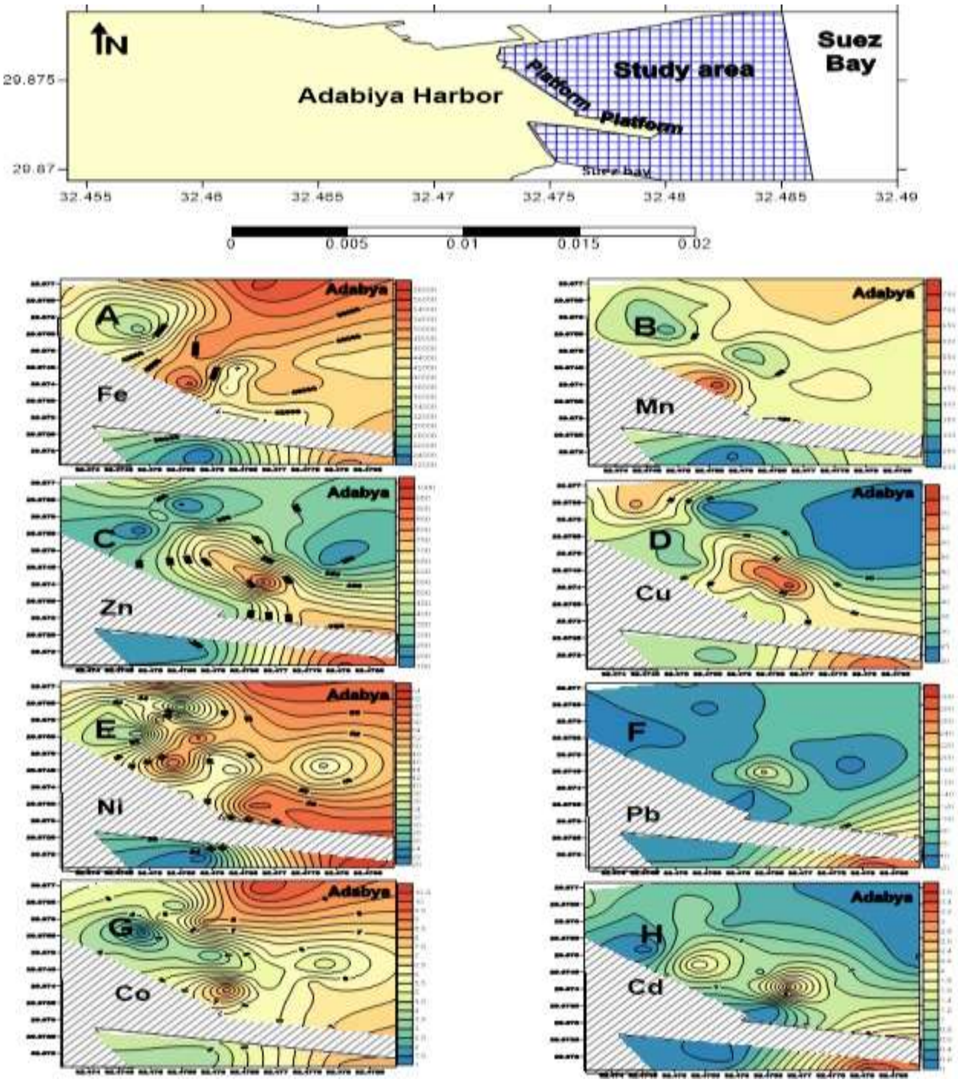

Fig. 2: The distribution pattern of heavy metal contents (FSG) in Adabiya Harbour.

The leachable Cu at the studied harbours showed significantly higher occurrences in the FSG group than in the bulk sediments. The distribution patterns of the leachable Cu showed an increasing beside the wharfs of the navigation harbours at Adabiya and El Zaitiya harbours attributed to industrial, storm water runoff, municipal and vessel discharges from antifouling coatings and in-water hull cleaning from private, commercial and military and sediment fluxes (Johnson and Gvovhoug, 1998) (Figs. 2D and 3D). The leachable Ni showed higher contents in the FSG group than in the bulk sediment at the studied harbours. At Adabiya harbour, the leachable Ni showed uniform high Ni content covering the harbour area (Fig. 2E).The patterns of distribution of the leachable Ni at El Zaitiya harbour showed the highest contents toward the wharfs indicating to shipyard, the removal from atmosphere and surface run-off, discharge of industrial and municipal waste. (Fig. 3E).

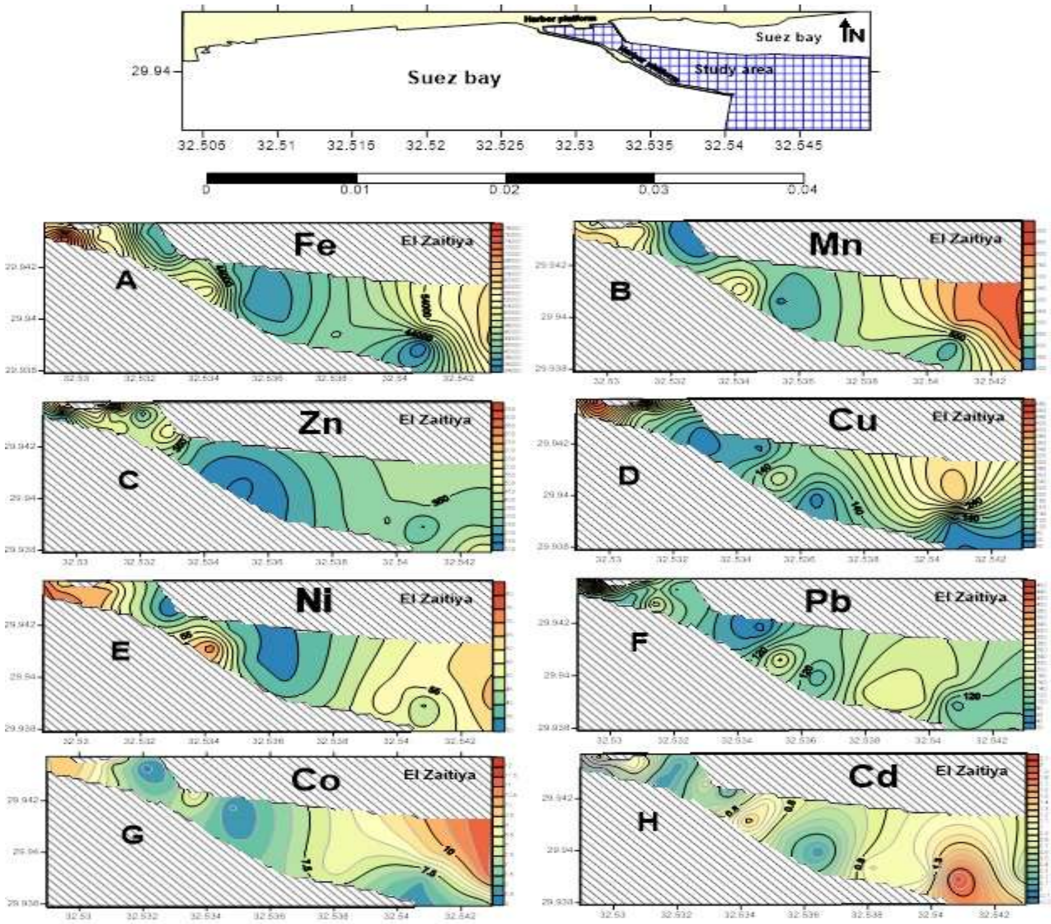

Fig. 3: The distribution pattern of heavy metal contents (FSG) in El Zaitiya Harbour

The leachable Pb showed significantly higher occurrences in the FSG group than in the bulk sediment at the studied harbours. The distribution pattern at Adabiya showed increasing toward the wharf, meanwhile El Zaitiya showed hot spot in the inner part of the harbour due to the maritime activities such as oil seepages from boats and tankers and industrial effluents (Figs. 2F and 3F). The leachable Co showed significantly higher occurrences in the FSG group than in the bulk sediment at El Zaitiya harbour, on the contrast Adabiya harbour, the leachable Co showed significantly higher amounts in the bulk sediments than in the FSG. This situations indicating to Co may coated the coarse particle sediments much more than fine and particulate sediments. At Adabiya harbour leachable Co pattern showed gradual towards the mooring zone (Fig. 2G).The leachable Co at El Zaitiya harbour increased patterns inside the harbours beside the wharfs due to the maritime activities such as oil fuels, oil refineries and marine paints (Fig. 3G). The leachable Cd showed significantly higher existences in the FSG group more than in the bulk sediment at the two studied Harbours. The leachable Cd at the studied harbours was lower than 1.00µg/g (Figs. 2H and 3H).

Table 2: The average values of heavy metals in the bulk sediments and FSG at the studied harbours in comparison with the other studies in Egypt and worldwide.

Location	**Heavy metals concentration (µg/g)**								**Sediment type**	**References**
	Fe	**Mn**	**Zn**	**Cu**	**Pb**	**Ni**	**Co**	**Cd**		
El-Zaitiya (Z)	27153.91	182.43	180.47	67.02	62.81	19.01	6.91	0.02	Bulk sediments	Present study
	50924.94	532.15	377.61	195.38	145.95	54.61	7.72	0.78	FSG	
Adabiya (D)	17777.75	155.56	134.62	35.15	20.27	15.78	12.37	0.14	Bulk sediments	
	43965.42	476.88	456.94	109.42	67.12	47.35	5.65	1.01	FSG	
The Red Sea Ports of Egypt	3803.67	142.62	60.56	40.87	33.94	20.67	3.13	1.15	(Ø3+Ø4+ Ø5)	El Metwally (2017)
Quseir Harbor	14000	902	21.35	4.12	10.47	26.52	5.73	1.01	Bulk sediments	Mansour *et al.*,(2011)
Safaga Harbor	12000	1145	15.39	9.07	21.56	38.37	6.84	1.33		
Hurghada Harbor	10000	112	9.05	4.09	19.54	8.86	3.96	0.34		
Hurghada Harbor	1445.60	188.80	179.50	413.80	110.00	6.40	–	2.10	Ø4 and Ø5	Madkour and Dar (2007)
Hamrawin Harbor	1796	592	73	18	39	42	2.3	2.3	Bulk sediments	Madkour *et al.*,(2012)
Hamrawin Harbor	–	1145.00	15.40	9.10	21.60	-	–	1.30	Bulk sediments	Madkour *et al.*. (2006)
Suez Bay	503.25	90.35	36.82	18.87	28.82	59.35	11.08	3.3	Bulk sediments	El-Moselhy and Abd El-Azim (2005)
Tourist harbor	1000	16.21	6.60	8.77	0.12	8.53	-	0.06	Bulk sediments	Mansour *et al.*,(2013)
Suez Bay	25200	-	43.89	29.28	40.53	33.54	7.51	2.41	Bulk sediments	El Moselhy *et al.*, (1999)
Suez Bay	-	-	3.64	5.55	22.06	-	-	3.28	Bulk sediments	El Moselhy and Gabal (2004)
Gulf of Suez and the northern part of the Red Sea	–	–	65.42	49.56	33.52	–	–	3.52	<20 mm fractions.	Hamed *et al.*, (2009)

El Samaka Village	1700	24.53	11.03	2.62	1.63	2.88	-	0.15	Bulk sediments	Mansour *et al.*,(2013)
Desert Rose Resort	4300	77.14	19.73	3.84	4.97	4.91	-	0.07		
El Esh	2600	49.59	12.63	3.73	1.17	2.07	-	0.12		
Abu Shaar	3200	65.08	9.55	4.47	0.06	20.83	-	0.15		
NIOF	2900	61.65	14.89	3.97	1.12	4.06	-	0.1		
Hurghada coast	–	53.97	114.46	75.83	49.04	–	–	3.82	Ø3(0.250mm)	Dar *et al.*, (2016a)
	–	44.60	111.94	38.98	51.07	–	–	4.04	Ø4(0.125mm)	
	–	52.49	120.53	39.76	55.53	–	–	4.02	Ø5(<0.063mm)	
Safaga coast	–	133.19	215.71	62.06	50.58	–	–	6.41	Ø3(0.250mm)	
	–	147.07	200.85	51.60	61.63	–	–	6.56	Ø4(0.125mm)	
	–	107.24	172.82	47.86	70.31	–	–	6.33	Ø5(<0.063mm)	
Hamrawin coast	–	110.98	79.77	54.54	48.34	–	–	10.07	Ø3(0.250mm)	
	–	72.36	140.35	46.06	41.56	–	–	9.03	Ø4(0.125mm)	
	–	130.08	130.39	57.16	56.87	–	–	9.37	Ø5(<0.063mm)	
El-Esh area	7000	153	14.46	76.74	11.28	9.78	3.59	0.50	Bulk sediments	Mansour *et al.*, (2011)
W.El Gemal	2916	536.6	79.1	36.2	41.7	51.4	1.8	0.08	Bulk sediments	Madkour (2005)
Abu Shar	563.65	-	9.35	1.30	4.32	-	-	0.65	Bulk sediments	Madkour *et al.*,(2015)
Abu Galawa	432.35	-	3.26	0.38	2.67	-	-	0.37		
Umm Al Huwaytat	1876.53	-	14.32	5.08	11.65	-	-	1.06		

Marsa Shuni	1485.89	-	11.98	1.38	7.97	-	-	0.56		
Mabahiss Bay, North Hurghada	–	77.00	15.76	13.14	43.56	33.67	50.54	3.11	Bulk sediments	Attia and Ghrefat (2013)
Safaga Gulf	1268.68	80.18	76.23	17.33	15.94	11.29	–	–	Bulk sediments	Dar, (2014)
	2170.62	223.72	120.48	49.19	15.57	14.46	–	–	Ø5	
Red Sea , Egypt	3490	127.09	22.64	1.94	3.26	11.40	9.70	0.10	Bulk sediments	Salem *et al.*, (2014)
Gulf of Suez	2511.98	382.86	85.28	7.71	47.77	14.84	–	3.26	Bulk sediments	Masoud *et al.* (2012)
Gulf of Aqaba	3150.24	485.40	58.23	8.86	31.23	13.03	–	2.43	Bulk sediments	
Red Sea proper	3072.68	377.63	75.04	17.92	44.38	28.93	–	4.30	Bulk sediments	
Gulf of Aqaba	544.80	229.70	35.10	5.80	–	13.90	11.20	2.86	Bulk sediments	Youssef and El-Said (2011)
Jeddah Isalmic Port Coast	–	–	32.2	22.50	41.40	–	–	35.50	Bulk sediments	Abdelrahim *et al.*, (2011)
Hamrawin Bay	1270.13	283.55	99.63	20.11	73.35	–	–	–	Bulk samples	Dar *et.al.*, (2016b)
	3467.43	1138.85	359.49	68.45	150.60	–	–	–	(Ø3+Ø4+ Ø5)	
Shalateen	996.71	50.18	24.28	35.62	18.44	–	–	–	Bulk samples	
	3096.5	173.32	79.20	154.37	45.16	–	–	–	(Ø3+Ø4+ Ø5)	
Sharm El bahary	1156.52	123.7	36.82	21.86	42.10	–	–	–	Bulk samples	
	3725.19	479.41	159.44	91.76	96.49	–	–	–	(Ø3+Ø4+ Ø5)	
Abu Dabab	1336.41	150.26	43.72	18.32	51.49	–	–	–	Bulk samples	

	3109.76	491.53	122.45	49.41	124.79	–	–	–	(Ø3+Ø4+ Ø5)	
Qula'an	944.61	82.27	36.20	17.39	22.91	–	–	–	Bulk samples	
	2950.69	321.5	135.13	47.47	54.63	–	–	–	(Ø3+Ø4+ Ø5)	
Aden port, Yemen	-	128.6	19.9	77.3	23.9	34.54	82.19	-	Bulk sediments	Nasr *et al.*, (2006)
Port Jackson, Sydney, Australia	-	-	651	188	346	-	-	-	Bulk sediments	Birch & Taylor (2002)
harbours in Gulf of Finland (Neva Bay), Baltic Sea	-	-	289.5	119.8	170.7	-	-	0.68	Bulk sediments	Ussenkov, (1997)
Port Klang, Selangor, Malaysia	8140	1838.9	492.4	118.4	128.98	74.6	25	0.81	Bulk sediments	Sany *et al.*, (2013)
Suva harbor, Fiji	3130	-	154.6	82.2	57.8	-	-	-	< $Ø_4$	Maata and singh (2008)
three harbours along Iranian Oman Sea coast	-	-	292.5	149.5	895.5	73.5	-	-	($Ø_1$,$Ø_2$,$Ø_3$,$Ø_4$&< $Ø_4$)	Hamzeh *et al.*, (2013)
	-	-	99	42.17	92.4	63.7	15.2	-	Bulk sediments	
Caspian Sea, Persian Gulf	-	-	60	19	13	42	15	-	Bulk sediments	Agah *et al.*,(2011)
Mahandi basin, India	88.93	59.36	90.18	-	-	-	-	-	Bulk sediments	Sundaray *et al.*,(2011)
Black Sea, Turkey	29500	538.3	150.6	99.5	15.57	39.37	0.95	-	Bulk sediments	Topcuoğlu *et al.*,(2002)

Correlation coefficients and the uncertainty

At Adabiya Harbour, Fe showed strong positive correlation with Mn (r = 0.80), Ni (r = 0.71) and fair positive Co (r = 0.60) indicating to that the Mn, Ni, and Co tend to accumulate with Fe as oxides. The fair positive correlation of Fe with TOM% (r = 0.55) indicating to most of Fe were accumulated in the particulate sediments from anthropogenic sources. Mn showed fair positive correlation with Ni (r = 0.59) and strong positive Co (Fig. 4) indicating to oxidation phases for these metals. The excellent positive correlation of Zn with Cu (Fig. 4), fair positive Ni (r = 0.53), very strong with Pb (r = 0.71) and Cd (Fig. 4) indicating to these metals accumulated from anthropogenic sources. Cu showed moderate positive correlation with Pb (r = 0.63) and Cd (r = 0.62) assured the navigation sources. The positive correlation of Ni with Co (r = 0.64) indicating to the maritime sources. The positive correlation of Pb with Cd (Fig. 4) indicating to the maritime effluents. Cd showed fair positive correlation with FSG% (r = 0.52) indicating to navigation activities.

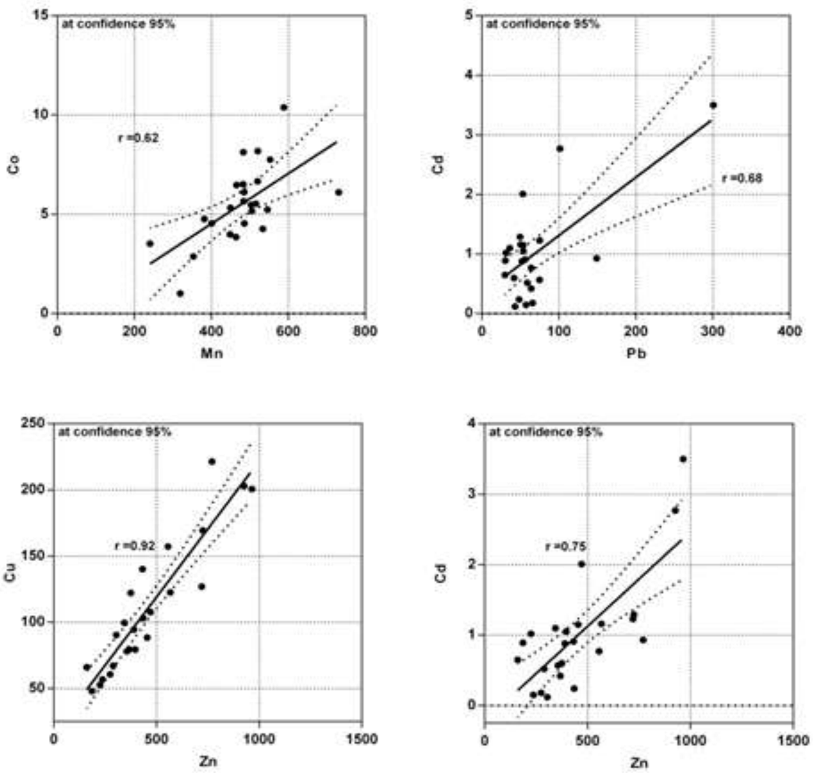

Fig. 4: The Uncertainty relationships of Mn, Ni, Pb and Zn with Co, TOM%, Cd and Cu (at 95% confidence) at Adabiya Harbor.

At El Zaitiya Harbour, Fe showed strong positive correlation with Mn (r = 0.79), fair positive Cu (r = 56), excellent positive with Ni (Fig. 5) and strong with Co (Fig. 5) indicating to that the Mn, Cu, Ni and Co tend to accumulate with Fe as oxides. Mn showed excellent positive correlation with Ni (Fig. 5) and moderate positive with Co (r = 0.69) indicating to oxidation phases for these metals. The fair positive correlation of Zn with Cu (r = 0.50) and Pb (r = 0.50) indicating to these metals accumulated from anthropogenic sources. Cu showed strong positive correlation with Pb (Fig. 5) and fair positive with Co (r = 0.54) assured the navigation sources. The fair positive correlation of Ni with Co (r = 0.56) indicating to the maritime sources.

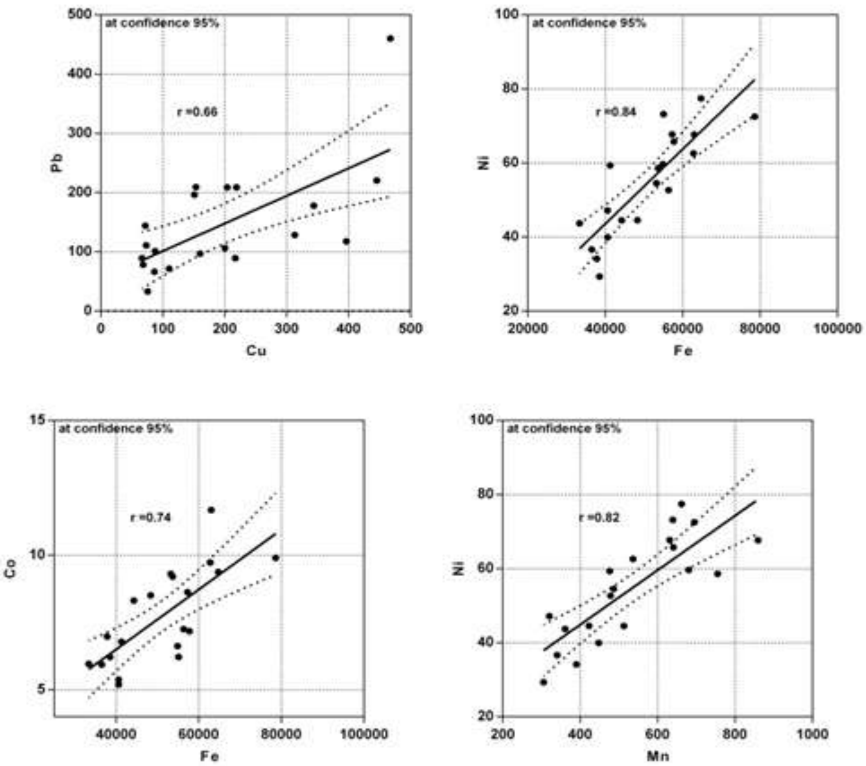

Fig. 5: The Uncertainty relationships of Fe and Mn with Ni, Pb, Co and TOM% (at 95% confidence) at El Zaitiya Harbor.

CONCLUSION

Adabiya and El Zaitiya Harbours were intensively used in maritime activities; transport of goods and landing of oil and gas. The heavy metal contaminations in the bottom sediments are derived from the repairing, maintaining and shipyard. These stressors are causing acrimonious ecological risk on the marine ecosystem components; sediment nature inside these harbours. The concentration of heavy metals in fine sediment group FSG ($\varnothing_3$, $\varnothing_4$ and $<\varnothing_4$) were higher than in the bulk sediments. The FSG are considerably effective in accumulation of the contaminants and transfer to the marine ecosystem. El Zaitiya Harbour recorded higher leachable averages of Fe, Mn, Zn, Cu, Ni and Pb than Adabiya Harbour mainly due to the calm conditions and the closing nature of El Zaitiya harbour. These conditions provide suitable conditions for the metals accumulation under the highly reducing conditions. The distribution patterns of different metals in both harbours showed the highest metal occurrences below the unloading wharfs of these harbours indicating to that these metals were accumulated mainly from the maritime activities and at the centers due to the eddy currents from the ships motion. Fe showed positive correlation with Mn, Cu, Ni and Co indicating to that these metals tend to accumulate with Fe as oxides. Fe and Mn have nearly showed the same distribution patterns. Most of the heavy metals increased beside or below the wharfs due to the effect of the maritime activities.

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ARABIC SUMMARY

تقييم بعض الفلزات الثقيلة في الرواسب القاعية بموانئ الزيتية والأدبية - خليج السويس – مصر

أحمد ربيع الجندي[١] ، فاروق أحمد سليمان[٢] ، محمود عبد الراضي دار[١] ، أحمد رمضان حسن[١]، لمياء إسماعيل محمدين[١] ، محمد على حسان[١]*

١- شعبة البيئة البحريه ، المعهد القومي لعلوم البحار والمصايد ، مصر
٢- قسم الجيولوجيا ، كلية العلوم ، جامعة قناة السويس ، مصر

تم تحليل عينات رواسب FSG وعينات رواسب Bulk لتقدير كل من Feو Mn و Zn و Cu و Ni و Pb وCo و Cd في موانئ الأدبية والزيتية فى الطرف الشمالى لخليج السويس باستخدام مقياس الطيف الامتصاصى الذري باللهب (AAS). كانت FSG تمثل المكونات الأساسية لرسوبيات قاع البحر بمتوسط ٧٠,٦٢% من اجمالى الرواسب في ميناء الزيتية وتمثل ٧٠,٣٨% من اجمالى الرواسب فى ميناء الادبيه مما يشير الى الترسيب تحت الظروف البيئيه الهادئه. كان الحديد الناقل الرئيسي للمعادن الثقيلة المختلفة ، وكان متوسط تركيز كل من Fe و Zn في FSG (٥٠٩٢٤.٩٤؛ ٣٧٧.٦١ ميكروغرام / غرام) حوالي مرتين ونصف ضعف تركيزه فى bulk (27153.9 ؛ ١٨٠.٤٧ ميكروغرام / غرام) في ميناء El Zaityia وحوالي ثلاثة أضعاف فيFSG (43965.42 ؛ ٤٥٦.٩٤ ميكروغرام / غرام) أكثر من bulk (17777.75 ؛ ١٣٤.٦٢ ميكروغرام / غرام) في ميناء الأدبية. وفى نفس الاتجاه ، سجلت مستويات تركيزات كل من Mn، Cu، Ni و Pb في FSG حوالي ثلاثة أضعاف (٥٣٢.١٥ ؛ ١٩٥.٣٨ ، ٥٤.٦٠ ، ١٤٥.٩٤ ميكروغرام / جم) في ميناء الزيتية و (٤٧٦.٨٨ ؛ ١٠٩.٤٢ ، ٤٧.٣٥ ، ٦٧.١١ ميكروغرام / غرام) في ميناء الأدبية واكثر من تركيزها فى عينات bulk (١٨٢.٤٣ ، ٦٧.٠١، ١٩.٠١، ٦٢.٨٠ ميكروغرام / غرام) في ميناء الزيتية (١٥٥.٥٦، ٣٥.١٤، ١٥.٧٨، ٢٠.٢٧ ميكروغرام / غرام) وميناء الأدبية على التوالي.