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Assessment of heavy metals pollution in marine surface sediments of Gaza Strip, southeast Mediterranean Sea

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ABSTRACT - The current study investigates the grain-size distribution of the sediments in two surveys along coastal line of the Gaza Strip, at the tide and shelf zones. The concentrations of Zn, Pb, Mn, Cu, Co, and Cd in the surface sediments of the study area were evaluated from thirty location sites selected in the two zones. The grain size-distribution of the sands in tide zone along the study area shows that the predominant grain-size was medium- to fine-grained, while the predominant grain-size in the shelf was fine- to very fine-grained. For the heavy metal concentrations, the results show that the mean concentration values in the shelf along the study area are higher than those in tide zone, except the Pb. The mean concentrations of heavy metals in the tide zone of Zn, Pb, Mn, Cu, Co, and Cd are 11.56, 15.86, 20.49, 1.72, 3.24, and 0.90 mg/kg respectively, while the concentrations in the shelf are 14.92, 14.07, 198.07, 2.00, 4.51, and 1.30 mg/kg, respectively. Generally, the results suggest that the heavy metal levels increase with decreasing the average grain-size of the sediments in the study area. The beach of Gaza Strip is considered as one of the most polluted areas due to the adverse effect of effluents from land-based sources. Domestic untreated wastewater discharges and fishing activities in the harbors area may possibly the major source of the observed higher levels of heavy metals contamination, especially the cadmium and lead. However, the concentration levels of the studied heavy metals in the study area are under the limits comparing with EPA and Ontario guideline standards, except the Cd level is mainly above the limits of EPA and Ontario.

Keywords: Gaza Strip; grain-size distribution; heavy metals; pollution.

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1. INTRODUCTION

Heavy metals are considered among the most serious contaminants of aquatic ecosystems, due to their high potential to enter and accumulate in the food chain. Under certain environmental conditions in aquatic systems, heavy metals may accumulate to reach a toxic concentration and cause health and ecological damage. The main sources of heavy metal pollution are the run-off from agricultural and urban areas, discharges from mining, factories and municipal sewer systems, leaching from dumps and former industrial sites, and atmospheric deposition (El-Serehy et al., 2012).

Sediments are the final destination of trace metals, as a result of adsorption, precipitation, exchange processes, chemical reactions, biological activity and a combination of those phenomena. Sediments can become a source of metals, releasing them into the overlying water column. Heavy metals in minerals and rocks are generally harmless and only become potentially toxic when they dissolve in water. Marine organisms can accumulate trace metals from the dissolved phase and from ingested food. Metals enter the environment naturally as a result of chemical and physical weathering of rocks, leaching of soils, and volcanic activity, and as a result of urban, industrial and agricultural activities. Both anthropogenic and natural processes can contribute to the trace metal contamination in the coastal sediments. On the other hand the trace metal variability in the sediments has been found to be related to grain size, mineralogy, and organic carbon (Mansour et al., 2013).

In recent years there have been increasing interests regarding heavy metal contaminations in the environments, apparently due to their toxicity and perceived persistency within the aquatic systems. There are basically three reservoirs of metals in the aquatic environment: water, sediment and biota. Sediments are important sinks for heavy metals and also play a significant role in the remobilization of contaminants in aquatic system under favorable conditions and interaction between water and sediments (Balasim, 2010).

The main objectives of the current study are: (1) estimate heavy metal concentrations and to evaluate their contamination level in the sediments; (2) describe the distribution pattern of heavy metals in sediments; (3) correlate the heavy metal concentrations with average particle size distribution in the study area.

1.1. The Study Area

The coastline of Palestine is broadly concave, trending generally NNE-to-SSW (Fig. 1). It lies between two parallel lineaments. The eastern, or onshore, lineament is an escarpment that is locally steeper than 45 degrees and rises as high as 50 m above mean sea level (MSL) (Neev et al., 1987). A sequence of late Pleistocene to Holocene sediments crops out along the cliff. The top of this sequence extends eastward to form Palestine's now-elevated alluvial coastal plain. The western, or offshore, lineament is a low submarine escarpment. It forms the western limit of a patchy abraded terrace that is a few hundred meters wide.

The coastal plain adjoins the coastline on the land and the continental shelf beneath the ocean. Both areas contain broadly curved subparallel sand ridges that are similar to each other. River valleys and ridge bifurcations provide smaller interruptions. The ridges necessarily are farther apart at the southwest and converge toward the north because the combined coastal plain and shelf narrows to the north. Yet has relatively smooth slopes toward an approximately uniform 130 m shelf break, and because the base of each ridge has approximately the same elevation along its entire length. These characteristics are to be expected for the deposition of coastal sand ridges, but they are unusual for purely tectonic features. Local people have mapped three accessible ridges on land and refer to them as kurkar ridges. People have used these ridges' hard sandstone, also called kurkar, extensively for construction since ancient times (Neev et al., 1987).

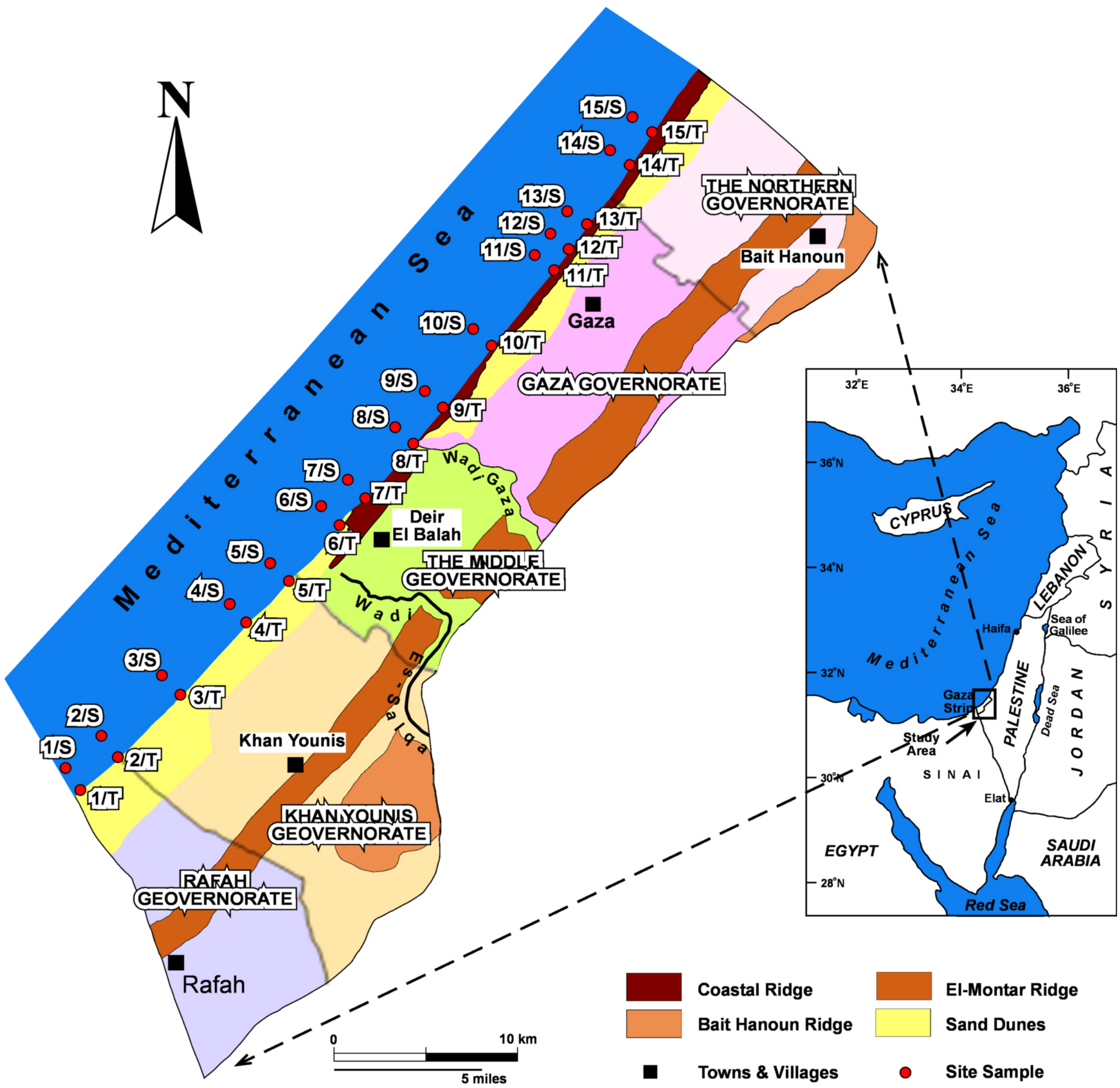

Fig. 1 - Location map of the study area (after Ubeid, 2010).

The Gaza Strip which is situated in the south-western part of Palestine on the Mediterranean Sea's southeast coastal plain (Fig. 1), between longitude 34°20` and 34°25` East and latitude 31°16` and 31°45` North. Gaza Strip is bordered by Egypt from the south, Negev desert from the east and the green line from the north. Its area is about 365 km², it has a length of about 45 km along the coastline from Beit Hanoun in the North to Rafah in the South, and its width ranges from 6 km in the North to a maximum of 12 km in the South (GEP, 1994; Ubeid, 2011a; 2016; Ubeid and Al-Agha, 2016). The three kurkar ridges define its topography. The coastal ridge is up to 50 m above MSLand extends up to the current coastline in the west. The Al-Montar and Beit Hanoun ridges run along its middle and the eastern parts (Fig. 1). Stratigraphically, these ridges belong to the Pliocene-Pleistocene Kurkar Group (Fig. 2). They consist of marine and continental calcareous sandstone (Bartov and Arkin, 1980; Frechen et al., 2004; Al-Agha and El-Nakhal, 2004; Galili et al., 2007; Ubeid, 2010), intercalated with red, sandy loam soils, called locally hamra, which is the Arabic word for red (Yaalon and Ganor, 1973; Ubeid, 2010, 2011b). Deep depressions separate the ridges 20 to 40 m above MSL with alluvial deposits.

The coastal zone is a band of water and land along the marine shoreline in which different activities interact. It includes sand dunes in the south and north, coastal kurkar cliffs in the middle to the north, non-urban areas, and part of Gaza valley, which is also called Wadi Gaza. The coastal zone covers approximately 74 km², of which 2.7 km² are beaches (Al-Agha, 2000).

The coastline has a straight and sandy shore. The near-coast continental shelf slopes down with a gradient of 1:100. The irregular and rocky seabed of the coastal shelf to the depth of 100 m is 28 km wide in the south and 14 km wide in the north. The seabed drops quickly beyond the depth of 100 m. Its sediments consist mainly of sand 25 m deep, with muddy places near the Wadi Gaza.

1.2. Sources of Sea Water Pollution of Gaza Strip

The sandy coast of the Gaza Strip is one of the most beautiful areas in Palestine. However, several spots along the coast are used as waste disposal and landfills (Zaqoot et al., 2012; Ubeid and Albatta, 2014; Ubeid and Al-Agha, 2016). According to the municipal sources in Gaza, some million cubic meters of waste water are disposed of in the Mediterranean annually. About 110,000 m³ per day of untreated or partially treated wastewater is discharged into the Mediterranean Sea, which mostly coming from around eight sewage stations and Wadi Gaza, which are pumping sewage into the seawater (Fig. 3). The sewage is either disposed near the seashore or few meters inside the seawater (Abualtayef et al., 2014; Al-Agha, 1993, 1999, 2000; Ubeid and Al-Agha, 2016). The pollution presents a major health risk for the swimmers and marine life; in addition it affects the quality of consumed fish in this area.

This contamination can be controlled by the introduction of wastewater recycling and reuse in the Gaza Strip.

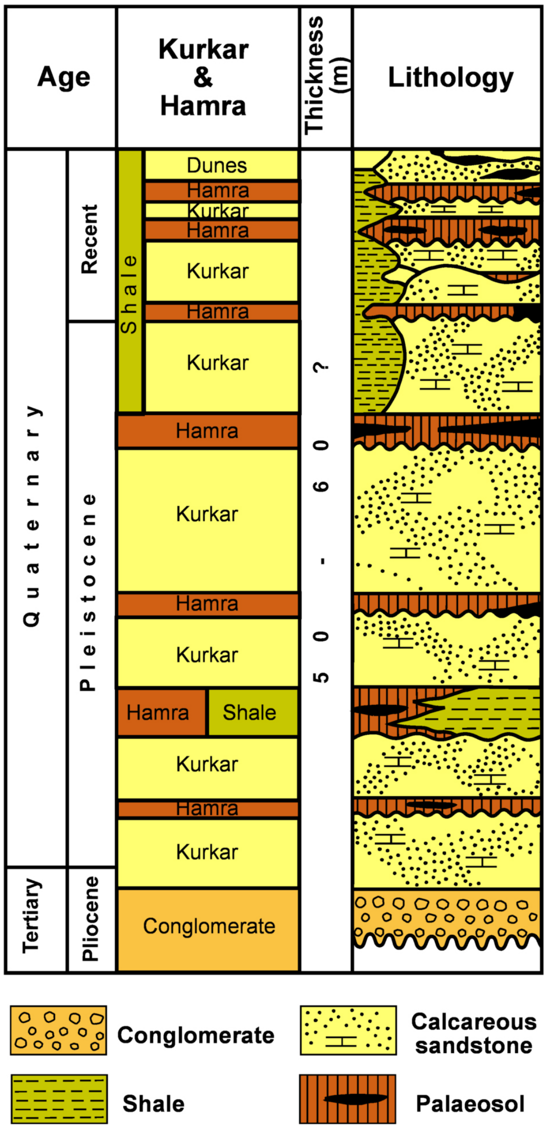

Fig. 2 - The lithology and stratigraphic succession of Plio-Pleistocene of kurkar and hamra alternations (Gaza Formation) in Gaza Strip (after Abed and Al Weshahy, 1999).

2. MATERIALS AND METHODS

2.1. Sediments Sampling and the Target Area

To investigate the distribution of the grain-size and the heavy metals in tide and shelf zones along the Gaza Strip Sea, a total of 30 samples were collected in February 2015 from upper 20 cm of sands sediments along approximately 45 km of the Gaza Strip Mediterranean Sea, from the southern to the northern border. Fifteen samples were collected from the tide zone and further 15 from the shelf. The samples in the shelf located about 350 m from shoreline at each tide sampling site toward the sea (Fig. 1). The selected parameters of the study sites were referred to expect pollutant sources of heavy metals such as harbors, and outlet sewage stations. The sampling sites were located by GPS device. The coordinates and description of sampling sites for both tide and shelf are shown in table 1.

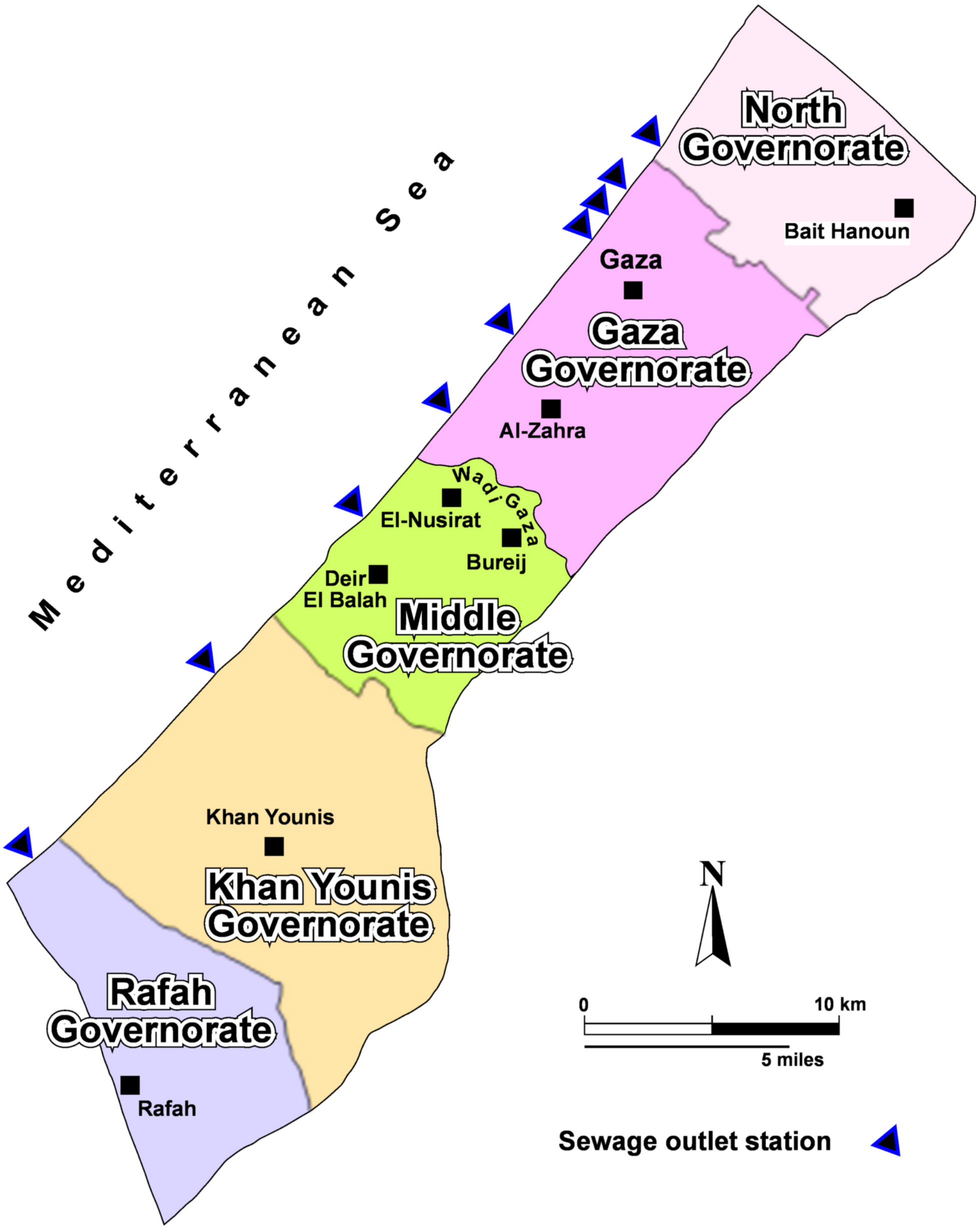

Fig. 3 - Sewage outlet stations along the beach of Gaza Strip.

2.2. Grain-size Analysis

Primarily the coarse particles were removed from samples by sieve (2000 µm). Then, the samples were dried at 105 C° for 24 hours in an oven. After drying, sieving method was used by sieve shaker to classify the particle sands of each sample, eight sieves were used (2000, 1180, 600, 425, 300, 212, 150, 63 µm). The initial sands of each sample was constant at 100 g, and the duration of shaking was about 15 minutes for each sample. The retained weight of sands in each sieve was determined separately. The results of sieve analysis are generally expressed in terms of the percentage of the total weight of sample that passed through different sieves.

2.3. Chemical Analysis

For extraction of heavy metal from marine sediments, the standard method described by American Public Health Association (APHA, 1998) was used. Triplicates of sieved, dried and homogenized 4 gram samples, with mesh sizes (2000, 1180, 600, 425, 300, 212, 150, 63 µm) were microwave-digested with a HNO_3-H_2SO_4-HCl acid mixture according to APHA (1998). After acid digestion, the sample solutions were cooled and filtered using No. 1 Whatman paper. The filtered solution was made up to 50 ml by 2% nitric acid with de-ionized double-distilled water and analyzed for Zn, Pb, Mn, Cu, Co, and Cd by Flame Atomic Absorption Spectrophotometer (FAAS) using UNICAM 929 model. At each step of the digestion processes of the samples, acid blanks (laboratory blank) were prepared using an identical procedure to ensure that the samples and chemicals that being used are not contaminated. The results were expressed as mg/kg dry weight for sediment samples. Wavelengths and detection limits of the FAAS for the analyzed metals are shown in

Site No.	Coordinates		Location	Area description
	E	N		
1	34.220913	31.32495	Rafah	Outlet sewage, near the Egyptian Board
2	34.236676	31.338293	Rafah	
3	34.260727	31.358991	Khan Younis	
4	34.288805	31.384231	Khan Younis	Outlet sewage
5	34.307534	31.399489	Khan Younis	
6	34.331428	31.419923	Deir El Balah	Harbor Fishing
7	34.342284	31.430082	Deir El Balah	Outlet sewage, Deir El Balah camp
8	34.363001	31.451082	Al Zawaida	
9	34.376172	31.464635	Wadi Gaza	Outlet sewage
10	34.398651	31.488493	Gaza	Outlet sewage (Al Baider)
11	34.426432	31.516942	Gaza	Outlet sewage (Al Shalihat)
12	34.433735	31.525086	Gaza	Outlet sewage & Harbor Fishing (Gaza Harbor)
13	34.442271	31.534046	Gaza	Shati Camp
14	34.461574	31.555999	North	Opposite of Mariote
15	34.472782	31.569241	North	Al Soudania

Tab. 1 - Coordinates of sampling sites in the study area.

Element	Wavelength (nm)	Detection Limit (mg/l)
Pb	217.0	0.070
Mn	279.5	0.020
Zn	213.9	0.010
Cu	324.8	0.033
Cd	228.8	0.013
Co	240.7	0.600

Tab. 2 - Wavelengths and detection limits of Atomic Absorption Spectrophotometer.

Table 2. ArcGIS 10.1 software was used to present the heavy metal distributions in the study area (Fig. 4).

2.4. Data Statistical Analysis

The GRADISTAT software was used to determine the grain-size distribution and statistical analysis. This software uses the linear interpolation to calculate statistical parameters (Folk and Ward, 1957). In other hand the heavy metals data were processed by Microsoft Excel sheets and uploaded to the Statistical Package for the Social Sciences (SPSS) and analyzed using minimum, maximum, mean and standard deviation tools. In addition the Pearson correlation coefficient (a measure of linear association) and paired sample test are used to detect significant variations of heavy metal elements in sediment samples.

3. RESULTS AND DISCUSSION

3.1. Sediment Characterization

Table 3 summarizes the grain-size distribution in the study area.It shows that in the tide zone,the predominant grain-size is medium- to fine-grained. The grain-size was variable from about 31% to 77% of medium-grained, and about 5% to 42% of fine-grained. On the other hand, the predominant grain-size in the shelf was very fine- to fine-grained, which variable from about 27% to 67% of very fine-grained,and about 4% to 17% fine-grained. Generally, the results show that the grain-size decreases from southern to northern partsof the study area, this result coincides with Ubeid (2011b), and the grain-size decreases toward the sea direction.The segregation of the grain-sizes of the sediments towards the northern parts and sea direction in the study area werereferred to the variation in wave energy and the morphology of the beach (Ubeid, 2011b).

3.2. Heavy Metal Distribution

The concentrations of Zn, Pb, Mn, Cu ,Co and Cd in the sediments of the study area along the Gaza Strip Coast are shown in table 4; and are illustrated in figure 4.

As observed from the results, the concentration of the Zn in tide zone varied between 3.10-34.23 mg/kg with a mean value about 11.56 mg/kg. The highest concentration was 34.23 mg/kg was recorded at site 11/T, which located around the Al Shalihat and Gaza Harbor (Tab. 1 and Fig. 1). The highest value referred to the sewage outlet station at this site. Whereas, in the shelf, it varied between 12.20 and 20.70 mg/kg with a mean value about 14.92 mg/kg. The highest concentration (20.70 mg/kg) was found at site 14/S in the north and opposite of the Mariote resort. However, the results show that the Zn concentrations in the sediments increase towards the sea direction. Generally, the high level of the Zn concentrations refer to sewage outlets discharge and domestic and industrial sewage which pour into the sea from the Gaza harbor.

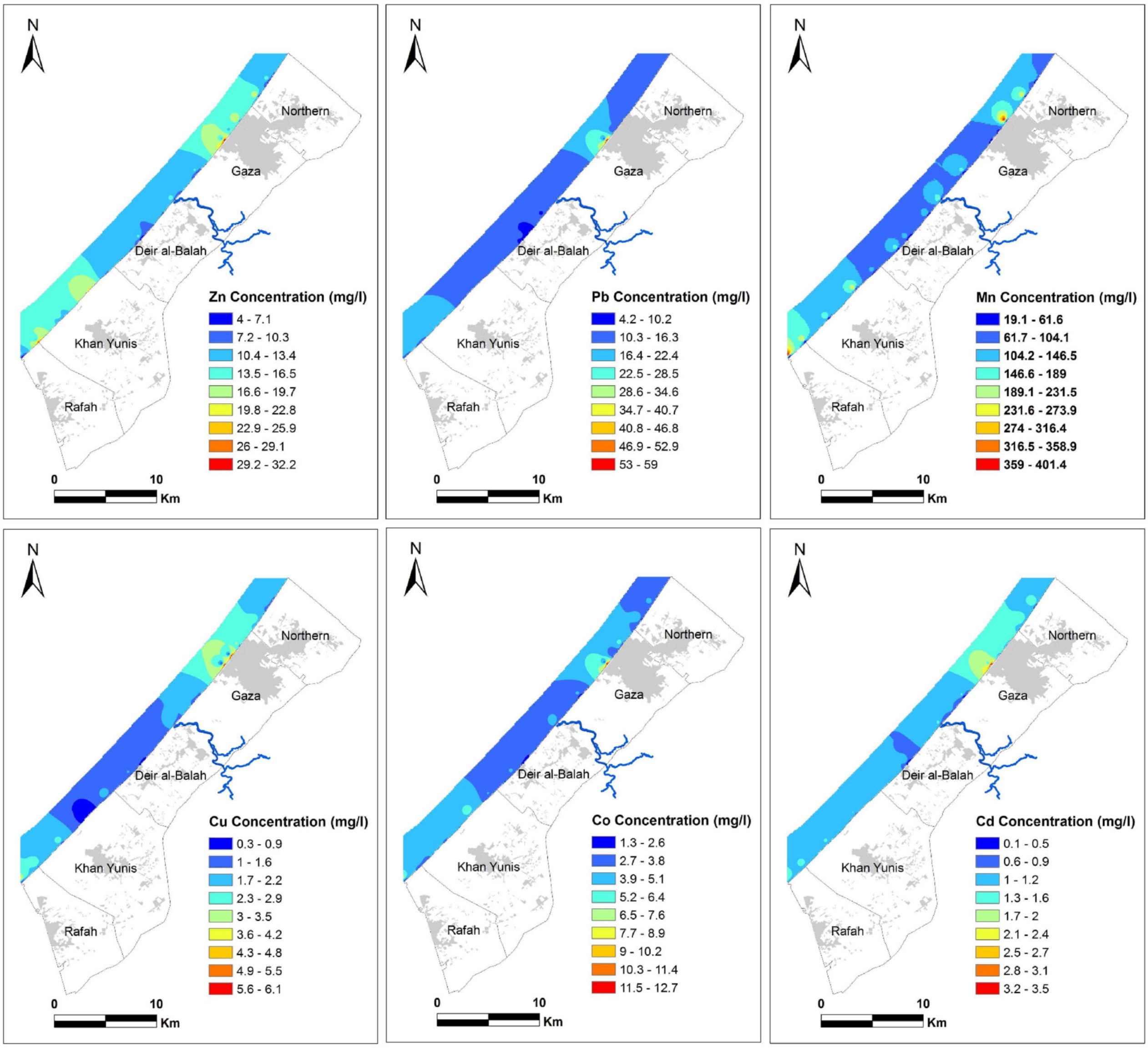

Fig. 4 - The spatial distribution of the heavy metal concentrations in sediment of study area.

However, the Zn concentrations in the sediments of the study area along the Gaza Strip Coast were under the standard limits of WHO (50 mg/kg).

Lead concentration in the tide zone varied between 3.43 and 63.69 mg/kg, with mean value was about 15.86 mg/kg, and the standard deviation was 13.62. The highest concentration (63.69 mg/kg) was found at site 11/T in the north direction of the area. On the other side, the Pb concentration in the shelf varied between 9.38 and 19.50 mg/kg with a mean value about 14.08 mg/kg, and standard deviation was 2.81. The highest concentration (19.50 mg/kg) was found at site 3/S at Khan Younis in the south direction of the area. The high level of the Pb concentrations in shelf zone were found at sites 1/S, 2/S, and 3/S in the south of the study area. Therefore, the logical explanation for these values was due to the domestic and industrial waste which discharge into the sea from Al Arish port in Egypt, and by the currents movement of the sediments. The Pb concentrations can reach to these sites and accumulate in the seabed due to the gravity. Overall, the Pb concentrations in the tide zone was slightly exceeded than that the results in the shelf.

The distribution of Pb concentrations in tide zone along Gaza Strip was nearly range from 9 to 15 mg/kg, except the site 11/T (63.69 mg/kg) and site 7/T (3.43 mg/kg). There was a positive relation between the Pb and Zn, since the maximum level at site 11/T and the minimum level at site 7/T were similar. Overall, the site samples were under the standard limit of EPA which was 31 mg/kg, except the level at site 11/T. The highest level value of Pb at site 11/T which locates at Al Shalihat resort in Gaza City refers to sewage outlet station at this site.

The concentrations of the Mn in the tide sediments varied between 8.71 and 43.03 mg/kg with a mean value about 20.49 mg/kg, and standard deviation of 11.93. The highest concentration (43.03 mg/kg) was found at site 11/T in the north. Whereas, the Mn concentration levels in the shelf along Gaza Strip Coast were fluctuated

	Sample No.	Very Coarse Sand %	Coarse Sand %	Medium Sand %	Fine Sand %	Very Fine Sand %	Silt + Clay %
Tide zone	1/T	1.0	13.0	73.6	12.1	0.2	0.1
	2/T	4.8	14.8	51.5	27.6	0.9	0.3
	3/T	1.9	6.1	49.1	41.8	1.1	0.0
	4/T	23.1	27.2	31.3	17.6	0.7	0.1
	5/T	1.5	9.4	65.3	23.3	0.5	0.1
	6/T	17.4	31.7	45.0	5.6	0.3	0.1
	7/T	1.2	6.5	50.9	39.2	1.5	0.8
	8/T	1.2	9.6	76.6	12.4	0.2	0.0
	9/T	1.9	14.7	61.7	21.1	0.3	0.3
	10/T	0.3	5.0	61.8	31.3	1.2	0.4
	11/T	0.4	3.2	49.9	43.9	2.2	0.4
	12/T	3.7	13.0	53.6	28.5	0.8	0.4
	13/T	8.6	32.3	56.0	3.2	0.0	0.0
	14/T	1.3	14.0	76.4	8.2	0.2	0.0
	15/T	6.5	37.3	51.1	5.1	0.0	0.0
Shelf zone	1/S	23.9	3.1	6.5	27.1	35.4	4.0
	2/S	1.5	1.4	4.7	33.1	50.5	8.7
	3/S	0.6	0.9	3.5	32.2	58.9	3.9
	4/S	2.3	1.9	6.7	34.4	47.9	6.9
	5/S	1.3	1.2	7.5	48.8	35.6	5.5
	6/S	2.5	1.0	7.3	37.2	49.2	2.8
	7/S	2.8	1.1	7.9	49.2	38.8	0.1
	8/S	0.4	0.8	8.2	47.0	43.4	0.2
	9/S	0.5	0.9	5.7	35.6	55.4	1.9
	10S	1.3	1.7	10.5	47.6	33.8	5.0
	11/S	0.5	0.6	5.7	47.1	38.6	7.4
	12/S	1.2	1.1	10.7	62.7	24.2	0.1
	13/S	13.5	1.6	5.3	35.8	38.7	5.1
	14/S	8	1.9	13.4	44.7	27.3	4.7
	15/S	7.7	1.0	16.5	56.4	17.9	0.5

Tab. 3 - Grain-size distribution of marine surface sand samples in the study area.

between 92.78 and 407.10 mg/kg, the mean value was about 198.07 mg/kg, and the standard deviation was 92.18. The highest concentration (407.10 mg/kg) was found at the site 1/S at Rafah in the south. The highest level concentrations of Mn were observed at 11/T, 1/S, 13/S, and 14/S in the study area were referred to sewage outlet stations which discharge in the beach, and Al Arish port in Egypt and Gaza harbor where 1/S and 11/S were located around them, are indicators for the contribution of the anthropogenic in these values of Mn at those sites. In general, the concentration levels of Mn in all the observation sites were in the safe side and under the limit (460 mg/kg) according to EPA standard limits.

Copper concentration levels in the tide zone along Gaza Strip were fluctuated between 0.26 and 6.56 mg/kg, the mean value was about 1.72 mg/kg, and the standard deviation was 1.93. The highest concentration (6.56 mg/kg) was found at site 12/T inside the Gaza harbor. Whereas, the Cu concentrations in shelf varied between 0.26 and 3.86 mg/kg with a mean value was about 2.00 mg/kg, and standard deviation was 0.88. The highest concentration (3.86 mg/kg) found at site 1/S in Rafah near the Egyptian border in the south. Overall, the highest levels of Cu were observed at sites 1/S, 2/S, and 3/S in the south, which are located to the north of the Al Arish port in Egypt, and sites 12/T, 13/S,14/S and 15/S in

	Site No.	Zn	Pb	Mn	Cu	Co	Cd
Tide zone	1/T	5.25	14.96	12.57	0.80	2.68	0.98
	2/T	27.29	14.76	36.57	1.46	2.52	1.00
	3/T	11.08	16.0	41.96	1.17	2.98	0.90
	4/T	20.66	13.54	13.05	0.87	3.14	0.68
	5/T	8.11	14.48	14.92	0.77	3.14	0.87
	6/T	8.94	12.89	14.07	0.77	3.14	0.81
	7/T	3.1	3.43	16.61	0.26	1.08	0.00
	8/T	8.2	14.09	16.62	0.84	2.84	0.93
	9/T	5.83	14.44	17.99	1.17	2.73	0.34
	10/T	5.96	10.33	28.14	0.97	1.68	0.16
	11/T	34.23	63.69	43.03	6.19	13.68	3.72
	12/T	16.9	15.22	20.19	6.56	2.68	1.06
	13/T	9.21	10.5	13.23	1.78	2.39	1.03
	14/T	5.0	10.08	8.71	1.57	1.88	0.80
	15/T	3.74	9.57	9.79	0.67	2.09	0.30
Shelf zone	1/S	14.48	17.81	407.1	3.86	6.91	1.45
	2/S	12.78	18.18	245.62	2.68	4.84	1.33
	3/S	14.11	19.5	185.95	2.65	4.95	1.29
	4/S	19.06	14.31	240.45	0.26	6.28	1.25
	5/S	13.07	12.85	123.8	2.07	3.89	1.07
	6/S	12.95	12.39	175.64	1.66	4.01	1.18
	7/S	14.25	12.0	125.03	1.58	3.83	1.15
	8/S	13.52	9.38	141.29	1.37	3.22	0.96
	9/S	15.12	10.59	192.35	2.07	4.58	1.33
	10/S	14.08	12.04	170.05	2.00	4.18	1.32
	11/S	12.2	13.28	92.78	1.05	3.23	1.36
	12/S	12.56	14.56	102.57	1.16	2.95	1.33
	13/S	20.18	14.35	371.44	2.93	5.75	1.39
	14/S	20.7	15.54	250.55	2.59	4.86	1.50
	15/S	14.71	14.39	146.48	2.07	4.22	1.60

Tab. 4 - Heavy metal concentration (in mg/kg) in the sand samples of the study area.

the north which are located around the Gaza harbor in the study area, these harbors consider as a source of heavy metals pollutions at these sites, in addition to the sewage outlet, especially in Gaza harbor where there was inside it sewage outlet station. Even that, all sites in the study area were under the permissible limit according to EPA standards which was 16 mg/kg.

The concentration levels of the Co in the tide sediment zone along the Gaza Strip Coast range between 1.08 and 13.68 mg/kg, with a mean value was about 3.24 mg/kg and standard deviation of 2.95. The highest concentration level (13.68 mg/kg) was found at site 11/T in north of the area. The Co concentration levels in the shelf along Gaza Strip Coast were fluctuated between 2.95 and 6.91 mg/kg, the mean value was about 4.51mg/kg, and the standard deviation was 1.13. The highest concentration (6.91 mg/kg) was found at the site 1/S at Rafah in the south direction of the study area. These results were still in the same homogeneity of the other elements in the study area which resume that sites (11/T and 1/S) have the highest level of the concentrations. Overall, the concentrations of the Co along the study area were under the limit of Ontario standard, which was 50 mg/kg.

In the tide zone, the Cd concentrations varied between 0 and 3.72 mg/kg with a mean value about 0.90 mg/kg, and standard deviation of 0.85. The highest concentration (3.72 mg/kg) was found at site 11/T exactly north the Gaza harbor and inside Al Shalihat resort, and there are a domestic outlet sewage which discharge into the Gaza sea at this site. Whereas, in the shelf zone, the Cd concentrations varied between 0.96 and 1.60 mg/kg with a mean value of 1.30 mg/kg, and standard deviation of 0.16. The highest concentration (1.60 mg/kg) was found at site 15/S in the north. As in the previous metals the high level concentrations of Cd found at site 11/T around the Gaza harbor in the north within the tide zone. While, all the sites in shelf zone were around the same value of Cd concentration, which range between 0.96 and 1.60 mg/kg. According to EPA standards for Cd in the sedimentswas 0.6 mg/kg.Unfortunately, most of the sites along the study area present above this limit.

The statistics of chemical analysis results in the tide zone sediments (Tab. 5) show that the highest concentration among the six selected heavy metals was the Pb with concentration about 63.69 mg/kg. On the other hand, the highest mean was 20.49 mg/kg for the Mn. The maximum standard deviation was in Pb with value about 13.62. Whereas, the statistics of chemical analysis results in the shelf zone sediments show that the highest concentration; the highest mean; and the maximum standard deviation among the six selected heavy metals was for the Mn with a value of 407.10; 198.07; 92.18 mg/kg respectively. According to Fernandez et al. (2000), the highest value of lead concentration in the sediments mostly related to Fe-Mn oxide segments and had preservation in marine sediments. Additionally, it could refer to human activity as brought a huge amount of mechanical workshops and batteries wastes into the sea, and the fishing boats activities, including the wastewater discharge into the sea. The highest mean value which found in the Mn, refers to the huge quantity of the municipal wastewater discharges which presents the main anthropogenic source of manganese (WHO, 2004).

Generally, the high level concentrations of the selected heavy metals (Zn, Pb, Mn, Cu ,Co and Cd) in the study area (tide and shelf zones) were 34.23, 63.69, 407.10, 6.56, 13.68, and 3.72 mg/kg respectively. The mean value concentration of these were 13.26, 14.97, 105.95, 1.86, 3.87, and 1.10 mg/kg respectively (Tab. 5). Figure 4 illustrates the distribution of the selected heavy metals (Zn, Pb, Mn, Cu ,Co and Cd) in the study area. These concentration levels were under the standard limits of the pollution in sediments comparing with the EPA and the Ontario standard (Tab. 6), except the Pb, it was above the standard limits only at site 11/T in tide zone due to swage discharge in the beach; and the exception includes the Cd, where it was above the standard limits in the study area.

The Pearson's correlation coefficients among the heavy metals (Zn, Pb, Mn, Cu, Co, and Cd) in the sediments of the study area shows strong significant positive correlation between Co and Cd (0.91), Pb and Co (0.88), Pb and Cd (0.86), andotherspositive correlationswereobservedbetween Zn and Co (0.72), Zn and Cd (0.75) (Tab. 7 and Fig. 5).This suggest that these elements came from a common an anthropogenic source.

	Metal	Min.	Max.	Mean	Std. Deviation
Tide zone	Zn	3.10	34.23	11.57	9.21
	Pb	3.43	63.69	15.87	13.62
	Mn	8.71	43.03	20.50	11.40
	Cu	0.260	6.56	1.72	1.93
	Co	1.08	13.68	3.24	2.95
	Cd	0.000	3.72	0.91	0.85
Shelf zone	Zn	12.20	20.70	14.91	2.76
	Pb	9.38	19.50	14.07	2.80
	Mn	92.78	407.10	198.07	92.18
	Cu	0.260	3.86	2.00	0.880
	Co	2.95	6.91	4.51	1.13
	Cd	0.960	1.60	1.30	0.160
Total area	Zn	3.10	34.23	13.26	6.94
	Pb	3.43	63.69	14.97	9.70
	Mn	8.71	407.10	105.95	108.22
	Cu	0.26	6.56	1.86	1.47
	Co	1.08	13.68	3.87	2.28
	Cd	0.00	3.72	1.10	0.63

Tab. 5 - Statistical descriptive of the heavy metals in sand samples of the study area.

Metals	EPA	Ontario Canada	Present study (mean)	
			Tide Zone	Shelf zone
Zn	120	120	11.57	14.91
Pb	31	31	15.87	14.07
Mn	460	-	20.50	198.07
Cu	16	16	1.72	2.00
Co	-	50	3.24	4.51
Cd	0.6	0.6	0.91	1.30

Tab. 6 - Limits values (in mg/kg) according to EPA, WHO, and the results from the study area along Gaza Strip Coast in both, tide and shelf zones.

Cd	Co	Cu	Mn	Pb	Zn	Metals
					1.00	Zn
				1.00	0.65	Pb
			1.00	0.20	0.33	Mn
		1.00	0.27	0.63	0.57	Cu
	1.00	0.62	0.44	0.88	0.72	Co
1.00	0.91	0.66	0.33	0.86	0.75	Cd

Tab. 7 - The correlation coefficient matrix among the heavy metals in surface sediments of the study area.

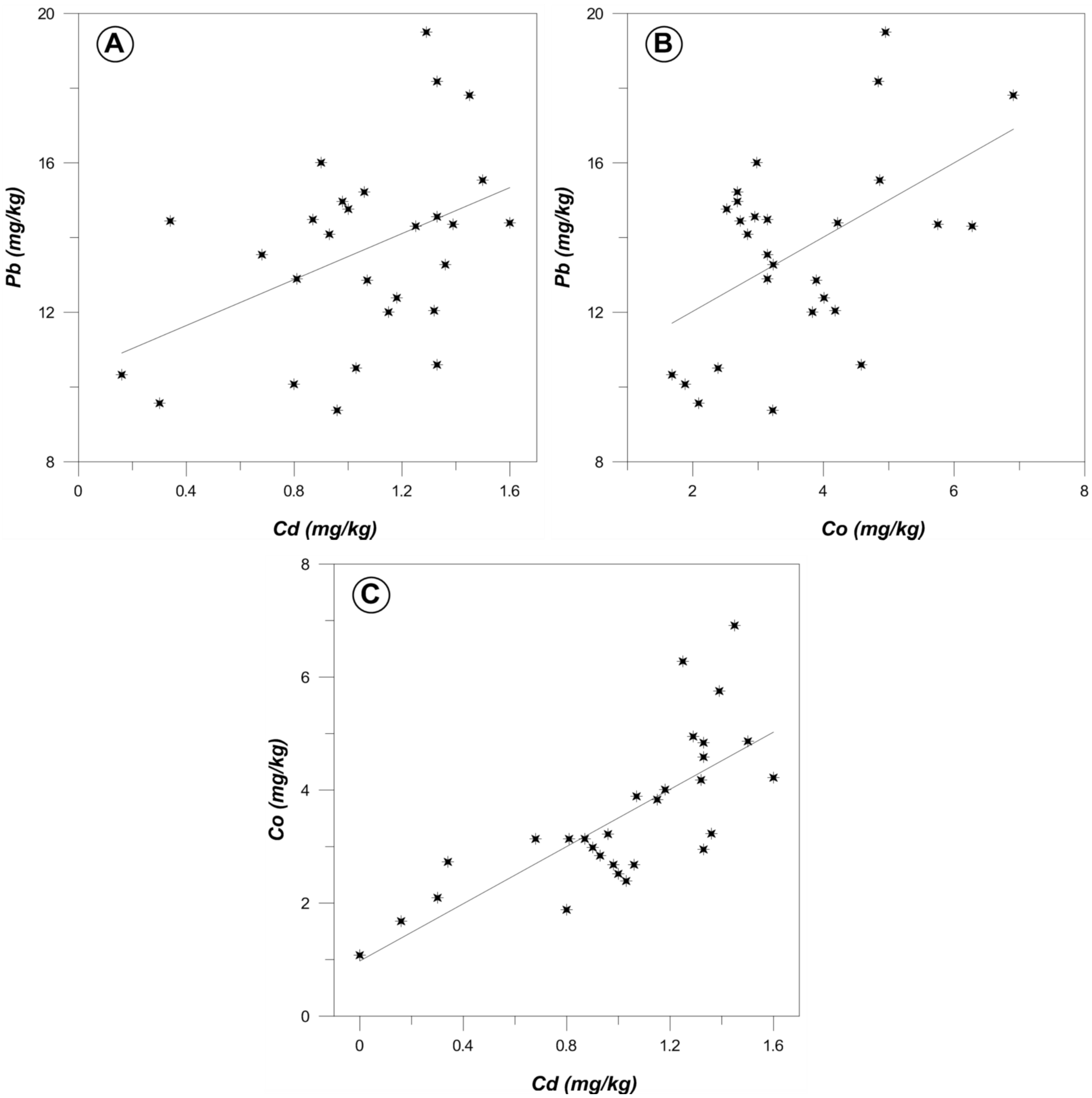

Fig. 5 - The significant correlation among selected heavy metals in the study area.

On the other hand, the plotting of three heavy metals (Pb, Cd, and Co) as bivariate scatter plots show that there were two groups of points divided the graph into two discrimination fields (tide and shelf). Figure 6 depicted the relationships between the these discrimination fields, they were overlap as in Pb vs Cd, and Pb vs Co, or tangency as in Co vs Cd.

However, the main sources of the heavy metals were the sewage outlet stations which discharge in the beach, the Gaza harbor in the north, where inside it was found outlet station; additionally Al Arish port in Egypt in the south, where the domestic and industrial waste from which discharge into the sea and carried by the currents to south of the study area. These suggest the high level concentration of selected heavy metals in surface sediments in the sites which located very close or around the sewage outlet, around to Gaza harbor in the north direction, and the sites in south direction of the study area

In General, the average of fine-grained in the shelf were increased comparing with tide zone (Tab. 3). The particle size of sediment is a particularly important factor because it significantly affects the concentrations of the associated pollutants. Where, the fine-grained sediments representing the higher rate of surface and ionic adsorption power, are more capable in the adsorption of the pollution (Horowitz and Elrick, 1987; De Mora et al., 2004).

The study shows that the concentration of heavy metals

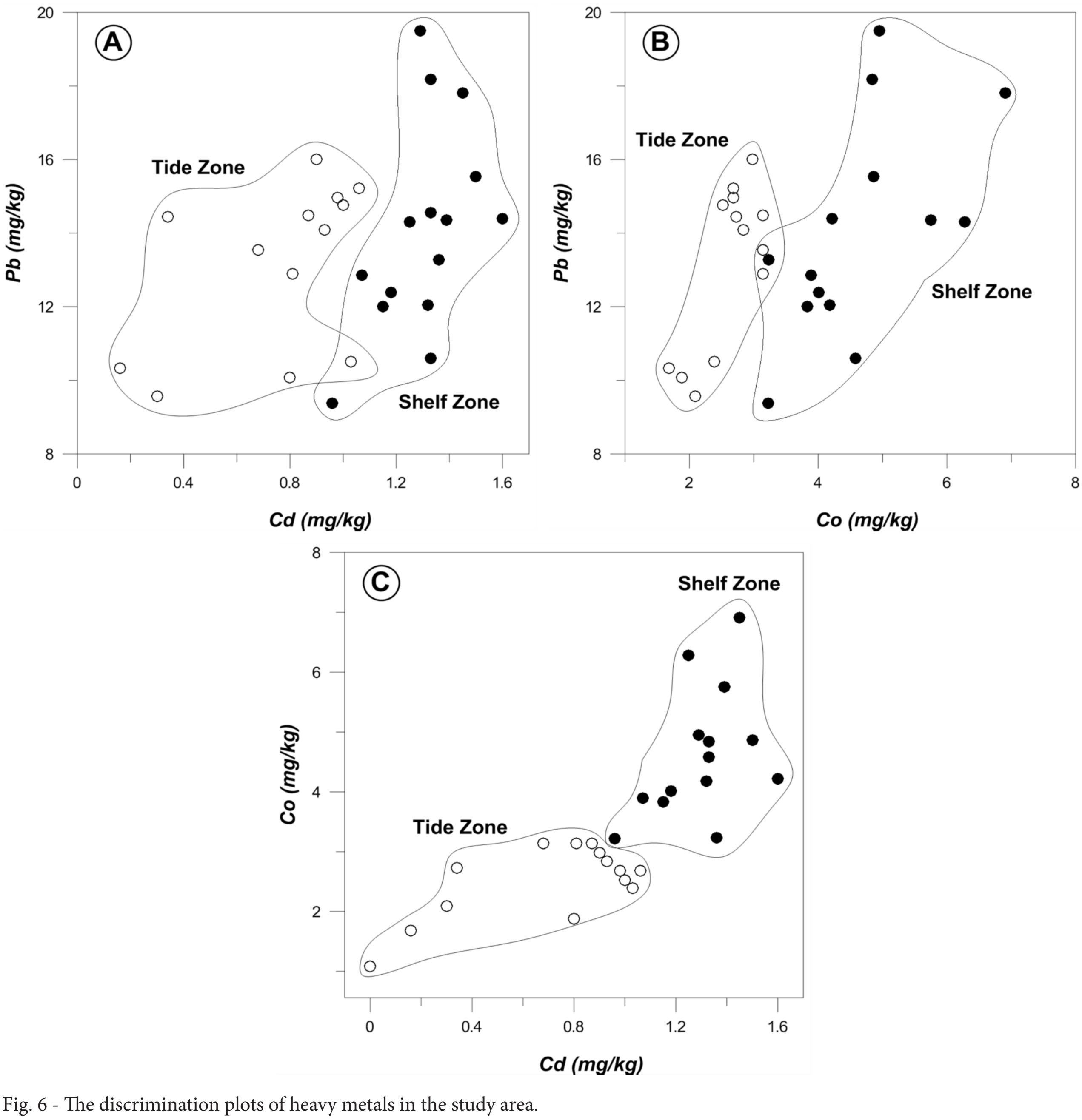

Fig. 6 - The discrimination plots of heavy metals in the study area.

increases with the decreases of average particle size, and the highest concentrations were measured in the finest fraction (Tabs. 3 and 4). The results demonstrate that the heavy metal concentrations were significantly correlated with average particle size which is in agreement with previous studies (Rodríguez et al., 2010; Duyusen and Akinci, 2013; Li et al., 2015).

4. CONCLUSION

The grain-size distribution carried out along two parallel lines survey in the tide zone and in marine zone (about 350 m in the sea far from line survey of tide zone). The results show that finning in the grain-size from tide to marine and from south to north directions. The predominant grain-size sands in tide zone was medium- to fine-grained,while it is fine- to very fine-grained sands in shelf.

The mean concentration values of heavy metals in the shelf zone along the study area were higher than those in the tide zone, except the Pb, it has higher level in the tide zone than the shelf.

In the tide zone the mean concentrationvalues of the selected heavy metals (Zn, Pb, Mn, Cu, Co, and Cd) were 11.56, 15.86, 20.49, 1.72, 3.24, and 0.90 mg/kg respectively. Whereas, the mean values of these metals in the shelf zone were 14.92, 14.07, 198.07, 2.00, 4.51, and 1.30 mg/kg respectively.

The concentration levels of the selected heavy metals (Zn, Pb, Mn, Cu, Co, and Cd) increase with the decrease of average particle size of marine sands of the study area, where the highest concentrations were found in the finest fraction towards the shelf and north direction.

The main sources of the heavy metals in the study area were the sewage outlet stations which discharge in the beach, the Gaza harbor in the north, and Al Arish port in Egypt in the south, where the domestic and industrial waste from which discharge into the sea and carried by the currents to south of the study area.

The concentration levels of the heavy metals Zn, Mn, Cu, Co and Pb in sands of tide zone and shelf were under the limits comparing with EPA and Ontario guideline standards, whereas the Cd level was mainly above the limits of EPA and Ontario.

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