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HYDROGRAPHICAL CONDITIONS AND BENTHIC ASSEMBLAGES IN THE SUEZ GULF, EGYPT

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ABSTRACT: The coastal development and human activities along the Suez Gulf leading to sedimentation, degrade the quality of water, disturbing the natural structure and functions of aquatic communities. The Suez Gulf is a large semi-closed area with a 346 km long coastline on the western beach side. The prevailing physicochemical parameters in shallow intertidal waters were measured seasonally over the year. Benthic faunas in the sampling sites were studied indicating their regional distribution in relation to the impact of different environmental parameters in the intertidal region. The concentration of copper in seawater reached high level at St. IV (4.57 ug/l), which is exposed to sewage and petroleum hydrocarbons. The grain size of the sediment is a determining factor for the organic carbon concentration and the sandy substrate enhances organic matter degradation processes. A large number of oil fields are present along the western coast of the Suez Gulf, therefore, cadmium and organic matter appeared to be high. The values of pH did not vary greatly among the different sampling sites. It was high at El-Ein, El-Sukhna and Ras-Shukeir due to the disposal of mainly acidic sewage and industrial effluents of the two stations Adabiya and Ras-Gharib respectively. The macrobenthos included 71 species embraced mainly from Mollusca (53.5% Gastropoda and 12.7% Bivalvia) and the other invertebrates included 7 groups namely, Rhizostoma, Polychaeta, Cirripedia, Amphipoda, Isopoda, Decapoda and Echinodermata. The distribution of benthos is affected by the temperature and salinity of seawater. The concentration of organic matter in seawater and in sediments in shallow waters shows high values in the central part of the Gulf of Suez.

KEY WORDS: Suez Gulf, water quality, sediments, bottom fauna, influence of pollution.

INTRODUCTION

The Red Sea region is one of the richest areas with macroinvertebrates of Indo-Pacific marine ecosystem. The Gulf of Suez is considered a large semi-closed basin. Its western coastline is approximately 346 km long. The water depth is shallow flat bottom in comparison to the Red Sea and Aqaba Gulf and do not exceed than 90 m (Badr and Crossland, 1939; Nawar, 1981). Immigrant species belonging to the Indo-Pacific region have a high percentage in the Gulf of Suez in comparison to percentage of immigrant species belonging to the Mediterranean Sea or none of immigrants belong to endemic Red Sea species (Goldschmid, 1999).

During the last three decades, increases of coastal development and human activities along the coastal region of the gulf leading to sedimentation degrades in the quality of water, disturbance the natural structure and functions of aquatic communities. In addition, it is considered a main international marine route for oil transportation by shipping from the Red Sea to the Mediterranean Sea. These lead to a great change in habitats of the benthos assemblages with negative effective on the regional distribution of marine invertebrates and decreasing the value of fisheries and recreation of the area.

There are two main sources of metals in seawater; 1) coming from the geochemical background of the oceans and seas and 2) coming from several drains as rivers, industrial, agricultural and sewage wastes. Generally, metals are potentially toxic to living organisms at variable concentrations. In spite of these elements are in trace amounts but having essential role to physiological functions of certain organisms or to the ecological system as a whole.

The marine life along the coastal areas is in general threatened due to the increasing of various economic activities. Most coastlines of the Red Sea and Gulf of Suez are dominated by coral reef communities that representing them one of a good economic resource. The impact assessment of pollution on the benthos structure was reviewed by Hargrave and Thiel (1983) and Hartnail (1984) and by El-Komi (1996, 1997) who studied the distribution of the macrobenthos assemblages in the shallow intertidal along the western and eastern coasts of the Gulf of Suez of Egypt.

The aim of this study is to estimate the different hydrographical parameters of water and sediment in the shallow intertidal waters in relation to the geographical distribution of macrobenthos communities of the Suez Gulf to decreasing the impacts of degradation of water quality on marine ecosystem.

MATERIAL AND METHODS

The physicochemical parameters of seawater and sediments were determined seasonally from seven stations (Fig. 1) and also the bottom faunas were collected seasonally during the period extended from May 1995 to April 1996.

The Study Area:

Seven sites were selected for this study that represented the predominant prevailing hydrographical characteristics in the shallow intertidal region. Namely the 1st station (Adabiya) is exposed to three sources of pollution (domestic drainage, oil refineries and ship's effluents); the 2nd station (El-Ein El-Sukhna) located away with 10 kms from an oil transshipped (SUMED) which reached 78 x 10 6 ton/yr in 1981 (Mancy, 1983); the 3rd station (Zaafarana) is subjected to less amount of oil pollution; the 4th station (Ras-Gharib) is exposed to high amount of sewage and oil pollution from oil terminal company of the city, which produces 1.1 x 10 6 ton/yr (Mancy, 1983); the 5th Station (Ras-Shukeir) is considered the center of oil production and shipment of oil from oil fields including off shore wells. It is located near the oil production company terminals (GAPICO) of Ras-Gharib and Ras-Shukeir; the 6th Station (Gabal El-Zeit) is exposed to slight oil pollution. It has a wide intertidal flat and its coasts subjected to strong agitation and upwelling of water during most of the year periods (El-Sabah and Beltagy, 1983) and the 7th Station (Hurghada) localized pollution problems are mainly due to increasing coastal development activities including large urbanization, tourist centers and industrial development in addition to some indication of coastal oil pollution around the harbour.

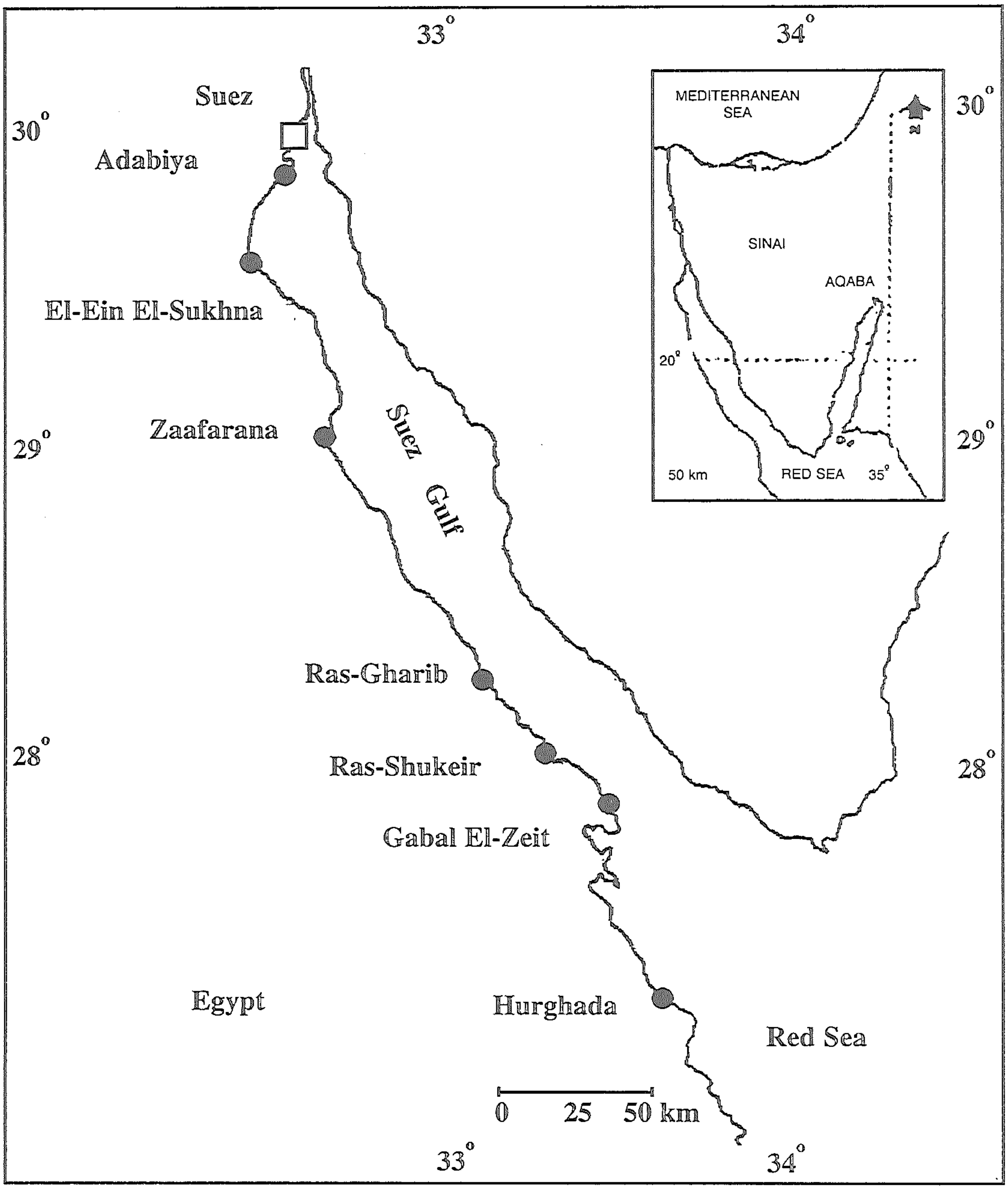

Fig. 1. The locations of the sampling sites along the Suez Gulf, Egypt.

Hydrographical parameters:

Physicochemical analysis of Seawater:

The physical and chemical parameters of seawater in the shallow intertidal waters were analyzed seasonally over the year. Water samples were collected from the study sites to determine the following parameters:

1) Temperature of the surface seawater was measured by using a simple bucket thermometer.
2) Hydrogen ion concentration (pH) was determined in the field by using digital pH meter (Checkmate modular testing system M 90).
3) Salinity (S ‰) was measured in the laboratory by using an inductive saliniometer (S.C.T. meter) from yellow spring's instruments co. model 33.
4) Dissolved oxygen (DO) was analyzed according to the Winkler method proposed by Harvey (1955).
5) Chemical oxygen demand (COD) was carried out according to the procedure proposed by Ellis *et al.* (1946).
6) Biological oxygen demand (BOD) was calculated according to standard methods (APHA 1989). It is defined as the amount of oxygen consumed by respiration process in a limited volume of water and incubated in the dark at constant temperature (20°C) for a certain time (5 days). The amount of the remaining oxygen was determined, and the corresponding oxygen in the samples.
7) Determination of the heavy metals in water was determined according to APDCMIBK system as described in the standard method of American Public Health Association (APHA 1989). These metals were calculated in micrograms of metals per liter of sample (ug/l).

Physicochemical analysis of Sediment:

1) Determination of the heavy metals in sediment was determined according to Oregioni and Aston (1984). The metals were determined by AAS (Atomic Absorption Spectrophotometer). The results obtained were expressed in ppm.
2) Sediment analysis at the different stations was sampled in May 1995. The sediment samples were obtained by using a core (10-cm diameter) to a depth of approximately 5-cm. Sub samples of sediment were taken for analysis of particle size composition, percentage organic matter and carbonate content.
3) Organic matter content in the sediment was determined in the samples by using the standard method (Jorgensen, 1977)
4) Carbonate content ($CaCO_3$) was determined according to the method described by Presely (1975) based on the titration against HCl using phenolphthalene indicator.

Macrobenthos communities:

At each station quantities random survey samples of the macrobenthic organisms were collected, by using an iron frame quadrate (lm^2), through a series of transects perpendicular to the shoreline in the shallow intertidal waters. After collection each sample was washed through 0.75-mm mesh sieves. In the laboratory the sorting and identification of the macroinvertebrates were carried out.

RESULTS

Physicochemical analysis of seawater:

Water temperature: As shown in Table 1 the maximal water temperature of the surface seawater of the intertidal zone along the western coast of the Suez Gulf was estimated by a mean 27.21°C, SD +_0.7 in summer season, while the degree of temperature was dropped to a mean 16.43°C, SD +_ 0.79 during winter.

Table 1. Seasonal variation in the values of the different physicochemical parameters of the surface seawater measured at the different stations along the western coast of the Suez Gulf, during May 1995 to April 1996.

Parameters	Seasons	I	II	III	IV	V	VI	VII	Mean	St.Dev
Temperature (oC)	winter	15.00	16.00	17.00	17.00	17.00	17.00	16.00	16.43	0.79
	spring	23.00	27.00	25.00	24.50	25.00	23.50	25.00	24.71	1.29
	summer	26.00	27.00	27.50	28.00	27.00	27.00	28.00	27.21	0.70
	autumn	16.00	18.50	16.00	19.00	18.50	16.00	20.00	17.71	1.68
Mean		20.00	22.13	21.38	22.13	21.88	20.88	22.25	21.52	1.11
St.Dev.		5.35	5.35	5.72	5.74	5.04	4.87	5.27	5.32	5.26
Salinity (‰)	winter	39.14	39.73	39.64	39.00	39.40	40.11	39.16	39.45	0.39
	spring	40.13	40.48	40.53	40.20	40.43	40.80	40.84	40.49	0.27
	summer	40.33	41.43	41.36	41.10	41.82	42.10	41.91	41.44	0.60
	autumn	39.54	40.11	40.01	39.35	40.13	40.22	40.50	39.98	0.40
Mean		39.79	40.44	40.39	39.91	40.45	40.81	40.60	40.34	0.42
St.Dev.		0.55	0.55	0.73	0.75	0.94	1.01	0.91	1.13	0.84
pH	winter	8.13	8.00	8.11	8.30	8.14	8.12	8.13	8.13	0.09
	spring	8.16	8.24	8.18	8.32	8.16	8.20	8.17	8.20	0.06
	summer	8.32	8.26	8.26	8.31	8.27	8.28	8.22	8.27	0.03
	autumn	7.88	7.90	8.00	8.14	7.83	7.80	7.78	7.90	0.13
Mean		8.12	8.10	8.14	8.27	8.10	8.10	8.08	8.13	0.08
St.Dev.		0.18	0.18	0.18	0.11	0.09	0.19	0.21	0.20	0.16
DO (mgO2/l)	winter	5.22	5.47	5.00	3.75	4.05	4.70	4.82	4.72	0.62
	spring	5.47	6.00	5.20	4.15	4.48	4.46	5.12	4.98	0.65
	summer	4.80	5.00	4.70	3.45	3.73	5.45	4.38	4.50	0.71
	autumn	5.80	6.42	5.53	4.52	4.92	5.12	5.33	5.38	0.62
Mean		5.32	5.72	5.11	3.97	4.30	4.93	4.91	4.89	0.65
St.Dev.		0.42	0.42	0.62	0.35	0.47	0.52	0.44	0.41	0.38
COD (mgO2/l)	winter	1.90	1.96	1.18	0.73	1.02	1.30	1.30	1.34	0.45
	spring	2.43	2.31	2.20	1.22	1.18	1.33	1.78	1.78	0.54
	summer	0.70	0.73	0.68	0.60	0.64	0.71	0.73	0.68	0.05
	autumn	2.77	3.20	3.00	1.38	1.57	1.57	2.00	2.21	0.76
Mean		1.95	2.05	1.77	0.98	1.10	1.23	1.45	1.50	0.45
St.Dev.		0.91	0.91	1.02	1.04	0.38	0.39	0.37	0.56	0.65
BOD (mgO2/l)	winter	2.74	2.99	2.79	2.15	2.45	2.63	2.38	2.59	0.28
	spring	3.23	3.36	3.06	2.30	2.74	2.81	3.14	2.95	0.36
	summer	2.65	2.75	2.00	1.76	1.85	2.04	2.16	2.17	0.38
	autumn	3.38	3.78	3.66	2.58	2.93	3.00	3.45	3.25	0.43
Mean		3.00	3.22	2.88	2.20	2.49	2.62	2.78	2.74	0.36
St.Dev.		0.36	0.36	0.45	0.69	0.34	0.47	0.42	0.61	0.47

Salinity (‰): The maximal 42.10 ‰ was recorded at station VI during summer with mean 41.44‰, SD +_0.6. The low salinity values were detected during winter reached 39.14‰ at St. I with mean 39.45 ‰, SD +_0.39.

Hydrogen ion concentration (pH): pH value of seawater has a narrow limit with mean 8.13, SD +_0..08 The variations in the pH values were relatively very low at the different stations as well as during the different seasons.

Dissolved oxygen (DO): The value of the dissolved oxygen of the surface seawater decreased to 3.45 mgO_2 /l at station IV in summer (mean 4.50 mgO_2/l, SD +_0.71) and the maximum value was 6.42 mgO_2/l at station II during autumn (mean 5.38 mgO_2/l, SD +_0.63).

Chemical oxygen demand (COD): During autumn the value of COD was relatively high (~3.1 mgO_2/l) at Sts. II and III with mean 2.21 mgO_2/l, SD +_0.76. These values decreased to 0.68 and 0.6 mgO_2/l at Sts. III and IV respectively during summer with mean 0.68 mgO_2/l, SD +_0.05.

Biological oxygen demand (BOD): The value of BOD varied between 2.58 mgO_2/l at St. IV and 3.78 mgO_2/l at St. II during autumn with mean 3.25 mgO_2/l, SD +_0.43. Its value declined to1.76 mgO_2/l at station IV during summer (mean 2.17 mgO_2/l, SD +_0.38).

Heavy metals in sea water (ug/l):

Cadmium (Cd): The concentration of cadmium in shallow waters was higher during winter season measured 1.3 ug/l at St. I with mean 0.79 ug/l, SD +_0.49 (Table 2). Its value dropped to 0.07 - 0.11 ug/l during summer with mean 0.09 ug/l, SD +_0.02.

Copper (Cu): The concentration of copper in water at St. VII declined to 0.29 ug/l during summer (mean 0.65 ug/l, SD +_0.29), while the maximum value was 4.57 ug/l at station IV during winter with mean 2.12 ug/l, SD +_1.36.

Lead (Pb): Also concentration of lead was high during winter reached 4.36 ug/l at St. IV (mean 2.08 ug/l, SD +_1.34) and the lower value was 0.40 ug/l at St. VII during summer with mean 0.78 ug/l, SD +_0.34.

Zinc (Zn): During winter the concentration of Zn in seawater was maximum (22.85 ug./l, with mean 14.53 ug/l, SD +_5.03) at St. IV during winter, while the low value was 5.45 ug/l (mean 8.89 ug/l, SD +_2.92) at St. VII during summer.

Iron (Fe): Iron content in water was minimal with 1.88 ug/l at station VII during summer (mean 4.09 ug/l, SD +_1.73) and maximum value of 17.0 ug/l at station IV during winter (9.62 ug/l, SD +_4.23).

Cobalt (Co): Cobalt content in seawater measured 0.28 ug/l at station II during summer with mean 0.35 ug/l, SD +_0.06 and it raised up to 2.57 ug/l at station I during winter with mean 1.40 ug/l, SD +_0.70.

Heavy metals in sediments (ppm dry weight):

Cadmium (Cd): The content of cadmium in sediments of shallow intertidal region during May 1995 showed insignificant values (Table 3), which varied from 0.70 ppm at St. VI to 2.30 ppm at St. I with mean 1.43 ppm, SD +_0.53.

Table 2. Seasonal variations in the values of the different heavy metals of the surface seawater at the western coast of the Suez Gulf during May 1995 to April 1996.

Param.	Seasons	I	II	III	IV	V	VI	VII	Mean	St..Dev.
Cadmium (Cd)	Winter	1.30	0.38	0.82	1.60	0.67	0.42	0.31	0.79	0.49
	Spring	0.27	0.21	0.23	0.33	0.22	0.26	0.71	0.32	0.18
	Summer	0.11	0.08	0.08	0.13	0.07	0.11	0.07	0.09	0.02
	Autumn	0.16	0.13	0.11	0.15	0.09	0.18	0.10	0.13	0.03
Mean		0.46	0.20	0.31	0.55	0.26	0.24	0.30	0.33	0.18
St.Dev.		0.56	0.13	0.35	0.70	0.28	0.13	0.30	0.35	0.21
Copper (Cu)	Winter	3.16	1.11	2.33	4.57	1.78	1.14	0.78	2.12	1.36
	Spring	2.44	0.81	1.46	2.38	1.45	0.95	0.67	1.45	0.72
	Summer	0.98	0.42	1.11	0.61	0.55	0.61	0.29	0.65	0.29
	Autumn	1.05	0.66	1.55	0.94	0.88	0.72	0.51	0.90	0.34
Mean		1.91	0.75	1.61	2.13	1.17	0.86	0.56	1.28	0.61
St.Dev.		1.07	0.29	0.51	1.80	0.55	0.24	0.21	0.67	0.58
Lead (Pb)	Winter	3.05	0.83	2.55	4.36	1.88	1.22	0.65	2.08	1.34
	Spring	2.08	0.71	1.71	2.58	1.22	1.00	0.55	1.41	0.75
	Summer	1.20	0.41	0.81	1.25	0.72	0.66	0.40	0.78	0.34
	Autumn	1.85	0.62	1.33	2.08	0.85	0.80	0.46	1.14	0.63
Mean		2.05	0.64	1.60	2.57	1.17	0.92	0.52	1.35	0.76
St.Dev.		0.77	0.18	0.73	1.31	0.52	0.24	0.11	0.55	0.43
Zinc (Zn)	Winter	18.83	10.33	16.04	22.85	13.33	11.71	8.62	14.53	5.03
	Spring	15.87	9.41	13.86	20.33	11.22	10.22	7.82	12.68	4.33
	Summer	10.22	6.22	10.62	13.86	8.66	7.22	5.45	8.89	2.92
	Autumn	13.45	7.78	12.11	16.04	10.11	8.77	6.21	10.64	3.44
Mean		14.59	8.44	13.16	18.27	10.83	9.48	7.03	11.68	3.91
St.Dev.		3.65	1.81	2.33	4.07	1.97	1.93	1.45	2.46	1.00
Iron (Fe)	Winter	12.88	5.68	10.11	17.00	8.87	8.00	4.81	9.62	4.23
	Spring	10.68	4.28	8.65	12.11	7.72	7.11	3.29	7.69	3.18
	Summer	5.55	2.78	4.33	7.00	3.85	3.26	1.88	4.09	1.73
	Autumn	7.79	3.33	5.59	9.72	4.82	4.20	2.34	5.40	2.58
Mean		9.23	4.02	7.17	11.46	6.32	5.64	3.08	6.70	6.34
St.Dev.		3.22	1.27	2.67	4.24	2.37	2.27	1.29	2.45	1.05
Cobalt (Co)	Winter	2.57	1.00	1.28	1.93	1.65	0.84	0.56	1.40	0.70
	Spring	0.40	0.32	0.37	0.40	0.24	0.64	0.40	0.40	0.12
	Summer	0.32	0.28	0.32	0.36	0.38	0.46	0.35	0.35	0.06
	Autumn	0.36	0.33	0.34	0.38	0.45	0.54	0.42	0.40	0.07
Mean		0.91	0.48	0.58	0.77	0.68	0.62	0.43	0.64	0.60
St.Dev.		1.11	0.35	0.47	0.78	0.65	0.16	0.09	0.51	0.31

Copper (Cu): Copper content in sediments fluctuated from low value 0.56 ppm at St. VI to the high value 13.94 ppm at St. I with mean 5.30 ppm, SD +_5.18. Copper is an important trace constituent in clay. It is an essential element; therefore, its uptake by marine biota may be increased with high temperature.

Lead (Pb): A wide variation was noticed for Pb content in sediments that ranged from 5.33 (at station VI) to 42.15 ppm (at station III) with mean 21.11 ppm, SD +_12.49. The concentration of lead in sediments of Suez Gulf, from the Red Sea is higher than other Egyptian areas (Beltagy, 1984), but it lies within the concentration of the unpolluted sediment, as recorded by GESAMP (1982).

Zinc (Zn): The zinc content in sediment measured maximal of 0.82 ppm at St. I and minimal of 0.50 ppm at St. II with mean 71.0 ppm, SD +_15.03.

Iron (Fe): Concentrations of Fe in sediments showed high values at the sampling sites which increased up to 149.08 ppm at St. VII and droped to only 13.97 ppm at St. II with mean 100.17 ppm, SD +_53.89.

Cobalt (Co): Cobalt content in sediments was lowest 1.0 ppm at station VI and the high value reached 4.67 ppm at station II (mean 3.1 ppm, SD +_1.28).

Organic matter in sediment:

The percentage of organic matter content in sediments is one of the most important sediment components that ranged from 0.5 % (at St. II) to 2.67 % (at St. I) with mean 1.62, SD +_1.05 (Tables 3 and 4).

Carbonate content ($CaCO_3$): The percentage of carbonate content in sediments was very low at St. VI (13.33 %) and the highest ones was recorded at St. III (97.33%) with mean 65.62, SD +_31.16.

Sediment particle size composition: The sediments texture was composed mainly of median sand with 77.73 % of the total grain size while low percentage was 44.11 % at St. V (mean 58.51, SD +_11.65). At station V the sediment texture fluctuated between coarse sand, fine sand and median sand with a maximal value of 20.75 %, 26.22 % and 44.37 % respectively. The grain size analysis at 15-meter distance from the shoreline revealed that the dominant type of sediment is the median sand, which fluctuated from 43.45 % and 77.77 % at Sts. V and II respectively.

State of pollution:

The degree of pollution was estimated from the field observations as the percentage coverage of oil and litter inside each frame on the backshore area. Also the type of oiling (patchy, thin films, tar balls), the degree of oiling (light, medium, heavy) and the age of oiling (fresh, aged) were determined. It was observed that the middle part of Suez Gulf was in general highly polluted where the area surrounding the oil production localities of Adabiya, Zaafarana and Gabal El- Zeit. The area of Zaafarana is a zone of intense aged oil patches accumulation, with large percentage covering about 80 % of the shoreline area. On the other hand, occurrence of litter was found more at Sts. IV and VII than at Sts. II and V.

Table 3. Fluctuation in the values of the different heavy metals in the sediments at the western coast of the Suez Gulf during May 1995.

Cd		2.30	1.16	1.15	1.51	1.88	0.70	1.30	1.43	0.53
Cu		13.94	3.96	4.38	0.71	2.56	0.56	11.00	5.30	5.18
Pb	Sed.	20.16	33.24	42.15	16.85	13.69	5.33	16.33	21.11	12.49
Zn		82.0	50.0	90.0	63.0	79.0	55.0	78.0	71.00	15.03
Fe		116.5	13.97	144.5	87.37	44.16	145.64	149.08	100.17	53.89
Co		3.67	4.68	2.00	3.67	4.00	1.00	2.67	3.10	1.28
% Med.Sand		68.67	77.73	48.85	58.36	44.11	52.19	59.65	58.51	11.65
% Fine Sand		18.18	16.15	20.02	3.85	27.73	9.7	15.12	15.82	7.60
% Org.matt.	Sed.	2.67	0.50	2.47	0.37	1.97	0.73	2.63	1.62	1.05
% Carbonate		29.33	82.00	97.33	76.33	73.00	13.33	88.00	65.62	31.61

Table 4. Sediments particle size, organic matter and carbonate for the different stations along the western coast of the Suez Gulf during May 1995.

St.	Size class Distance from shore line	% gravel (> 2mm)	% very coarse sand (2-1mm)	% coarse sand (1-0.5 mm)	% median sand (0.5-0.25 mm)	% fine sand (0.25-0.125 mm)	% very fine sand (0.125-0.063 mm)	%silt and clay < 0.063 mm	% organic matter	% carbonate
	5 meters	-	3.39	8.5	68.43	19.8	0.28	-	0.9	25
I	10 meters	-	3.8	9.05	68.71	17.65	0.1	0.69	3.1	28
	15 meters	-	3.45	8.93	68.88	17.1	0.54	2	4	35
	5 meters	-	2.45	3.6	77.67	16.24	0.04	-	0.2	80
II	10 meters	-	2.23	3.63	77.74	16.2	0.2	-	0.6	82
	15 meters	-	2.04	3.94	77.77	16	0.25	-	0.7	84
	5 meters	0.68	12.73	16.9	51.11	18.17	0.19	0.01	1.8	78
III	10 meters	-	10.68	19.85	49.1	20.14	0.23	0.02	2.1	79
	15 meters	-	10.35	19.8	46.35	21.74	0.65	0.21	3.5	81
	5 meters	0.04	0.5	37.2	58.35	3.84	0.07	-	0.3	75
IV	10 meters	-	0.52	37.22	58.35	3.84	0.07	-	0.3	76
	15 meters	-	0.52	37.24	58.37	3.88	0.09	-	0.5	78
	5 meters	-	8.5	20.75	44.37	26.33	0.16	0.01	1.6	71
V	10 meters	-	6.44	20.66	44.5	28.15	0.22	0.03	2	73
	15 meters	-	6.67	20.52	43.45	28.72	0.54	0.01	2.3	75
	5 meters	0.32	8.33	30.44	53.09	7.68	0.14	-	0.6	11
VI	10 meters	-	8.25	30.2	52.11	9.25	0.19	-	0.7	13
	15 meters	-	5.92	30	51.38	12.17	0.53	-	0.9	16
	5 meters	-	3.5	21.11	60.75	15.27	0.36	-	0.9	85
VII	10 meters	-	3.22	21.1	59.41	15	0.27	1	3.25	88
	15 meters	-	3.01	21	58.8	15.1	0.44	1.75	3.75	91

Nature of substratum:

The intertidal area exhibits a wide variation in nature of substrate. Hard bottom represents about 25 % of the total substrates. The intertidal zone of the western coast of Suez Gulf is usually extended to a wide distance of 40m from the shoreline. Sandy bottom located at Sts. I, II and IV and silty bottom was found at Sts. III and V.

Macrobenthic communities: The benthic fauna assemblages in the shallow intertidal waters did not greatly differ at the sampling sites and during the periods of collections (Fig. 2). Mollusca dominated the bottom fauna communities both in their species compositions and their intensities that were represented with 87.6%, while the other groups yielded 0.3 to 2.4% of a total number individuals (Table 5). The abundance of benthic fauna at the sampling sites was recorded in high density at Sts. IV (Ras Gharib) and VII (Hurghada) yielding 148 ind./m^2 and 144 ind./m^2 respectively with mean 80 ind./m^2, SD +_63.4). On the other hand, benthos biomass was denser at Sts. II (El-Ein El-Sukhnas), IV, and VI (Gabal El-Zeit) which attaining respectively 146.7, 318.8 and 165.4 g/m^2 with mean 147.9 g/m^2, SD +_81.0. The changes in the total abundance were relatively high during spring and summer seasons attaining about 30% of the total number of recorded bottom fauna. At St. IV the intensity of gastropods was highest which numbered 116 ind./m^2 (mean 58.8 ind./m^2, SD +_46.02) and weighted 70.28 g/m^2 (mean 76.33 g/m^2, SD +_77.2). High contribution of gastropods and bivalves communities were recorded seasonally and regionally in the numerical abundance and wet weight of bottom fauna collected from the various sampling sites. *Patella caerula* is considered one of the main constituents of the gastropods habits the rocky surfaces in the infratidal zone. Its density reached 11.3 ind./m^2 at St. II and 13 ind./m^2 at St. IV (mean 8.2 ind./m^2, SD +_4.41). Its corresponding biomasses were 18.53 g/m^2 and 33.41 g/m^2 (mean 7.8 g/m^2, SD +_13.12).

It was noticed that the total biomass of invertebrates in the intertidal zone along the western coast of Suez Gulf could be arranged in the following sequence – Gastropoda > Bivalvia > other bottom fauna > *P. caerulea.* The intensity levels of the bottom fauna at the different stations were higher at Sts. IV and VII rather than the remainder stations while their occurrence was during spring > autumn > winter > summer.

Statistical analyses:

Linear regression analysis: The correlation between the hydrographical condition data revealed more significant by using the square matrix at the 95% confidence [Pearson correlation coefficient (r)] at P level < 0.05 indicated some significances (Table 7).

The salinity of seawater is significantly and correlated negatively with the heavy metals concentrations in water.

The value of seawater`s pH is positively correlated with the Cu, Pb, Zn and Fe in water.

The contents of COD and BOD in water are significantly and correlated positively with DO in water while BOD is correlated positively with COD in water.

The content of cobalt in sediments is significantly and correlated negatively with the content of Fe in sediments.

The percentage of organic matter in sediments is correlated positively with the contents of Cu and Zn in sediments.

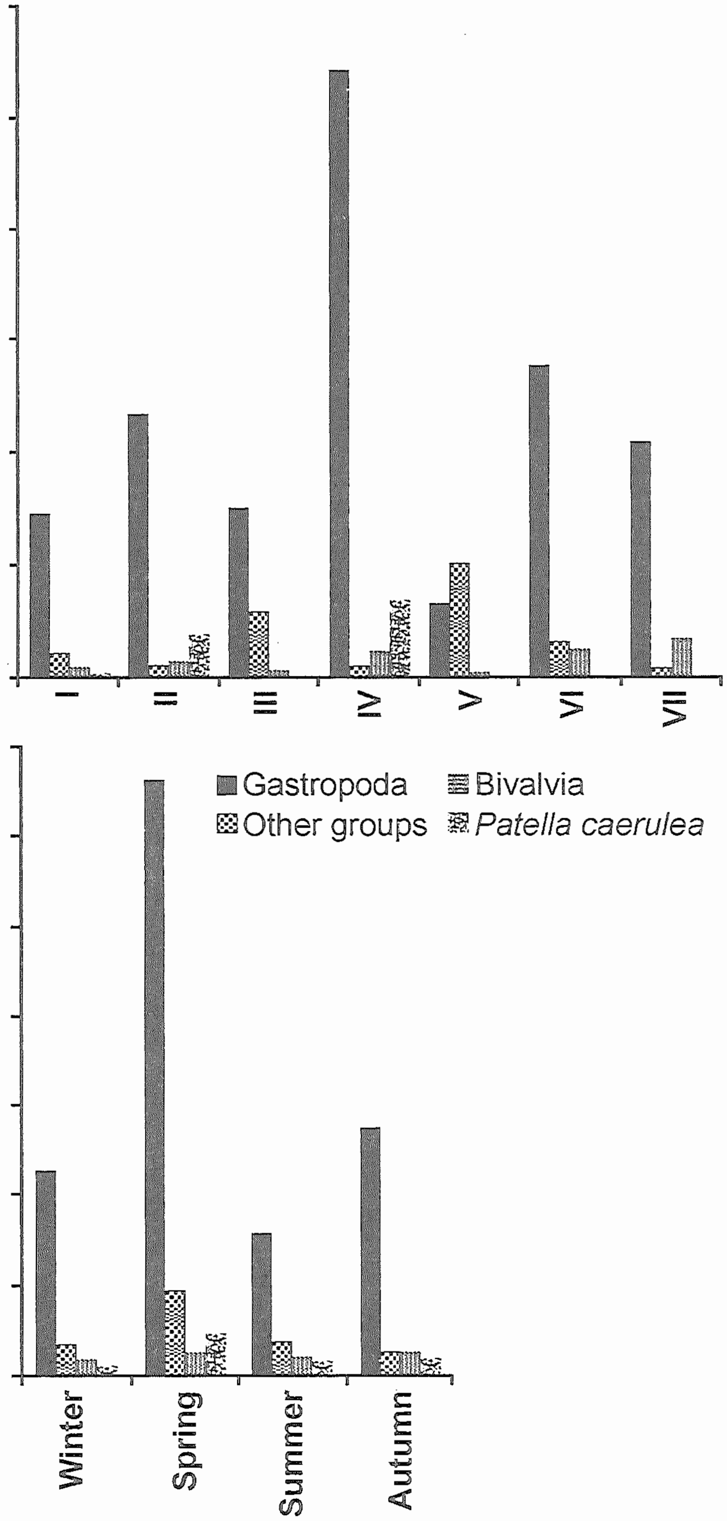

Fig. 2. The regional and seasonal variations of the benthos group's biomass (g/m^2) in the shallow intertidal waters at the sampling sites along the western coast of the Suez Gulf during May 1995 to April 1996.

Multivariate analysis:

Principal Component Analysis (PCA): The extraction of principal component of the physiochemical parameters of seawater and sediments in shallow intertidal region at the study areas are shown in Table 8. The factor loadings of PCA of hydrographical parameters indicated that salinity is negatively correlated among the component of factor 1 while pH is positively correlated. On the hand, the concentration of heavy metals (Cd, Cu, Pb, Zn Fe, Co) in water are highly positively correlated and contributed to the content of the factor 1. The component of factor 2 showed negative correlation to only two parameters namely DOC and Cu content in sediments. The proportional of the percentage of total variance of the first three factors is 73.16% (Table 8), while the components of factor 1 account for 35.94% of the variance in the system that is larger than variance of factor 2. The factor scores of PCA indicates that the highest scores (> 1.0) contribute to

Table 5. The total abundance (as mean of no. ind. /m² during different seasons) of main benthic groups recorded at the sampling stations along the western coast of the Suez Gulf through year 1995.

Parameters/stat.	I	II	III	IV	V	VI	VII	Mean	Sd.Dev.	%
Rhizostoma	0.5	0.8	0.0	0.0	0.0	0.0	0.3	0.2	0.32	0.3%
Polychaeta	3.8	2.3	0.5	1.8	0.0	1.75	1.3	1.6	1.24	2.0%
Cirripedia	1.5	0.0	1.0	2.5	0.0	1.3	0.3	0.9	0.92	1.2%
Amphipoda	3.0	1.0	0.8	1.3	1.3	3.8	2.3	1.9	1.13	2.4%
Isopoda	2.0	0.8	0.8	0.8	1.0	2.5	1.8	1.4	0.70	1.7%
Decapoda	0.3	1.0	0.0	0.8	0.3	1.3	5.5	1.3	1.90	1.6%
Polyplacophora	0.3	1.8	0.0	0.0	0.3	0.0	1.5	0.5	0.76	0.7%
Gastropoda	33.0	73.8	16.6	116.0	5.6	46.5	120.3	58.8	46.02	73.8%
Bivalvia	14.3	2.0	11.5	11.8	6.5	4.8	6.5	8.2	4.41	10.3%
Patella caerulea	1.3	11.3	1.3	13.0	0.0	0.0	3.8	4.4	5.48	5.5%
Echinodermata	0.0	1.3	0.3	0.3	0.0	1.0	0.8	0.5	0.51	0.6%
Total no. ind. /m²	59.8	95.8	32.6	148.0	14.8	62.8	144.0	80	63.4	100%
%	10.8%	17.3%	5.9%	26.8%	2.7%	11.3%	26.0%			
No. of spp.	36	26	19	25	15	28	46			

Table 6. The total weight (g/m²) of gastropods, bivalves, bottom fauna and *Patella caerulea* at the different stations along the western coast of the Suez Gulf.

groups	I	II	III	IV	V	VI	VII	Mean	Sd.dev.	%
Gastropoda	72.70	116.58	74.97	270.28	32.60	138.22	103.82	115.59	76.33	78.2%
Bivalvia	10.19	4.57	29.13	4.40	49.55	15.43	3.54	16.69	17.07	11.3%
Bottom fauna	4.08	7.04	2.98	10.69	1.21	11.74	16.31	7.72	5.44	5.2%
Patella caerulea	1.39	18.53	0.83	33.41	0.00	0.00	0.71	7.84	13.12	5.3%
Biomass g/m²	88.4	146.7	107.9	318.8	83.4	165.4	124.4	147.9	81.0	
% of biomass	8.5%	14.2%	10.4%	30.8%	8.1%	16.0%	12.0%			
Total no. ind./ m²	59.8	95.8	32.6	148.0	14.8	62.8	144.0	79.9	63.4	
No. of spp.	36	26	19	25	15	28	46	27.9	10.4	
A / S	1.7	3.7	1.7	5.9	1.0	2.2	3.1	2.8	1.8	
B / A	1.5	1.5	3.3	2.2	5.6	2.6	0.9	2.5	1.6	

Table 7. **Correlation between the different hydrographical parameters of the shallow intertidal waters and sediments at the sampling sites along the Suez Gulf during May 1995 to April 1996 r= Pearson correlation coefficient (marked correlations are significant at $p < 0.005$).**

Parameters	Temp	Salinity	pH	DO2	COD	Cd-wa	Cu-wa	Pb-wa	Zn-wa	Fe-wa	Cu-sed	Zn-sed	Fe-sed
COD				0.957 p=.001									
BOD				0.995 p=.000	0.95 p=.001								
Cd-wa		-0.877 p=.010											
Cu-wa		-0.846 p=.016	0.781 p=.038			0.962 p=.001							
Pb-wa		-0.845 p=.017	0.843 p=.017			0.985 p=.000	0.99 p=.000						
Zn-wa		-0.819 p=.024	0.878 p=.009			0.977 p=.000	0.983 p=.000	0.995 p=.000					
Fe-wa		-0.808 p=.028	0.843 p=.017			0.984 p=.000	0.976 p=.000	0.991 p=.000	0.99 p=.000				
C0-wa		-0.779 p=.039				0.847 p=.016	0.834 p=.020	0.822 p=.023	0.786 p=.036	0.852 p=.015			
Cd-sed													-0.848 p=.016
%Org.m											0.755 p=.050	0.904 p=.005	

the component of factor 1 is at St. IV and it negatively correlated at Sts II and VII while, it is positively at St. VI and negatively at St. I.

Table 8. Extraction of principal components Eigenvalues, factor loading and factor scores. Extraction: Principal components.

		% total	Cumul.	Cumul.									
Fgactors	Eigenval	Variance	Eigenval	%									
1	7.91	35.94	7.91	35.94					Factor loadings				
2	4.78	21.74	12.69	57.68					Extraction: Principal components				
3	3.41	15.48	16.09	73.16					Marked loadings				
4	2.42	11.00	18.51	84.16					are > 0.007				
5	1.70	7.71	20.21	91.87									
6	1.03	4.67	21.24	96.54									
Factor	Factor	Factor	Factor	Factor	Factor	Factor		Fact.	Fact.	Fact.	Factor	Fact.	Fact.
Loading	1	2	3	4	5	6		Scores	1	2	3	4	5
TEMPERATURE	-0.30	0.45	0.55	-0.54	0.14	0.25		ST_I	0.87	-1.78	-0.52	0.81	-0.65
SALINITY	-0.79	0.51	-0.24	0.01	0.03	-0.16		ST_II	-1.10	-0.39	1.89	0.50	-0.08
PH	0.82	0.27	0.33	-0.05	0.30	0.09		ST_III	-0.02	-0.45	-0.56	-0.58	1.84
DO2	-0.55	-0.67	0.19	0.36	0.17	-0.11		ST_IV	1.73	0.97	0.91	-0.13	0.37
DOC	-0.34	-0.82	0.24	0.25	0.23	-0.11		ST_V	-0.02	0.28	-0.26	-1.52	-1.44
BOD	-0.58	-0.69	0.17	0.29	0.12	-0.13		ST_VI	-0.39	1.30	-0.94	1.51	-0.26
CD_WA	0.96	-0.12	0.10	0.10	0.06	0.04		ST_VII	-1.07	0.06	-0.52	-0.57	0.22
CU_WA	0.93	-0.21	0.00	-0.01	0.17	-0.14							
PB_WA	0.96	-0.12	0.03	0.00	0.15	-0.04							
ZN_WA	0.95	-0.06	0.09	-0.01	0.18	-0.09							
FE_WA	0.97	-0.04	0.03	0.05	0.07	-0.09							
CO_WA	0.84	-0.28	-0.17	0.18	-0.32	-0.14							
CD_SED	0.49	-0.63	-0.03	-0.30	-0.47	0.13							
CU_SED	-0.10	-0.79	-0.26	0.04	-0.08	0.51							
PB_SED	-0.13	-0.51	0.35	-0.21	0.66	-0.32							
ZN_SED	0.18	-0.49	-0.58	-0.56	0.22	0.01							
FE_SED	0.05	0.05	-0.78	0.22	0.46	0.31							
CO_SED	0.13	-0.39	0.73	-0.31	-0.40	0.06							
%ORG_MAT	-0.12	-0.62	-0.62	-0.39	0.07	0.17							
%CARBONATE	-0.21	-0.02	0.51	-0.72	0.33	0.21							
%MED_SAN	-0.15	-0.46	0.63	0.49	-0.05	0.32							
%FIN_SAN	-0.34	-0.48	-0.23	-0.55	-0.30	-0.43							
Expl.Var	7.91	4.78	3.41	2.42	1.70	1.03							
Prp.Totl	0.36	0.22	0.15	0.11	0.08	0.05							

DISCUSSION

The physicochemical parameters of seawater and sediments at the sampling sites along the Gulf of Suez are characterized by higher values of temperature and salinity of water in the south region than those in the north region. According to Talling (1976) water temperature depends upon various factors including radiation`s income, surface exchange with air temperature, back radiation and latent heat of evaporation. The salinity depends upon influences of temperature, the turbulence in water column and topography of area (Abdel Salam, 1981).

The Suez Gulf is strongly influenced by the northwesterly winds which drive the surface waters into the Red Sea (Morcos, 1970) showing the temperate character of the gulf with seasonal temperature changes markedly affected with the surrounding land. In contrast, the Red Sea and Gulf of Aqaba have deeper water with narrow, shallow marginal shelves and steep walls plunging 500-1800 m to the deeper floor. Therefore, the large water volume avoids them from the impacts of the surrounding lands and so that the environmental variations are not as seasonal or extreme as in the Suez Gulf (Fishelson, 1971; Morcos, 1970).

The maximum dissolved oxygen was shown during autumn with a value of 6.42 mgO_2/l at station II and the minimum value was 3.45 mgO_2/l at station IV during summer. It`s high value in winter and spring and it`s low value in summer attributed to a good mixing in the water column (Girgis, 1980) while the slight increase in dissolved oxygen content during winter and spring is due to the increase of oxygen solubility (Ross, 1977). However, the oxygen concentration in the Red Sea was relatively low because of its higher salinity and the hot characteristic of the area.

Heavy metals pollution, particularly involving lead and cadmium, have become serious problems (Lasheen, 1987; Sillanpaa and Jansson, 1992; Ali, 1993). Cadmium level is relatively high due to the presence of many oil fields along the western coast of the gulf. These results coincide with El-Moselhy (1993). The photic zone affects cadmium reduction in the upper water layer to increase the productivity of phytoplankton (Simpson, 1981). In the present investigation, cadmium appears to be lower in summer (0.07, 0.11 and 0.13 at stations VII, I and IV respectively), which is affected by municipal sewage making a good habitat for growing the phytoplankton and algae.

The concentration of copper in seawater show high level at St. IV (4.57 ug/l), which is exposed to sewage and petroleum hydrocarbons and its level was 3.16 ug/l at St. I due to the corrosion of ships , hulls coating with anti- fouling paint. Most antifouling paints contain about 100 to 200 gm of cupric oxide/liter (GESAMP, 1982). On the other hand, copper is essential element for marine biota that increased with high temperature.

Data analyses of heavy metals indicated that the seasonal variations of the trace elements might attribute to consuming of these elements by different marine organisms to decomposing of dead organic matter and to transporting air-borne material to the sea by strong winds during wintertime.

Due to the materialization and oil activities the cadmium content in sediments was higher in summer than in winter. This may be attributed to the precipitate of decomposed organic matter, which is increase with high temperature. Cadmium content showed a higher value (2.30 ppm) at station I due to the oil activities besides sewage discharge and domestic drainage of Suez City.

EL-Moselhy (1993) found that the content of lead in sediments was lower in the southern part than in the northern part of the Gulf of Suez, Suez Bay. This may attribute to the high amount of suspended organic matter coming from the municipal sewage of Suez City and other industrial wastes that precipitate on the bottom. The present study declared that the concentration of Pb in sediments of the Suez Gulf is higher than other Egyptian sites and this agrees with Beltagy (1984), GESAMP (1982) and EL-Moselhy (1993).

The concentration of zinc attained higher level at station III and the lower level at station II. It plays an important role in the biology and geological processes where the optimum growth of phytoplankton is dependent on the adequate supply of essential heavy metals such as zinc. Its minimal values were in summer, due to the consumption by phytoplanktons that increase in spring and summer as stated by Salah (1959) and this may agree with Thompson *et al.* (1932) who reported that the removal of zinc from water is by phytoplankton, which spread in spring and summer.

It is evident that the grain size of the sediments is a determining factor for the organic carbon concentration. On one hand, sandy substrate enhances organic matter degradation processes. Trask (1932, 1939) mentioned that the organic matter content of sediment increases more or less progressively, as the constituent grains become finer. This concept coincides with the result of some of the present samples containing relatively more fine particles and slightly agrees with the majority of samples lacking the fine fraction in their sediment composition.

The carbonate content of the surface samples ranged between 11% and 85% of 5 meter from the shoreline. Very low carbonate concentrations (11%) are found at station VI. The environment in this area is highly polluted by sewage to the extent of impeding the growth of molluscs. Besides, the organic content result in the ultimate dissolution of transported calcareous matter. Precisely, the highest contents of carbonate are associated with the highest sand content (85%). Pelecypods, gastropods and their shell fragments together with foraminifer tests and ostracod shells are ubiquitous in the sand fraction.

Generally, the regional distribution of the organic matter shows an increase in the central part and a decrease in both the outside parts of the area under investigation. The distribution of organic matter in the sediments is dependent upon: a) the organic material supply which is either particulate transported from the Gulf of Suez or oil materials thrown out to the beach by waves, b) the temperature and aeration of sediments (rate of oxidation of the organic matter) and c) the hydrodynamic regime (El-Askary *et al.*, 1988).

The distribution of macrobenthos have source level of carbonate and organic in bottom sediments and the distribution of algae is not affected because the hydrocarbon is not essential to be found in soluble forms in water (Widdows *et al.*, 1982). According to Thorson (1960) and Connell (1961a) the distribution of animals and their species composition depend upon the nature of substrata that is affected by competition for space.

Rocky intertidal regions support much richer and more interesting fauna and flora than do sandy regions as recorded in Sts. IV, VI and VII of the western coast of the Suez Gulf of the north Red Sea ecosystem. Behairy *et al* (1992) reported that the reef growth increased markedly in the north Red Sea and declined in the south. They also reported that the main factor controlling coral reef development could be attributed to the water-cooling in winter and for high sedimentation in the Gulf of Suez.

The distribution of animals and the range of distribution of a species may be attributed to nature of substratum and presence of another species with similar requirement for their competition for space. (Connell 1961b). According to Thorson (1960) the bottom substratum is considered "master factor" responsible for the settling of nearly all-pelagic larvae of bottom in large quantities determining the composition of bottom fauna. The planktonic or pelagic organisms are more affecting with environmental conditions during shorter time rather than benthos population. The sandy and muddy sand intertidal areas sustained the lowest concentration of benthos. Therefore, it can be concluded that the distribution of these organisms in low counts along the shallow intertidal areas point to a pronounced pollution effect in the middle part of the gulf, adjacent to the area of petroleum companies.

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