

Physicochemical and Eutrophication Parameters of Coastal Water and Geochemical Characteristics of Bottom Sediments East of Rosetta Area, Mediterranean Sea, Egypt

Soaad E. El-Gohary, Hermine R. Zaki and Mona F. Elnaggar

National Institute of Oceanography and Fisheries, Kayet-Bay, Al-Anfoushy, Alexandria, Egypt

Abstract: This study serves as a base data to assess the future changes in the physicochemical characteristics of coastal surface water within the framework of building power plant station on the base-land opposite to the investigated area. Therefore this study aims to measure the physicochemical and eutrophication parameters, the grain size analysis and some heavy metals concentrations. The average water temperature was ($25.99 \pm 1.33^\circ\text{C}$), pH ranged from 7.62 to 7.97; Salinity average was ($37.992 \pm 1.38\text{psu}$) and Transparency was ($1.83 \pm 0.52\text{m}$). Dissolved oxygen, biochemical oxygen demand and chemical oxygen demand were ($9.586 \pm 2.37\text{mg/L}$), ($0.00535 \pm 0.06\text{mg/L}$) and ($1.0547 \pm 0.70\text{mg/L}$) respectively. Chlorophyll-a was ($0.0087 \pm 0.01\mu\text{g/L}$). Dissolved organic matter and total suspended matter were ($2.10 \pm 1.35\text{mg/L}$) and ($13.168 \pm 0.98\text{mg/L}$) respectively. Ammonium, nitrite and nitrate averages were ($0.324 \pm 0.269\mu\text{g/L}$), ($0.0200 \pm 0.023\mu\text{g/L}$) and ($0.0165 \pm 0.010\mu\text{g/L}$) respectively. Total nitrogen was ($2.83 \pm 0.788\mu\text{g/L}$). Salinity variations and pH values were significant. Oxygen measurements reveal well oxygenated water column. Dissolved inorganic nitrogen showed depletion in most locations and pointed out the following order $\text{NH}_4 > \text{NO}_2 > \text{NO}_3$ to classify the investigated area as oligotrophic and mesotrophic. Grain size analysis showed the dominance of mud.

Key words: Rosetta • Seawalls • Physicochemical Parameters • Nutrients • Sedimentological Characteristics

INTRODUCTION

Rosetta promontory is located in the eastern part of Abu-Qir Bay at about 60 km east to Alexandria. This region is considered as one of the most important areas of trade, agriculture, fishing and some industrial activities in Egypt. The promontory was formed by sediment delivered to the Mediterranean coast of Egypt by Rosetta branch of River Nile. Rosetta promontory has been subjected to the worst severe erosion, Frihy *et al.* [1]. The annual rates of shoreline change demonstrated higher erosion occurs adjacent to the Rosetta estuary. The totaled approximately 100m/yr before the construction of the two dolos seawalls in 1991, Frihy and Lotfy [2]. The seawalls were constructed inland and extend seaward to a length of 1.5 and 3.35km. The seawalls stand 6.75m above mean sea level, Frihy [3]. The two seawalls have succeeded in stopping the erosion along the tip of the promontory. Two small spits have been formed toward the main entrance of the Nile on both west and east of the Rosetta estuary. Submerged ebb tide sand bar "shoals" have formed directly in front of the estuary where the waves are breaking, Frihy and Geamai [4]. The area of study lies

under the effect of both discharge from Rosetta branch, as well as, the effect of Mediterranean Sea invasion in this area. However Rosetta branch receives considerable amounts of pollutants from agricultural areas and sewages. El-Gohary [5] pointed that, industry were identified as being the major source of water pollution in this area. The metal industries wastes represent about 50% of the total wastes discharges and industrial effluents, as well as, agricultural and domestic sewages constitute a real threat to the aquatic ecosystems, El-Bouraie *et al.* [6]. Previously, the Chemical characteristics of the eastern Mediterranean water have been studied on a limited basis, Yilmaz *et al.* Yacobi *et al.*, Kress and Herut, Fahmy, Fahmy and Abdel fattah [7-12].

MATERIALS AND METHODS

Area of Study: The area of study extends from Latitude $31^\circ 27.75'$ Longitude $29^\circ 29.89'$ to Lat. $31^\circ 29.15'$ Long $30^\circ 32.76'$ at about 15 km east of the Rosetta Estuary at the north-western coast of the Nile Delta on the Mediterranean Sea of Egypt (Fig. 1 and Table 1).

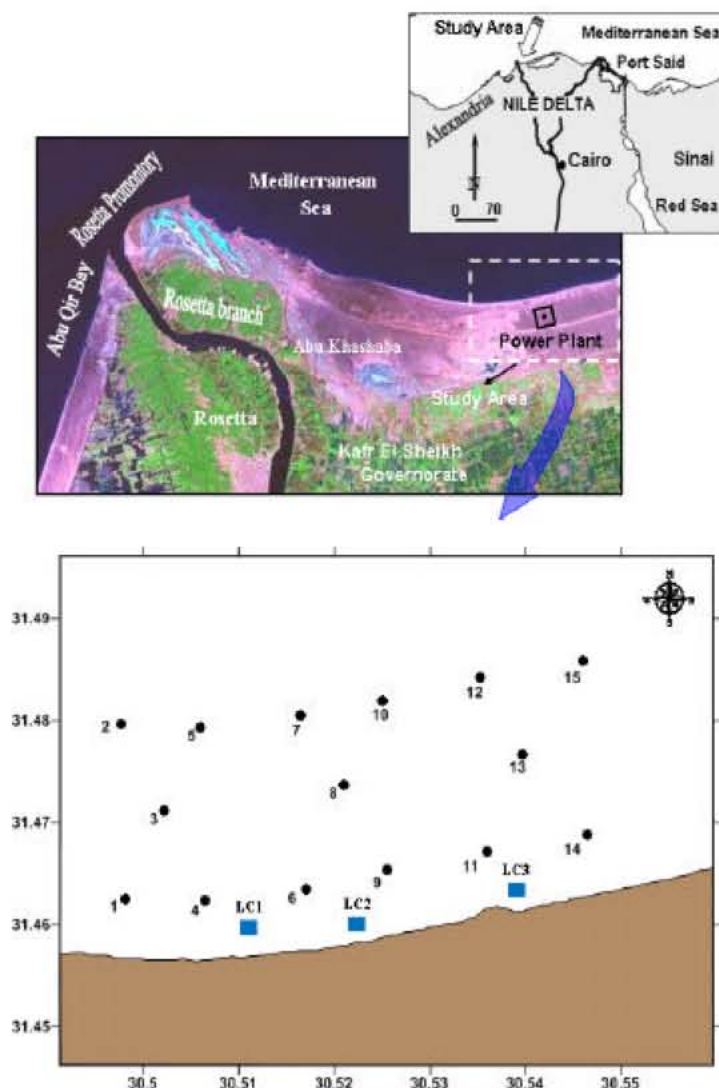


Fig. 1: Location map of water and sediment samples.

Table 1: Geographic coordinates of the collected seabed sediment samples as well as water samples

Station No.	Geographic coordinates		Water depth (m)
	Lat (°)	Long (°)	
1	31 27.75	30 29.89	-5
2	31 28.78	30 29.86	-10
3	31 28.27	30 30.13	-8.3
4	31 27.74	30 30.39	-5.5
5	31 27.76	30 30.36	-9.7
6	31 27.81	30 30.02	-6.5
7	31 28.83	30 30.99	-9.7
8	31 28.42	30 31.26	-8.0
9	31 27.92	30 31.53	-4.2
10	31 28.92	30 31.50	-9.2
11	31 28.03	30 32.16	-4.1
12	31 28.05	30 32.12	-9.3
13	31 28.60	30 32.38	-7.0
14	31 28.13	30 32.79	-3.6
15	31 29.15	30 32.76	-9.0

The present study aims to describe and measure the physicochemical and eutrophication parameters of surface water (NH_4 , NO_2 , NO_3 , TN, TP, TSM, PO_4 , SiO_4 , Chl-a and transparency), as well as, grain size analysis of the sediment samples and measure the concentrations of some heavy metals (Zn, Cr and Pb). The present data serve as a base data to assess the future changes in the physicochemical characteristics of the coastal water within the framework of building power plant station on the base-land opposite to the investigated area (Fig.1).

Sampling and Methods: Water sampling has been carried out in the framework of project of building power plant construction in the study area. The sampling took place in May 2010.

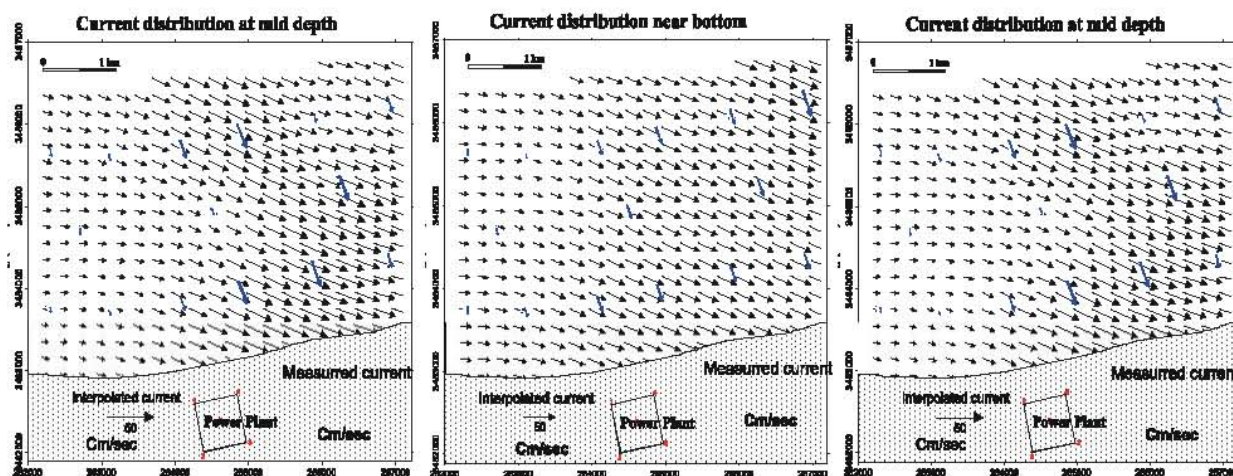


Fig. 2: Spatial distribution of measured currents (blue) and interpolated currents (black) at near surface, mid-depth and near-bottom. Current is mainly directed to the E and SE

Fifteen water samples, as well as, fifteen sediment samples have been collected. Water samples were collected in duplicate form from 20cm below the water surface and near bottom to avoid the floating materials, using a high quality PVC Niskens's bottle.

Table 1 lists geographic coordinates of these stations. Three stations (LC_1 , LC_2 and LC_3) were used to measure the long shore currents at each station Fig. 2 water depth measured by Eco-sounder and corrected relative to the mean sea level.

Water temperature, pH, salinity and transparency were obtained directly in the field from surface at each station using the Metter Toledo probes. These probe measurements were calibrated for each of these parameters following the procedures described by APHA [13].

Dissolved Oxygen (DO) and ammonium (NH_4-N) samples were collected first by Niskens's bottles then fixation was carried out for each sample just after collection. DO was determined on the same day of collection using the classical Winkler method, APHA [13]. COD was measured following the procedure described by Carlberg [14]. Transparency was measured using a white enameled Secchi disk.

Total suspended matter (TSM) was obtained from 3 liters water samples, which filtered through 0.45 μm membrane filters previously washed, dried and weighed. The filters with its contents were dried at 105°C until constant weight. The difference in the dry weight of filters before and after filtration was expressed in mg/L suspended matters.

Chlorophyll-a determination was performed in a volume of 3 liters water sample, which filtered in the same day of collection using 0.45 μm membrane filters. The filters were kept in the deep freezer until analysis. Chlorophyll-a in the phytoplankton cells retained on the filters was extracted using 90% acetone and measured spectrophotometrically at 630, 645, 665 and 750 nm wave lengths, Strickland and Parsons [15].

Ammonium was determined using the indophenols blue technique, IOC [16]. Nitrite, nitrate, reactive phosphate and silicate were determined in the filtered water samples (using GF/C filters) following the techniques described by Strickland and Parsons [15]. Total phosphorus and total nitrogen were estimated in unfiltered water samples, Valderrama [17]. Measurements of different nutrients and Chl-a were carried out spectrophotometrically using HACH DR-2000 direct reading spectrophotometer. Synthetic standards, as well as, international reference materials (Bach VKI 9-2-0894 for NH_4-N , NO_3-N and PO_4-P and bach10-2-0894 for TP and TN) were intended for quality control i.e. they typically intended for measurement and control of trueness and precision of analysis, as well as, for the optimization of analytical instruments and methods.

Total hydrocarbons (THC) was extracted from 2 liters water sample using a mixture of N-Hexane and dichloromethane, then purified, preconcentrated by rotavapor, then measured using the fluorometer, IOC [18]. THC was extracted from sediments with methanol and potassium hydroxide and separated with pentane then measured using the fluorometer. Chrysene was used as standards for total hydrocarbon measurements in water

and sediment samples, IOC [16]. Sediment samples were collected by grab sampler. The samples were transported to the laboratory and stored frozen until analysis. The seabed sediment sub-samples were analyzed to determine heavy metals. These heavy metals include chromium, lead and zinc. The heavy metals were determined in sediments following the methods, UNEP/IAEA [19]. Grain size analysis has been made according to Folk method [20]. The total carbonate content was determined according to Molenia method [21].

RESULTS AND DISCUSSIONS

Geochemical Characteristics of Bottom Sediments:

The grain size analysis, as well as, the geochemical analyses is listed in (Table 2). The investigated bottom sediments showed the dominance of mud as a significant component in sediments texture, whereas the prevailed textures include mud, sandy mud and muddy sand. According to Frihy *et al.* [22] textural and mineralogical distributions are attributable to processes that erode the mouth of the modern Rosetta branch, transport carbonate sediments derived from the Abu- Qir carbonate ridge and rework relict sediment from the former Canopic channel and its sub delta. Transport patterns interpreted on the basis of petrology complement information determined from measurement of bottom currents and longshore transport. Together, this information indicates that much of modern Abu-Qir Bay is a sediment sink on the Nile delta margin.

According to Summerhayes *et al.* [23] over the past 5000 years that sea level has been stable; there have been three phases of sedimentation. During the early or classical phase, several small distributaries discharged sediment through an arcuate, wave-dominated delta front; westerly currents forced plumes of suspended sediment east along the coast, causing the formation of a middle shelf mud belt and keeping the outer shelf virtually free of fines. In phase 2, over the past 500 years, discharge became confined to two distributaries, leading to coastal progradation at Rosetta and Damietta. As a result most sediment away from the Rosetta and Damietta Cones are probably relict or palimpsest. In phase 3, after construction of the Aswan High Dam in 1964, the river was dammed near its mouths and wave erosion began to cause serious coastal retreat at Rosetta and Damietta. The shoreline probably will continue to retreat until the delta front becomes once more smooth and arcuate.

The carbonate contents (Table 2) varied from 10.1% to 21% with an average of 15%. The carbonate diminish might be interpreted on the basis of fluvial supply of the river Nile to the area of study and also could be attributed to unsuitable conditions for the flourishing of the calcareous organisms in the area of investigation.

The total hydrocarbon measured in the bottom sediments are listed in Table 2 and illustrated in Fig. 3. The total hydrocarbon ranged from 2.6 μ g/ g in the western side of the study area and attained its maximum 28 μ g/ g in the eastern side with an average of 10.2 μ g/ g.

Table 2: Grain size and geochemical analyses of bottom samples

Station No.	Sand%	Mud%	Sediment type	Carbonate%	Total hydrocarbon (μ g/g)	Cr (μ g/g)	Pb (μ g/g)	Zn (μ g/g)
1	2.55	97.45	Mud	10.38	28	1.173	0.055	0.318
2	8.00	92.00	Mud	10.50	28.0	1.727	0.063	0.62
3	13.20	86.80	Sandy mud	14.27	8.1	0.998	0.065	0.588
4	42.10	57.90	Sandy mud	10.40	8.1	0.996	0.067	0.579
5	3.42	96.58	Mud	10.50	2.8	0.915	0.069	0.567
6	40.40	59.60	Sandy mud	20.79	8.8	0.908	0.069	0.480
7	7.70	92.30	Mud	10.50	8.0	0.905	0.070	0.42
8	36.40	63.60	Sandy mud	20.79	8.1	0.903	0.071	0.39
9	56.20	43.80	Muddy sand	20.10	8.1	0.91	0.075	0.398
10	65.72	34.58	Muddy sand	14.50	8.8	0.912	0.077	0.412
11	48.25	51.75	Sandy mud	20.20	8.8	0.920	0.081	0.472
12	66.03	33.97	Muddy sand	20.30	8.7	0.924	0.088	0.50
13	46.50	53.50	Sandy mud	21.00	8.2	0.926	0.09	0.53
14	36.60	63.40	Sandy mud	10.40	8.1	0.927	0.094	0.589
15	12.10	87.90	Sandy mud	10.10	2.6	0.940	0.164	0.470
Min	2.55	33.97		10.10	2.6	0.903	0.055	0.318
Maxim	66.03	97.45		21.00	28.0	1.727	0.164	0.62
Aver.	32.34	67.66		14.98	10.2	1.0	0.10	0.50

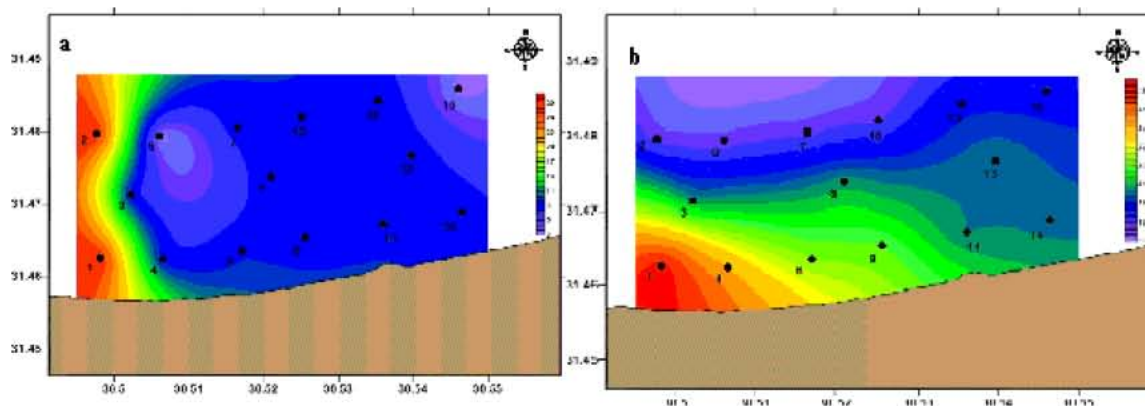


Fig. 3: Areal distribution of total hydrocarbon in sediment and water (a THC in sediment, b THC in water).

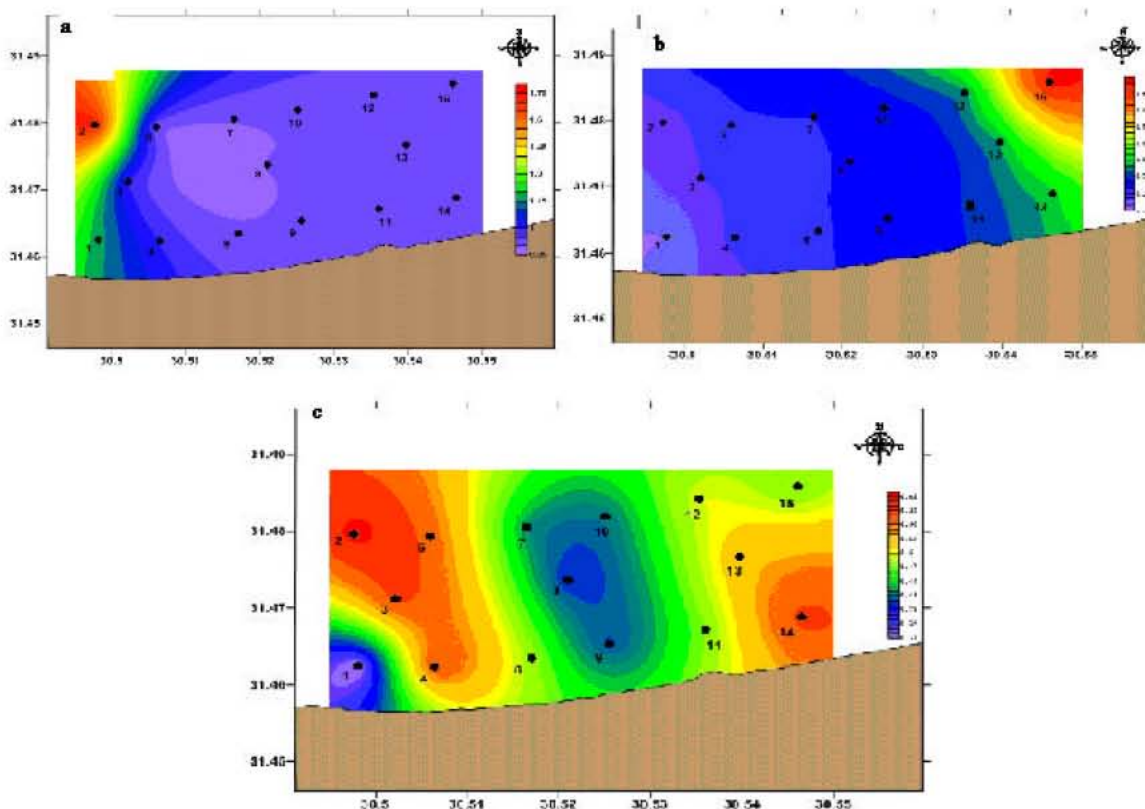


Fig. 4 a and b: areal distribution of Chromium and Lead in the bottom sediments: (a) Cr, (b) Pb.

Fig. 4 c: areal distribution of Zinc in bottom sediment.

This might be attributed to the current regime in the investigated area whereas the currents are mainly directed to the E and SE (Fig. 2). As seen in (Figure 3a), the spatial distribution of total hydrocarbon in the bottom sediments of the study area is systematically diminishes with distance toward the east. This could be attributed to the influx of fresh water discharged from Rosetta branch loaded with industrial and agricultural wastes, as well as, the wastes discharged from ships.

Fig. 3 b illustrates that, the real distribution of total hydrocarbon in water follows the same trend of increase westward. It might be interpreted on the basis of long shore currents which may be greatly affecting the transport of both water masses and sediments.

The distributions of measured heavy metals are listed in Table 2 and illustrated in Fig. 4 a and b. Chromium records its maximum concentration ($1.727 \mu\text{g/g}$) in the western side of the investigated area and the minimum

Table 3: physicochemical characteristics of water

Station No.	Water dep.(m)	Temp. °C	p H	S _{psu}	DO mg/L	COD mg/L	BOD mg/L	DOM mg/L	TSM mg/L	Chl -a µg/L	Trans(m)
1	5	29.99	7.92	34.15	11.61	1.06	0.01	1.92	11.92	0.016	1.2
2	10	26.16	7.7	37.31	9.72	1.55	0.02	3.52	12.82	0.022	1
3	8.3	25.88	7.78	37.75	10.21	1	0.01	1.8	12.85	0.005	1.5
4	5.3	26.2	7.82	37.82	9.72	0.45	0.02	0.81	12.88	0.016	2
5	9.7	25.6	7.82	38.22	9.72	0.45	0.02	0.81	12.9	0.005	2.2
6	6.5	25.6	7.91	38.52	9.72	1.05	0.015	1.9	12.91	0.004	2.5
7	9.7	26.31	7.92	37.03	10.53	0.45	0.01	0.81	12.7	0.005	2.25
8	8	25.93	7.62	37.66	10.69	2.84	0.09	5.12	12.9	0.0031	2.3
9	4.2	26.24	7.82	38.1	11.34	0.45	0.07	0.81	12.94	0.008	2.6
10	9.2	26.29	7.82	37.74	10.53	0.45	0.069	0.81	12.8	0.01	2.3
11	4.1	26.31	7.7	38.09	10.04	1.45	0.056	3.5	12.95	0.018	1.4
12	9.3	25.58	7.92	38.71	10.85	1.09	0.081	1.92	12.98	0.002	1.4
13	7	25.55	7.97	38.84	11.18	1.05	0.075	1.9	12.97	0.004	1.5
14	3.6	24.84	7.83	39.4	4.37	0.44	0.016	0.8	15.3	0.0067	1.3
15	9	23.44	7.8	40.55	3.56	2.04	0.24	3.68	15.7	0.0048	2
Min	3.6	23.44	7.62	34.15	3.56	0.44	0.01	0.8	11.92	0.002	1
Max	10	29.99	7.97	40.55	11.61	2.84	0.24	5.12	15.7	0.022	2.6
average	7.2	25.99	7.82		9.586	1.0547	0.053	2.1	13.168	0.0087	1.83
Std±	1.33	1.33	0.1		2.37	0.7	0.06	1.35	0.98	0.01	0.52

value (0.903µ g/ g) at the middle zone of the study area with an average of 1.0µg/ g. In contrast to chromium, lead attains its minimum value (0.055µg/ g) in the western side and the maximum (0.164 µ g/ g) in the eastern side with an average of 0.10µg/ g. An irregular distribution of Zinc is recorded Fig. 4c, whereas its maximum concentration 0.62µg/g in the western side and attains its minimum (0.318µg/ g) in the same side but with general trend of increasing eastward with an average of 0.50 µg/g.

Fig. 4 a and b: areal distribution of Chromium and Lead in the bottom sediments: (a) Cr, (b) Pb.

According to El-Bouraie *et al.* [6] Rosetta Branch of river Nile is subjected to severe pollutants of domestic, sewage, agricultural and industrial pollution. In their study, the distribution of heavy metals (Al, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) were measured in surface river water and the bed sediments of Rosetta Branch and the impacts of heavy metals on the water quality were monitored.

According to Rifaat [24] the major factors controls the distributions of metals in sediments of the Nile cone are: Factor 1 terrigenous mud -calcareous sand; Factor 2 Aragonite mud-terrigenous sand; Factor 3 Algal sand; and Factor 4 Aragonite.

Physicochemical and Eutrophication Parameters of Coastal Water

Physico-Chemical Parameters: Results of physicochemical characteristics of the collected water samples are summarized in Table 3.

Water Temperature: The water temperature was strictly related to seasonal conditions, waves, current, motions and time of samples collection. Temperature consider as a controlling factor for most of physicochemical parameters Table 5. It ranges between 23.44 and 29.99°C with an average of 25.99±1.33°C. The geographic distribution of temperature of the study area indicates a general uniform pattern, whereas Fig. 5a illustrates a general trend of decrease eastward throughout the area of investigation. Statistically there are well established positive relationships between temperature and each of DO and Chl-a also highly negative associations found between T and each of S_{psu}, BOD and TSM.

Salinity: Distribution patterns of salinity showed wide variation fluctuated between 34.147psu and 40.547psu with an average of 37.992±1.38 psu. In contrast to the temperature, the salinity shows a general trend of increase eastward Fig. 5b. The variation of salinity was significant due to the effect of fresh water entering from Rosetta branch of river Nile and affecting on the investigated area. These results indicate that, present load of organic matter and nutrients reached the water masses of coastal area. It is clear that the salinity levels were dependent on the amount of discharged fresh water derived from the effluent of land-based sources. Also salinity values showed a trend of the increase towards the offshore stations, due to mixing with the Mediterranean coastal waters and status of prevailing winds and currents.

Table 4: nutrients & total hydrocarbon (THC) in the water samples (µg/l)

Station No.	(NH ₄ -N)	(NO ₃ -N)	(NO ₂ -N)	(D I N)	(TN)	R- (PO ₄ -P)	TP	Reactive (SiO ₄ -Si)	THC
1	0.175	0.0153	0.0067	0.197	2.80	0.0452	0.093	0.287	560
2	0.539	0.0112	0.0074	0.557	2.56	0.0350	0.080	0.345	108
3	0.861	0.0300	0.0133	0.904	3.94	0.0335	0.080	0.300	230
4	0.180	0.0153	0.0068	0.202	3.60	0.04825	0.094	0.290	420
5	0.203	0.0160	0.0068	0.226	3.65	0.0460	0.096	0.290	109
6	0.070	0.0160	0.0068	0.093	3.65	0.0459	0.095	0.290	320
7	0.553	0.0112	0.0075	0.572	2.562	0.0350	0.080	0.330	112
8	0.084	0.0137	ND	0.098	1.00	0.0274	0.072	0.517	234
9	0.090	0.0137	0.0616	0.166	3.14	0.0276	0.075	0.520	300
10	0.560	0.0112	0.0074	0.578	2.56	0.0350	0.080	0.350	115
11	0.070	0.0137	0.0617	0.146	3.14	0.0276	0.076	0.521	220
12	0.049	0.0113	0.0079	0.068	2.56	0.0350	0.080	0.360	170
13	0.245	0.0137	0.0616	0.321	3.13	0.0276	0.075	0.567	220
14	0.742	0.0438	ND	0.786	1.60	0.0949	0.163	1.552	210
15	0.441	0.0111	0.0042	0.456	2.53	0.0276	0.062	0.172	160
Min.	0.049	0.0111	0.0042	0.068	1.00	0.0274	0.062	0.172	108
Max.	0.861	0.0438	0.0617	0.904	3.94	0.0949	0.163	1.552	560
Aver.	0.324	0.0165	0.0200	0.358	2.83	0.0392	0.087	0.446	252.5
SD±	0.269	0.010	0.023	0.267	0.788	0.017	0.023	0.326	126.41

Table 5: Correlation matrix between different parameters measured in the surface coastal water and sediment of study area, p = 0

	Sand %	Mud %	co3 %	THC (µg/g)	Cr (µg/g)	Pb (µg/g)	Zn (µg/g)	WD (m)	TC°	p H	S‰	D.O mg/L	COD mg/L	BOD mg/L	DOM mg/L	TSM mg/L	Chl-a µg/L	Trans (m)	NO2	NO3	NH4	TN	RP	TP	RS (SiO4-Si)
Sand%	1.0																								
Mud%	-1.0	1.0																							
Carbonate%	0.7	-0.7	1.0																						
Total hydrocarbon (µg/g)	-0.3	0.3	-0.2	1.0																					
Cr (µg/g)	-0.4	0.4	-0.4	0.8	1.0																				
Pb (µg/g)	0.0	0.0	-0.1	-0.5	-0.3	1.0																			
Zn (µg/g)	-0.1	0.1	-0.3	-0.1	0.3	0.0	1.0																		
Water depth(m)	-0.3	0.3	-0.2	-0.1	0.2	0.1	0.1	1.0																	
Temp. °C	-0.2	0.2	-0.1	0.7	0.3	-0.7	-0.5	-0.3	1.0																
p H	0.1	-0.1	0.0	0.0	-0.3	0.0	-0.1	0.0	0.2	1.0															
S‰	0.3	-0.3	0.2	-0.7	-0.4	0.7	0.5	0.1	-1.0	-0.1	1.0														
D.O mg/L	0.2	-0.2	0.4	0.3	0.1	-0.8	-0.3	0.1	0.7	0.1	-0.7	1.0													
COD mg/L	-0.1	0.1	0.3	0.1	0.2	0.3	-0.2	0.2	-0.2	-0.6	0.1	-0.1	1.0												
BOD mg/L	0.1	-0.1	0.1	-0.4	-0.2	0.9	-0.2	0.2	-0.6	-0.2	0.6	-0.5	0.5	1.0											
DOM mg/L	-0.1	0.1	0.3	0.2	0.3	0.3	-0.1	0.2	-0.1	-0.6	0.1	-0.1	1.0	0.5	1.0										
TSM mg/L	0.0	0.0	-0.3	-0.4	-0.2	0.8	0.3	-0.1	-0.8	-0.1	0.8	-1.0	0.1	0.6	0.1	1.0									
Chl a µg/L	-0.2	0.2	-0.3	0.7	0.7	-0.3	0.1	-0.3	0.5	-0.3	-0.5	0.1	0.0	-0.3	0.1	-0.3	1.0								
Trans(m)	0.2	-0.2	0.2	-0.6	-0.6	0.0	-0.4	0.1	-0.2	0.0	0.2	0.1	-0.1	0.2	-0.2	0.0	-0.5	1.0							
Nitrite (NO2-N)	0.4	-0.4	0.6	-0.1	-0.2	0.0	-0.1	-0.4	0.0	0.1	0.1	0.3	-0.1	0.1	0.0	-0.2	0.1	0.0	1.0						
Nitrate	-0.1	0.1	-0.2	-0.1	-0.1	0.0	0.4	-0.4	-0.2	0.0	0.2	-0.5	-0.3	-0.3	-0.3	0.4	-0.1	-0.3	-0.2	1.0					
Ammonium	-0.4	0.4	-0.6	0.0	0.2	0.1	0.4	0.2	-0.2	-0.1	0.1	-0.4	-0.2	-0.1	-0.2	0.4	0.0	-0.3	-0.3	0.6	1.0				
Total Nitrogen(TN)	-0.1	0.1	0.0	-0.1	0.0	-0.2	0.3	0.0	0.1	0.3	-0.1	0.3	-0.5	-0.3	-0.4	-0.3	0.1	0.1	0.3	-0.1	-0.1	1.0			
Reactive phosphate	-0.1	0.1	-0.4	0.0	0.0	-0.1	0.3	-0.4	0.0	0.2	0.1	-0.5	-0.4	-0.4	-0.4	0.4	0.0	-0.2	-0.4	0.8	0.3	-0.2	1.0		
Total phosphorus	0.0	0.0	-0.3	0.0	-0.1	-0.1	0.3	-0.5	0.0	0.2	0.1	-0.4	-0.4	-0.5	-0.4	0.3	0.0	-0.2	-0.3	0.8	0.3	-0.2	1.0	1.0	
R(SiO4-Si)	0.2	-0.2	0.0	-0.1	-0.1	0.1	0.2	-0.5	-0.2	0.0	0.3	-0.4	-0.2	-0.2	-0.2	0.5	-0.1	-0.3	0.1	0.8	0.3	-0.5	0.8	0.8	1.0

Saad and Younes [25] recorded that, salinity in Abu – Qir Bay fluctuated between 37.62±2.68 psu and 38.64±1.73 psu closes to the results found in the present study (Table 3). There are strong negative correlations were found between S psu and each of total hydrocarbon (THC) and T°C (r= -0.7 and -1.0 respectively) (Table 5). This can be interpreted on the basis of entering fresh water to the investigated area loaded by organic matter and nutrients.

pH-Value: The pH values ranged between 7.62 at station 8 and 7.97 at station 13 Fig. (6a) reveals homogenous distribution and a limited range of variation throughout the entire area of study. The low pH values resulted most probably from the effect of fresh water discharged from Rosetta branch and the land- based sources. Saad and Younes [25] found that, pH of Abu Qir Bay for surface water ranged between 7.13 and 8.39. These values are very close to that of the present study.

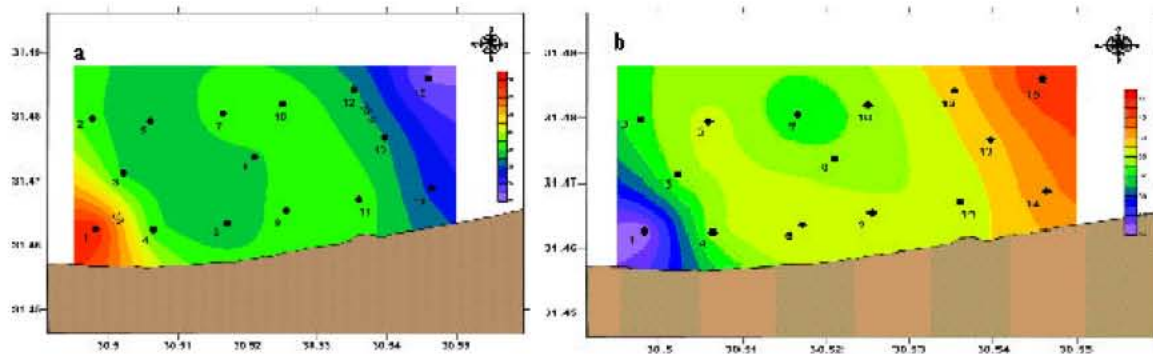


Fig. 5: Temperature and salinity measurements in the investigated area (a) Temperature, (b) Salinity.

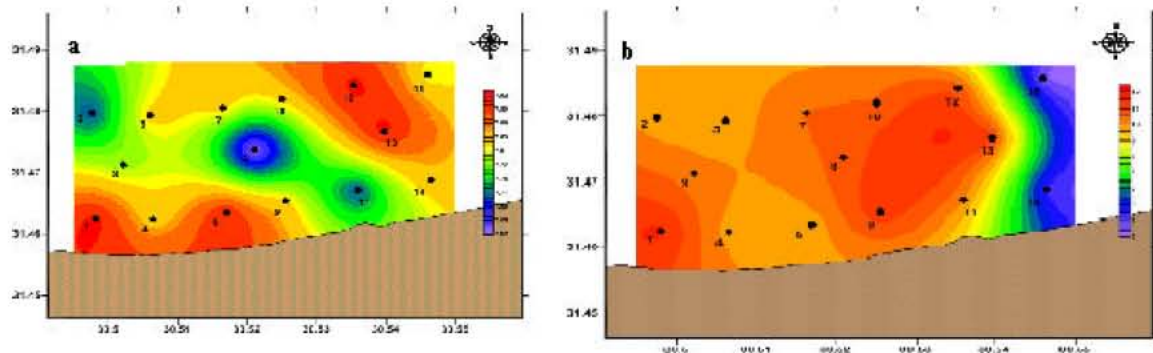


Fig. 6: Spatial distribution of pH and dissolved oxygen in the investigated area; (a) pH, (b) DO.

Dissolved Oxygen (DO): Dissolved oxygen is one of the most important parameters which affect on the water masses and in assessing the degree of pollution in the aquatic environment. The measurements of DO reveal relatively well oxygenated water column in the most stations (Table 3). Some other stations showed marked depletion of DO (4.37, 3.56) mg/L at stations 14 and 15 respectively. These lower values may be attributed to the fresh water discharged from Rosetta branch and land-based sources. DO values ranged between 3.56 mg/L - 11.61 mg/L with an average of 9.58 ± 2.37 mg/L. Fig. 6 b revealed that, the majority of the studied area shows a homogenous distribution of dissolved oxygen followed by a sharp decrease at the eastern extremity attaining its minimum value 3.56 mg/L. This decrease could also interpret on the basis of presence of two artificial sea walls in this site acting as a breaker zone leading to accumulation of phytoplankton species. Abbas *et al.* [26] attributed the depletion of DO in Lake Edku to the effect of drainage water poor in oxygen. He owed this depletion to the consumption of oxygen through the oxidation of organic material.

Biochemical Oxygen Demand (BOD): BOD measures the amounts of oxygen consumed by microbial oxidation and

is most relevant to waters rich in organic matter. The concentration values ranged between 0.01 mg/L-0.24 mg/L with an average of 0.05 ± 0.06 mg/L. The distribution of BOD reverse to that of DO (Fig. 7a) whereas the majority of the studied area is occupied by lower BOD values attaining its relatively maximum (0.24 mg/L) at the eastern extremity. Positive correlations were found between BOD and both of COD and S psu. Also negative correlations were observed with DO and T°C (Table 5)

Chemical Oxygen Demand (COD): COD is a measure of capacity of water to consume oxygen during the decomposition of organic matter and oxidation of inorganic chemicals such as ammonium and nitrite. COD measurements are commonly measured in samples of waste waters or of natural waters contaminated by domestic or industrial wastes. In the area of study, COD values ranged between 0.44 mg/L and 2.84 mg/L with an average of 1.05 ± 0.70 mg/L. Fig. (7b) illustrates an aerial distribution attaining its maximum value (2.84 mg/L) in the middle zone of the area of investigation surrounded by a stepwise decrease. COD is related to BOD. It is important to mention that, both forms of (COD and BOD) don't necessarily measure the same type of oxygen consumption.

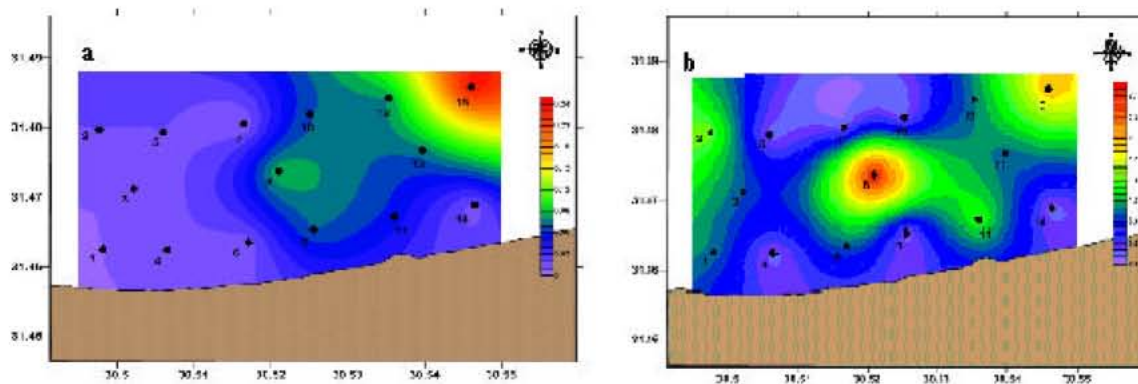


Fig. 7: Spatial distribution of biochemical and chemical oxygen demand in the investigated area; (a) BOD, (b) COD.

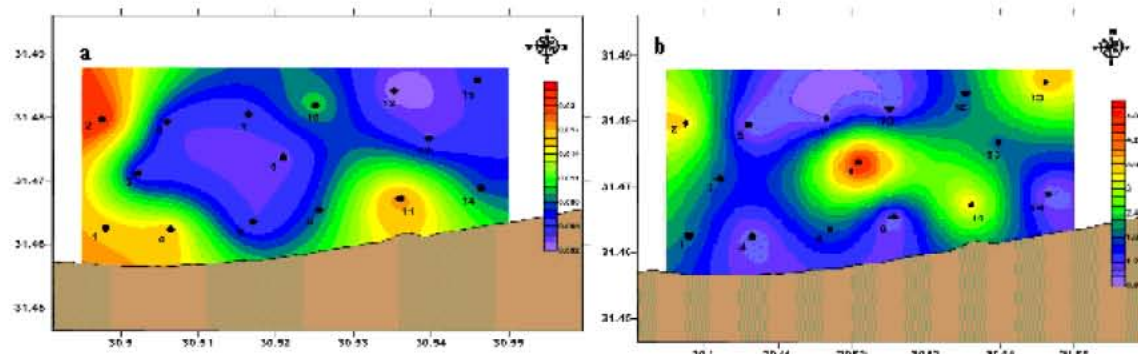


Fig. 8: Spatial distribution of Chl-a and dissolved organic matter in the investigated area; (a) Chl-a, (b) DOM.

Chlorophyll-A: Chlorophyll- a is regarded as the essential pigment responsible for the photosynthetic activity of algae and its concentration in a water mass is a fairly good index of standing crop. Chl-a concentration in surface water ranged between 0.002 and 0.022 $\mu\text{g/L}$ with average $0.009 \pm 0.01 \mu\text{g/L}$, (Table 2). Chl-a distribution pattern shows relatively lower values at deeper stations decreasing seaward (Fig. 8a). Fahmy [11] measured Chl-a concentrations in water of Aqaba Gulf which ranged from 0.07-0.24 $\mu\text{g/L}$ with an average of 0.16 $\mu\text{g/L}$. He classified the area of study as oligotrophic zone. Giovanardi and Tromellinie [27] pointed out that, oligotrophic seawater is characterized by less than 1.7 $\mu\text{g/L}$ Chl-a and higher than 9.9 m secchi disk visibility. Statistically, strong positive correlations were found between Chl-a and each of THC and $T^\circ\text{C}$. Also negative correlation between Chl-a and Spsu (Table 5).

Dissolved Organic Matter (DOM): Dissolved organic matter values ranged between 0.8 and 5.12 mg/L with an average of 2.10 ± 1.35 mg/L (Table 3). Fig. (8b) revealed that, DOM distribution pattern resembles to that of COD attaining the maximum value at the same site of the maximum value of COD. Strong positive correlation is

found between DOM and each of COD and BOD (Table 5).

Transparency: It is a measure of the penetration of light through the water column. The highest transparency was recorded at station 9 (2.6 m). It ranged between 1.00 – 2.6 m with an average 1.83 ± 0.52 m. Transparency shows higher values in the middle zone decreasing eastward revealing the effect of suspended matter on the transparency of the investigated area (Fig.9a), Table (3). Based on Chl-a concentrations and Transparency values, the area under investigation can be classified under oligotrophic and mesotrophic states, Abbas [26]. Significant negative correlations were recorded between transparency and each of THC and Chl-a (Table 5).

Total Suspended Matters (TSM): TSM are relatively high in the surface water and ranged between 11.92- 15.7 mg/L with an average 13.17 ± 0.98 mg/L (Table 3). Fig. (9b) revealed that, the major part of the studied area covered with lower homogenous total suspended matter values followed by a stepwise increase eastward till the eastern extremity. This may be attributed to presence of artificial seawall in the area of study affecting the level of total

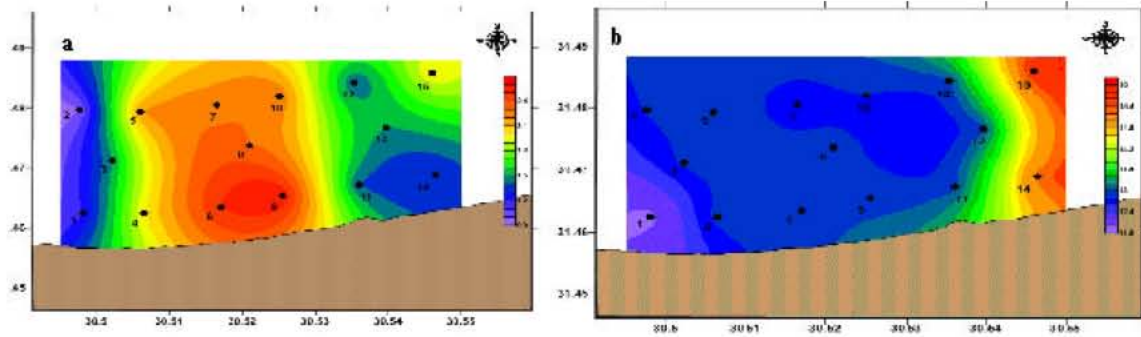


Fig. 9: Spatial distribution of transparency and total suspended matter in the investigated area; (a) Trans, (b) TSM.

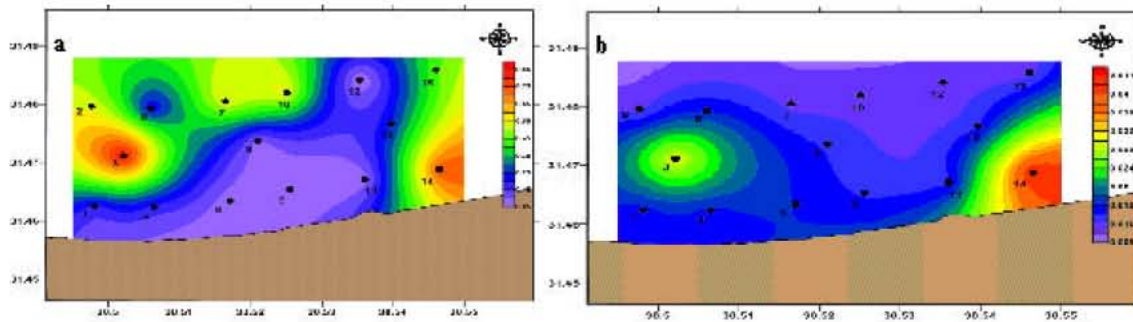


Fig. 10: Spatial distribution of ammonia and nitrate in the investigated area; (a) Ammonium, (b) Nitrate.

suspended matter, particularly at stations 14 and 15 which located in front of sea wall. Statistically; there are significant positive correlations were observed between TSM and both of S_{psu} and BOD indicating presence of source for TSM loading into the study area beside an extensive biological activity, Rifaat [24]. TSM showed significant negative correlations with temperature and dissolved oxygen indicating the association of TSM with low pH- water discharged from Rosetta branch loaded with organic matter and nutrients. Also may be attributed to the artificial seawall and the effect of prevailing wind and currents. Saad and Younes [25] found positive correlations between TSM and S_{psu} in Abu- Qir Bay and negative correlation between TSM and pH. He attributed the high TSM in Abu- Qir Bay to the extensive biological activity.

Eutrophication Parameters

Nutrients (NH₄, NO₃ and NO₂): Ammonium (NH₄-N) is the first inorganic product in the regeneration of organic nitrogenous materials. It may be used as a good indicator for the degree of pollution, Thomas [28]. Moreover Vanloon and Duffy [29] suggested that, ammonium is discharged into water bodies by industrial wastes when organic matter decompose in water and soil and the

nitrogen is released in reduced form, i.e. ammonium ions or ammonia depending on the ambient pH. The pattern of ammonium distribution recorded high concentrations ranged between 0.049- 0.861 µg/L NH₄-N with an average 0.324±0.269µg/L (Table 4). According to Hutchinson [30]; a decrease in ammonium concentrations is accompanied with an increase of phytoplankton population. Moreover, Harvy [31] suggested that, most species of phytoplankton utilize ammonium in preference to the other inorganic form. This might explain the decrease of ammonia in the present investigated area. A distinctive distribution of ammonium is shown in Fig. (10a), whereas the deeper western extremity is occupied by relatively higher values of ammonium concentrations followed by middle zone of lower concentrations and then the eastern extremity with relatively higher concentrations. Table (5) reveals positive correlation between NH₄ and NO₃, while negative correlation observed between ammonium and carbonate.

Nitrate (NO₃-N) is the most stable form of inorganic nitrogen in aqueous environment and is the end product of nitrification process in natural waters, Riley and Chester [32]. It fluctuated between 0.011 and 0.0438 µg/L with an average of 0.0165±0.010µ g/L (Table 4). Fig. (10b) reveals a homogenous areal distribution pattern with a slight increase eastward.

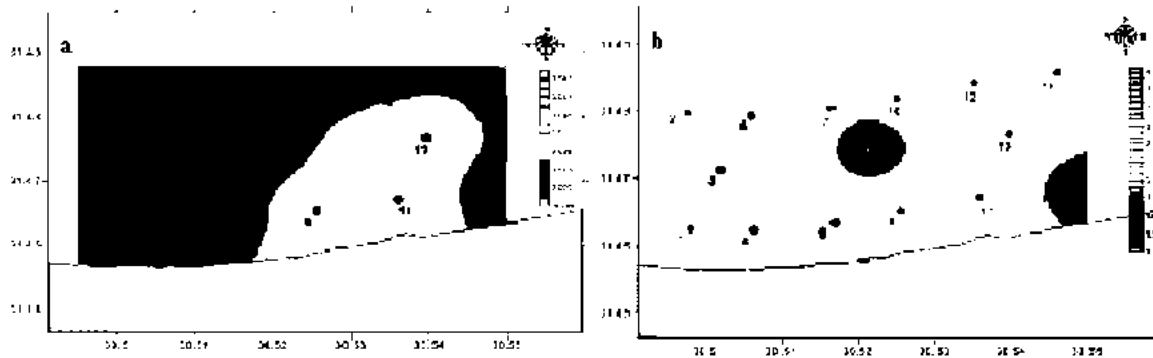


Fig. 11: Spatial distribution of nitrite and total nitrogen in the investigated area; (a) Nitrite, (b) Total nitrogen.

Nitrite ($\text{NO}_2\text{-N}$) appears in the water mainly as a result of biochemical oxidation of ammonia (nitrification) or reduction of nitrate (denitrification), Abbas [26]. In the area of study nitrite varied between 0.004 and 0.062 $\mu\text{g/L}$ with an average of $0.019 \pm 0.023 \mu\text{g/L}$ (Table 4). Nitrite is an intermediate oxidation state between ammonia and nitrate in the aquatic habitats. It might be possible to the state of equilibrium between oxidation and reduction processes, making up the nitrogen cycle (Rakestraw and Wattenberg [33-34]. The distribution pattern of nitrite showed two areas, the first occupies the western extremity with relatively lower values of nitrite concentrations and the eastern with relatively higher concentrations (Fig.11a).

Dissolved Inorganic Nitrogen ($\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$ and $\text{NO}_2\text{-N}$): Dissolved inorganic nitrogen (DIN) for the coastal water of the present study suggested that, the form of inorganic nitrogen was very low fluctuated between (0.068-0.904 $\mu\text{g/L}$) at stations (12,3) respectively with an average of $0.358 \pm 0.267 \mu\text{g/L}$. The different forms of inorganic nitrogen take the following order $\text{NH}_4\text{-N} > \text{NO}_3\text{-N} > \text{NO}_2\text{-N}$, which indicate increase the rate of ammonium production and/or increase the rate of NO_3 consumption by indigenous phytoplankton, UNESCO/FAO/UNEP and UNDP/UNESCO [35, 36]. Fahmy [11] suggested that, nitrogen in Aqaba Gulf of coastal water principally present in particulate and dissolved organic forms which is quite in accordance with the general understanding of phytoplankton dynamics. The presence of organic nitrogen in high concentrations may suggest its role in providing the investigated area with some of DIN components through the microbial decomposition of organic forms.

Total Nitrogen: Total nitrogen (TN) concentrations were listed in Table (4) showed general depletion with relatively restricted variation. The concentrations of TN ranged

between 1.00 and 3.944 $\mu\text{g/L}$ at stations 8 and 3 respectively with an average of $2.83 \pm 0.788 \mu\text{g/L}$ (Table 4). The difference between DIN and TN pointed to presence of nitrogen in the form of organic and / or particulate forms. Riley and Chester [32] suggested that, the organic nitrogen is assimilated by aquatic organisms in a much slower rate than inorganic species. Fahmy [11] found that, nitrogen exist in surface coastal water of Aqaba Gulf mainly in particulate and dissolved organic forms. Almost homogenous distribution with relatively higher concentration values with two spots of lower values at the middle and the eastern side of the investigated area (Fig. 11b). The higher values of TN may be attributed to the effect of El-Tabia pumping station and El-Maadia out let in the western part of the investigated area.

Reactive Phosphate ($\text{R-PO}_4\text{-P}$): The absolute concentration of the reactive phosphate observed in the present study fluctuated between 0.027 and 0.095 $\mu\text{g/L}$ $\text{PO}_4\text{-P}$ with an average of $0.039 \pm 0.017 \mu\text{g/L}$ (Table 4). In contrast to total nitrogen, reactive phosphate showed almost homogenous distribution with relatively lower concentrations along the major part of the area of investigation. The higher concentrations of reactive phosphate were recorded at the eastern boarder of the studied area (Fig. 12a). Positive correlation was found between reactive phosphate and nitrate. Also negative relationship with DO was observed (Table 5).

Total Phosphorus (TP): Total Phosphorus (TP) ranged between 0.062 and 0.163 $\mu\text{g/L}$ with an average of $0.087 \pm 0.023 \mu\text{g/L}$ (Table 4). It reveals the same mode of distribution as that of reactive phosphate (Fig.12b). The lower concentrations of $\text{R-PO}_4\text{-P}$ and TP indicate that, phosphate is present in organic and particulate forms > dissolved form. Statistically positive correlation was observed between TP and both of nitrate and reactive

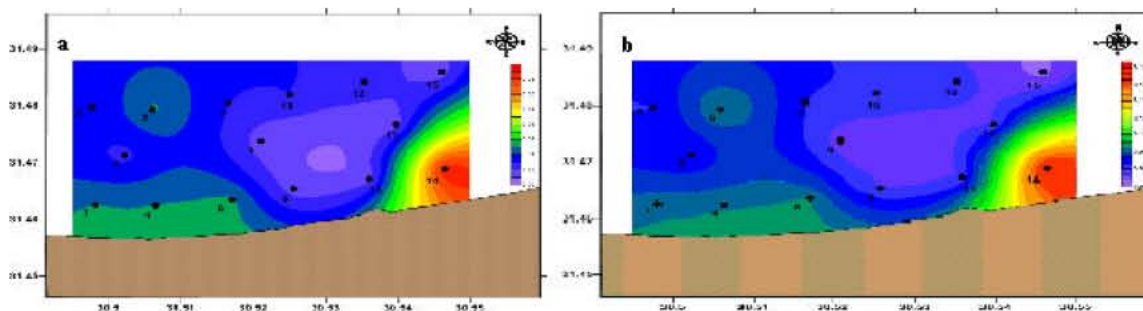


Fig. 12: Spatial distribution of reactive phosphate and total phosphorus in the investigated area; (a) Reactive P, (b) Total P.

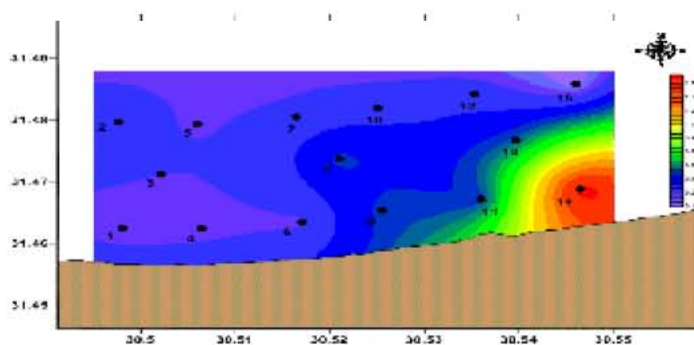


Fig. 13: Spatial distribution reactive silicate in the investigated area; R-Silicate

phosphate (Table 5). While negative correlations with water depth and BOD were noticed. This might be interpreted on the basis of the fact that, nitrogen and phosphorus are incorporated into the biomass. This explains the role of phytoplankton in nitrogen consumption, Fahmy [10].

Reactive Silicate (R-SiO₄Si): Reactive Silicate is often the most abundant acidic substance other than that of bicarbonate in inland waters, Hutchinson [30]. Silica constitutes a major nutrient component for diatoms (the dominant phytoplankton group). The growth of these organisms in natural waters is regulated by the availability of silica in the dissolved state. Results showed that concentrations of reactive silicate varied between 0.173- 1.55 µg/l with an average 0.446±0.326µg/l (Table 4). It shows the same mode distribution of both reactive phosphate and total phosphorous (Fig 13). There are positive relationships between R-SiO₄ and each of the following; TSM, NO₃, R-PO₄ and TP. Also negative correlation was found with water depth and TN (Table 5).

Statistically; Temperature was a controlling factor for Salinity, dissolved oxygen, biochemical oxygen demand(BOD), Total suspended matter (TSM) and

chlorophyll-a. On the other hand, BOD and TSM were greatly affected by DO. The other both forms of oxygen i.e. BOD and COD were controlling factors in variations of dissolved organic matter (DOM) and TSM. Concerning the nitrate was the most effective factor in the variation of Ammonium, reactive Phosphate, total phosphorus and reactive silicate.

ACKNOWLEDGMENT

Our deep grateful thanks are directed to Professor Omran Frihy professor of Marine Geology, Coastal research institute for supplying the Material for this research and his continuous encourage achieving this work. We are greatly indebted to Prof. Dr. Mohamed Ali Shata, professor of Marine Geology, Marine Geology and Geophysics Lab for giving much of his time in guidance and fruitful discussion. Our sincere thanks are owed to Mr. I. Gamiee for his technical support through the study. My deepest and warmest thanks are also indebted to Miss Suzanne M. El-Grabawy, assistant lecturer, Marine Geology and Geophysics Lab., National Institute of Oceanography and Fisheries, Alexandria Branch for help in surfer program usage in this research.

REFERENCES

1. Frihy, O.E., M.A. Fanos, A.A. Khafagy and P.D. Komar, 1991. Nearshore sediment transport patterns along the Nile Delta Egypt. *Coastal Eng.*, 15: 409-29.
2. Frihy, O.E. and M.F. Lotfy, 1994. Mineralogy and texture of beach sands in relation to erosion and accretion along the Rosetta Promontory of the Nile Delta Egypt. *J. Coastal Res.*, 10: 588-99.
3. Frihy, O.E., 2001. The necessity of environmental impact assessment (EIA) in implementing coastal projects: lessons learned from the Egyptian Mediterranean. *Coast. Ocean and Coastal Management*, 44: 489-516.
4. Frihy, O.E. and I. Geamai, 1991. Facies analysis of Nile delta continental shelf sediment off Egypt. *Netherlands J. Sea Res.*, 27: 165-171.
5. El-Gohary, F.A., 1990. Waste water management in Shubra El- Khema, 2nd Egyptian seminar on industrial waste water management, Cairo, Egypt, pp: 1-21.
6. El Bouraie, M.M., A.A. El Barbary, M.M. Yehia and E.A. Motawea, 2010. Heavy metal concentrations in surface river water and bed sediments at Nile Delta in Egypt. *Suo 61(1)*: 1-12 — Research notes. Suoseura — Finnish Peatland Society.
7. Yilmaz, A., D. Edigar, O. Basturk and S. Tugrul, 1994. Phytoplankton fluorescence and deep chlorophyll maxima in the north eastern Mediterranean. *Oceanologica Acta*, 17: 69-77.
8. Yacobi, Y., T. Zohari, N. Kress, A. Hecht, R.D. Roberts, A.M. Wood and W.K. Li, 1995. Chlorophyll distribution through southeastern of the water mass. *J. Marine System*, 6: 179-190.
9. Kress, N. and B. Herut, 2001. Spatial and seasonal evolution of dissolved oxygen and nutrients in the southern Levantine Basin (Eastern Mediterranean Sea). *Deep Sea Research I, Oceanographic research paper II*: 2347-2372.
10. Fahmy, M.A., 2001. Hydro- chemical and nutrients of the open Mediterranean Sea waters in front of Egypt during 2001. *Bull. Nat Inst. Ocean ogr. and Fisher., A.R.E.*, 27: 113-132.
11. Fahmy, M.A., 2001. Preliminary study on the hydrochemistry of the Egyptian coastal water of Aqaba Gulf as a unique ecosystem during year 2000. *Bull. Nat Inst. Ocean ogr. and Fisher., A.R.E.*, 27: 95-112.
12. Abdel Fattah, H.N.B., 2003. Geo-environmental studies on the coastal area of the Nile Delta, Egypt. *M. Sc. Mansoura Univ.*, pp: 143.
13. APHA (American Public Health Associations), 1995. Standard methods for the examination of water and waste water 19^{Ed}, Washington, D.C.
14. Carlberg, S.R., 1972. New Baltic Manual. International council for the exploration of the sea. Cooperative research report series A. No. 29, 30, Copenhagen.
15. Strickland, J.D.H. and T.R. Parsons, 1972. A practical handbook of seawater analysis. *Fish Res. Bd. Caned. Bull.* 157 2nd edition, pp: 310.
16. IOC (Intergovernmental Oceanographic Commission), 1982. The determination of petroleum hydrocarbons in sediments. *Manuals and Guides No. 11.*, IOC/UNESCO. Paris.
17. Valderrama, J.C., 1981. The simultaneous analysis of total nitrogen and total nitrogen and total phosphorus in natural waters, *Marine Chemistry*, 10: 109-122.
18. IOC (Intergovernmental Oceanographic Commission), 1984. Manual for monitoring oil and dissolved/dispersed petroleum hydrocarbons in marine waters and on beaches, *Manuals and guides No. 13*, IOC/UNESCO Paris.
19. UNEP/IAEA, 1985. Determination of total metal in marine sediments by Atomic Absorption Spectrophotometer. *Reference methods for marine pollutants*, 27: 33-99.
20. Folk, R.I., 1974. Petrology of sedimentary rocks. *Hemphill Pub l. Co. Austin Texas*, pp: 170.
21. Molenia, B.F., 1974. A rapid and accurate method for analysis of calcium carbonate in small samples. *J. Sediment Metrol.*, 44: 589-590.
22. Frihy, O.E., A.A. Moussa. and D.J. Stanley, 1994. Abu-Qir Bay, a sediment sink off the northwestern Nile delta, Egypt, *Marine Geology*, 121 (1994):199-211.
23. Summerhayes, P.C., G. Sestini, R. Misdorpan and M. Nancy, 1978. Nile Delta: Nature and evolution of continental shelf sediments. *J. Marine Geol.*, 27: 1-2: 43-65.
24. Rifaat, A.E., 2005. Major controls of metals distribution off the Nile Delta, Egypt. *Egyptian journal of aquatic research*, 31(2): 16-28.
25. Saad, M.A.H. and W.A.N. Younes, 2006. Role of phosphorous and nitrogenous species in water quality of a coastal Egyptian heavily polluted Mediterranean basin. *International J. Oceans and Oceanography*, 1: 1-19.
26. Abbas, M.M., L. Shoukweer. and, D. H Youssef., 2001. Ecological and fisheries management of Edku Lake. 1. Hydrochemical characters of Edku Lake. *Bull. Nat Inst. Ocean ogr. & Fisher. A.R.E.*, 27: 65-93.

27. Giovanardi, F. and Tromellinie, 1992. Marine coastal eutrophication Proceeding of Internat. Conf. Bologna Italy, pp: 211-233.
28. Thomas, E.A., 1984. Untersuchungen an der limmat von Zurich bis wettingen 1943/44. I. Halfte-vjschr. Naturforsch. Ges. Zurich 91, 216-236 and 93 (Beiheft Nr.1): 1-92.
29. Vanloon, V.W. and S.J. Duffy, 2000. Environmental Chemistry. A Global Prespective, Oxford, New York.
30. Hutchinson, G.E., 1957. A treatise on limnology, I, John Wiley and Sons. Ltd., pp: 1015.
31. Harvy, H.W., 1974. The Chemistry and Fertility of Seawater. Cambridge University Press, London.
32. Riley, J.P. and R. Chester, 1971. Introduction to marine chemistry. Academic Press, London and New York, pp: 465.
33. Rakestraw, N.W., 1936. The occurrence and significance of nitrite in the sea. Biol. Bull., Woods Hole, 71: 133-167.
34. Wattenberg, H., 1937. Die chemischen Arbeiten auf der "Meteor"-Fahrt. Ann. Hydrogr. Berl. Sept. Beiheft, pp: 17-22.
35. UNESCO/FAO/UNEP, 1987. Eutrophication in the Mediterranean Sea. Report and proceeding of a scientific workshop, Bologna, Italy, pp: 32-33.
36. UNDP/UNESCO, 1978. Coastal protection studies. Final Technical Report, 1, Paris, pp: 155.