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Evaluation of water quality of Abu-Qir Bay, Mediterranean coast, Egypt

Waheed M. Emam[1], Abd El-Halim A. Saad[1], Khalid M. El-Moselhy[2] and Najat A. Owen[3]
1- Zoology Dept. Faculty of Science, Ain Shams Univ., Egypt
2- Pollution Dept. National Institute of Oceanography and Fisheries, Hurghada, Egypt
3- Zawiya Univ., Libya

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ABSTRACT

Abu-Qir Bay is a shallow semi-circular basin lies 35 km east of Alexandria City. It is considered a fertile marine habitat, comparing to other Egyptian Mediterranean coastal waters. The bay is suffered from many pollution sources, which discharged through El-Tabia outfall, Maadia outlet and the Rosetta branch of the River Nile. The present study aimed to assess the water quality of Abu-Qir Bay by measuring seasonal variation of physical and chemical characteristics of the bay water temperature, pH, salinity, DO, BOD, COD, ammonia, nitrite, nitrate, reactive phosphate and reactive silicate). The obtained data showed that the highest annual mean values of BOD and COD (3.81 and 15.29 mg/l, respectively) were recorded at station V which is affected by the water discharged from Rosetta branch of the River Nile. Ammonia and nutrients recorded its highest annual mean values at stations II and III; these stations are influenced directly by the water drainage from Lake Edku, which is mainly containing agricultural wastewater. In conclusion, Abu-Qir Bay needs more chemical and biological studies to reach the best way to manage and improve its water quality, as it is an important fishing area of the Mediterranean coast of Egypt.

1. INTRODUCTION

The Mediterranean Sea is a semi-closed sea, surrounded by highly populated and industrialized areas, that presents a low capacity of interchange of waters with the Atlantic Ocean and other surrounding seas. For millenniums, the Mediterranean Sea has been the scenery of human development, which has extensively influenced the coastal areas. More recently, the capacity of humans for modifying the environment has experienced an exponential enhancement. As expected, the Mediterranean Sea has not escaped from this process, and currently, it offers several examples of dramatic anthropogenic impacts. The coastal zone of Egypt on the Mediterranean extends from Rafah to the east to Sallum to the west for over 1200 km.

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It hosts five large lakes; namely Bardawil, Manzala, Burullus, Edku and Maryut which represent about 25% in area of the total wetland of the Mediterranean. Alexandria is an Egypt's largest city on the Mediterranean coast, and is one of the most important industrial centers, comprised 100 large factories and about 260 smaller ones (Abd-Alla, 1993), to cover about 40% of the nation's industry. It is also the main summer resort in Egypt; about 4 million citizen and two million summer visitors (Nasr, 1995).

Abu Qir Bay is a shallow semi-circular basin lying 35 Km east of Alexandria City. The bay has a shoreline of about 50 Km long and the maximum depth of about 16 m. The surface area of the bay is about 360 Km^2 and the water volume is 4.3 Km^3 (Said *et al.*, 1995). The bay is considered as a fertile marine habitat when compared with the other Egyptian Mediterranean coastal waters. As in many coastal regions near major urban areas, the bay is used for variety of purposes; commercial fishing, shipping, recreational boating, swimming and as a repository for sewage effluents. During the last three decades, the bay is facing the problem of pollution which discharges into the bay from different sources; El-Tabia Pumping Station (TPS), the outlet of Lake Edku and the Rosetta mouth of the River Nile. The estimated amount of untreated sewage and industrial wastes from 22 different factories pumped to Abu Qir Bay through TPS is of about 2 millions m^3/day. The exchange of water between Abu Qir Bay and Lake Edku occurring through El-Maaddiya channel (about 100 m long, 20 m wide and 3 m deep) is controlled by the prevailing wind and the difference in water level between the bay and the lake. Actually, the amount of brackish water discharged from the lake to the bay is at a rate, of about 3.3 million m^3/day (ASRT, 1984).

The importance of Abu-Qir site and its suffering from different sources of pollution thirst a lot of researchers to study the area in biological, ecological and pollution issues (Abdel-Moneim and Shata, 1993; El-Deek, 1995; Youssef and Masoud, 2004; Abd Allah *et al.*, 2006; Kholeif, 2008).

Monitoring of the environmental quality is of great importance to determine the order of effectiveness of all the adopted governmental steps and to determine if further steps are required to improve the quality of the environment. Thus, the objectives of the present study were set to assess the water quality of Abu-Qir Bay by measuring seasonal variation of physical and chemical characteristics of the bay water temperature, pH, salinity, DO, BOD, COD, ammonia, nitrite, nitrate, reactive phosphate and reactive silicate, to put a monitoring and management plan for development this important ecosystem.

2. MATERIALS AND METHODS

Inshore water samples were collected seasonally from 5 stations along Abu Qir Bay during the period from 2009 to 2010. (Fig.1). Station I is located in the western side of the bay at Abu Qir head affecting by El-Tabia pumps, stations II and III were selected to represent the impact of Lake Edku outlet (west and east Maaddiya channel), stations IV is located in front of Edku village and affected by human activities, while station V is found in the eastern side of the bay directly west of Rosetta mouth and affected by Rosetta branch of Nile River.

Water temperature was measured at the time of sampling with an ordinary thermometer graduated to 0.1^{o}C, while pH was measured in situ with a portable digital pH meter (Orien, model 201) accurate to 0.01. Water salinity was determined by measuring the electrical conductivity using an induction salinometer (BEKMAN model No. RS7C). Dissolved oxygen was determined by Winkler method (Strickland and Parsons, 1975 and APHA, 1995). Biochemical oxygen demand (BOD) was determined by incubating a sealed sample of water for five days and measuring the loss of oxygen from the beginning to the end of the test. Chemical oxygen demand (COD) was measured according to Standard Methods for the Examination of Water and Wastewater (APHA, 1995). Nutrient salts (NO_3, NO_2, PO_4 and SiO_4) and ammonia were determined according to methods described by Grasshoff (1976).

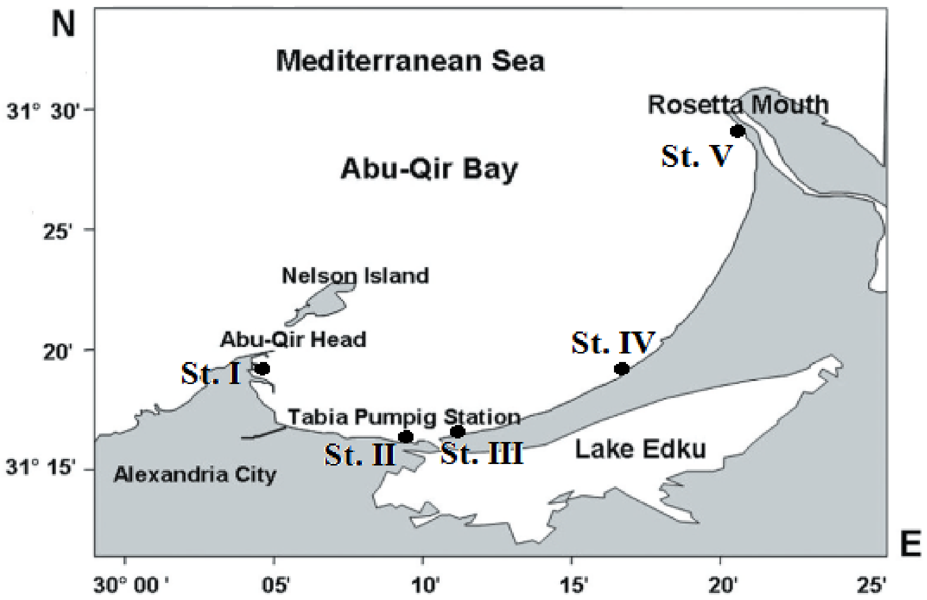

Fig. 1: Map of Abu-Qir Bay showing the sampling stations

3. Results and Discussion

3.1 Physico-chemical parameters

Seasonal variation values of water temperature, pH, salinity, DO, BOD and COD at different stations along the Abu-Qir Bay is presented in Table 1. Temperature of surface water in Abu-Qir Bay fluctuated between 19.00^oC at stations (II and IV) during winter and 29.20^oC at station I during summer. Generally, variations in surface water temperature depend on climatic conditions, sampling time, position and mean daily number of sunshine hours and also affected by specific characteristics such as turbidity, wind force, plant cover and humidity (Khaled, 1997). The highest pH values were recorded at station IV (9.07) during summer with an annual mean of 8.11.This elevation may attributed to sewage and agricultural wastes from Lake Edku and human activities of Edku village, while the minimum value was found at station V with an annual mean of 7.93, affected by fresh water from Rosetta mouth of the River Nile. According to the seasonal variation pH value, it can be stated that summer recorded the highest value, because increasing of temperature usually stimulates phytoplankton photosynthetic activity causing more consumption of carbon dioxide and the rise of pH, while the relative decrease of pH values during winter may be related to the high solubility of CO_2 in water, leading to the formation of HCO_3^-, and decrease of both CO_3^{--} contents and pH values (Golterman, 1975). The seasonal difference of water salinity in the investigated area showed values varying between 28.70 - 39.90, 32.61 - 38.83, 34.08-39.80 and 40.70 - 43.90 ‰ during spring, summer, autumn, and winter respectively. Regionally, the lowest values of salinity in Abu-Qir Bay were recorded at stations II and III with annual mean of 34.49 and 35.35 ‰, respectively. This is probably due to the effect of water with low salinity discharged from Lake Edku.

The seasonal variations and annual mean of DO, BOD and COD in water samples from Abu-Qir Bay are tabulated in Table (1). Annual mean of DO showed that its lowest value (7.45 mg O_2/l) was found at station I followed by stations II and III (7.85 and 7.93 mg O_2/l, respectively). These low values in comparing to the other stations are mainly attributed to the polluted wastewater from El-Tabia Pumping Station (station I) and Lake Edku (stations II and III). With respect to the seasonal variation of DO, the highest values during autumn and winter may be related to the decrease in the air temperature leading to increase the solubility of the atmospheric oxygen, and the photosynthetic activity due to abundance of phytoplankton (Abdo, 2002).

Table 1: Seasonal variation of physical and chemical parameters in Abu-Qir- Bay water.

Season	Station	Temp. ^{o}C	pH	S ‰	DO (mg/l)	BOD (mg/l)	COD (mg/l)
Spring	I	23.30	7.98	39.90	7.98	3.15	10.48
	II	28.00	7.98	28.70	7.22	3.50	11.78
	III	27.20	7.72	33.80	3.99	1.98	6.39
	IV	26.50	8.07	35.00	7.07	3.32	11.25
	V	25.00	7.68	38.00	10.44	3.05	17.15
Summer	I	29.20	8.98	35.57	7.92	3.50	10.00
	II	29.00	8.98	32.76	8.98	2.43	12.30
	III	28.10	8.72	32.61	7.65	2.98	11.56
	IV	29.00	9.07	34.08	7.89	3.04	11.76
	V	29.00	8.68	38.83	7.85	2.63	14.13
Autumn	I	22.00	7.75	36.70	6.02	2.49	7.30
	II	21.50	7.86	35.10	8.05	1.99	9.20
	III	19.00	8.23	34.30	8.04	1.49	9.56
	IV	22.00	7.87	39.30	10.97	2.49	14.01
	V	22.00	7.93	39.80	14.98	5.99	16.30
winter	I	21.00	7.40	43.50	7.87	2.69	10.60
	II	19.00	7.34	41.40	7.14	2.14	8.70
	III	20.00	7.35	40.70	12.03	3.65	13.65
	IV	19.00	7.42	40.80	12.29	3.71	14.69
	V	20.00	7.42	43.90	11.81	3.55	13.58
Annual mean	I	23.88	8.03	38.92	7.45	2.96	9.60
	II	24.38	8.04	34.49	7.85	2.52	10.50
	III	23.58	8.01	35.35	7.93	2.52	10.29
	IV	24.13	8.11	37.29	9.55	3.14	12.93
	V	24.00	7.93	40.13	11.27	3.81	15.29

On the other hand, the lowest values of DO recorded during spring and summer probably due to the elevation in temperature accompanied with a decrease in the solubility of atmospheric oxygen surrounding to water (Cole, 1979). This illustrates that the oxygen concentration is affected by the temperature pattern. The seasonal variations of the BOD in the area under investigation showed variable values which ranged between 1.98-3.50, 2.43 - 3.50, 1.49-5.99 and 2.14-3.71 mg O_2/l during, spring, summer, autumn and winter, respectively. Annual mean of BOD indicated that the highest value was at station V (3.81 mg O_2/l). In general, BOD values increase gradually during winter and autumn, and reaches its maximum during summer. This may be due to the increasing of microorganisms which needs DO for oxidizing the organic matter (Hamed, 2003). Water is considered fairly pure with a BOD of 3 ppm and of doubtful purity when the BOD value reaches 5 ppm (Anon, 1975). A comparison between these recommended levels and those observed in the present study area shows that the BOD of the Abu-Qir Bay is moderately high indicating load of different pollutants into the bay from different sources. The recorded values of COD in the present investigation area showed more or less similar pattern of BOD. The relatively high values of BOD and COD in Abu-Qir bay exhibited that the bay is exposed to continuous untreated sources of pollution.

3.2 Nutrient salts

Riley and Chester (1971) reported that the most important forms of nutrients in seawater of the inorganic nitrogen are ammonia, nitrite and nitrate; the concentrations of these nutrients usually lie in the range of 0.15-3.00 mgNH_3-N/l, 0.01-3.00 mg NO_2-N/l and 0.10 – 35.00 mg NO_3-N/l in oxygenated water. Nutrient salts play an important role in the balance between organisms of the food chain in the aquatic environment, as well as expressed directly to the quality of water. In the present study, ammonia and nutrients values in seawater collected from different locations of Abu-Qir Bay are illustrated in Table (2).

Table 2: Seasonal variation of ammonia and nutrient salts in water of Abu-Qir Bay.

Season	Station	Amm. (µgNH_4-N/l)	Nitrite (µgNO_2-N/l)	Nitrate (µgNO_3-N/l)	Phosphate (µgPO_4-P/l)	Silicate (µgSiO_4-Si/l)
Spring	I	195.30	10.50	71.80	19.34	56.35
	II	474.60	53.20	21.29	49.10	19.32
	III	432.60	64.40	45.36	50.59	37.03
	IV	133.00	21.70	15.09	44.64	8.05
	V	142.10	5.60	9.70	29.76	17.17
Summer	I	153.30	13.50	22.80	37.20	99.75
	II	432.60	48.40	60.70	137.95	34.20
	III	390.60	68.60	33.20	114.70	65.55
	IV	91.00	35.08	28.60	111.60	14.25
	V	100.10	16.90	9.40	77.50	31.35
Autumn	I	140.70	8.32	26.41	22.32	63.56
	II	261.80	30.06	42.16	102.35	30.50
	III	185.50	52.32	48.49	98.42	47.53
	IV	200.90	24.80	22.43	83.60	15.92
	V	98.70	6.82	10.82	167.30	30.96
Winter	I	58.10	12.61	18.05	30.05	78.05
	II	336.00	38.40	34.31	96.40	24.56
	III	302.40	70.06	56.85	87.23	48.29
	IV	264.60	42.16	64.51	102.30	10.25
	V	106.40	20.15	22.62	44.90	26.53
Annual mean	I	136.85	11.23	34.77	27.23	74.43
	II	376.25	42.52	39.62	96.45	27.15
	III	327.78	63.85	45.98	87.74	49.60
	IV	172.38	30.94	32.66	85.54	12.12
	V	111.83	12.37	13.14	79.87	26.50

Ammonia is biologically active compound present in most water as normal degradation product of nitrogenous organic matter. It reaches ground surface water through discharge of sewage and industrial waters containing ammonia as a byproduct or wastes from different sources of human activities (Train, 1978). The seasonal variations of ammonia in water of Abu-Qir Bay showed variable values which ranged between 133.00-474.60, 91.00-432.60, 98.70-261.80 and 58.10-336.00 µgNH_4-N/l during spring, summer, autumn and winter, respectively. The pronounced increased in ammonia content during spring may be attributed to the decomposed organic matter and probably due to drying off of algal blooms (Jana *et al.*, 1983). The highest values of ammonia were recorded at stations II and III (376.25 and 327.78 µgNH_4-N/l) which are affected by the drainage water of Lake Edku.

Nitrite concentration in Abu-Qir Bay varied between 5.60-64.40, 13.50-68.60, 6.82-52.32 and 12.61-70.06 µgNO_2-N/l during spring, summer, autumn and winter, respectively. The highest values of nitrite were recorded during winter may be due to oxidation of ammonia by nitrifying bacteria (Takahashi *et al.*, 1982; Tezuka, 1985). In contrast, the relative decrease in NO_2^- contents during warm seasons mainly attributed to utilization by phytoplankton in surface water and its reduction by denitrifying bacteria (El-Wakeel, and Wahby, 1970). Regionally, station III exhibited the absolute maximum of nitrite (63.85 µg NO_2-N/l) comparing to all studied stations, which mainly revealed the impact of sewage and agricultural wastes discharged from Lake Edku. More or less, nitrate showed similar pattern recorded for nitrite in the present investigated area (Table 2). Nitrate ranged between 9.70-71.80, 9.40-60.70, 10.82-48.49 and 18.05-64.51 µgNO_3-N/l during spring, summer, autumn and winter seasons, respectively; and the highest annual mean was recorded also at station III (45.98 µgNO_3-N/l).

Dissolved inorganic phosphate in the investigated area showed seasonal variation of 19.34-50.59, 37.20-137.95, 22.32-167.30 and 30.05-102.30 µgPO_4-P/l in the surface water during spring, summer, autumn and winter, respectively. The high values recorded during autumn may be attributed to release of phosphate from sediment to water through water agitation by wind and current. The lower phosphate values recorded during spring attributed mainly to the uptake of phosphorus by algae, bacterial, phytoplankton and zooplankton. Stations II and III recorded the highest annual value of phosphate (96.45 and 87.74 µgPO_4-P/l), which is mainly due to the effect of Lake Edku drain.

Concentration of silicate in the different inshore stations of Abu-Qir Bay was fluctuated between 8.05-56.35, 14.24-99.75, 15.92-63.56 and 10.25-78.05 µgSiO_4-Si/l during spring, summer, autumn and winter, respectively. The increase in silicate contents during summer may be attributed to the increasing in solubility of silicon with elevation of temperature, or may be due to degradation of dead diatoms (Sommer and Stable, 1983). During winter, the slight increase in silicate content depends on the degradation of diatoms and other microorganisms (Bailey-Watts, 1976. According to the regional distribution, annual mean of silicate exhibited its highest value in station I (74.43 µgSiO_4-Si/l), while the lower one was at station IV (12.12 µgSiO_4-Si/l).

Table (3) shows the average values of nutrients in the present study comparing to other Egyptian waters. It can be observed that the levels of nutrient salts recorded in the present study were comparable with the previous studies. In addition, the level of nutrients indicated that Abu-Qir Bay is in the eutrophic state according to the standard levels reported by Franco (1983).

Table 3: Comparison between nutrients concentratios (µmol/l) of the present study and other Egyptian waters.

Area	NH_4	NO_2	NO_3	PO_4	SiO_4	Reference
Abu-Qir Bay	16.07	2.30	2.37	2.43	1.35	Present study
Abu-Qir Bay	4.85	1.34	9.78	0.57	---	Ahdy, 1999
Bitter Lakes	1.59	0.52	2.91	0.62	3.13	Hamed *et al.*, 2012
Temsah Lake	2.78	0.92	6.16	1.03	4.99	Hamed *et al.*, 2012
Lake Manzalla	63.10	3.48	5.91	11.56	94.11	Hamed, 2003
Lake Manzalla	128.45	5.81	9.25	24.60	142.50	Fahmy *et al.*, 1997
Oligotrophic level	0.51		0.51	0.05		Franco, 1983
Eutrophic level	2.02		4.02	0.30		

The calculated values of N:P ratio recorded during summer (6.96), autumn (5.42 and winter (8.88) were lower than that of Redfield ratio (16:1) (Redfield *et al.*, 1963), which indicated that nitrogen is the limiting factor for phytoplankton growth in Abu-Qir Bay during these seasons. In contrast, N: P ratio was lower than that of Redfield ratio during spring (19.42) indicating that phosphorus is the limiting factor.

Relationships between all pairs of measured parameters in Abu-Qir Bay were calculated and tabulated in Table (4). It can be noticed that: 1) temperature showed positive significant correlation with pH (r = 0.792) and negative correlations with salinity and DO (r = -0.663 and–0.417) which indicated that solubility of DO decreases with increasing temperature. 2) pH values had negative correlation with salinity (r =-0.603). 3), salinity showed positive correlation with DO (r =0.501) and negative correlation with NH_4 (r = -0.547). 4) Positive significant correlations were observed between DO and BOD, COD & PO_4 (r = 0.700, 0.828 & 0.446). 5) BOD is significantly correlated with COD (r = 0.616) which is probably due to the factors responsible for organic matter degradation either chemically or biologically are similar. 6), there is positive significant correlation between nutrient salts in nitrogen forms (NH_4, NO_2 and NO_3) indicating that the sources of nitrogen input in Abu-Qir Bay are similar.

Table 4: Correlation coefficient between pairs of measured parameters in Abu-Qir Bay.

	Temp.	pH	S‰	DO	BOD	COD	NH_4	NO_2	NO_3	PO_4	SiO_4
Temp.	1.000										
pH	0.792*	1.000									
S‰	-0.663*	-0.603*	1.000								
DO	- 0.417	- 0.241	0.501*	1.000							
BOD	0.007	- 0.061	0.229	0.700*	1.000						
COD	- 0.026	- 0.028	0.303	0.828*	0.616*	1.000					
NH_4	0.199	0.016	-0.547*	- 0.286	- 0.246	- 0.276	1.000				
NO_2	0.071	0.056	- 0.442	- 0.191	- 0.276	- 0.231	0.781*	1.000			
NO_3	- 0.248	- 0.068	- 0.035	- 0.035	- 0.251	- 0.269	0.475*	0.493*	1.000		
PO_4	- 0.035	0.284	- 0.134	0.446*	0.240	0.296	0.215	0.357	0.155	1.000	
SiO_4	0.081	0.197	0.043	- 0.253	- 0.073	- 0.406	- 0.101	- 0.081	0.073	- 0.290	1.000

* Significant at $p < 0.05$

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