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Effect of pollution on the hydrochemical characteristics of different water types in El-Max Bay area, west of Alexandria, Egypt

M.A. SAID, M.S. EL-DEEK, Th.H. MAHMOUD and M.A. SHRIADAH

National Institute of Oceanography and Fisheries, Kayet Bay, Alexandria, Egypt

El-Max Bay, west of Alexandria, has a surface area of about 19.4 km² and volume 190.3 x 10⁶ m³. It receives a heavy load of wastewater (2.4 x 10⁹ m³/year), both directly from industrial outfalls and indirectly from Lake Maryut via El-Max Pumping station. Seven marine trips were carried out in El-Max Bay during the period from January 1988 to January 1989 using a motor boat. Temperature, salinity, pH, alkalinity, dissolved oxygen, oxidizable organic matter, hydrogen sulphide, phenolic compounds and nutrient salts were measured at surface and bottom from seven sampling stations.

The surface water temperature varies from a minimum of 14.2 °C in January to 28.9 °C in August. Based on the distribution of surface salinity, four types of water are identified:

Mediterranean sea water (salinity > 38.5‰), diluted sea water with a salinity range between 30 and 38.5‰, mixed water (salinity 10 to 30‰) and mixed land drainage with a salinity of less than 10‰. The hydrochemical characteristics of these water types are discussed in detail. The present work deals with the first attempt to study the pollution in El-Max Bay based on the determinations of the total phenolic compounds in the Bay water. The total phenol is generally present in higher concentrations in the nearshore stations decreasing seaward. At the surface, it varies from a maximum of 231.11 ppm nearshore in June to a minimum of 53.16 ppm at the offshore stations. At the bottom, it decreases from 195.22 ppm nearshore in April to reach 21.21 ppm in February at the open sea stations.

INTRODUCTION

During the last two decades Mediterranean coast of Egypt has witnessed significant evolution. An increasing number of industries has been built up and considerable tehnological developments have taken place. Consequently, this part of the Mediterranean Sea is presently facing the problem of water pollution at some level, which is expected to increase in the future.

The major types of pollution sources are domestic sewages, industrial wastes, agricultural run- off through Lake outlets, river discharges and oil pollution.

El-Max Bay, west of Alexandria, extends for about 15 km between El-Agamy headland to the west and the western harbour to the east and from the coast to a depth line of about 15 meters. The Bay has a mean depth of 10 m. Its surface area is of about 19.4 km^2 and its volume 190.3 x 10^6 m^3. It receives a heavy load of wastewater (2.4 x 10^9 m^3/year) both directly from industrial outfalls and indirectly from Lake

Maryut via El-Max Pumping stations (Table 1). This is mainly agricultural drainage water collected by El-Umum Drain, but also comprises the overflow from Lake Maryut.

Table 1. Volume of water discharged to El-Max Bay through El-Umum Drain (10^6 m^3).

Month	Total discharge	Month	Total discharge
January , 1988	284.187	July , 1988	168.901
February , 1988	208.529	August , 1988	188.385
March , 1988	194.241	September , 1988	194.996
April , 1988	144.746	October , 1988	243.493
May , 1988	151.541	November, 1988	231.215
June , 1988	163.692	December, 1988	251.665

The configuration of El-Max Bay, its mayor hydrography and chemical character have been studied by: EL-WAKEEL and EL-SAYED (1978); ABDALLAH (1979); SARBA (1979); MAHMOUD (1979 and 1985); FARAG (1982) and RIFAAT (1982). The first survey of chromium in inshore waters of Alexandria was conducted by ABDOUL-DAHAB and HALIM (1986 and 1988 a) in El-Max Bay. EL-GINDY *et al.* (1986) estimated the residence time of the fresh water input to El-Max Bay as 2.08 days. ABDOUL-DAHAB and HALIM (1988 a) determined the sedimentation rate in El-Max Bay (0.85 cm y^{-1}) by studying sediment cores from the area. Spatial distribution and speciation of Tin compounds in sediments of Alexandria coastal belt was studied by ABDOUL-DAHAB and HALIM (1988 b).

The aim of the present work is an attempt to illustrate the extent of the influence of the polluted water on the characteristics of El-Max Bay waters and to shed more light on the pathways of the pollutants in the Bay.

MATERIAL AND METHODS

Throughout the period from January 1988 to January 1989, seven trips were carried out in El-Max Bay using a motor boat. Temperature, salinity, dissolved oxygen, pH, hydrogen sulphide and total phenol were measured at surface and bottom from seven hydrographic stations. Fig. 1. presents El-Max Bay area and locations of sampling stations.

Water temperature was measured using protected reversing thermometer attached to a Niskin water sampler. Temperature corrections were made using calibration curves. Salinity determinations were carried out using the Beckman induction Salinometer (Model RS-7C).

pH measurements were carried out using a pH-meter (Orien Research Model 201 digital pH-

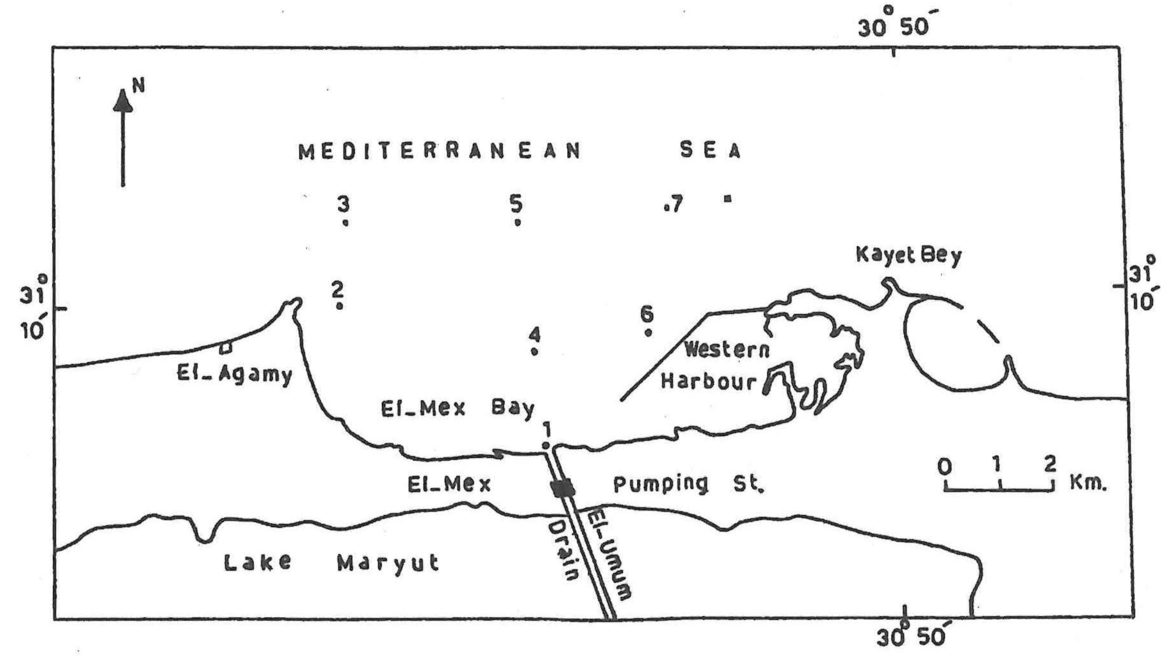

Fig 1. El-Max Bay area and the locations of the sampling stations

meter). Alkalinity was determined according to the method of THOMPSON and ANDERSON (1940) using all necessary precautions of STRICKLAND and PARSONS (1965). Samples for determinations of dissolved oxygen were fixed on board and analyzed in the laboratory, according to the method described by STRICKLAND and PARSONS (1975). Results were expressed in ml/l. Oxidizable organic matter was determined according to the method of ELLIS *et al.* (1946) by oxidizing the water sample with permanganate solution and the produced oxides dissolved in the sample were titrated as oxygen. Hydrogen sulphide was determined by the titrimetric method described in the Standard Methods of Water Analysis published by the american Public Health Association (1965). Phenol determinations were carried out colorimetrically with antipyrine method using a Shimadzu-Double-Beam model spectrophotometer UV-150-02. Reactive phosphate was determined by the method of MURPHY and RILEY (1962). Nutrient salts (ammonia, nitrite and nitrate) were determined according to GRASSOFF (1976).

During the period of investigation, the monthly climatological data concerning wind speed and direction from Alexandria Meteorological Station were made available through the Egyptian Meteorological Authority - Cairo, Egypt.

RESULTS AND DISCUSSION

Temperature measurements

The surface water temperature varies from a minimum of 14.20 °C in January to a maximum of 28.9 °C in August. Lower values of water temperature are registered in February. The water temperature reaches higher values (26.00 - 28.9 °C) during the period from June to August. The bottom temperature is relatively higher than the surface water during the winter months (Jan. and Feb.), while it is relatively lower throughout the year, with a difference of 0.9 °C.

Water quality and water types

Salinity in the investigated area varies regionally within a wide range, from Mediterranean shelf water in the north to brakish water near El-Umum Drain outlet. The salinity values change widely according to the distance of the different sites from the effluents. The minimum surface salinity (4.969 ‰) is observed during November within El-Umum Drain (station 1) and the maximum one (38.683 ‰) is found in April at the open sea stations. Bottom water, on the other hand, shows less pronounced salinity variation. Its salinity ranges between 29.053 ‰ in January, 1988 and 39.656 ‰ during January 1989.

To reach an understanding of the extent to which the runoff water mixes with sea water and affects the water quality, it is found convenient to identify specific water types. As mentioned earlier, the surface salinity in the area shows large regional variations, ranging from undiluted sea water to undiluted drain and sewage water. Accordingly, salinity is chosen as the main tool for water type identification. Based on the distribution of surface salinity in the investigated area, four types of water are identified:

1. Mediterranean Sea water (S) of salinity > 38.50 ‰ .
2. Diluted sea water (D) with a salinity range from 30.00 to 38.50 ‰ .
3. Mixed water (M) salinity 10 to 30 ‰ , and
4. Mixed land drainage (L) with a salinity of less than 10 ‰ .

According to EL-MAGRABY and HALIM (1965), SAID (1979) and ABDEL-MOATI and SAID (1987), the salinity value 38.5 ‰ was taken to represent the inner boundary of the neritic water off Alexandria. This value still could be generally accepted and will be used here to identify the limits within which the diluted sea water extends horizontally seawards.

The horizontal extension of each water type is highly variable and depends upon the pattern of circulation and the rate of outflow. The surface salinities and the corresponding water types are represented in Figs. 2 and 3.

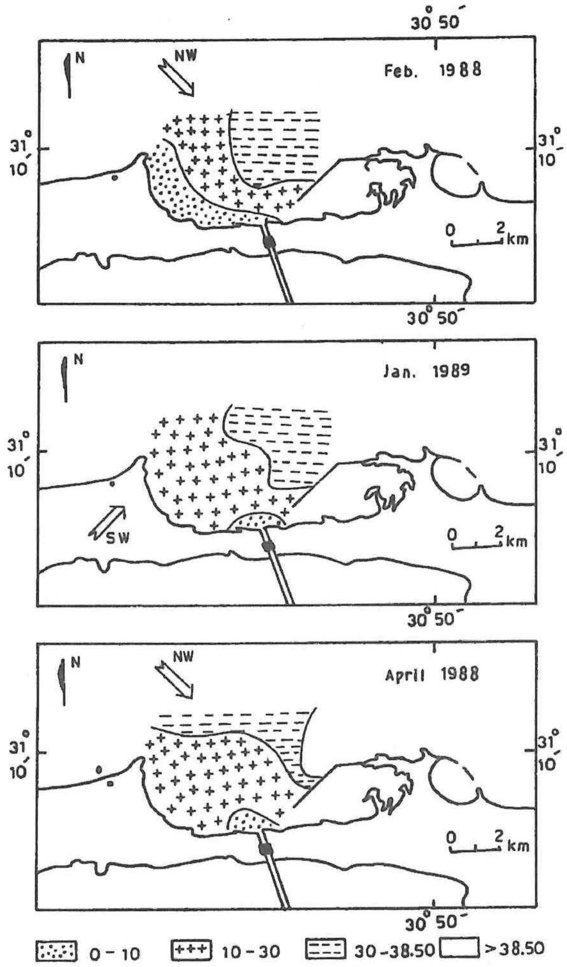

Fig 2. Distribution of the surface water types

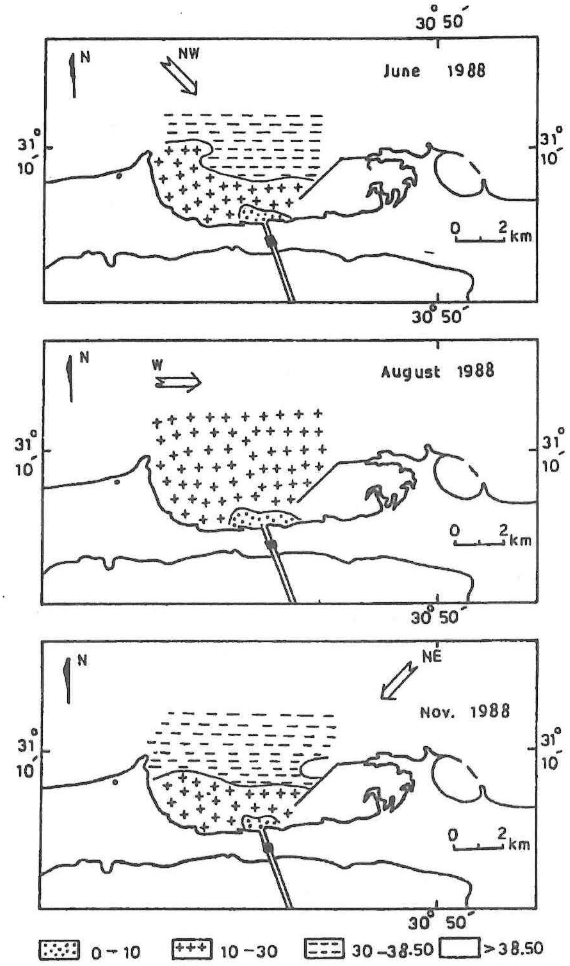

Fig 3. Distribution of the surface water types

During the winter months (Fig. 2), as a result of the increased drainage water discharged through El-Umum Drain (Table 1) the prevailing type occupies almost all the area. In February, the mixed land drainage type with a salinity of less than 10 ‰ spreads a considerable distance beyond the Bay to reach El-Agamy area.

In April, under the action of the northwest prevailing wind of an average speed of about 4.62 m/sec, the mixed water (salinity 10 to 30 ‰) diluted sea water with a salinity range from 30 to 38.50 ‰ occupies the offshore zone. The pure Mediterranean water type could only be found at the eastern part of the investigated area (Fig. 2).

As a result of the increased drainage water discharge during June (164 x 10^6 m^3), the investigated area is completely occupied by both the mixed and diluted sea water (Fig. 3). In August, by the action of the prevailing winds, the mixed water type of salinity < 30 ‰ extends to the offshore area.

During November, according to the prevailing northeasterly winds of an average velocity 3.63 m/sec, the mixed water occupies the southern half of El-Max Bay whereas the diluted sea water type occupies the northern part. The eastern part of the investigated area shows a salinity value corresponding to that of undiluted Mediterranean water (Fig. 3).

The water types referred to above have the following characteristics (Table 2 and Figs. 4 and 5):

1. Mixed land drainage water type is slightly brackish and is characterized by very low salini-

Table 2a. Seasonal variations of the hydrochemical characteristics of average values for the land drainage water type "T" (0-10 S ‰)

Parameter	S	T	Dissolved oxygen	HS^-	Organic matter	pH	Alka-linity	Phenol	Ammonia	Nitrite	Nitrate	Phospho-rus	Chloro-phyl *a*
Month	‰	°C	$mlO_2\ l^{-1}$	$mgHS^-\ l^{-1}$	$mgO_2\ l^{-1}$		$millieq.l^{-1}$	ppm	µM	µM	µM	µm	mgm^{-3}
January 1988	5.629	14.20	1.79	1.31	9.94	7.78	5.40	186.25	32.20	2.52	0.08	1.19	0.24
February 1988	6.543	14.93	1.52	1.14	7.07	7.80	4.76	207.37	40.74	1.74	2.70	5.62	0.21
April 1988	5.996	21.07	1.70	0.96	1.46	7.75	4.36	140.16	57.66	3.87	4.41	9.26	0.06
June 1988	5.653	27.25	0.85	1.08	2.39	8.50	2.87	153.75	7.54	0.63	0.67	0.55	0.01
August 1988	6.012	28.41	0.81	2.23	6.66	7.60	5.62	**	72.20	4.87	19.50	1.10	0.11
November 1988	4.969	19.60	3.12	0.80	1.68	7.99	5.61	**	**	**	**	**	0.72
January 1989	7.236	14.20	2.93	0.99	6.62	7.50	5.66	**	**	**	**	**	0.90

** not sampled

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Table 2b. Seasonal variations of the hydrochemical characteristics of average values for the Mixed Water type "M" (10-30 S ‰)

Parameter		S	T	Dissolved oxygen	HS^-	Organic matter	pH	Alkalinity	Phenol	Ammonia	Nitrite	Nitrate	Phosphorus	Chlorophyl *a*
Month		‰	°C	$mlO_2\ l^{-1}$	$mgHS^-\ l^{-1}$	$mgO_2\ l^{-1}$		$millieq.l^{-1}$	ppm	µM	µM	µM	µm	mgm^{-3}
January	1988	22.920	14.80	2.21	1.69	3.66	7.98	4.03	124.81	24.05	3.06	8.78	4.71	0.12
February	1988	16.235	15.45	1.82	0.83	4.80	8.35	3.89	89.99	31.91	0.41	3.40	6.51	0.18
April	1988	22.661	19.50	2.08	0.85	2.66	8.06	3.45	148.87	28.40	4.17	9.29	3.94	0.11
June	1988	28.190	26.50	2.21	1.14	1.72	8.10	3.14	147.10	3.78	17.24	22.27	0.70	0.15
August	1988	25.312	28.38	1.60	2.00	5.26	7.73	4.19	**	16.89	3.57	16.15	0.84	0.07
November	1988	30.000	22.40	3.50	0.82	3.99	7.68	4.37	**	**	**	**	**	0.23
January	1989	27.307	14.80	3.47	0.14	5.29	7.23	3.56	**	**	**	**	**	0.27

** not sampled

Table 2c. Seasonal variations of the hydrochemical characteristics of average values for the diluted water type "D" (30-38.5 S ‰)

Parameter / Month	S (‰)	T (°C)	Dissolved oxygen ($mlO_2\ l^{-1}$)	HS^- ($mgHS^-\ l^{-1}$)	Organic matter ($mgO_2\ l^{-1}$)	pH	Alka-linity (millieq.l^{-1})	Phenol (ppm)	Ammonia (µM)	Nitrite (µM)	Nitrate (µM)	Phospho-rus (µm)	Chloro-phyl *a* (mgm^{-3})
January 1988	36.924	15.27	2.28	0.76	4.80	7.92	2.82	62.54	4.97	0.59	0.17	7.39	0.32
February 1988	35.827	16.00	3.37	0.90	2.40	7.79	3.23	97.39	8.83	0.77	3.58	3.67	0.12
April 1988	33.121	19.70	2.55	0.60	1.20	8.08	3.04	68.59	12.71	2.66	17.49	1.74	0.08
June 1988	36.335	26.28	2.00	0.99	1.94	8.30	3.40	103.13	5.46	7.62	16.71	3.56	0.06
August 1988	---	---	---	---	---	---	---	**	---	---	---	---	---
November 1988	35.162	22.72	3.68	0.81	0.95	7.98	3.78	**	**	**	**	**	0.14
January 1989	34.032	15.27	3.35	0.30	4.31	7.70	3.08	**	**	**	**	**	0.16

** not sampled

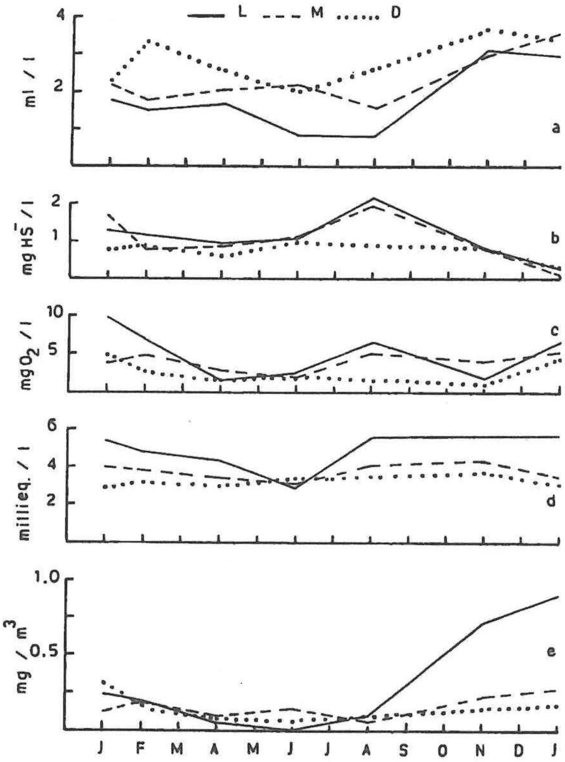

Fig 4. Seasonal variations of: a - dissolved oxygen, b - hydrogen sulphide , c - organic matter, d - alkalinity and e - chlorophyll *a*

ty ranging between 4.97 ‰ and 7.236 ‰ and temperature between 14.20 °C and 28.41 °C. This water type is also characterized by a low oxygen content (0.81 and 3.12 ml O_2 l^{-1}), its high concentration of hydrogen sulphide (0.29 - 2.23 mg HS^- l^{-1}) and of oxidizable organic matter (1.46-9.94 mg O_2 l^{-1}). It was characterized by a pH ranging from 7.50 to 8.50. It also had the highest alkalinity ranging between 2.87-5.66 millieq. l^{-1}. Highest concentrations of chlorophyll *a* were also found in this water type (0.061-0.90 mg pigment m^{-3}). It is also characterized by high average concentrations of dissolved ammonia 72.2 µm, average nitrite 4.87 µm and average nitrate 19.5 µm. The concentrations of inorganic phosphorus in this water type were also very high 5.62 µm. The highest concentrations of total phenolic compounds are found in this water type (140.16-207.37 ppm).

2. Mediterranean water „S" differed greatly from water type „L". It represents pure Mediterranean water free from the effects of land drainage. Its salinity ranged between

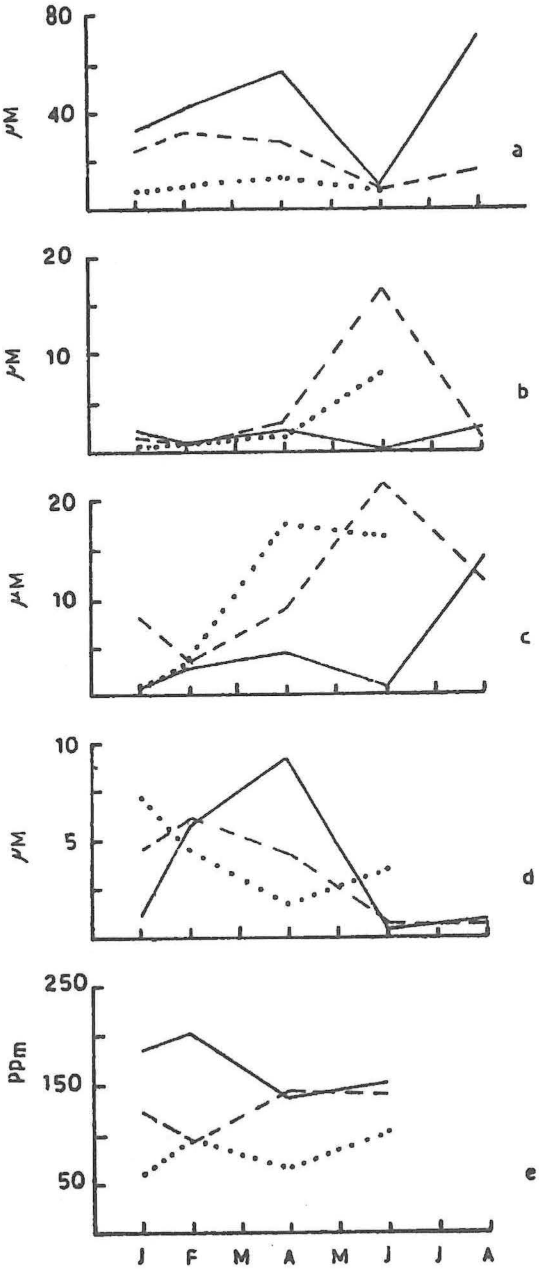

Fig 5. Seasonal variations of: a - ammonia , b - nitrite , c - nitrate, d - phosphorus and e - phenolic compounds

38.60 ‰ and 38.68 ‰ and its temperature ranged between 18.6 °C and 25.5 °C. It was characterized by a pH ranging between 7.90 and 8.01 and by alkalinity concentrations ranging between 2.91 and 3.52 millieq. l^{-1}, lower than of type „L" water. The dissolved oxygen content ranged between 2.74 and 3.70 ml O_2 l^{-1}, higher than that of type „L" water. It contained the lowest concentration of hydrogen sulphide, reaching 0.76 mg HS^{-} l^{-1}, and the lowest concentration of oxidizable organic matter (0.21-2.26 mg O_2 l^{-1}). The chlorophyll *a* concentration was low with a minimum value of 0.07 mg pigment m^{-3} and a maximum value of 0.14 mg pigment m^{-3}. Concentrations of dissolved ammonia, nitrite and nitrate were also very low as compared with their concentrations at water type „L". Average concentration of dissolved ammonia is 4.3 μm, of nitrite is 0.43 μm and of nitrate is 18.58 μm. The inorganic phosphorus compounds content was low (0.84 μm).

3. Water type „M" and „D"; these water types represent intermediate stages between water type „S" and water type „L". Water type „M" had a higher salinity than water type „L" but still lower than that od water type „S". Salinity ranged between 16.24 ‰ and 28.19 ‰ . Temperature values ranged between 14.80 °C and 28.38 °C. Comparing water types „M" and „L", it appears that the concentration of dissolved oxygen (1.6 and 3.57 ml O_2 l^{-1}) is still low, but higher than for type „L". The hydrogen sulphide concentration ranged between 0.14 and 2.00 mg HS^{-} l^{-1}. This water type is also characterized by a pH ranging between 7.23 and 8.35, higher than that of type „L" water, and by alkalinity concentrations ranging between 3.14 and 4.37 millieq. l^{-1}, lower than that of type „L" water. The concentration of oxidizable organic matter and chlorophyll *a* were lower in this type than in water type „L". Maximum organic matter was 5.29 mg O_2 l^{-1} and maximum concentration of chlorophyll *a* was 0.27 mg pigment m^{-3}. Except in June, the concentrations of nutrient salts were generally lower than those in type „L". Maximum concentration of dissolved ammonia was 28.4 μm, nitrite 3.57 μm and of nitrate 16.15 μm. Their respective minimum concentrations were 3.78, 0.41 and 3.4 μm respectively. The concentration of inorganic phosphorus ranged between 0.70 and 6.51 μm. Concentrations of total phenolic compounds are low as compared to water type „L" (89.99-148.87 ppm).

4. Water type „D" represents diluted sea water. Its salinity ranged between 31.327 ‰ and 38.212 ‰ (i.e. less than 38.5 ‰). Temperature ranged between 15.29 °C and 26.28 °C, pH between 7.70 and 8.30. The alkalinity average values of the „D" water type were lower than their values in type „M" with a maximum value of 3.78 and a minimum of 2.82 millieq. l^{-1}. The dissolved oxygen concentrations were higher than those of type „M" water with a maximum of 103.13 and a minimum of 62.54. Water with a maximum of 3.68 and a minimum of 2.00 ml O_2 l^{-1}. Hydrogen sulphide and oxidizable organic matter concentrations were lower than their concentrations in type „M" water. Maximum hydrogen sulfide was 0.99 mg HS^{-} l^{-1} and maximum organic matter was 4.80 mg O_2 l^{-1}. Their respective minimum concentrations were 0.30 mg HS^{-} l^{-1} and 0.95 mg O_2 l^{-1}. The maximum value of dissolved ammonia was 12.71 and its minimum value was 5.46 μm, nitrite maximum value was 7.62 and its minimum was 0.59 μm and nitrate maximum value was 17.49 and its minimum value was 0.17 μm. The inorganic phosphorus content ranged between 7.39 μm and 1.74 μm. The total phenolic compounds concentrations were lower than those of type „M" water with a maximum of 103.13 and a minimum of 62.54 ppm.

CONCLUSIONS

As the bay receives considerable amount of agricultural drains and waste waters (2.4 x 11^9 m^3/year), the need to pay much attention to the potential effects of anthropogenic inputs upon the water types and the hydrochemical characteristics of the bay is obvious.

Our study revealed that the hydrochemical characteristics as well as the water type of the bay are greatly affected by these different effluents.

Based on the salinity values, the water type could be classified into four different categories, namely: mixed land drainage water „L", Mediterranean water „S", mixed water „M" and diluted water „D".

The most important features which distinguish water type „L" from other types are the low salinity, low oxygen content, high concentration of hydrogen sulphide, organic matter, alkalinity, chlorophyll *a*, nutrient salts (mainly present in the ammonia form) and total phenolic compounds. On the contrary, water type „S", free from the effects of drainage water, has high salinity values and relatively high oxygen content but low alkalinity, hydrogen sulphide, organic matter, chlorophyll *a* , nutrient salts. The study also pointed out that water types „M" and „D" are affected to a certain extent by land drainage water which is more clear in „M" water type than in „D" water type.

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Utjecaj zagađenja na hidrokemijska svojstva različitih tipova vode u području zaljeva El-Mex, zapadno od Aleksandrije u Egiptu

M.A. SAID, M.S. EL-DEEK, Th.H. MAHMOUD i M.A. SHRIADAH

Nacionalni institut za oceanografiju i ribarstvo, Kayet Bay, Aleksandrija, Egipat

KRATKI SADRŽAJ

Pošto zaljev prima znatne količine otpada i otpadnih voda od poljodjelstva (2.4×11^9 m^3/god), očito je da je neophodno obratiti pozornost na moguće utjecaje na tipove vode i hidrokemijska svojstva zaljeva.

Naš rad otkrio je da različiti efluenti snažno utječu kako na hidrokemijska svojstva tako i na tipove vode u zaljevu.

Na osnovu vrijednosti slanosti tipove vode svrstali smo u četiri različite kategorije: miješana voda kopnenih otpada „L", Mediteranska voda „S", miješana voda „M" i razblažena voda „D".

Najvažnije odlike koje čine razliku između „L" tipa vode i ostalih tipova jesu niska slanost, niski sadržaj kisika, visoka razina vodikovog sulfida, organske materije, alkaliniteta, klorofila *a* , hranjivih soli (najčešće prisutnih u obliku amonijevih soli) i ukupni fenolovi spojevi. Suprotno tome, „S" tip vode koji nije pod utjecajem kopnenih otpadnih voda, pokazuje visoke vrijednosti slanosti, relativno visoki sadržaj kisika ali istovremeno niski alkalinitet, te niske vrijednosti vodikovog sulfida, organske materije, klorofila *a* i hranjivih soli.

Ustanovljeno je također da kopneni ispusti djeluju na „M" i „D" tipove vode u izvjesnoj mjeri, i to više na „M" nego na „D" tip vode.