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HYDROGRAPHIC OBSERVATIONS ON POLLUTION IN ABU KIR BAY, ALEXANDRIA, EGYPT

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SPLIT 1976

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INTRODUCTION

Until recently, Abu Kir Bay was one of the important breeding and nursery grounds for many economically important fish and shell-fish. As a result of the industrial development in the vicinity of the Bay and the damming of the Nile River, the chemical and hydrographic features of the Bay have been significantly altered in the last few years. Consequently, the Bay has lost much of its economic biological importance.

The objectives of this study were to determine the circulation pattern in the southwestern part of Abu Kir Bay and the effect and extent of mixing with different sources of pollution and land drainage during different seasons.

Abu Kir Bay is a semicircular bay with an average depth of about 10 m. It is bordered to the west by Abu Kir peninsula and to the east by the Rossetta peninsula where the Rosetta Branch of the Nile River discharges into the sea. South of this peninsula, Edfina Barrage was erected on the Rosseta Branch to control the flow of the Nile into the sea. Prior to the damming of the Nile River, about 40 x 10^6 tons of Nile water discharged annually into the Mediterranean through the Rosseta Branch during the flood season (late summer through autumn).

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During that period, the surface salinity of Abu Kir Bay was lowered to about 8‰ off Rosetta and about 24‰ in front of Abu Kir (Dowidar, 1965; Dowidar and El-Maghraby, 1971). During the rest of the year, the amount of Nile water reaching the sea was almost negligible. After the damming of the Nile River and since 1966 the amount of Nile water discharged into the Mediterranean through the Edfina Barrage has been greatly reduced, being on the average about 3000×10^6 m^3 per year. Moreover, contrary to the condition prior to the damming of the Nile, most of this amount is discharged during winter. Although it had no effect on the western part of Abu Kir Bay, it lowered the surface salinity of the eastern part of the Bay to about 37‰. In other seasons its effect was almost confined to the Rosetta estuary.

Abu Kir Bay is conected to the adjoining Lake Edku by the El-Maadiya Channel, which is a shallow canal 2 m deep and about 200 m wide. Lake Edku is a shallow brackish water lake extending about 19 km south of Abu Kir Bay from the east to the west. Its maximum depth barely exceeds 150 cm. The chlorosity of the lake proper varies between 0.4 to 200 g/L.

Lake Edku receives monthly about 83 to 280×10^6 m^3 of drainage water through three main drains, Edku, El-Boseily and Barzik, discharging into the eastern part of the lake (Table 1). This large amount of drainage water reaching the lake creates an almost permanent slow stream of drainage water which flows westward and finally discharges into Abu Kir Bay through El-Maadiya Channel.

Table 1. Volume of drainage water (in 10^6 m^3) discharged into Lake Edku in 1968, 1969 and 1970.

	Idku drain			El-Boseily drain			Barzik drain		
Month	1968	1969	1970	1968	1969	1970	1968	1969	1970
January	—	64	55	—	11	10	—	18	14
February	—	93	86	—	9	3	—	10	7
March	—	123	133	—	19	18	—	26	20
April	—	129	138	—	21	18	—	24	22
May	—	123	135	—	28	27	—	26	24
June	118	140	142	28	27	30	30	31	29
July	139	140	140	32	27	28	35	31	22
August	142	147	153	31	28	21	41	34	33
September	148	153	157	29	31	18	38	36	37
October	127	144	148	21	22	17	32	30	31
November	118	123	118	13	14	13	23	22	23
December	97	129	126	7	12	7	20	19	20

The circulation pattern in Abu Kir Bay is largely dependent on the mixing of inflowing oceanic Mediterranean water with the waters discharged into the Bay from three sources. These sources include: a) polluted water discharged from the El-Tabia pumping station; b) brackish water of Lake Edku discharged through El-Maadiya Channel; and c) river water discharge from the Rosetta branch of the Nile River. Discharge from the El-Tabia pumping station has become of significance as a result of developing industry. The discharge includes drainage water from the El-Behera Province as well as industrial wastes from several industries of which the Racta and National paper factories are the most important. The discharge into the southwestern portion of the Bay through the pumping station is of the order of 1,850,000 m^3 per day. Penetration of Lake Edku water into Abu Kir Bay is mostly controlled by the amount of land drainage into the lake and the prevailing wind.

METHODS AND MATERIALS

Twelve stations were selected in the southwestern part of Abu Kir Bay and adjacent Lake Edku. These stations were selected so as to be representative of the various hydrographic conditions of concern in this study. Surface sampling for salinity and oxygen was made monthly at each station for one complete year during the period September 1968 through August 1969.

As the chemical composition of Lake Edku water as well as the mixed water in Abu Kir Bay is basically different from that of seawater away from land runoff, the fundamental equation relating chlorinity and salinity of seawater (Knudsen, Forsch and Sorensen, 1902) cannot be applied to these waters. Hence, empirical equations relating chlorinity and salinity were computed in the present investigation for the different water types in the investigated area. To obtain these empirical formulae, the following parametres were measured in a limited but representative number of samples: a) gravimetric salinity according to the method of Morris and Riley (1964); b) precise chlorinity titration according to Mohr-Knudsen method. The silver nitrate solution was standardized against the international Copenhagen standard sea water (chlorinity — 19.375‰). High accuracy was obtained by weighing the 15 ml samples (Bather and Riley, 1954). The equations relating chlorinity and salinity were computed from the results of both determinations using the least square method. Dissolved oxygen was determined according to the standard method of Winkler (Harvey, 1955; Strickland and Parsons, 1965).

RESULTS

Based on the distribution of salinity in Abu Kir Bay, four types of water have been identified. Each water type represents different degress of mixing of three main water sources, i. e. Mediterranean water, lake water and polluted water. The four water types are: a) Mediterranean seawater designated as Type S (salinity $>$ 38.0‰); b) diluted seawater designated as Type D (salinity 35 to 38‰); c) mixed water which includes 2 types, Type M_1 (salinity 20 to 25‰) and Type M_2 (salinity 5 to 20‰); d) Lake Edku water designated as Type L (salinity $<$ 5‰). The salinity value of 38‰ is taken as representing the inner boundary of the neritic water off the Nile Delta and is slightly affected by land drainage. The salinity of the polluted water from the El-Tabia pumping station is about 2.5‰ while that of Lake Edku never exceeds 5‰.

The following is an account of the distribution and seasonal variation cf the diferent water types in the area investigated during the period September

1968 through August 1969. The distribution and seasonal variation are based on the distribution of the surface isohalines characteristic of the water types.

Autumn 1968. — As shown in Figure 1, the mixed water (M_1) and diluted seawater (D) occupied most of the inner south-western part of Abu Kir Bay. As indicated from the isohalines and the direction of the prevailing wind, dilution in the Bay may be attributed to the discharge from the El-Tabia pumping station. In September, the prevailing wind was northwest (frequency 51.2 percent) with an average velocity of 7 to 10 knots. The effluents from the pumping station were directed easterly thus affecting the entire south-western part of the Bay. The effect, however, diminished eastward and northward. Throughout this season the 20‰ isohaline occurred at the northern opening of El-Maadiya Channel and mixed water of Type M_2 covered the Channel and penetrated 2 to 3 km into Lake Edku. This suggests a sea-lake current which resulted in raising the salinity of the northern part of Lake Edku to 8.12‰ at station 6.

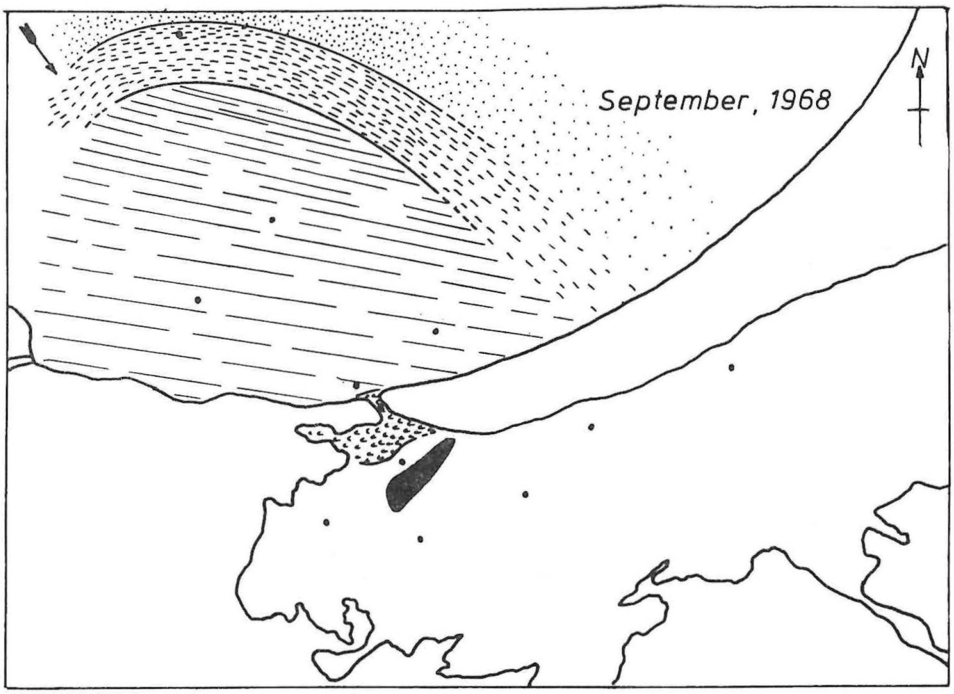
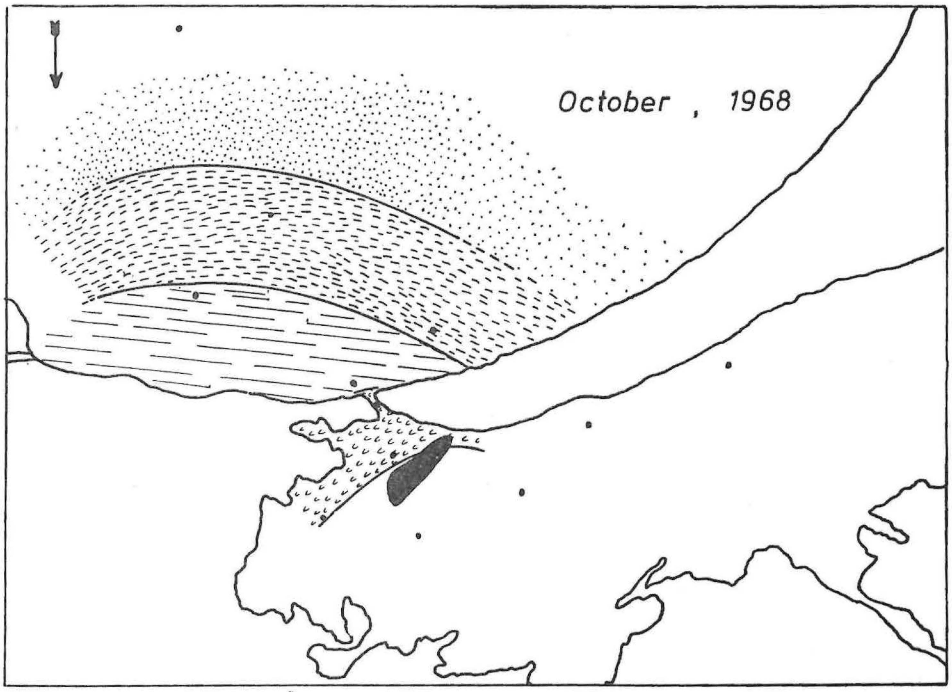
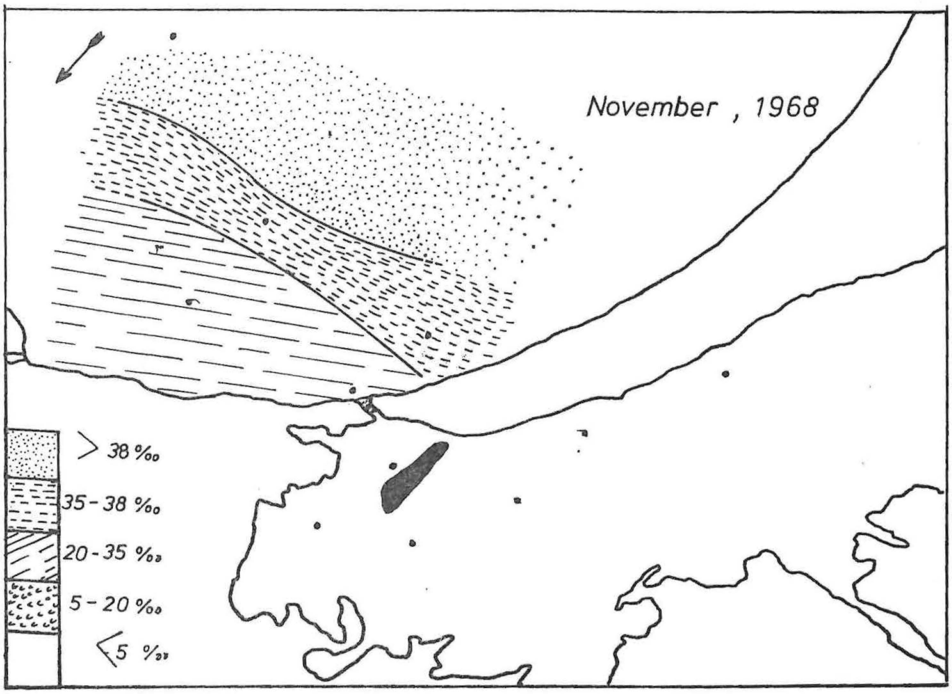


Fig. 1 — Distribution of water types S (salinity > 38‰), D (salinity 35—38‰), M_1 (salinity 20—35‰), M_2 (salinity 5—20‰) and L (salinity < 5‰) in Abu Kir Bay and Lake Edku by month during Autumn 1968. Arrow designates the dominant wind direction.


October , 1968


November , 1968
> 38 ‰
35 - 38 ‰
20 - 35 ‰
5 - 20 ‰
< 5 ‰

Winter 1969. — During this season, the prevailing wind varied between southwest and northwest and resulted in the formation of either a lake-sea current or a sea-lake current, depending on the direction of the wind. As shown in Figure 2, mixed water (Type M_2) occupied most of the western part of Lake Edku while Type M_1 was confined to a small area in Abu Kir Bay. Most of the polluted water discharged from the El-Tabia pumping station was driven in a northerly direction and probably resulted in the formation of water Type D.

The distribution of the various water types in February reflected the effect of wind direction and velocity. The average velocity of the prevailing wind was 16 knots with the dominant component northwest. This may have induced a sea-lake current, resulting in the pattern of salinity of distribution. Water Type D covered almost the entire southwestern part of the Bay and evidently penetrated into Lake Edku, forming M_1 and M_2. The source of dilution in Abu Kir Bay was evidently the discharge from the El-Tabia pumping station.

Spring 1969. — The conditions during this season (Figure 3) represented a transition between the preceeding season and the following summer. From March onward, mixed water (M_1 and M_2) retreated from Lake Edku. The

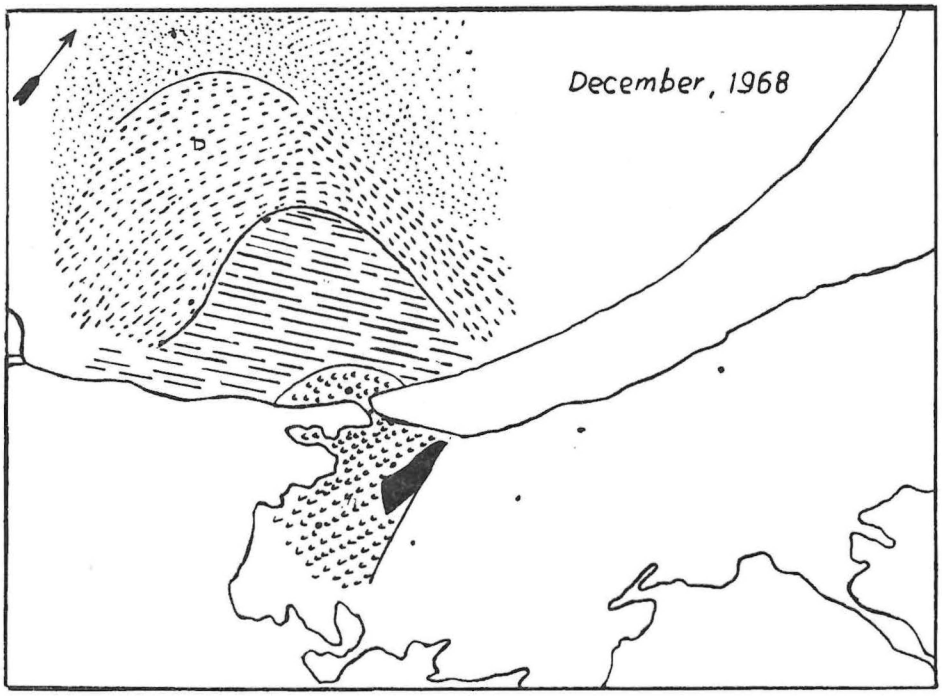
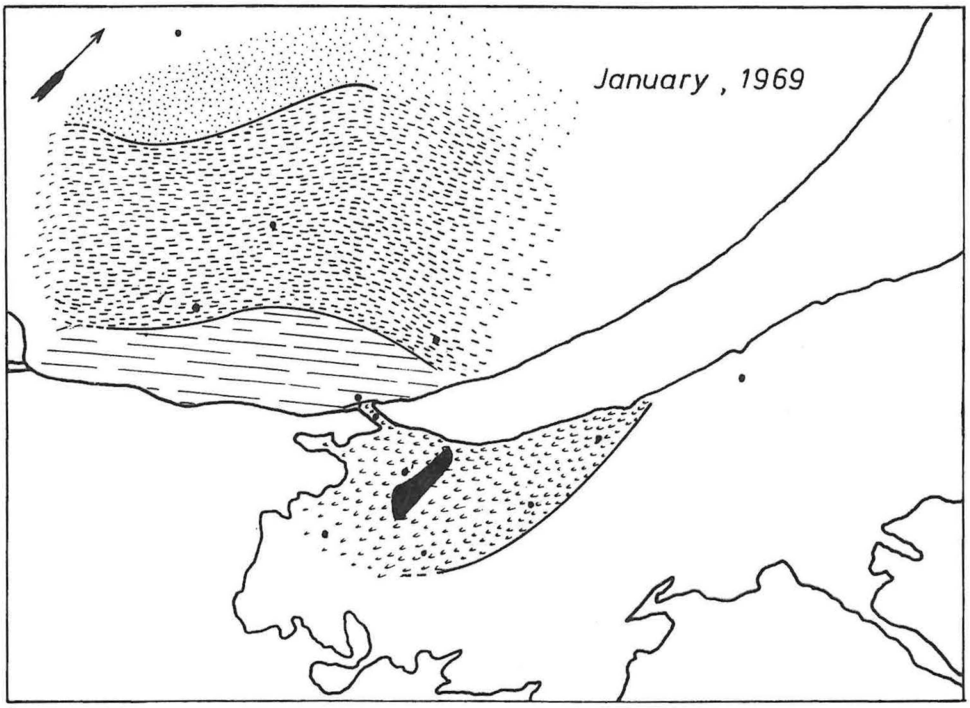
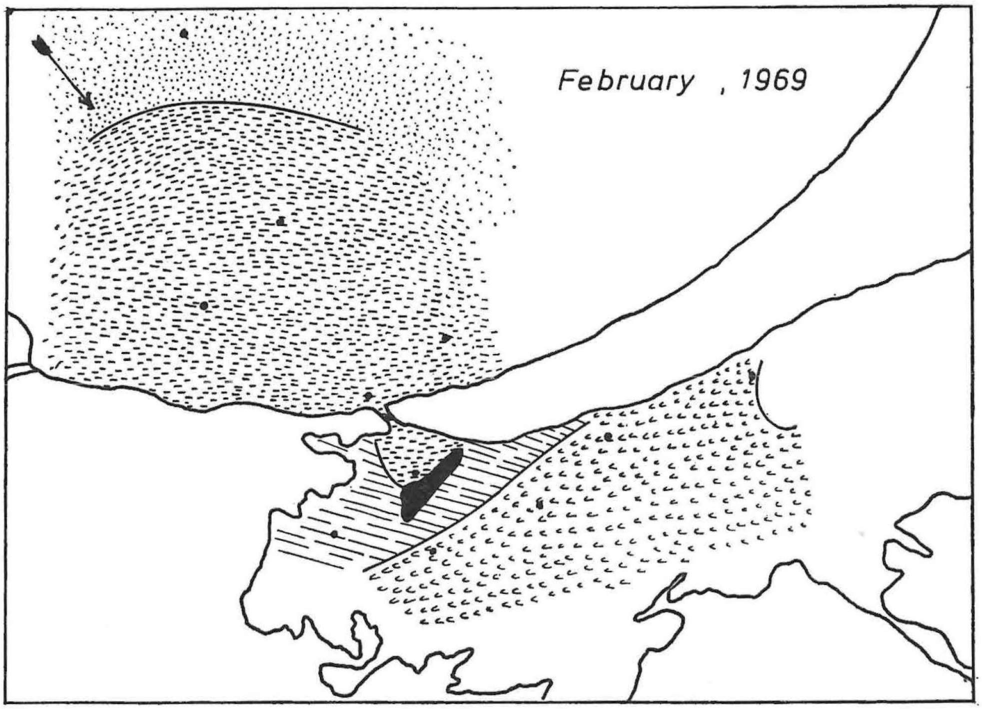
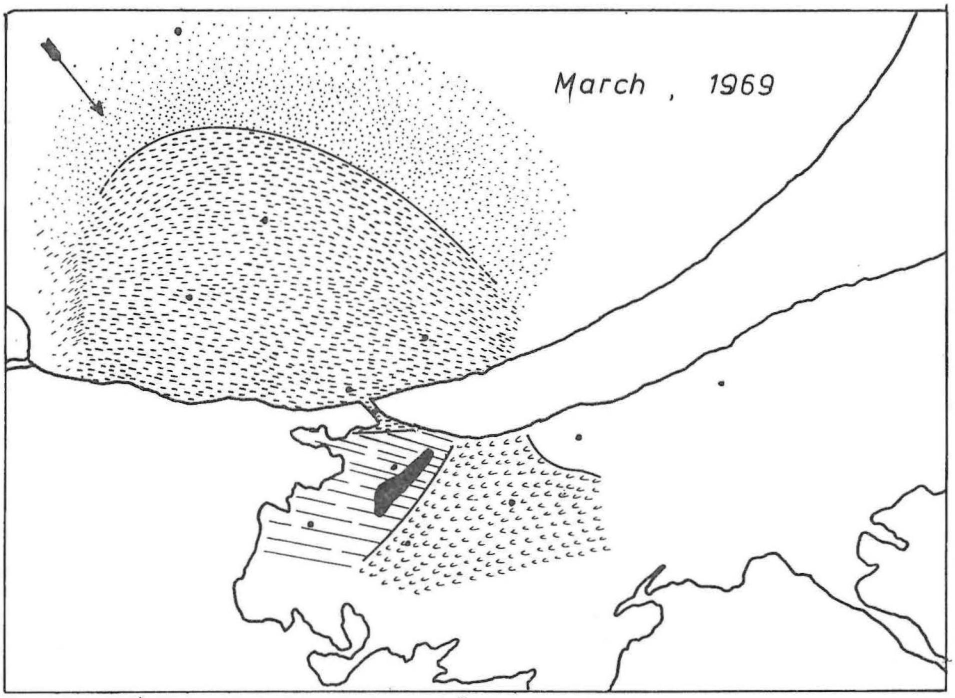
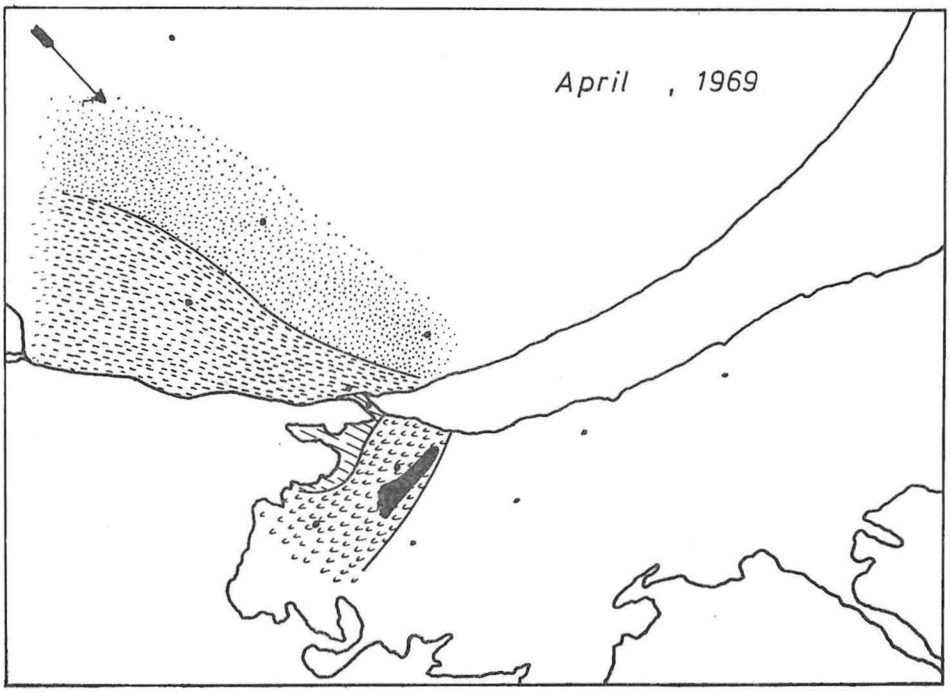


Fig. 2 — Distribution of water types S (salinity > 38‰), D (salinity 35—38‰), M_1 (salinity 20—35‰), M_2 (salinity 5—20‰) and L (salinity < 5‰) in Abu Kir Bay and Lake Edku by month during Winter 1968. Arrow designates dominant wind direction.


January , 1969


February , 1969


March , 1969


April , 1969

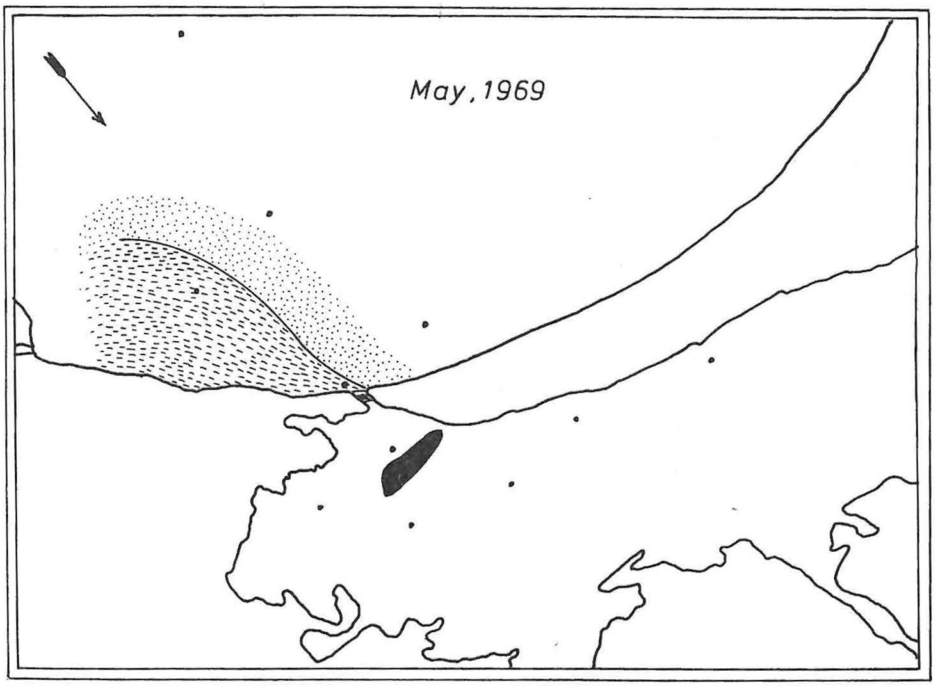


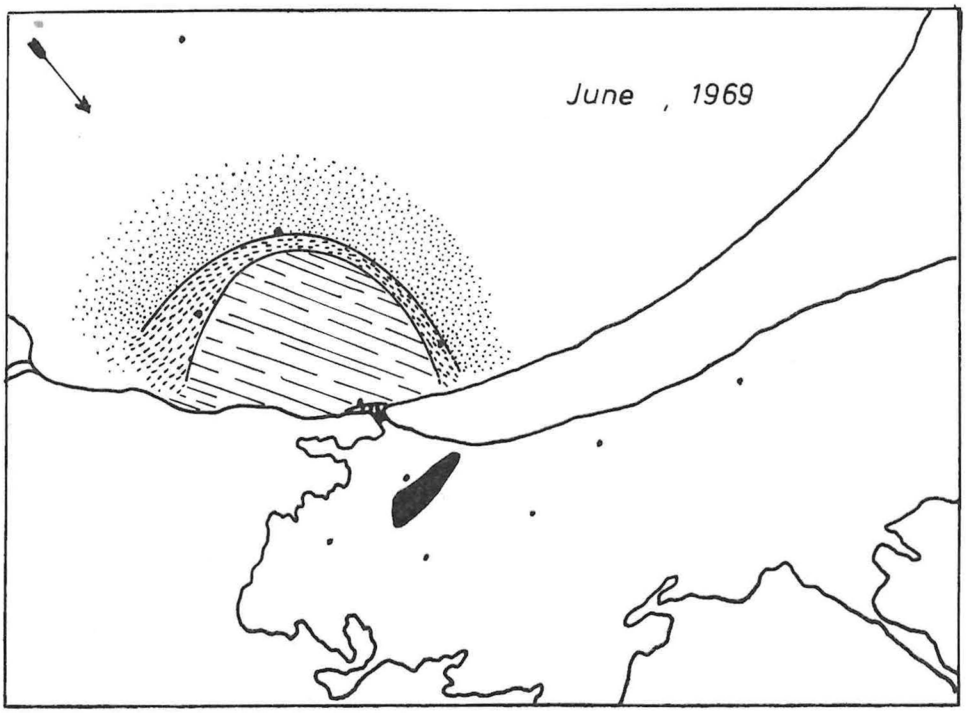
Fig. 3 — Distribution of water types S (salinity > 38‰), D (salinity 35—38‰), M_1 (salinity 20—35‰), M_2 (salinity 5—20‰) and L (salinity < 5‰) in Abu Kir Bay and Lake Edku by month during Spring 1969. Arrow designates dominant wind direction.

condition in May was highly significant. The salinity in El-Maadiya Channel was 2.09‰ and in Abu Kir Bay, about 1.5 km from the Channel, 38.01‰. This indicates that the mixing between the waters of the Bay and the Lake was very insignificant (see below). The increased quantity of drainage water discharged into Lake Edku (Table 1) and the prevailing northerly wind (frequency, 68 percent) were probably responsible for creating this pattern of distribution of the water types. Water Type D, covering the southwestern part of Abu Kir Bay, was the result of dilution caused by discharge from the El-Tabia pumping station.

Summer 1969. — As a result of the increased drainage water discharged into Lake Edku, a lake-sea current flowing through El-Maadiya Channel was formed. Lake water (Type L) penetrated a considerable distance into Abu Kir Bay (Figure 4). Further spreading into the Bay, however, was rather restricted as a result of the prevailing northerly winds. Water Type M_2 was very restricted while M_1 occupied a considerable area in the vicinity of the channel. The effect of discharge from El-Tabia was probably confined to a restricted area near the outfalls.

Distribution of Oxygen. — Figure 5 shows the distribution of dissolved oxygen for the area investigated. The concentration of dissolved oxygen in Type S ranged from 3.24 to 4.79 ml/L, reflecting the normal concentration for the Mediterranean water off the Nile Delta (E m a r a, H a l i m and M o r c o s, 1973). The concentration in the mixed water showed wide variation during the different seasons (Table 2). During autumn, M_1 had lower values than Types D and S. This may have been due to mixing with polluted water from the El-Tabia pumping station. According to A b b a s (1970), the dissolved oxygen content of the polluted water rarely exceeded 3.0 ml/L and he attributed the low oxygen content to the high organic content of the polluted water. This supports the assumption that the mixed waters were mostly affected by the water discharged from the El-Tabia pumping station during Autumn.

During the winter, the oxygen content of Types M_1 and M_2 increased considerably, reflecting the effect of mixing with highly oxygenated Lake Edku water. The mixed water types were either entirely or partly located in the Lake. As shown in Figure 2 mixed water type M_2 occurred inside the Lake in December and January while in February types M_1 and M_2 both occurred inside Lake Edku.



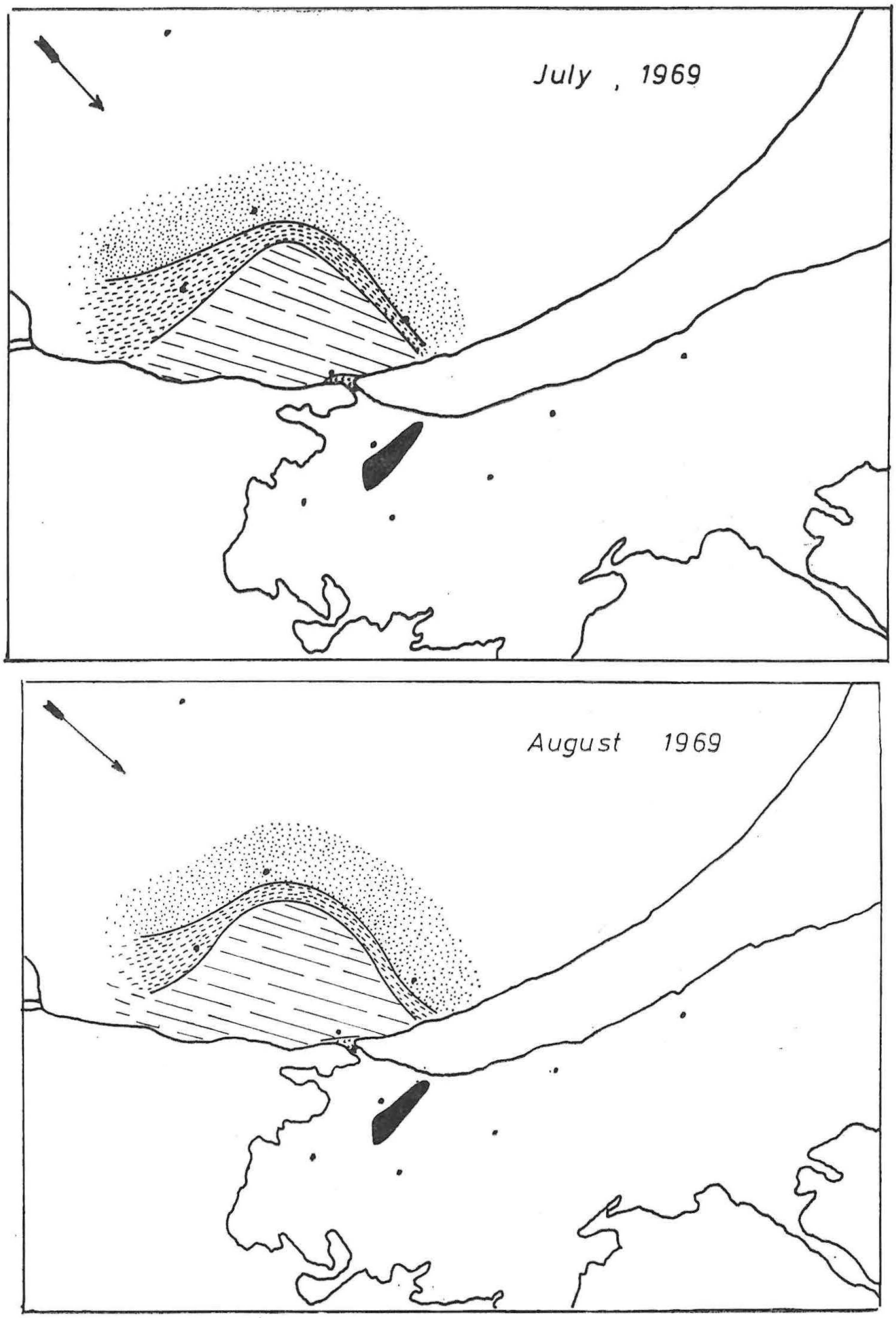


Fig. 4 — Distribution of water types S (salinity > 38‰), D (salinity 35—38‰), M_1 (salinity 20—35‰), M_2 (salinity 5—20‰) and L (salinity < 5‰) in Abu Kir Bay and Lake Edku during Summer 1969.

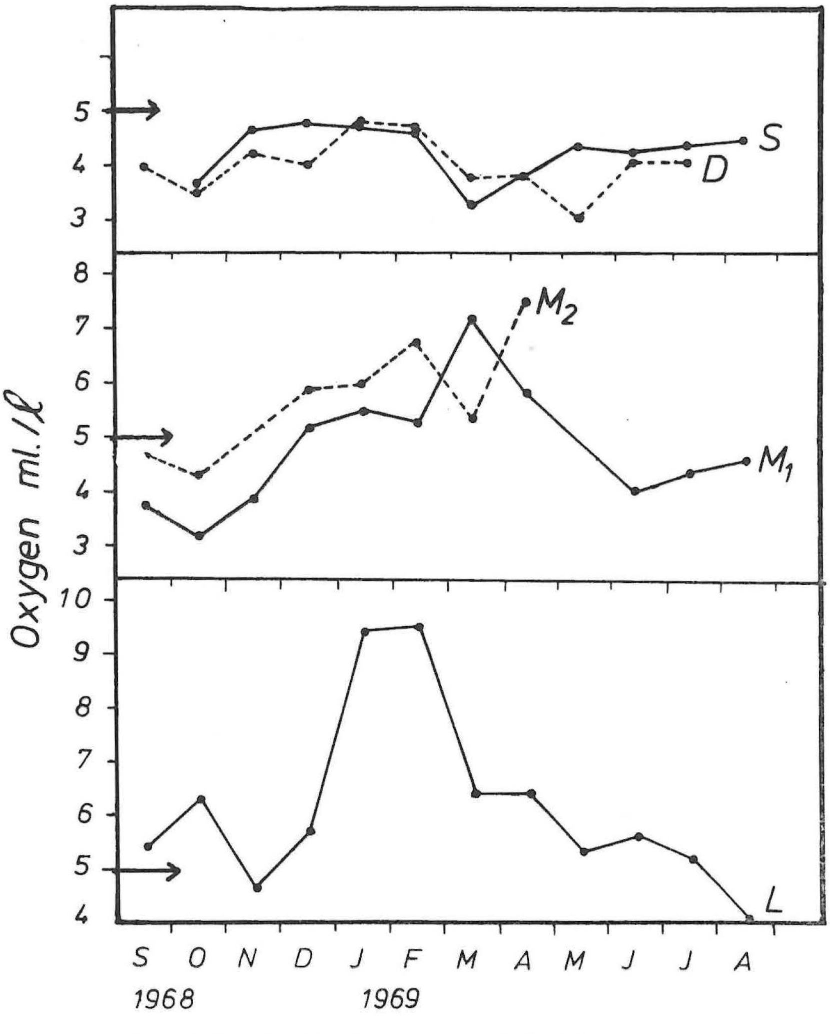


Fig. 5 — Seasonal variation in dissolved oxygen (ml/L) in different water types (S, D, M_1, M_2, L) in Abu Kir Bay and Lake Edku.

During summer, mixed water Type M_1 occurred exclusively inside the Bay; the oxygen content, although lower than that of winter, was significantly higher than autumn values, probably due to mixing with the highly oxygenated out-flowing Lake water. Water Type M_2 was very localized around the northern end of El-Maadiya channel.

The oxygen content of Type D showed the effect of polluted water from the El-Tabia pumping station. With the exception of March, Type D showed almost invariably lower oxygen content than Type S, indicating that dilution of the latter was caused by water of lower oxygen content (polluted water) than by highy exygenated (Lake) water.

Table 2. Seasonal variation in dissolved oxygen (ml/L) in the different water types in Abu Kir Bay and Lake Edku.

Month	Type S	Type D	Type M_1	Type M_2	Type L
September 1968		3.98	3.74	4.65	5.41
October	3.67	3.51	3.17	4.30	6.30
November	4.64	4.20	3.85	—	4.63
December	4.79	4.00	5.17	5.84	5.68
January 1969	4.64	4.79	5.49	5.94	9.39
February	4.58	4.68	5.27	6.78	9.51
March	3.24	3.75	7.14	5.32	6.39
April	3.80	3.80	5.80	7.45	6.36
May	4.30	3.00	—	—	5.32
June	4.20	4.00	3.95	—	5.59
July	4.30	4.00	4.30	—	5.20
August	4.40	—	4.50	—	4.04

DISCUSSION AND CONCLUSIONS

It is clear that the hydrographic conditions of Abu Kir Bay, especially the southwestern part, are mostly dependent on the interaction of water from sources, including polluted water discharged from the El-Tabia pumping station, the brackish water of Lake Edku and Mediterranean water and the wind regime during different seasons. The influence of discharged polluted water, having low salinity and low oxygen content, is seen in the south-western part of the Bay. The northward and eastward distribution of diluted sea water (Type D) generally with low oxygen content, depends on the prevailing wind. During late winter and through spring, Type D extended southward to the El-Maadiya Channel and may at times penetrate into Lake Edku to a considerable distance in February. During summer, Type D may have spread easterly and mixed with the outflowing brackish Lake water. The latter condition seems to be a regular phenomenon during summer and autumn.

Penetration of Lake water, with its high oxygen content, into Abu Kir Bay is mostly controlled by the amount of drainage water discharged into the Lake as well as the direction of the prevailing wind. Thus during summer, a lake-sea current is usually established causing the dilution and increasing the oxygen content of a considerable area in the Bay near the El-Maadiya Channel. The result of dilution is the formation of the mixed water types.

It is of interest to mention that the amplitude of tides of the south-western Mediterranean is very small, reaching a maximum of about 30 cm on the Egyptian coast. However, it may affect the exchange of water between Lake Edku and Abu Kir Bay through El-Maadiya Channel particularly during spring when the highest and lowest tides occur. The pattern is semidiurnal, resulting in a slow lake-sea current occurring in the morning and a reserse sea-lake current at midday.

The transition from winter to summer can be seen by the conditions that prevailed during May 1969. The rise of water level in Lake Edku, caused by increased drainage water, pushed Lake water in a northerly direction to El-Maadiya Channel, while the prevailing wind drove the Bay water in a southerly direction. These two factors nearly balanced each other at the El-Maadiya Channel and created a strong horizontal salinity gradient. The salinity in El-Maadiya Channel was 2.09‰ and rose to 38.01‰ about 1.5 km from the Channel into Abu Kir Bay. Thus mixing between water from the Lake and the Bay was very insignificant.

The pollution of Abu Kir Bay, due to disposal of wastes from the paper factories, is more or less limited to the southwestern area near the El-Tabia outfalls. The polluted water, however, may extend under certain conditions, eastward and northward, and thus affect large areas of the Bay. The extension of polluted water is easily detectable and traceable because of its low oxygen content. Although mass mortality of fish and other animals have not been reported in the Bay, the plankton content of the polluted area is very low and benthic life in front of the El-Tabia outfalls is completely lacking (unpublished data). The large stocks of juvenile *Mugil* spp. that previously occupied the Bay have drastically declined. These and other changes in the biology of the Bay are most probably due to the discharge of polluted water from the El-Tabia pumping station. It is expected that continued discharge of wastes from paper factories in increasing quantities will damage the marine life of the entire Bay.

CONCLUSIONS

The pattern of circulation in the southwestern part of Abu Kir Bay is a dynamic one, changing seasonally and even monthly. The presence of mixed water either in Lake Edku or in Abu Kir Bay is controlled by two factors, the velocity and frequency of the prevailing northerly wind and the amount of drainage water received by the Lake.

The pollution of Abu Kir Bay is due to industrial discharge from paper factories into the southwestern part of the Bay. The distribution of the discharge is the most widespread in summer and autumn.

SUMMARY

Abu Kir Bay is a semicircular bay lying 30 km nort of Alexandria between Rosetta peninsula and Abu Kir peninsula. The Water circulation in the Bay is largely dependent on the mixing of the inflowing Mediterranean water with waters discharged into the Bay by 3 main sources of land runoff: a) brackish water from the adjoining Lake Edku through El-Maadiya Channel, b) industrial polluted water pumped out into the Bay the El-Tabia pumping station, c) river water discharged from the Rosetta branch of the Nile river.

The last mentioned source is, however, of little importance since the damming of the Nile.

The circulation pattern in the southwestern part of Abu Kir Bay has been studied based on the distribution of surface salinity and oxygen content of 12 stations selected to represent the different water types occurring in the Bay and adjoining Lake Edku. In the area investigated it has been possible to identify 4 types of water: a) proper seawater, Type S (salinity > 38‰); b) diluted seawater, Type D, (salinity 38—35‰); c) mixed water which is subdivided into Type M_1 (salinity 35—20‰) and Type M_2 (salinity 20—5‰); d) proper Lake water, Type L (salinity < 5‰).

While water Type D occurred exclusively in the Bay and the Type L occurred always in Lake Edku, the presence of mixed water (M_1 and M_2) either in the Lake or in the Bay was controlled by the velocity and frequency of the prevailing northerly winds and the amount of agricultural drain water reaching the Lake. Usually, increased amounts of drain water occurred in summer and coincided with low velocity northerly winds, thus favouring a lake-sea current and water Types M_1 and M_2 occurred in the Bay.

The reverse condition occurred in winter and seawater was pushed southwards when Types M_1 and M_2 occurred inside the lake.

The circulation pattern concerning the distribution of the 4 water types in the area and the effect and extent of the industrial polluted water in the southwestern part of Abu Kir Bay is detailed.

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HIDROGRAFSKA OPAŽANJA U ODNOSU NA POLUCIJU U ABU KIR ZALJEVU KOD ALEKSANDRIJE

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KRATAK SADRŽAJ

Abu Kir je polukružni zaljev, smješten između poluotoka Rosseta i Abu Kir, 30 km sjeverno od Aleksandrije. Cirkulacija vode u zaljevu u velikoj mjeri ovisi o miješanju izvorno mediteranske vode s tri kopnene vode: a) brakičnom vodom jezera Edku koja ulazi kroz kanal El Maadiya; b) industrijskom otpadnom vodom ubacivanom u zaljev iz crpne stanice El-Tabia; c) riječnom vodom iz grane Nila Rosetta. Ovaj posljednji izvor je, međutim, nakon izgradnje nilske brane od male važnosti.

Raspodjela površinskog saliniteta i sadržaja kisika na 12 postaja odabranih s ciljem da pokažu različite tipove voda koji se javljaju u zaljevu i pokrajnom jezeru Edku, omogućila je izučavanje cirkulacije vode u jugozapadnom dijelu zaljeva Abu Kir. Bilo je moguće odrediti 4 tipa vode: a) čistu morsku vodu tipa S (salinitet $> 38‰$); b) zaslađenu morsku vodu tipa D (salinitet 38—35‰); c) izmiješanu vodu podijeljenju u tip M_1 (salinitet 35—20‰) i tip M_2 (salinitet (20—5‰); d) jezersku vodu tipa L (salinitet $< 5‰$).

Dok se voda tipa D javlja isključivo u zaljevu, a tip L uvijek u jezeru Edku, izmiješana voda M_1 i M_2 je prisutna u jezeru ili zaljevu u ovisnosti o brzini i frekvenciji prevladavajućih sjevernih vjetrova te o količini poljoprivredne drenažne vode. Povećana količina drenažne vode se javlja ljeti i koincidira s malom brzinom sjevernih vjetrova što uslovljuje strujanje iz jezera prema moru. U zaljevu to uslovljuje pojavljivanje tipova voda M_1 i M_2. Obrnuti uslovi se javljaju zimi kada je morska voda potiskivana prema jugu, pa se tipovi M_1 i M_2 javljaju u samom jezeru.

U radu je detaljno prikazana cirkulacija i raspodjela spomenutih tipova vode te utjecaj i rasprostranjenje industrijske otpadne vode u jugozapadnom dijelu zaljeva Abu Kir.