Qatar Univ. Sci. J. (1991), 11: 379 - 390

CIRCULATION AND WATER MASSES AND THEIR IMPLICATION ON POLLUTANT TRANSPORT DURING SUMMER IN ABUQUIR BAY (EGYPT)

By

A.A.H. EL-GINDY*, S. SHEREET*** and S. EL-SHIEKH**
*Marine Science Department, Qatar University, Qatar.
**Alexandria University, Faculty of Science, Egypt.
***Research assistants at the Institute of Research and Coastal Protection Studies, Alexandria.

Key Words: Circulation, water masses, pollutant transport

ABSTRACT

Abuquir Bay is a shallow area with a mean depth of about 10 meters, and it is affected by significant sources of industrial and agricultural pollutants. Water masses, the distribution of dissolved oxygen and total suspended matter, as well as the water circulation in this area are discussed using hydrographic data collected in September, 1984, at 40 stations.

In Summer, horizontal distributions of oxygen, salinity and currents showed a strong outflow from the Maadia outlet, which connects the bay with Idku Lake. Therefore, it is expected that agricultural pollutants from Lake Idku are dispersed in the above current direction. The density current plays an important role in the observed water movement in the bay. The high concentration of suspended matter was associated with lower oxygen values due to oxidation of organic matter. The currents are strong enough to initiate the sediment movement and to intensify the coastal processes. This sediment motion could also transport adsorbed pollutants to the offshore area.

INTRODUCTION

Abuquir Bay is a relatively sheltered semi-circular area east of Alexandria, lying between $31^{0}16' - 31^{0}28'$ N and $30^{0}04' - 30^{0}20'$ E, fig. (1). This bay was the delta of one of the old River Nile branches (Canopic branch) and it was formed due to subsidence of the land and the recent rise of sea level. However, wave and current action have permanently modified the shore line of the area (detailed technical report, 1973).

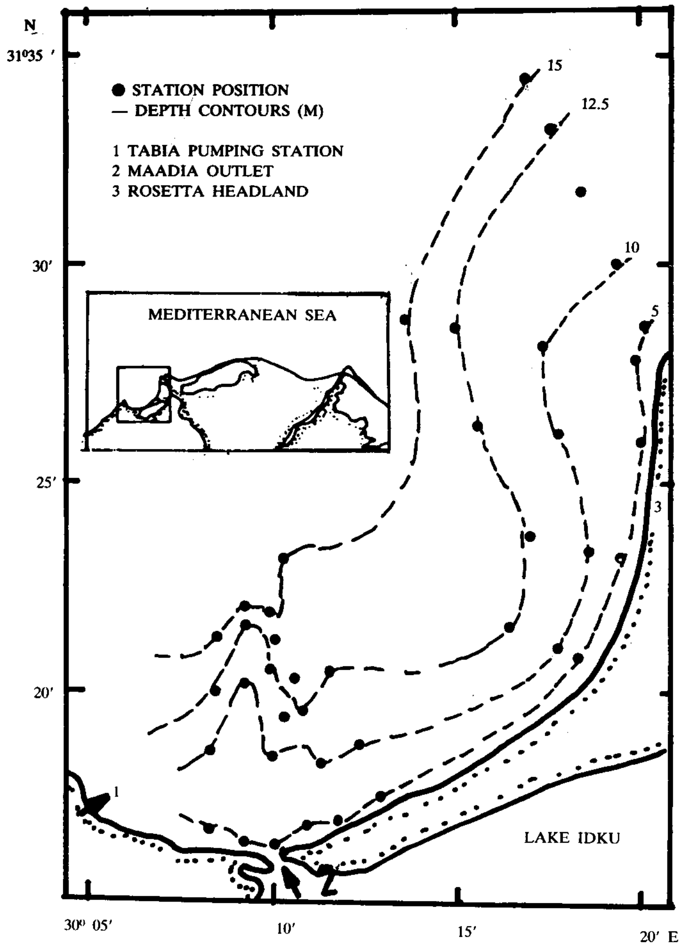


Fig. 1: Abuquir Bay map showing depth contours, and positions of hydrographic stations occupied in Summer, 1984.

The bay is shallow; the mean depth south of the line joining Rosetta and Abuquir headlands is less than 10 meters. Hence, the circulation in the bay is expected to be variable under the action of wind stress and fresh water discharge from the El-Tabia pumping station, El-Maadia and the Rosetta tributary, fig. (1).

A study of circulation and hydrography in this area is important for two reasons:

1. This area receives substantial amounts of industrial wastes (mainly from the El-Tabia pumping station) and agricultural wastes (mainly from Idku Lake), and is consequently highly polluted.
2. The coastal sediments of the Nile delta, including Abuquir Bay consist of loose

sediments and, therefore, they are susceptible to great variability due to the action of currents, as well as by waves and tides.

This study could lead to a greater understanding of pollutant transport in the region. In previous studies of this region, the hydrographic stations were either distant from each other or concentrated in a narrow nearshore area with depths less than 6 meters. Manohar (1976) concluded that, from accretion and erosion estimations, it is necessary to extend the current measurements to offshore waters in order to understand the sediment dynamics along the Egyptian Mediterranean coast.

DATA AND METHODS OF ANALYSIS

Forty stations were occupied, from 27th August to 3rd September, 1984, to cover nearly the whole bay. Station depths ranged between 5 and 15 meters. At each station, current velocity, salinity, dissolved oxygen concentration and suspended matter concentration were determined at depths of 1, 5, 10 and 15 meters. Echosounder profiles were also taken during this survey to determine the bathymetric features of the area.

The temperature was measured using reversing thermometers and an inductive salinometer was used to determine the salinity. The total amount of suspended matter was found out by the filtration of one liter of water sample through 0.45 mm membrane filters. Current values were obtained using direct reading current meters, averaging observations over 3 minutes.

Finally, the dissolved oxygen concentration was determined using the standard chemical method of Strickland and Parsons (1868).

RESULTS AND DISCUSSION

A. The water masses:

The water masses of Abuquir Bay were studied by Sharaf El-Din *et al* (1980) using the data from 8 monthly cruises taken between January, 1977, and February, 1987. Two water masses were identified. One was confined to the upper 10 meters and the inner part of the bay, with lower salinity. The other water mass was found under the first water mass in the offshore water and was characterised by a higher salinity. The first water mass was diluted by fresh water from land sources, while the latter one represents Mediterranean water. The main characteristics of these two water masses are shown by table (1).

Table 1
Characteristics of water masses in Abuquir Bay in 1977 after Sharaf El-Din, Gerges, Osman and Said (1980)

Season	Upper 10 meters		Below 10 meters	
	T°C	S°/00	T°	S°/OO
Winter	16.5-17.3	37.4-38.5	16.9-17.8	38.8-39.1
Spring	17.1-18.5	38.0-38.8	16.7-17.1	38.8-39.3
Summer	25.0-28.0	38.8-39.2	—	—
Autumn	22.0	38.9-39.2	—	—

The Summer average amount of fresh water discharged by the Tabia Pumping station is about 54.10^6 m^3/month (Aboul Dahab, 1989). In 1977, the amount of fresh water discharged in the bay, during Summer, was (193-195) 10^6 m^3/month from lake Idku and 15.10^6 m^3/month from the Rosetta tributary. In Winter, Lake Idku discharges about 80.10^6 m^3/month, while the Rosetta tributary contributed (2000-2080)10^6 m^3/month. Thus, the River Nile was the major source of fresh water to the bay in Winter while in Summer, Idku lake was the major contributor. In Summer, the large inputs of fresh water from Idku Lake is expected to cause more pollution by agricultural wastes (Sharaf El-Din *et al*, 1980).

Data collected during Summer, 1984 (Internal Report, 1984) are shown in fig. (2). They indicate that the water density (sigma T) in the bay lies between 23.6 and 26.4 with the least values near Maadia outlet and in the upper part of water column. The characteristics of the two main masses in the bay are:-

1. Upper 5 meters near Maadia outlet: T: 26.0−27.3°C, S: 36.0−36.3°/00.
2. Below 10 meters depth and offshore: T: 25.7−26.1°C, S: 39.1−39.4°/00.

The horizontal distribution of near surface and bottom salinity is shown in figs. (3) and (4) respectively (Internal Report, 1984). These observations confirm that Lake Idku is the main source of fresh water in Summer, with a distinct near surface tongue in front of the Maadia outlet. The motion and heading of the Mediterranean water mass was implied by a high salinity tongue from the east of the bay near the bottom. The influence of the Tabia Pumping station discharge is not obvious in the latter two figures since observations were not taken close enough to this source. Midway between the Maadia outlet and Rosetta headland, there was an area with low salinity; these waters could be due to longshore flow in the nearshore zone from Maadia to Rosetta.

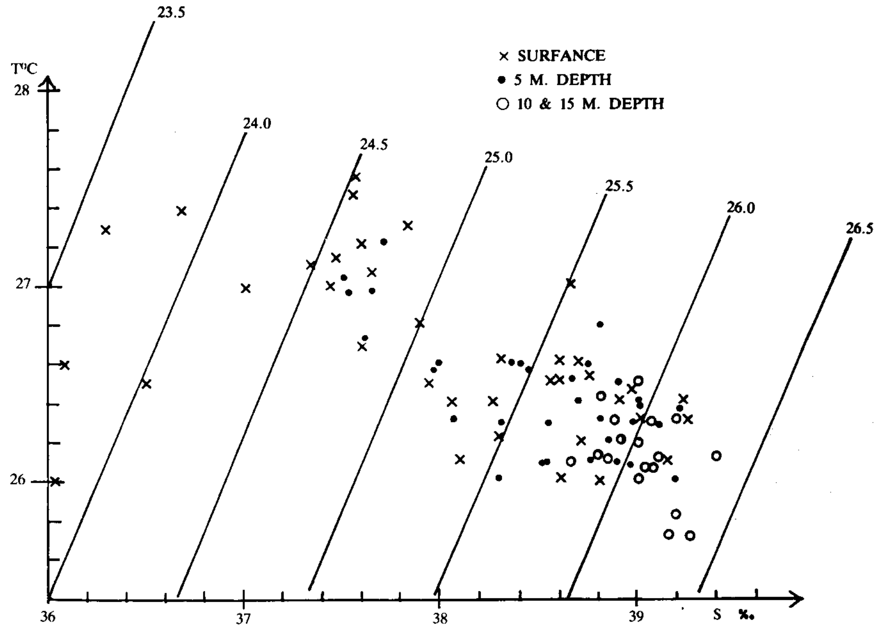
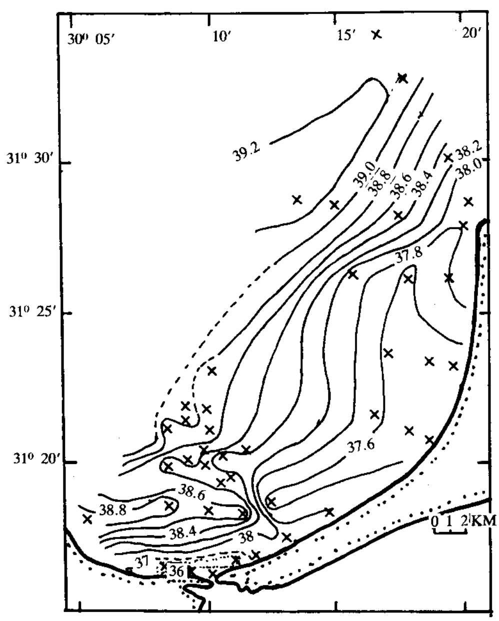


Fig. 2: The T-S diagram in Abuquir Bay, up to 15 meters depth.



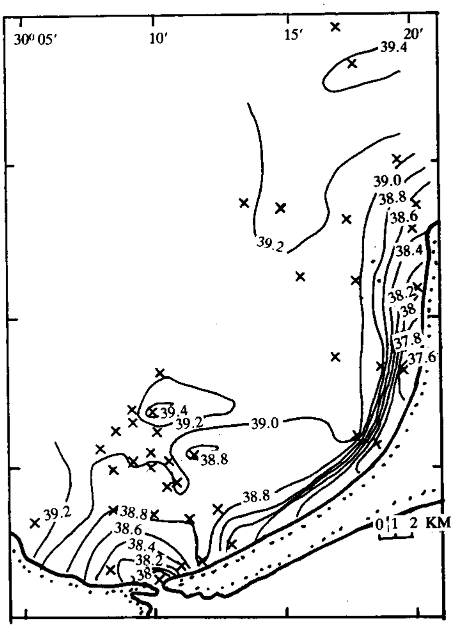
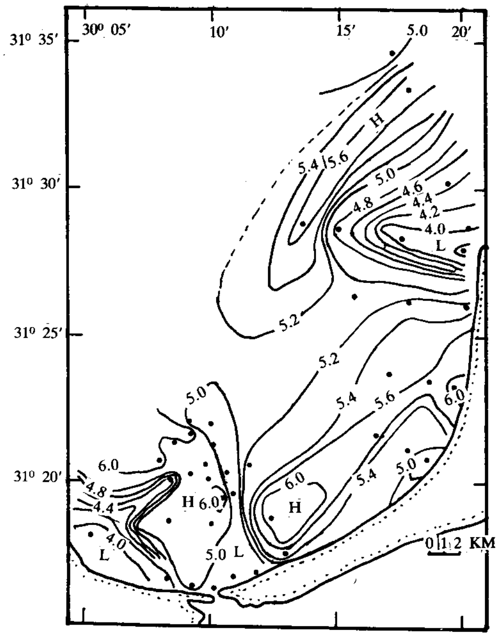


Fig. 3: Horizontal salinity distribution at surface in Abuquir Bay

Fig. 4: Horizontal salinity distribution, near bottom in Abuquir Bay.

B. The dissolved oxygen distribution in the bay:

The surface pattern of dissolved oxygen concentration shown in fig. (5), for Summer 1984, exhibits lower oxygen values offshore of the Tabia and Maadia outlets and mid-way between Rosetta and Maadia. This low concentration could be related to higher concentrations of organic matter brought by the fresh water discharge. On the other hand, the high oxygenated offshore water is associated with the Mediterranean water. Near bottom, the dissolved oxygen has a trend opposite to that in the upper water; zones with maximum values in the upper layer have minimum values in the lower layer (fig. 6).



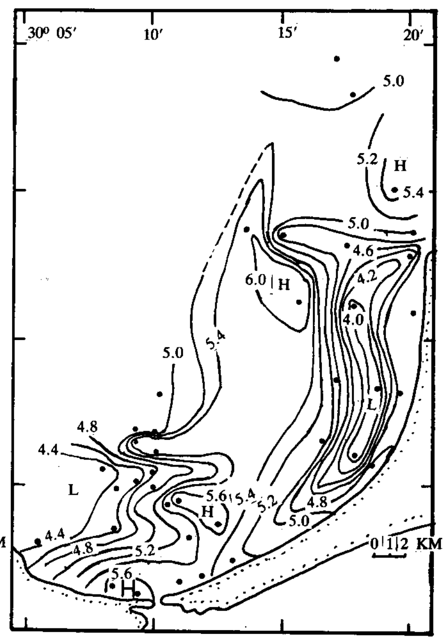


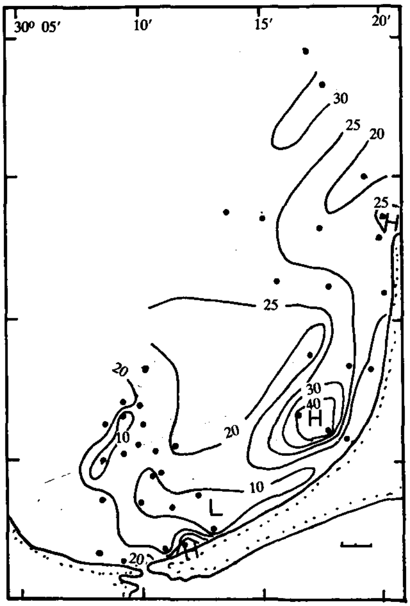
Fig. 5: Horizontal distribution of dissolved oxygen at surface in Abuquir Bay

Fig. 6: Horizontal distribution of dissolved oxygen near bottom in Abuquir Bay

C. Total suspended matter:

During the 1975 Chain cruise, the total suspended matter concentration in the Rosetta zone was surveyed on March 28-29 and April 10. Very high concentrations of suspended matter occurred after the March storm, with 31 gm/1 in the surface waters off the river mouth, compared to 1.1 gm/1 at the shelf edge. No river discharge occurred during that period, and the high suspended matter concentration was explained by the resuspension of muddy bottom sediments (Colin and Nancy, 1975), which depends on weather conditions.

Observations taken in Summer, 1984, show the total surface suspended matter ranged between 4 and 46 mg/1, fig. (7). Near the bottom, concentrations were between 11 and 47 mg/1. The highest concentrations were near Rosetta headland, in front of the Maadia outlet and near El-Tabia. These zones coincided with zones of minimum oxygen concentration in the upper surface layer; this evidence further confirms our interpretation above of the horizontal oxygen distribution in the bay.



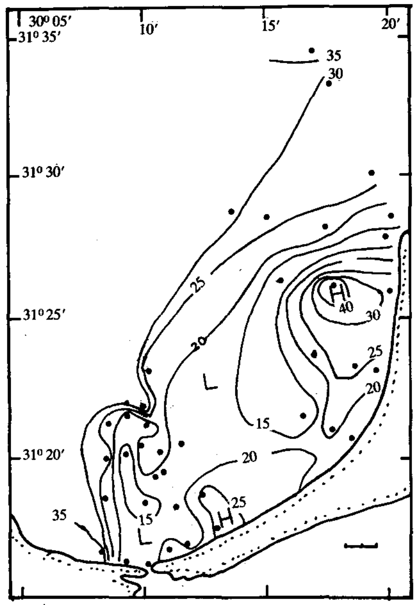


Fig. 7: Horizontal distribution of suspended matter at surface in Abuquir Bay

Fig. 8: Horizontal distribution of suspended matter near bottom in Abuquir Bay

D. Circulation in the bay:

According to Morcos and Hassan (1973), the current in the offshore waters of the bay, during August, 1966, was from NW with a speed of about 15-17 cm/sec. El-Sharkawi and Sharaf El-Din (1974) analysed Ekman current-meter observations taken at 5 meters depth, during the period 17-20 March, 1970. They also found a NW current, but with speeds ranging from 50 cm/sec in the inner part of the bay, to 5 cm/sec in the outer part of the bay. Current values taken at a 24 hour anchor station (near 31° 21′ N, 30° 13′ 00′ E), on 6-7 August, 1970, showed the tidal currents rotated in a clockwise direction. During the UNDP/UNESCO project for coastal protection studies (1971-1976), currents measured in Abuquir Bay, at a distance of 8.6 kms from Maadia outlet, over 52 days in April-June, 1974, at depths of 7 and 14 meters, indicated that currents were less than 5 cm/sec during more than

93% of the time (Manohar, 1976). Littoral currents along the Nile delta in the breaker zone were more active in Summer (i.e. the swell season). In August, 1977, two surface drogue experiments were carried out in the eastern part of the bay. Longshore currents were in the SE direction, with speeds of 8-12 cm/sec (Said, 1979). The currents in Maadia outlet (maximum depth 2 meters) were measured on a monthly basis from February to October, 1979. In each month the measurements were carried out for 5 to 24 hours, using an Ekman current-meter (Mohamed I., 1981). The predominant current along the channel axis was from Lake Idku to Abuquir Bay, except in October when the flow direction was sometimes in the opposite sense, with a speeds between 60 and 100 cm/sec. The application of two statistical models to determine current velocity, showed that the water exchange through the Maadia outlet was dependent on both wind velocity and mean salinity.

The present analysis of currents at 5 meters depth, fig. (9) and near bottom, fig. (10), shows that at both levels, near Maadia outlet, the predominant current was to the offshore, with speeds 10-36 cm/sec., in agreement with the direction after Mohamed I. (1980). This outflow was associated with the tongues of low dissolved oxygen and low salinity found in figs. (5) and (3). At nearshore stations, a longshore current from Maadia outlet to Rosetta headland was observed. This feature may explain the low salinity tongue found in the mid-way between Rosetta and Maadia. Near the Rosetta headland, there was an indication of an

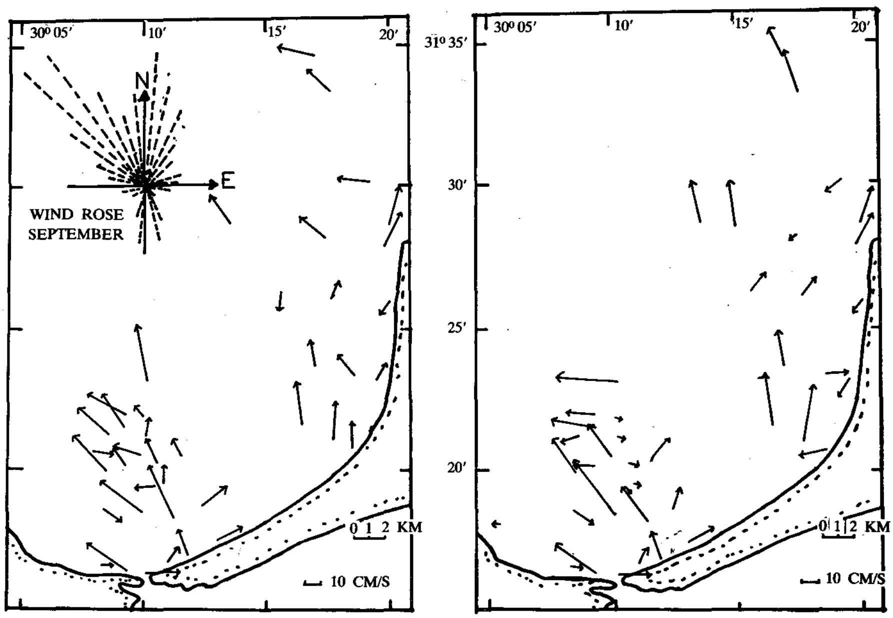


Fig. 9: Circulation pattern in Abuquir Bay at 5 meters depth, Summer, 1984
Fig. 10: Circulation pattern in Abuquir Bay near bottom, Summer, 1984.

anticlockwise eddy between the coast and the 10 meter depth contour. This eddy was also observed in December, 1983 by Elgindy *et al* (1984). The current regime suggests that active coastal processes are at work in the bay. The wind roses for September and August, 1984, exhibited that NW to NE winds were dominant, fig. (9), and that 99% of the wind speeds were less than 10 knots. During the cruise, the dominant wind direction was from 260-300^0, opposite to the predominant direction. This implies that density current was the major contributor to the water movement, and not the wind. This density current is due to the fresh water discharge to the bay. The wind is expected to mix the upper 10 meters of the water column and a one layer current system is produced with horizonal eddies as indicated by the circulation pattern.

CONCLUSIONS

Two water masses were identified in Abuquir Bay. The first water mass occupied the upper 5 meters near Maadia outlet with T-S characteristics as follows: 26.0−27.3^{0}C, 36.0−36.3^0/00. The second water mass was typically Mediterranean water, found below 10 meters depth, with T-S of: 25.7−26.1^{0}C, 39.1−39.4^0/00. Although these values differ from the some previously found, they agree with the findings of Sharaf El-Din *et al* (1980).

The circulation pattern indicated offshore currents flowing out of the Maadia outlet, associated with tongues of low salinity and low oxygen. In the east of the bay, a nearshore anti-clockwise eddy was found near Rosetta headland, associated with a longshore current moving from Maadia outlet to the east. The typical current direction opposed the predominant wind direction. We suggest that accounting for the longshore motion, density current was the dominant mechanism.

The total suspended matter concentration was generally between 10 and 30 mg/l, with extremely high values, up to 47 mg/1. The regions of high suspended matter concentration were mostly associated with low oxygen water. The horizontal distribution of suspended matter was not related to circulation or salinity patterns and it is likely to be related to turbulence generated by currents and waves near the bottom.

The implications of the above studies for pollution dispersion and shore processes are as follows:

1. The offshore current from Idku Lake, transports the agricultural pollutants to the bay following the current paths as explained above. The high concentration of the suspended matter may increase the residence time of pollutants adsorbed on the surface of the suspended matter.
2. The current speeds are strong enough to initiate the motion (resuspension) of

the bottom sediments in the bay. The strong currents near bottom, even beyond 15 meter depth, suggest that an active role is played by the sediment transport in the offshore water. This supports the findings by Manohar (1976).

ACKNOWLEDGEMENT

The authors are highly indebted to Prof. Khafagy, director of the Institute of Coastal Protection Studies, Alexandria, for his guidance during the cruises and field work. Thanks also to all staff members who took part in the cruises.

REFERENCES

Aboul Dahab O. 1989. Chromium biogeochemical cycle in Abukir Bay, East of Alexandria, Egypt. Estuarine, Coastal and Shelf Science 29: 327-340.

Colin P., N. Summerhayes and **N. Marks. 1976.** The Nile Delta evolution and collapse of continental shelf sediment system. Proceedings of seminar on Nile Delta sedimentology, held at Alexandria, Coastal Research Institute, Egypt, 25-29 October 1975, pp. 162-190.

Detailed technical report **1973.** Arab Republic of Egypt, Project EGY/70/581, Coastal erosion studies, Institute of Coastal Protection Studies, Alexandria.

El-Gindy A.H., S. Farrag and **A. El-Sedik. 1984.** Circulation pattern beyond the breaker zone along the Nile Delta coast during Winter. In unpublished internal report (CMSP/84/5). Institute of Coastal Research and Shore Protection, Alexandria, Egypt.

El-Sharkawi S. and **S.H. Sharaf El-Din, 1974.** Hydrographic structure and circulation patterns of Abuquir Bay near Alexandria, Egypt. Bull. Inst. Ocean. and Fish., Egypt, vol. 4, pp. 459-471.

Internal report 1984. Circulation patterns, hydrography and profiles beyond the breaker zone along the Nile Delta coast during Summer. CMSP/84/6 (unpublished).

Manohar M. 1976. Beach profiles and dynamic factors affecting the Nile Delta coast. Proceedings of seminar of Nile Delta sedimentology, held at Alexandria, 25-29 October, 1975, pp. 95-129.

Mohamed I. 1980. Exchange of water masses between Lake Idku and Abuquir Bay. M.Sc. Thesis, Alexandria University, Faculty of Science.

Morcos S. and **M. Hassan, 1976.** The water masses and circulation in the southern Mediterranean. Acta Adriatica, 18, 12, pp. 193-218.

Said M. 1979. Effect of oceanographic and meteorological factors on the transport of pollutants in Abuquir Bay. M.Sc. Thesis, Alexandria University, Faculty of Science.

Sharaf El-Din S.H., M.A. Gerges, M. Osman and **M.A. Said, 1980.** The effects of oceanographic and meteorolgogical factors on the transport of pollutants in Abuquir Bay. Ves Journee Etud. Pollutions, Caliari, CIESM, pp. 893-900.

Strickland, J.D.H. and **T.R. Parsons, 1968.** A practical handbook of seawater analysis. Fish. Res. Bd. Can. Bull. 167: 311 pp.

حركة المياه والكتل المائية وتأثيرها
على انتقال الملوثات في خليج أبو قير (مصر)
خلال (فترة الصيف)

أحمد عبالحميد الجندي و سامي شريط و شحاته الشيخ

يتضمن هذا البحث ملخصاً للدراسات السابقة في مجال التيارات البحرية والكتل المائية في منطقة خليج أبو قير ، كما يتضمن نتائج تحليل بيانات هيدروجرافية وبيانات عن التيارات البحرية مقاسه عند ٤٠ محطة خلال شهري أغسطس وسبتمبر ١٩٨٤ ، في نفس المنطقة .

وقد أظهرت التوزيعات الأفقية لدرجة الحرارة والملوحة وتركيز الأكسوجين ومتجهات سرعة التيار وجود تيار مائي قوي متجه من بحيرة أدكو الي الخليج ، حاملاً معه الملوثات الناتجة عن استخدام المبيدات الزراعية ، ومن المتوقع أن تنتشر هذه الملوثات في اتجاه هذه التيارت . وبدراسة بيانات سرعة الرياح ومقارنتها بتوزيع التيارات البحرية ، تبين أن انسياب المياه القليلة الملوحة من بحيرة أدكو ومن محطة ضخ المياه عن الطابية كان له دور هام في توليد التيارات البحرية في الخليج خلال فترة الدراسة .