WATER POLLUTION IN SUEZ BAY

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ABSTRACT

To study the water pollution problem in Suez Bay it was necessary in the first place to study the hydrography of the Bay. To do that seventeen trips were carried out in the Bay, in the period from May 1966 to June 1967, occupying eleven stations (fig. 1), and sampling the water at specific depths. Standard methods were used for determining the salinity, temperature, oxygen concentration and currents.

INTRODUCTION

The Suez Bay area is subject to pollution from three main sources :

(1) Industrial waste products which come from five great factories (three oil refineries, a fertlizer factory, and a paper mill).

(2) Domestic drainage of Suez city.

(3) Ships' oil and refuse.

Relevant facts about the industrial wastes, and domestic drainage appear in table (1).

TABLE (1)

Source of drains	Carrier	Volume of drains m^3/h	Oil content p.p.m.	p.p. m/m^3 of drains			
				Total hard.	Ca hard.	NaCl	T.D.S.
Fertlizer Co.	fresh w.	500	00	760	500	600	1200
Suez Pet.	saline w.	10,000	40	000	000	000	0000
Al-Nasr Pet. Co.	saline w.	10,000	35	000	000	000	0000
Misr Pet.	saline w.	1,000	35	000	000	000	0000
Kraft Co.	fresh w.	150	00	n.a.*	n.a.*	n.a.*	n.a.*
Domestic drainage	fresh w.	2,000	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*

* n.a. = not available.

No reliable statistics about ships' pollution exists as the whole of the Red Sea is considered a closed area for refuse by international agreement. Ships, however, wash their oil tanks and throw refuse surreptitirously in the Red Sea and Gulf of Suez. When the prevailing wind is southern, as happened 22% of the year (Meshal 1967) all ships' effluents are piled up at the head of the Gulf viz. the Suez Bay.

Because the volume of the polluted waste cannot be ignored with respect to the total volume of the Bay, a study of the hydrography of the Suez Bay was made to enable making the best use of the Bav as a waste product sink, while preserving to the most its living resources.

Due to the Middle East war (June 1967), oil refineries in the Suez area got rid of a huge amounts of oil by throwing it in Suez Bay. causing serious oil pollution to both water and beaches.

Description of the Suez Bay :

The Suez Bay (fig. 1), is a shallow extension of the Gulf of Suez, roughly elliptic in shape, with its major axis in the NE–SW direction. The average length along the major axis is 13, 2 km, its average width along the minor axis is 8.8 km. The mean depth is 10 m and the horizontal surface area is 77.13 km². The Bay is connected to the Gulf of Suez through most of its south eastern side where a channel is dredged to a depth of 12 m for navigational purposes. It is connected to the Suez Canal by a dredged channel of 12 m depth through the same side. The city of Suez and its major industries occupy the northern part of the Bay (fig. 1).

Seasonal water movements in Suez Bay :

Meteorological conditions in the Red Sea–Indian Ocean region is the factor that determines the seasonal variations of water in Suez Bay (Sverdrup 1942). As a result of these conditions, water level in the Bay rises sharply during autumn, reaching its maximum in September (Morcos 1960). It passes through its mean level in May-June on its way down, and again during October-November as it rises.

The greatest exchange of water between the Red Sea and the adjacent parts of the ocean takes place through the Straight of Bab-el-Mandeb. The exchange through the Suez Canal is relatively minor. Great interest is attached to that minor exchange however. It is an exchange which did not reach the equlibrium state for salt flow, and it is between two essentially different regimes of water.

In the Suez region, northerly winds prevail during most of the year, in general they are weak or moderate. When wind blows violently from NW, the water in the northern 50 km of the Gulf of Suez does not agitate because it lies in the wind shade of Ataqa Mountains on the western side of the Gulf. In winter, the wind comes from the west most of the time, when they come from the SW they become sufficiently strong as to produce high agitation in the Gulf of Suez.

The water circulation in Suez Bay, as well as the characteristics of water viz. temperature and salinity are determined by four factors :

(1) The seasonal variation in water level in Suez Bay.

(2) The great salinity of Suez Canal water due to dissolution of the salt layers of the Bitter Lakes. This water is usually driven into the Bay at the end of summer season.

(3) The variation of level due to tides whose range varies between 80 cm at neap tide and 140 cm at spring tide (Morcos 1960).

(4) The prevailing local winds, and the daily cycle of heating.

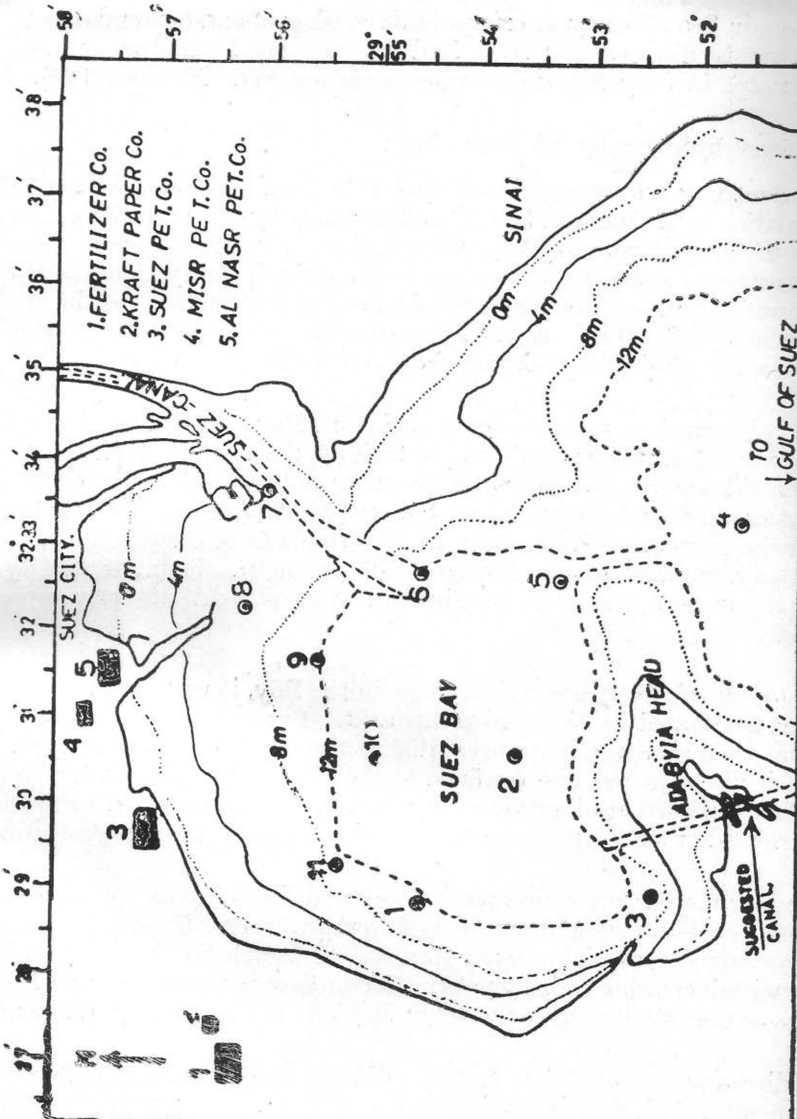

FIG. 1. SUEZ BAY, LOCATION OF STATIONS, SOURCES OF POLLUTION AND SUGGESTED CANAL.

The mean sea level is higher at Suez on the Red Sea than at Port Said on the Mediterranean Sea all the year except in July, August and September. Thus the surface flow is directed from the Red Sea to the Mediterranean Sea in all seasons except in July–September when it is reversed (Morcos (1960).

Results from hydrography of Suez Bay :

The Suez Bay has two sources of water: the Suez Canal and the Gulf of Suez. The circulation in the Bay can be followed generally by following the proper characteristics of the two water types. Observations showed that while salinity can be used as a tracer because the Canal water has a significantly higher salinity than the Gulf water, temperature is not suitable, as the temperatures of the two water bodies are near each other. Slight differences that occur between the Gulf water and Canal water diminish quickly as the water resides in the Bay.

From observations taken in the period from May 1966 to June 1967, (Meshal 1967), it was found that water from the Gulf of Suez enters the Bay on eastern side (Sinai side) while it leaves the Bay on the western side. Water from Suez Canal is generally deflected to the western coast. Therefore there is a persistent anticlockwise circulation in the Bay, as may result from Coriolis force, superimposed on any transient state. It also results in the maximum of salinity being found on the western side. The salinity and temperature do not vary appreciably with depth.

Due to the relatively great tidal range in the Bay, it was found that the currents were dominated by the tidal component. Currents at the entrance of the Suez Canal were always the strongest due to the constriction at the head of the Bay. Their direction was also confined to the direction of the Canal, either to or from. Thus the current observed at any station can be correlated more with the phase of the tide than with the permanent circulation in the seasonal situations.

Generally the oxygen concentration followed the temperature pattern being high at low temperatures and low at high temperatures. This is due to greater oxygen consumption at higher temperatures. Although the solubility of oxygen decreases with increasing salinity yet this factor does not produce any observable differences as the salinities over the whole Bay are not suffciently differentiated.

The discharge of water from factories did not appear to affect either the salinity, temperature, or the circulation, but it affected the oxygen concentration. The rejects of factories seemed to reduce its solubility and consume part of what was dissolved in water.

Maximum temperature was recorded in July/August, and minimum temperature in February (fig. 2). Maximum salinity was observed during September/ October, and minimum during May. (fig 2).

During winter the water mass in the Bay became nearly uniform due to better mixing. Table (2) showes the differences between the maximum and minimum salinities and temperatures in winter months.

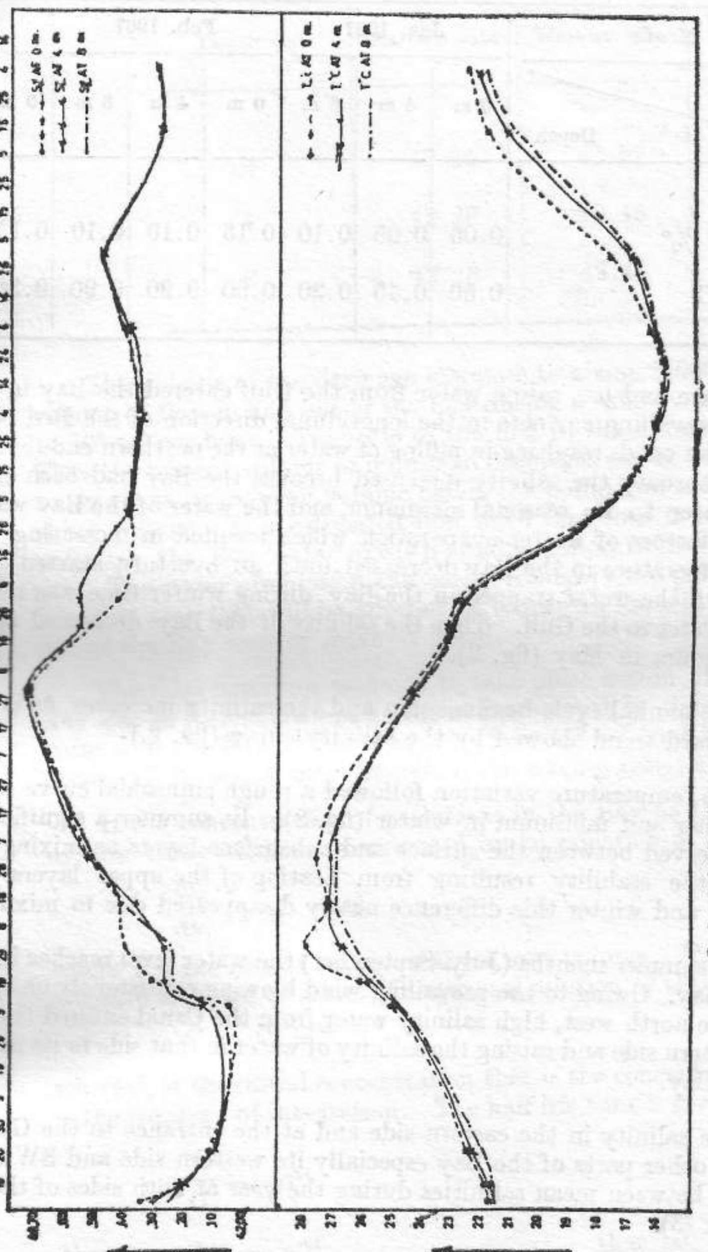

FIG. 2. MEAN VARIATION OF SALINITY AND TEMPERATURE IN SUEZ BAY.

TABLE 2.—DIFFERENCES BETWEEN MAX. AND MIN. SALINITIES AND TEMPERATURES IN WINTER IN SUEZ BAY.

Month / Property \ Depth	Jan. 1967			Feb. 1967			March 1967		
	0 m	4 m	8 m	0 m	4 m	8 m	0 m	4 m	8 m
Salinity %°	0.05	0.05	0.10	0.15	0.10	0.10	0.15	0.15	0.15
Temp. C	0.50	0.45	0.30	0.90	0.90	0.90	0.30	0.50	0.35

Warm and less saline water from the Gulf entered the Bay in winter owing to the prevailing currents in the longtidunal direction of the Red Se and to the prevailing winds resulting in pilling of water at the northern end (Sverdrup 1942).. After February the salinity increased because the Bay had been filled with the Gulf water to its seasonal maximum, and the water of the Bay was subject to normal factors of winter evaporation which resulted in increasing the salinity. The temperature in the Bay decreased until an overturn started to happen in April and the water trapped in the Bay during winter time was released as cold saline water to the Gulf. Then the salinity of the Bay decreased again reaching its minimum in May (fig. 2).

The annual cycle begins again and the salinity increases, as is obvious from the upward trend showed by the salinity curve (fig. 2.)

The temperature variation followed a rough sinusoidal curve with maximum in summer and minimum in winter (fig. 2). In summer a significant difference was observed between the surface and subsurface layers as mixing was impeded due to the stability resulting from heating of the upper layers. But during autumn and winter this difference nearly disappeared due to mixing.

During summer months (July–September) the water level reaches its lowest value in the Bay. Owing to the prevailing wind blowing consistently on the Suez Canal from the north west, high salinity water from the Canal entered the Bay hugging the western side and raising the salinity of water in that side to its maximum value in the Bay.

The salinity in the eastern side and at the entrance to the Gulf is less than that in other parts of the Bay especially its western side and SW corner. Comparison between mean salinities during the year at both sides of the Bay appears in table (3).

As the main industries are found on the northern and northwestern coast of the Bay, the pollutants are carried by the Bay water along the western side to the south-western corner where the Adabyia Head forces the water to circumcirculate it to the Gulf.

TABLE 3.—MEAN SALINITIES ‰ AT EASTERN AND WESTERN SIDES.

Depth (m)	Eastern side	Western side	Diff.
0	42.26	42.52	0.26
4	42.28	42.48	0.20
8	42.28	42.48	0.20

The volume of the drainage amounts to about 24000 m^3 per hour, while the volume of flow in and out of the Bay during a tidal cycle amounts to about 13.5 $\times 10^6$ m^3 per hour. The ratio of the first to the second is therefore 1.7×10^{-3}. Thus the present volume of industrial drainages can be expanded in the Suez area to six times its existing volume before the pollutants reach 1/100 of the tidal flushing volume. It is estimated that until that time is reached no real danger of polluting the Bay water exists by undue concentration of the industerial drainages. The water circulation can easily transport the pollutants out of the Bay. The first area that will be affected by concentration will be the southwestern corner of the Bay west of Adabyia Head.

The tidal motion is assumed to take place within all the volume of the Suez Bay due to its shallowness as the average depth is about 10 m only. The tidal volume in the Bay amounts to: 77.13×10^7 m^3, and the tidal prism volume is about: 77.13×10^6 m^3. Therefore the mixing ratio: $a = 0.10$ per tidal cycle.

If the concentration of pollutants in the Bay be C, then the rate of change of the concentration is expressed by an equation of the form, (Gade 1963), :

$$\frac{dC}{dt} + aC = T$$

where T is the rate of supply of C per unit volume. T is very small so its can be assumed as equal to zero. The general solution of this equation is given by :

$$C = C_o e^{-at}$$

where C_o is the initial concentration that is the concentration at $t = O$, and which is the constant of integration. The half life time is given by:

$$\frac{C}{C_o} = e^{-at}$$

therefore $1/2 = e^{-at}$ that is :

$$t = \frac{0.6931}{a} = \frac{0.6931}{0.10} = 6.931 \text{ per tidal cycle} = 3.587 \text{ days}$$

The tidal prism concept has been used to evaluate the ability of the Bay to remove pollution. This method assumes that the volume of water entering on the flood is completely free from pollution. It becomes completely mixed with the water already present in the Bay before the tide is reversed. The mixed water leaving on the ebb tide is then completely removed. In general neither of these assumption is justified and the flushing effect may be only a fraction of the estimated from the tidal prism concept.

Conclusions and recommendations :

Water from the Gulf of Suez enters the Bay via the eastern side. It meets the Canal water which enters the Bay hugging the western side and reaches the south western corner where the Adabyia Head forces the water to circumcirculate it to the Gulf. Thus there is a permanent anticlockwise circulation in the Bay and a clockwise circulation around the Adabyia Head. This circulation fluctuates with the tidal cycle. The incomming current is strengthened during the rising phase of the tide and the outgoing current is strengthened during the falling phase. The tidal current is often sufficiently strong as to mask the permanent circulation.

Because the existing industry and the planned expansions in Suez area are found on the the northern and western coast of the Bay, beaches from Suez to Adabyia on the western side are doomed. This is not very serious as beaches on the eastern side of the Bay (Sinai side) are free from pollution. They should be developed as the natural recreational area for the industrial development in the Suez area. Any industry producing pollutants should not be allowed on the eastern side of the Bay However, if beaches on the northern and western coast are to be saved, better conditions can be obtained by digging a canal crossing the Adabyia Head. It would be capable of carrying an average of 5×10^5 m^3/h. down to the Gulf (fig. 1). This canal must be kept dredged. It will facilitate the outflow of the Bay water into the Gulf.

Inforcement of the international agreement of keeping the Red Sea as a closed area for discharge of oil should be more actively persued by the concerned authorities.

Petroleum factories in the area should use oil–water seperators which must be designed for the maximum flow expected.

At present, the oil pollution condition of beaches and water in Suez Bay area is very serious as a result of throwing huge amounts of oil in the Bay during the Middle East war in June 1967. It is recommended that methods suggested in appendices I and II for the treatment and disposal of floating oil and removal of oil from contaminated beaches should be applied in Suez Bay area.

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APPENDIX 1

Methods Suggested for Treatment and Disposalof Floating Oil :

(A) *Covering the Floating Oil with Fibrous Material :*

Nearly complete removal of floating oil can be obtained by coating the patch with fibrous, cobweb-like threads of plastic material which are produced and applied by spraying a solution of plastic in a volatile solvent such as acetone. The oil and plastic form a monoeurable raft which can be gathered up manually or with the aid of a simple coveyer system. This has been carried out successfully on a pilot scale and under practical conditions (Warren Spring Lab. RR/ES/40).

This method may be expensive, but costs can be reduced by replacing the plastic material by other natural and cheap fibrous materials such as sisal string, dry hay or rice straw. The problem with this method is the provision of suitable spraying or distributing equipments.

(B) *Sinking With Powdered Solids* :

An apparently promising method for the treatment of floating oil is the distribution over the oil patch of a powder or fine granular solid of high true density which admixes with the oil, addheres to it and sinks it. An essential requirement is that the solid material should so fix and retain the oil that once submerged no oil is released to renew the contamination. Common and cheap materials such as sand, brickdust clinder, portland cement and limestone powder have been found to be equally effective for sinking oil (Warren Spring Lab. RR/ES/40, 1963).. If oil could be treated with sufficiently large quantity of these powders it might be permanently immobilised. The most convenient time of the year is summer months especially June and July when there is no strong winds which may disturb the spraying and distributing of the powdered solid, as well as the water surface in Suez Bay in these months is completely calm.

The Suez Bay is not a fishing area, so there is no fear that the sunken oil is liable to foul fishing gear. Distribution of the powdered solid is suggested by a helicopter.

(C) *Dispersion With Emulsifiers :*

Removing of floating oil can be achieved by spraying with an efficient solvent/emulsifier mixture and subsequently agitating with a powerful jet of water. An alternative procedure is to inject the emulsifier or cleanser into the hose stream itself using a branch pipe of the type used to inject a foaming agent into a fire house. In this way the water jet acts as a distributer and mixer.

A very efficient dispersant is obtained by preparing a 10 % solution of a non-ionic emulsifier (of the nonylphenol-ethylene oxide condesate type) in an aromatic solvent such as coal-tarn naphtha. The amount of cleanser required is from 25-50 per cent by volume of the oil depending upon the viscosity of the latter.

The major disadvantage of the use of emulsifier / solvent mixtures is their high toxity to shell fish at concentrations of the order of 10 p.p.m. in sea water (Warren Spring Lab. RR/ES/40, 1963).

It is preferably applied to Suez Bay in autumn and winter months when the sea surface is rough to allow great mixing.

Inview of the relafively great volume of water of Suez Bay, the tidal mixing that occurs twice a day and chosing the time of the year when the sea is rough, it is believed that even if large quantities were used the chance of serious damage to commercial fish or shell-fish would be very small compared with the advantages to the holiday and touring industry in cleaning water and beaches.

This method was succesfully applied in the Torrey Canyon disaster in Britain and it was concluded that there was little doubt that these chemicals cause considerable damage to the planktonic organisms which are present in the water to which they had been added (Simpson 1968).

(Condensed from:
Warren Spring Lab.
England, 1963, RR/ES/40.
with slight modification)

APPENDIX II

The Removal of Oil from Contaminated Beaches by Emulsifier Solvent Mixture :

It consists of spraying the contaminated area with the cleaning fluid at a rate which not, in most cases, exceeds a quarter of a gallon per square meter. The cleaning fluid should be applied not less than thirty minutes and not more than one hour before the tide reaches the area. This is nesessary to allow sufficient time for the fluid to penetrate the oil, but not long enough for the solvent to evaporate. Washing of beaches can be left to the action of the tide. It is strongly recommended that the area be hosed down with sea water as the tide approaches to allow the oil to disperse quickly into a large volume of water.

It is suggested that for the greatest economy a multinozzle spray lance should be used, this will enable the mixture to be applied uniformly over a reasonable width of beach. In rough surface beaches the use of stiff bruch during the hosing down process would facilitate the removal of oil. It is recommended that the process of cleaning Suez Bay area would be carried in summer days especially afternoon when the temperature is maximum for the day to allow contaminated oil to be free flowing.

In each case consulation with fisheries interests is needed before cleansers spraying is authorised either at sea or on the shore.

Condensed with slight modification from :
Warren Spring Lab. England, 1963. RR/ES/39.

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