STUDY OF THE SURFACE WATER INORGANIC PHOSPHATE IN THE SOUTH EAST MEDITERRANEAN

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ABSTRACT

Regional differences of inorganic phosphate content of the surface 0-10 m water layer appear in the south eastern Mediterranean coastal water. During autumn 1964 the water north to Alexandria attained 0.17—0.57 ug-at PO_4-P/L. Frequently, maximum values were observed in the nearshore waters of the Nile delta. The estimated discharge of about 8200.0 ton $P0_4$-P ions in the coastal region during autumn 1964 was decreased to about 160.2 ton PO_4-P ton in autumn 1966. Consequent decrease in the maximum phosphate concentration from about 1.60 in 1964 to about 0.16 ug-at PO_4-P/L in 1966 was observed. Formulae are constructed to explain th phosphate-chlorinity relationship under the conditions of simple mixiing of the Nile and sea water types. These fromulae are also used successfully to calculate the phsophate anomalies The deduced aniomalies are suggested to identify the water masses. They helped to detect the distribution of three of them wich are the transformed current water mass of Atlantic origin, the Nile delta nearshore mixed water mass and the coastal south eastern surface water mass of the Levantine basin.

INTRODUCTION

The offshore waters of the eastern Mediterranean Sea is known to attain low phosphate concentrations. Its south eastern part is the field of distribution of the discharged Nile and lake waters. Little is known about the influence of this Nile discharge upon the phosphate content of the coastal waters. The recent decline in the annual catch of some fishes was distinguishable especially the Sardines. The maximum Sardine landings used to occur during the autmun season at the time of maximum Nile discharge. This arouse the interest to investigate the change in the Nutrient salts especially the phosphate in the South Eastern Mediterranean waters.

The upper layers of the surface water are denoted by Halim et al (1967) to constitute a superficial water mass. The recent control of the discharged water volumes from the Nile branches were followed by significant changes in the phosphate concentration of the upper 10 m surface layer covering the south eastern Mediterranean. This fact may help in the identification of the derived water types of this upper layer and their source regions. It may also explain

the recent decline in the total fish catch, through its relation to the producivity of the fishery grounds.

MATERIAL AND METHODS

Since 1960 the interest of the oceanographic institutions in Egypt was aroused to make surveys in the coastal waters, Water samples were regularly collected from the south eastern Mediterranean coastal regions. Special care was given to this sampling during the autumn seasons.

This work is based mainly upon 1959-1961 oceanographical data published by S. Gorgy (1966) and the results of the analysis of collected water samples during the cruises of the Egyptian research boat "Faras-el-Bahr" in 1964 and the Russian research vessel "Ichtyology" in 1964, 1966 and 1970.

Excluding 1959-1960, the water samples were collected periodically from the standard depths 0, 10, 20, 30 50, 75, 100, 150, 300, 400, 500, 1000 m of 4 - 7 stations in the sections perpendicularly constructed upon the shore-line adjacent to the Arabs-Gulf, Abu Qir Bay, Rosetta outlet, El-Brullus Lake sea connection and Damietta outlet (Fig. 1, 2). All the water samples were analysed for the chlorinity, salinity and nutrient contents. Inorganic phosphate was determined colourimetrically according to the analytical techniques given by Harvey (1955).

The phosphate determinations during the cruise of "Faras-el-Bahr" in September 1964 and the Russian Research vessel "Ichtyolog" in October 1964, were made by visually comparing the colour of the samples with that of a standard solution in Hehner cylinders. A salt error factor of 1.3 was used for the correction of the readings. A Japanese photoelectric colorimeter of the type ANA-7D was used in the following 1966 and 1970-1971 cruises.

The regions covered by waters of maximum and minimum properties is assumed to represent the source regions of some derived water types. For analysis of water masses in those regions the core layer method developed by Wüst (1935) was used.

An attempt to construct a linear phosphate-chlorinity relationship for simple horizontal mixing between two water types of the surface 0-10 m layer was performed according to some modification of the method used by J.D. Burton (1970). The anomalies are calculated and used as a probable means to confirm the identification and limits of distribution of the water masses.

The Regional Variation of Inorganic Phosphate

The western surface waters :

The outflowing water volumes from Rostta and Damietta outlets before 1968, have rarely exceeded 3,00 km^3/month in the winter spring and the beginning of the summer seasons. The maximum water outflow was observed during the flood seasson in September and October and occasionally fluctuated between 3.33 and 19.29 km^3/month. Exceptionally greater discharge reaching 26.5 and 41.5 km^3 was recoded during the flood seasons (autumn) of 1960 and 1964 successively (El-Sayed El-Hehyawi and El-Tabbakh, under publica. tion). Undoubtedly, the seasonal variations in the water discharge, have significant influence upon the distribution of the surface water kinds and their characteristics along the Egyptian shores.

Measurements of inorganic phosphate of the eastern offshore surface Mediterranean waters indicate concentrations of 0.0—0·06 ug-at PO_4-P/L. David A· McGill (1967) found that they are Lower than those 0.08—0.16 ug-at PO_4-P/L in the western part. He concluded that the highest concentrations in these offshore waters of the Mediterranean are about half or less than its concentrations present in the eastern Atlantic waters. The surface waters of the regions adjacent to the point at Lat. 33° 30' N, Long. 31° 00' E attain less phosphate concentrations than 0·10 ug-at PO_4-P/L. Obviously these offshore regions north to the Egyptian shores are beyond the influence of the Nile discharge The surface water layer of the Arabs-Gulf and its northern offshore regions were found poor in phosphate. Significant changes are observed in the phosphate content which could be of periodical nature. During autumn 1964, a water mass of phosphate concentrations 0.09—0.10 ug at PO_4-P/L was spread in the near-shore regions of the Arabs-Gulf (Fig. 3). Some slight local variations could be traced northwards. The distribution

of the isolines in the western regions (Fig. 5) show an approximately semi-isolated south western water kind· The lack of data in the northern offshore waters during this year, makes it difficult to identify its origin·

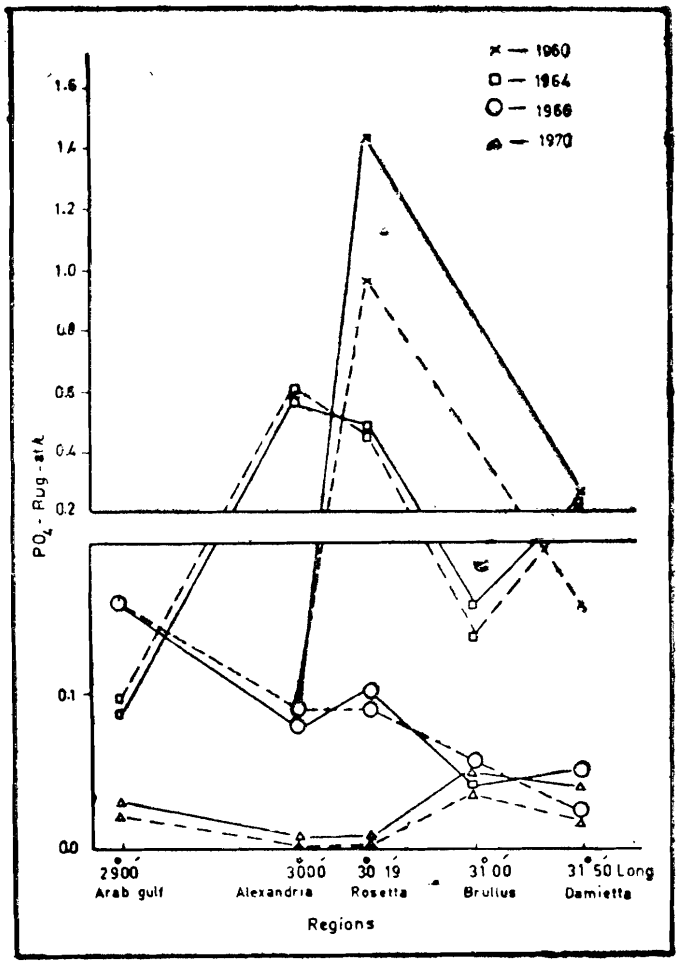

Fig. (3) The variation of the surface water inorganic phosphate values in the different regions at 10-20 miles north to the S.E. Mediterranean coasts.

The pattern of distribution of the phosphate concentration north west to Resetta outlet during autumn 1964 gave rise to the probability of the influence of the flood waters upon the regions between Lat. 32° 32' 00' and Lat. 33° 00' north to the Arabs-Gulf. Beyond the above mentioned regions which were within the reach of the Nile water influence, and in the far northern regions beyond Lat. 33° 20' N, the phosphate conentration decreased to about 0.09 ug-at/L. This could probably be a result of the influence of the countercurrent mentioned by Y. Halim *et al.* (1967) to flow beyond Lat. 32° 30' in a westward direction.

In autumn 1966, the nearshore waters of the Arabs-Gulf regions attained 0.16 ug-at PO_4-P/L and show analogous semi-isolated feature as in 1964. Other maximum values 0.13—0.15 ug-at PO_4-P/L were associated with chlorinity 21.65—21.69‰ in a point at Lat. 31° 45' N, Long. 29° 00' E. Gradual decrease in these maximum values were observed eastwards and suggested a tongue shaped eastward spreading along Lat. 32°00' N. According to the phosphate-chlorinty scatter diagram Fig. (7) the above mentioned features help to assume this tongue of water as the surface layer of the transformed Atlantic water current flowing along the south Mediterranean coasts.

Northwards to Lat. 32° 40' the surface water mass of low phosphate concentration as 0·00—0.08 ug-at/L was also observed in 1966 and show no indication to vary in its oirgin from that suggested water mass which covered these regions during 1960—1964.

During autumn 1970 the maximum inorganic phosphate concentrations reached 0.12—0.23 ug-at/L in the regions west to Alexandria along Lat. 31°45' N.

The waters north to Alexandria coasts :

During 1957-1960, significant phosphate concentrations were recorded in the contental shelf waters north to the delta coasts (Y. Halim, 1960; S. Gorgy, 1966). Values of phosphate concentrations as 0.02 - 0·34 ug-at PO_4-P/L were detected in the waters north to Alexandria (El-Maghraby & Halim, 1965). Significant differences could be detected in the waters of 0 - 10 m layer during the years 1964, 1966 and 1971 (Fig. 4). The water samples collected during the cruise of the research vessel "Faras-el-Bahr" in November 1964, attained very high concentrations. Its maximum reached 0.57 ug-at

PO_4-P/L at a point 2 miles north to Alexandria shores. Obvious decrease of this concentrations was found in a seaward direction. The average concentration during this year decreased from 0.50-0.53 ug-at/L near the shore line to 0.28 ug-at/L at about 40 miles seawards (Fig. 4). Concentrations as low as 0.17 ug-at/L were recorded beyond a point at about 55 miles north. The wide range of phosphate variation in the upper 10 m surface layer was characteristic to the waters prevailed during the autumn seasons of maximum Nile discharge in these regions. The influence of the discharged waters from Rosetta outlet during autumn could be easily detected from Fig. (5). The mixed Nile-sea water mass spreaded reaching the regions adjacent to Lat. 33° 00' north to Alexandria coast.

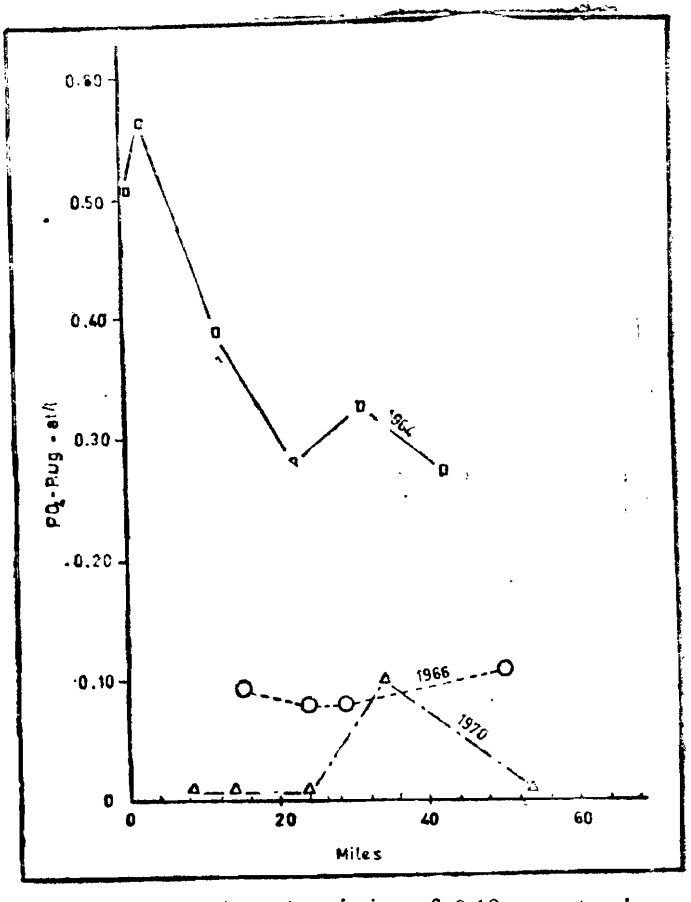

Fig. (4) The northward variation of 0-10 m water layer inorganic phosphate content according to the distance (in miles) from Alexandria coastal line.

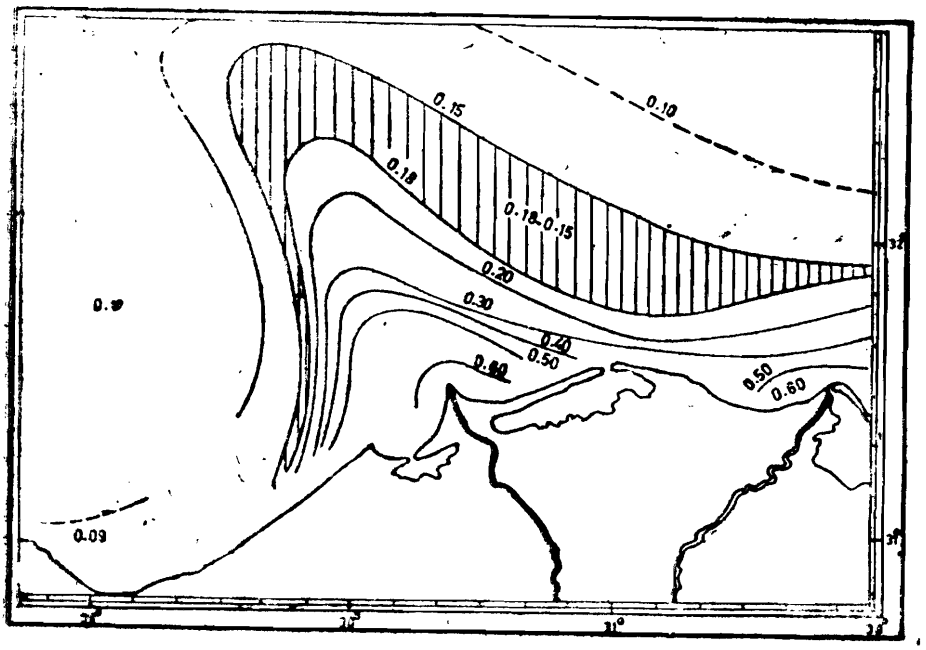

Fig. (5.) The distribution of the surface water inorganic phosphate which was assoc- iated with the discharge of about 41.5 km³ flood wate r from both the river Nile mouths in the S.E. Medi e ranean Sea.

Other pattern of distribution of lower phosphate concentrations in Alexandria coastal surface waters was observed during autumn 1966 (Fig. 6). It could be considered in good agreement with the amount of discharged flood waters from Rosetta outlet during this season (Table 2). The nearshoresurface waters attained concentrations 0.08 - 0.09 ug-at PO_4-P/L. During that season of 1966, it was uniform with the phosphate concentrations in the surface waters of the western regions. Exceptionally high phosphate concentrations as 0.13 ug-at/L could be detected at point near Lat. 32°08' N, Long 29° 45' E. It suggests the eastern limits of the tongue like pattern of spreading of the transformed current waters. In the far northern regions beyond Lat. 32° 30' N, Long. 29° 50' E, the spreading of the water type of poor phosphate concentration as 0.00 - 0.07 could be detected. The relation of its maximum phosphate concentrations (0.06 - 0.08 ug-at PO_4P/L) with its chlorinity suggests no variation in its origin form the offshore waters north to the Arabs Gulf (Fig. 6).

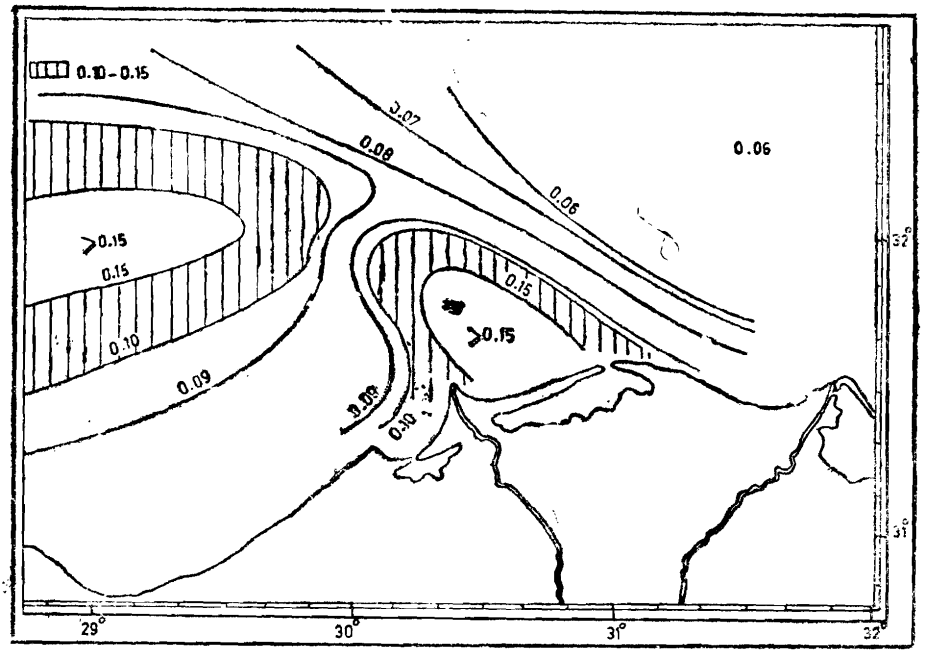

Fig. (6) The distribution of the surface water inorganic phosphate which was associated with the outflow of 6.5 km³ from Rosetta mouth in the S.E. Mediterranean Sea during autumn 1966.

The fluctuations of phosphate content north to Rosetta outlet :

During August 1957, the flood waters were found to contain about 6.38 ug-at/L (Halim, 1960). In May 1964, the average phosphate concentration in the waters out flowing from the center of the outlet was found 0.68 ug-at PO_4-P/L (Table 1).

TABLE 1. **Values of phosphate concentrations of water at Rosetta exist during May 1964 and November 1970.**

Date	Locality	Depth m.	PO_4-P ug-at/L
27-5-1964	The middle of the mouth	0.0	0.56
		1.5	0.79
3-11-1971	The middle of the mouth	0.0	0.90
		1.0	0.72

Referring to El-Maghraby & Halim (1965) it may be possible to consider the values of phosphate concentrations which was found during May 1964 not to deviate considerably from the average values attained by this water mass during the other months of no flood. Accordingly, the annual amount of discharged inorganic phosphate could be estimated as in Table (2).

TABLE 2. **The annual discharge of inorganic phosphate from the Nile mouths during** 1960–1972.

Year	Discharge during XII-VIII months		Discharge during IX-XI months		Total
	Nile water km^3	PO_4-P Ton	Nile water km^3	PO_4-P Ton	PO_4-P Ton
1960	15.20	320.4	25.52	5245.1	5565.5
1964	22.26	469.2	41.46	82.00.0	8669.2
1966	5.84	144.2	6.38	160.2	304.4
1972	3.70	78.0	0.40	10.0	88.0

The fluctuations in the sum of discharged phosphate ions is connected with the decrease of the discharged volumes of water. The discharged water from Rosetta outlet during autumn 1964 was about 3 times its magnitude in autumn 1966. In addition, the past reservation of the Nile flood waters in Lake Nasser behind the high Dam which began since 1965 resulte the partial consumption of its inorganic phosphate. Hence, the phosphat econcentration per unit volume decreased to an average of 0.81 ug-at PO_4-P/L in the outflowing waters from the mouth. This is indicated from its water analysis in 1972 (Table 1). It is important to denote that the actually discharged amount of phosphorus was higher than the amount estimated in Table (2). This assumption is based upon the fact that the available data do not include the concenrations of the organic and adsorbed froms. Meanwhile, the distribution of the phosphate content in the upper 10 m surface layer of the regions north to Resetta outlet may help to trace the rate of influence of the discharged phosphorous tons from this outlet upon the fertility of sea water.

The annual phosphate concentrations in this layer were found to fluctuate significantly in the regions 10-20 miles north to the outlet (Fig. 3). Relatively high phosphate concentrations as 0·40 · 1.60 ug-at PO_4-P/L were recorded during the period 1960-1964.

The variations in the origin of the water masses which dominated the upper 10 m layer in the regions north to Rosetta outlet may also be identified from the pattern of phosphate distribution in Figs. (5, 6)· In these figures the isolines of 0.10 - 0.15 ug-at PO_4-P/L characterising the mixed Nile-sea water mass show that it proceeded from the outlet in a north-westward direction. During autumn 1964, it attained the concentration of 0.60 ug-at PO_4-P/L in the regions surrounding the outlet. This concentrations decreased to 0.20 ug-t PO_4-P/L in the regions adjacent to a point at Lat. 32° 00' N, Long. 30° 11' E. The boundary isolines of 0.08 - 0.10 ug-at PO_4-P/L which separated the proper sea water from this mixed Nile-sea watér mass could be detected northwards beyond Lat. 33°00' (Fig. 5). The phosphate concentrations in the pure sea water varied betweén the analytical zero and a maximum of 0.07 ug-at PO_4-P/L· Its chlorinity reached about 21.77‰. The phosphate-chlorinity relationship of this water type show some probability of the south eastern Levantine water influence (Fig. 7).

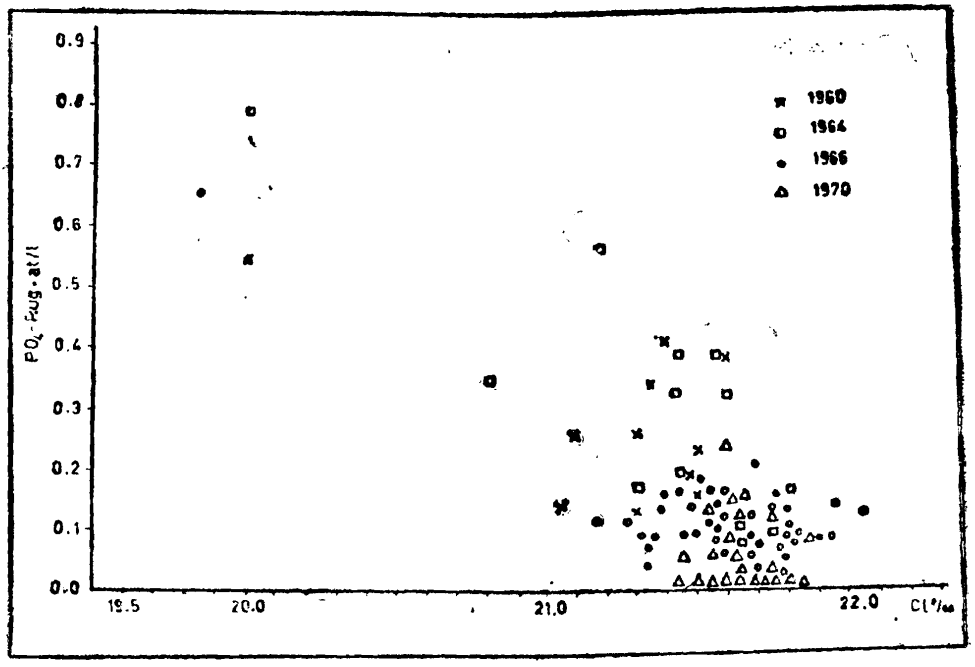

Fig. (7) The phosphate-Cl scatter diagram of the surface water attaining chlorinity ≧ 19.10% in the S.E. Mediterranean during 1960-1970.

Other water types of significantly low phosphate concentrations which covered the regions 10-20 miles from the coast during 1966, are shown in Fig (3). In autum, the upper 10 m layer attained an average 0·09 ug-at PO_4-P/L. It was lowered to the analytical zero in about 80% of the collected samples during 1970. These differences suggest that this kind of water might be derived from another water mass than the Nile water. The mixed Nile-Sea water mass attained maximum concentration of 0.16 ug-at PO_4-P/L in the source region surrounding the outlet (Fig.6).

Before 1965, such concentrations were frequently detected in the regions beyond a point not less than 30 miles from the outlett. In 1966, there was some probability of an extension of a narrow band of transformed current water of the Atlantic origin at Lat. 32° 00' N in a south eastward direction. This suggestion arise from the eastward pattern of distribution of the tongue like isolines of 0.13-0.08 ug-at PO_4-P/L from the western regions. This band of water attained chlorinity values 21.59—21.65 Cl ‰. The phosphate-chlorinity relationship of the samples from it help this suggestion (Fig. 7). Further decrease in the phosphate content to the values inbetween 0.0 and 0.06 ug-at PO_4-P/L, and an increase in the water chlorinity to more than 21.79‰ could be observed beyond Lat. 32° 30' N. These phosphate and chlorinity values suggest a uniform water type with that of the surface water of the eastern regions.

The variation of surface water phosphate in El-Brullus Damietta regionss :

The surface water north to El-Brullus coasts are expected to be under the influence of the discharge from El-Brullus lake-sea connection. During the period 1960-1964, the water mass which covered the regions 10-20 miles north to the outlet attained 0·14-1.00 ug-at PO_4-P/L (Fig. 3). Its chlorinity ranged from 15.90 to 21.40‰ and suggests the influence of fresh water. The observed drop in the phosphate concentration 0.03-0.05 ug-at PO_4-P/L during October 1966 may indicate a change in the origin of the spreading kind of water. These phosphate concentrations were associated with chlorinity values inbetween 21.64 and 21.80‰. Direct influence of the discharged lake waters could hardly be detected during the period 1960-1964 and 1966 (Figs.5,6). This was probably

attributed to the relatively small discharge from the lake-sea connection as compared with the main out flowing volumes from Rosetta and Damietta mouths. This insingnificant lake discharge continued till the end of 1966.

During November 1966, the flowing narrow band of the transformed Atlantic water become closer to El-Brullus outlet and attained about 0.09 ug-PO_4-P/L. Its chlorinity varied in between 21.64 and 21·69‰ in the locations along Lat. 31° 40' N. The northern limit which nearly bordered this water type extended along Lat. 31° 55' N (Fig.6). Beyond these northern limits a uniform spreading of the poor phosphate waters probably from the south eastern regions of the Levantine basin could be detected attaining an average 0.03 ug-at PO_4-P/L. These phosphate concentrations were found in the presence of chlorinity values ranging from 21.74 to 21.79‰. They were distributed in the stations beyond Lat. 32°N. Generally by the end of autumn 1966, the shallow regions west to EL-Brullus outlet were found covered by surface layer of the mixed Nile-sae water masses attaining high phosphate concentrations. The nearshore regions east to this outlet were covered by the transformed waters of higher chlorinity than 21.55‰ and about 0.07 ug-at PO_4-P/L. The south eastern waters of the Levantine basin could be detected in the open sea regions (Fig. 6). Some complex pattern resulting from the interaction of these three water masses may be met within this region and detected by the anomalous chlorinity and phosphate pattern of distribution. The distribution of the water currents shown by S. Gorgy (1966) and Y. Halim *et al.* (1967) is in good agreement with the above mentioned opinion. The variations in the water types covring Damietta coastal regions were mainly related with the change in the mass of discharged waters from the Damietta outlet. The influence of the discharged Nile water type was restricted to the period beforé 1965. This branch was closed at the end of 1965.

During autumn 1964 the minimum phosphate concentration found in the regions adjacent to Damietta mouth, reached 0.60 ug-at PO_4-P/L. The regions 10 — 20 miles north to the outlet were frequently covered by mixed Nile-Sea water mass attaining phosphate concentrations ranging from 0.16 to 0.25 ug-at PO_4—P/L. Its Chlorinity varied between 11.70 and 15.80‰. The phosphate content

increased with depth. The water layer found at 30 m depth in the shallow regions attained 0.42 ug-at PO_4—P/L (S. Gorgy, 1966).

The waters phospate concentration of the strface 0—10 m layer decreased to 0.13 ug-at PO_4—P/L in a point located at Lat. 32° 5', Long. 31° 56'. The spreading of the south eastern Levantine waters of chlorinity 21.72—21.78‰ and 0.06 ug-at PO_4—P/L could be traced in the open sea regions beyond Lat. 33° 00' Long 31° 50' E.

During October 1966 the phophate content of the surface water in the regions 10—20 miles to the outlet attained 0.12 ug-at PO_4-P/L. In November of the same year the regions surrounding the outlet were covered by water mass attaining 0.06—06 ug-at PO_4—P/L. The discharged Nile water during October and November 1966 was 3.86 and 1.02 km^3 sucessively. In addition there was probability of local influence of Lake EL-Manzalah outflowing waters through EL-Soffarah canal upon the surface water of these regions (Fig. 6). The offshore suface waters beyond Lat. 32° 00' attained higher chlarinity values than 21.75% and lower phosphate concentrations than 0.06 ug-at PO_4-P/L. In October 1970 the surfae water of the shallow nearshore regions attained chlorinity and phosphate content reaching 21.18%° and 0.03 ug-at PO_4-P/L (Fig. 3,7).

The surface water east of Port-Said :

The open sea regions north east and east to Port Said are mainly covered by water mass of relatively high chlorinity and low phosphate concentrations. Before the construction of the High Dame, the surface water chlorinity recorded by Selim A. Morcos (1967) at a distance of about 61 miles north to Port-Said, reached about 21.75‰. The influence of the Nile flood was detected by the same author to cover the near shore regions. In October 1964, the surface water in the regions adjacent to the postion at Lat. 31° 28' N, Long 32° 45' E, attained chlorinity 21.66‰ and 0.09 ug-at PO_4—P/L.

During autumn 1966, the surface water chlorinity in the station at Lat. 31° 56' N, long. 33° 40' E, was found 21.79‰. It was associated with 0.07' ug-at PO_4—P/L. Higher chlorinity values with nearly similar phosphate concentrations could be found in all

the shallower stations of the section taken at Long. 33° 40' E. It reached chlorinity about 21.92‰ and 0.08 ug-at PO_4—P/L in the regions of 13 m depth.

The Phosphate-Chlorinity Relationship

Minimum salinity 38.80—39.00‰ which nearly corresponds to the chlorinity values 21.48—21.60‰ were found during 1960—1961 in the western Egyptian coastal surface waters and denoted by S. Gorgy (1966) to indicate the influence of current of Atlantic water origin.

Wyrtki (1962) stated that even if the general trend of the spreading of water mass can be concluded without mistake, it is not possible to decide whether a particular distribution of properties is caused chiefly by a real flow or by large-scale horizontal mixing.

Thorade (1931) and Sverdrup, Johnson and Fleming (1946) have shown that tongue-like distribtion of propertices are not necessarily an indicaton of an actual flow.

Although the nutrients are not conservative, yet the following attempt to use the nutrients-chlorinity relationships may be useful to explain the reason for the variability in the distribution of properties.

The relation between the values of inorganic phosphate of the surface waters and their chlorinity is demonstrated in a scatter diagram (Fig. 7). It is based upon the results of analysis of surface samples attaining higher chloinity than 19.50‰ from about 140 stations taken during autumn 1960, 1961, 1964, 1966 and 1970. It is clear from this diagram that the values of low chlorinity were associated with high inorganic phosphate concentrations. The mixed Nile-sea water mass was distributed north to the outlets and the adjacent regions and appeared to attain low values of chlorinity and high phosphate concentrations. In Fig. (7), the waters of chlorinity 19.52-20.00‰ found during 1964, were associated with 0.09—0.75 ug-at PO_4—P/L. Other chlorinity values as 21.40, 21.66 and 21.80‰ show a decreasing range of variation between the maximum and minimum values reaching 0.42, 0.25, 0.08 ug-at PO_4 P/L successively. Inspite of the anomalous nature of the surface

water phosphate content, yet a general trend of linear relationship is clearly observed.

In autumn 1966, the lowest chlorinity values 21.18 — 21.39‰ were associated with about 0.11 ug-at PO_4—P/L. The surface waters of the shallow station at the position Lat. 39° 41'N, Long. 31°,35' E, attained chlorinity 21.99‰ and about 0.24 ug-at PO_4 — P/L. The highest chlorinity value reached 22.03‰ in the shallow waters east to Port Said and was associated with 0.12 ug-au PO_4— P/L. These relatively high phosphate concentrations could be considered anomalous values resulting from the influence of the neighbouring lake waters discharge or the diffusion of the desorbed phosphate ions from the bottom sediments. Other low phosphate concentrations as 0.0—0.09 wre frequently observed and characterise the surface open sea waters of chlorinity values which ranged from 21.30 to 22.03‰. During autumn 1970, the surface waters in the stations west to Port-Said were found to attain chlorinity which ranged from a minimum of 21.43‰ to a maximum of 21.83‰. The variation of inorganic phosphate concentrations associated with a particular chlorinity was also found to decrease with the increase in this chlorinity value. The chlorinity values 21.50—21.83‰. were found associated with 0.19—0.01 ug-at PO_4—P/L.

According to the above mentioned associations between the phosphate and chlorinity values, it is obvious that their relations during the period before 1965 were different from those observed in 1966 and the following years. The anomalous nature of the observed values of both variants suggests to construct simple mixing relationship between the properties of two water mases.

A consideration of the simple mixing between both the Nile water mass and a proper sea water type may help to construct the linear relationship at their different rates of mixing. For convenince, the offshore surface water of the Arabs-Gulf regions could be used to represent the properties of the sea water type.

The relationship before 1965 :

Burton *et al.* (1970) found that salinity and dissolved silicon follow a highly significant inverse correlation and fitted closely to linear relationships. They show that the calculated values were

nearly similar to the measured concentrations in the collected samples from the source regions. As a result of the normally inverse relation, it follows that the anomaly distribution may provide a suitable water mass tracer· Some variations may be associated with biological factors as the intense outbursts of phytoplankton production. In our case, the anomalous values will be relative to the properties of the surface offshore water of the Arabs-Gulf and the Nile flood water from the river mouths. The relationship, may probably be more reliable for the waters of 0—10 m layer where the spreading of the brackish water of minimum density reaches its maximum rate.

The average chlorinity of the surface 0-10 m water layer in the Arabs-Gulf regions and the western waters during October 1960 was about 21.65‰ (Table 3).

TABLE 3. **The surface water cholorinity in the Arabs-Gulf and the western coastal regions (taken from the data published by S. Gorgy, (1966)'**

Lat.	Long.	Depth m.	Chlorin - ity %	Lat.	Long.	Depth m.	Chlorin- ity %
33°56′	28°33′	0	21.73	31°50′	27°57′	0	21.62
		10	21.67			10	21.59
33°30′	28°55′	0	21.73	32°26′	25°19′	0	21.58
		10	21.63			10	21.58
33°04′	29°10′	0	21.78	33°47′	28°07′	0	21.67
		10	21.70			10	21.65
31°42′	29°51′	0	21.59	33°13′	27°12′	0	21.57
		10	21.54	—	—	—	—
	Average						21.648

Unforunately, the phosphate content observations in both the surface water of the western regions and the water from the Nile

mouths before 1965 were scarce. The Arabs-Gulf surface waters were found during October 1964 to attain average chlorinity 21.64‰ and 0.10 ug-at PO_4—P/L. This phosphate concentration could be taken to represent the average properties in these waters.

The minimum chorinity and maximum phosphate content found during the flood season of 1957—1959 in the Damietta mouth was 0.077‰, and 6.38 ug-at PO_4—P/L (Y. Halim, 1960). Accordingly, the linear relationship between the phosphate and chlorinity (Fig. 8 A) before the construction of Aswan High Dam is approximately estimated as follows :

$$PO_4\text{-P (ug-at/L)} = 6.4977 - 0.2978\ Cl‰.$$

The relationship after the construction of the High Dam :

In September 1970, the Arabs-Gulf offshore surface waters attained average chlorinity about 21.65‰ and about 0.06 ug-at PO_4—P/L (Table 4).

TABLE 4. **The surface water chlorinity and inorganic phosphate concentrations in the offshore Arabs-Gulf surface waters during September 1970**

Lat	Long	Depth m	Chlorinity ‰	Inorganic phosphate ug-at/L
31° 40′	29° 00′	0	21.65	0.15
		10	21.66	0.05
32° 0.5′	29° 00′	0	21.65	0.00
		10	21.67	0.00
31° 10′	29° 00′	0	21.65	0.12
		10	21 65	0.08
Average . .			21.655	0.066

Other changes of the discharged waters from the Nile outlets were observed in th autumn seasons after the construction of the Aswan High Dam. At the beginning of December 1972, the waters in Rosetta mouth attained an average chlorinity 0·44 Cl ‰. The corresponding average inorganic phosphate concentrations was 0.812 ug-at PO_4—P/L (Table 5).

TABLE 5. **The chlorinity and phosphate concentrations of the discharged waters from the Rosetta mouth at 12 December 1972.**

Depth	Chlorinity ‰	Inorganic phosphate ug-at/
0	0.270	0 56
1	0 297	0.90
2	0.865	0.92
3	0.308	0.90
5	0.405	0.78
Average . . .	0.441	0 812

The linear phosphate-chlorinity relationship expected for the simple mixing between the discharged Nile waters in the coastal regions and the proper sea water of the above mentioned properties after the construction of the Aswan High Dam (Fig. 8 B) could be approximately estimated by as follows :

$$PO_4\text{—P (ug-at/L)} = 0.8453 - 0.03596\ Cl‰$$

The difference between the calculated inorganic phosphate values and the observed concentrations in the Egyptian surface water of the Mediterranean, could be considered anomalous values. These anomalies may be attributed to physical processes other than the simple mixing. The biological processes may also have some influence upon these anomalies. This biological influence does not alter

the anomalies use as a means for tracing the water masses. The concept of a water mass do not only include the waters of specific physical and chemical properties but it also regards this waters as attaining specific biological characteristies.

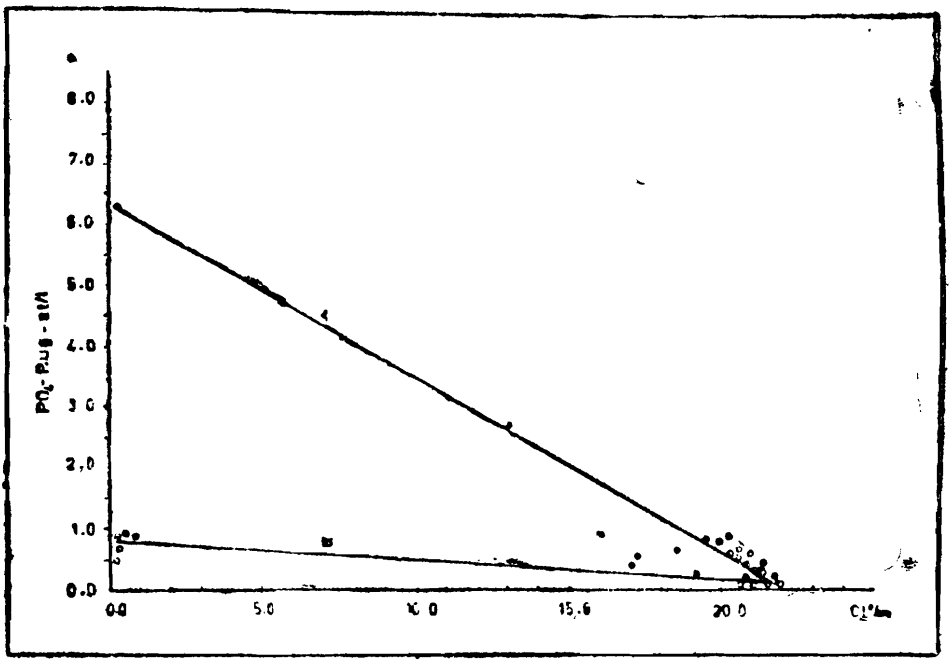

Fig. (8) The phosphate-CI relationship in the water kinds resulting from the simple mixing between the Nile and sea waters. (A) the straight line relationship before 1965, (B) the straight line relationshop after the construction of the High Dam.

The detection of water masses by the phosphate anomalies

The calculated anomalies in the surface 0-10 m layer, during October 1964 (Fig. 9), clearly help in identifying the surface water masses in the coastal regions. According to Nielsen (1912) the current waters along the southern Mediterranean coast have a tendenoy to circle the different areas in a counterclockwise direction. Positive anomalies of about 0.05 ug-at PO_4—P/L could be observed in the Arabs-Gulf surface waters. These western surface waters were boardered in the open sea regions north to Alexandria coasts by an isoline of relatively high positive anomalies reashing 0.20 ug-at PO_4—P/L which indicate clear discontinuity in the properties of the water masses in these regions.

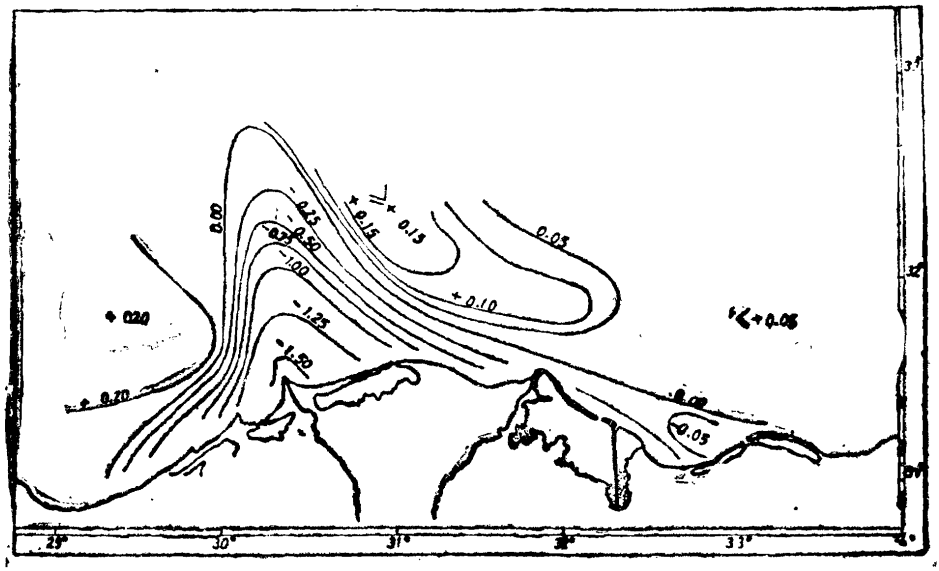

Fig. (9) The distribution of the PO_4-P anomalies per liter in the surface S.E. Mediterrnean waters during autumn 1964.

The shallow water regions north to Alexandria show high negative anomalies which are an extension to the negative values of anomaly isolines centered around Rosetta outlet. The highest negative anomalies of about 1.48 ug-at PO_4—P/L covered the regions of Abu Qir Bay and Rosetta shallow coastal waters.

Inspite of the variation in the negative values yet those which have not exceeded -0.05 ug-at PO_4—P/L covered the shallow regions of about 20 m depth in between Long. 31°45'E, and Long 33°00E.

Other positive anomalies covered the offshore regions north and south east to El-Brullus lake-sea connection. It constituted some complex pattern of distribution the center of which could nearly be observed in the offshore waters, north to El-Brulus-Damietta coastal line along Lat. 32° 00' N. This is in agreement with the current system indicated by Halim *et al.* (1967) in these regions. The highest values of these postive anomalies were centered in the adjacent regions to the position inbetween Long/31° 00' E, and Long 32° 00' E. The offshore south eastern surface waters of the Levantine basin especially in between Long. 32° 30' E, and Long. 33° 30' E, attained uniform properties with low positive anomalies of about + 0.34 ug-at PO_4—P/L.

After the construction of the Aswan High Dam, the coastal waters north to the delta were expected to attain different chemical properties. The reservation of the Nile waters in Lake Naser have changed them significantly. The estimated linear relationship (Fig. 8 B) for the simple mixing of both the Nile and sea water types after the construction of the High Dam, may be used to calculate the inorganic phosphate anomalies in the surface water layer during autumn 1966 (Fig. 10).

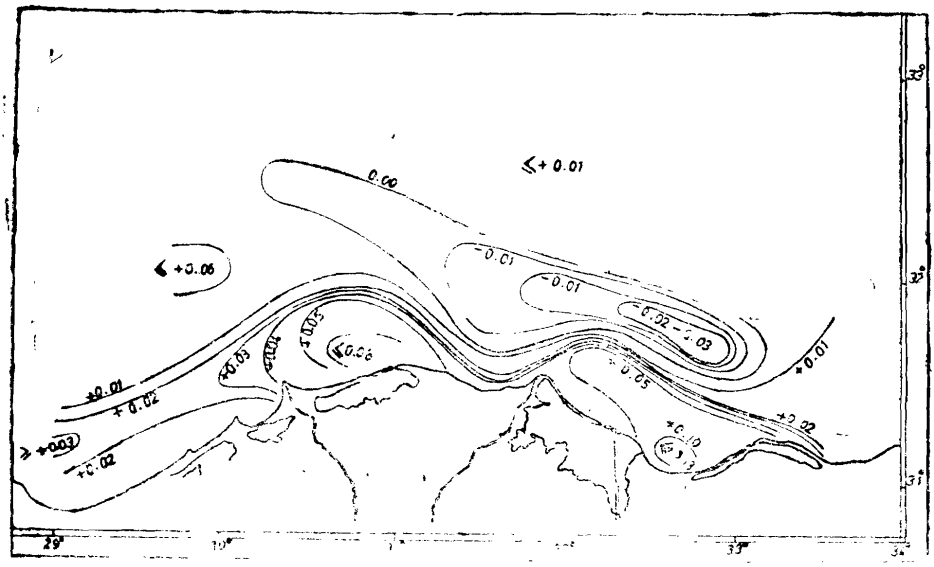

Fig. (10) The distribution of the PO_4-P anomalies per liter in the surface S.E. Mediterranean waters during November 1966.

The regions to the west of Alexandria were covered by waters of low positive anomalies and formed some narrow bands which extended to the offshore regions north to the delta. This suggests the probability of spreading current water of Atlantic origin especially the waters which attained positive anomalies as 0.02—0.06 ug-at PO_4 — P/L. Unfortunately there is lack of observations during autumn 1966.

The recent surveys during September 1970, show that the anomalies of inorgaic phosphate values were distributed along the western coastal line in between Long. 25°00' E and Long 30°00' E. Centered maximum positive anomalies of about 0.16 ug-at PO_4—P/L in between Lat. 31° 30' N and Lat. 320 00'N. suggests an eastward spreading water mass in these regions.

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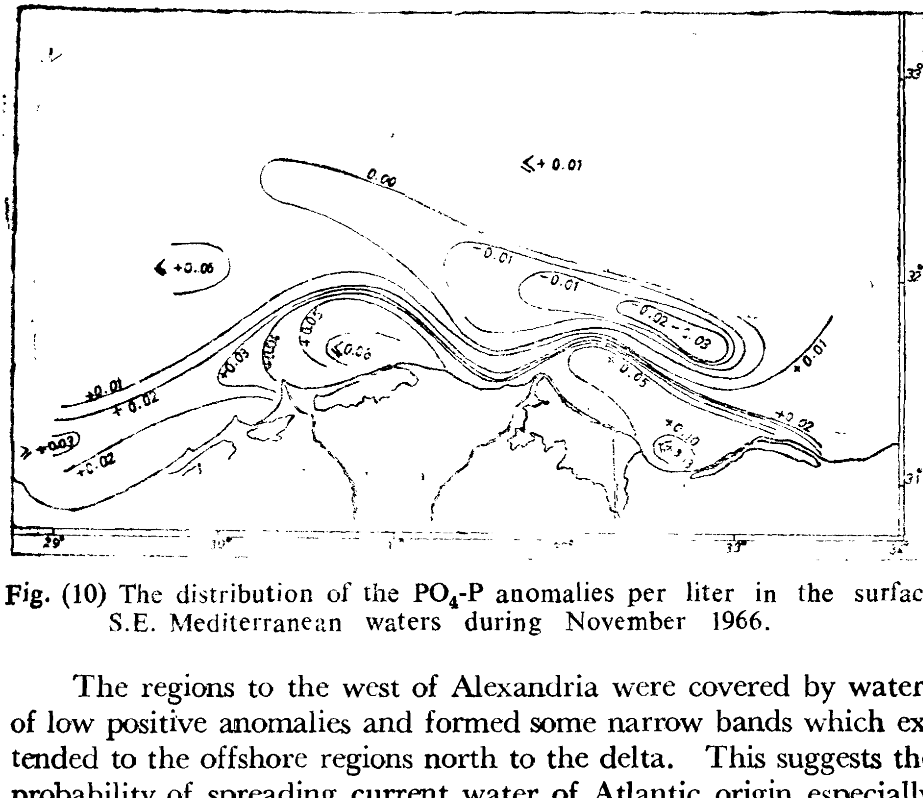

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In the shallow regions north to the delta coasts, a surface water body could be identified through its positive anomalies which were centered to the east of Rosetta outlet. Some increase in the anomalies values reaching 0.18 ug-at PO_4-P/L was observed during 1970. Its location coincides with the corresponding positives anomalies of 0.08 ug-at PO_4—P/L in the same regions during 1966.

On the contrary of the negative anomalies which were noticed during autumn 1964, and probably caused by dense phytoplankton blooming, the positive anomalies found in November 1966 suggests other reasons. The desorption and diffusion of phosphate ions from the superficial layer of sediments probably took place as a result of the change in the PH values and the rise of chlorinity. The values of the bottom water chlorinity which ranged from 21.50‰ to 21.77‰ and the gradual increase in its inorganic phosphate reaching 0.23 ug-at PO_4-P/L with depth helps this suggestion. This increase in chlorinity and phosphate was dominating the regions of 18—60 m depth. The oxidation process of the organic matter which may result-from significant mortality or excesive activity of founal components was probablly of some influence.

Complex pattern of distributing negative anomalies north and north east to the coastal line of Damietta-Port Said could be noticed again in 1966. The center of these anomalies was nearly located at Lat. 31° 36' N, Long. 32° 50' E.

In autumn 1970, the offshore regions beyond Lat. 32° 00' north to the El-Brullus-Damietta coastal line were covered by similar complex pattern of anomalies to that found in each of the previous 1964 and 1966 years. The discontinuity of the negative anomalies from the west to positive anomalies in the east of Long. 31° 00 E suggests different water masses (Fig. 11).

The coastal waters east to Long. 33°00' E were nearly uniform and attained positive anomalous values not exceeding 0.02 ug-at PO_4-P/L.

CONCLUSION

The distribution of inorganic phosphate values in the surface layer of the south east Mediterranean waters are characterised by some regional differences. The western coastal regions to Alexandria were covered by surface waters which attained 0.09-0.16 ug-at PO_4-P/L. The maximum values are frequently observed in the regions between Lat. 31° 30' and Lat. 32° 40'. This area is suggested as the field of influesce of the current waters of Atlantic origin. No significant variations in the distribution of the surface water phosphate could be detected in these regions.

Before the construction of Aswan High Dam, the regions north to Alexandria coasts were the field of distribution of bordering isolines between different western and eastern water masses. Under the influence of about 41.5 km^3 of outflowing Nile waters during autumn 1964, these coastal regions were covered by mixed surface waters of inorganic phosphate concentrations which ranged from 0.17 to 0.57 ug-at PO_4-P/L. The lower concentrations were recorded seawards beyond about 55 miles north.

After the construction of Aswan High Dam in 1966, the concentrations decreased in these regions to 0.08-0.09 ug-at PO_4-P/L. The recorded maximum values of about 0.13 ug-at PO_4P/L may be a continuation of the phosphate properties of the eastward current waters. The regions north to the Nile mouths and especially to Rosetta outlet constituted the source regions of the mixed Nile-sea water mass in the south eastern Mediterranean. An amount of approximately 8200.0 ton (PO_4-P) ions was discharged from the river mouths during autumn 1964. The volume of discharged Nile water from Rosetta outlet reached about 2/3 of the total Nile discharge during this season. The northern regions to this outlet were covered with mixed surface waters attaining .0.20-1.60 ug-at PO_4-P/L. The proper sea waters were detected to aquire a range from 0.00 to 0.07 ug-at PO_4-P/L in the regions approximately beyond Lat. 33° 00' N.

The decrease of the Nile discharge from about 41.5 km^3 in autumn 1964 to about 6.4 km^3 in autumn 1966 caused a decrease in the discharged phosphorus ions to less than 160.2 ton (PO_4-P) ions. A-consequent decrease in the area covered with the waters. of relatively high concentrations as 0.09-0.16 ug-at PO_4-P/L was detected during this season in the shallow regions adjacent to the outlet. The proper sea water of low phosphate content was detected sea-wards beyond Lat. 32° 00' N.

The shallow waters north to El-Brullus and Damietta coastal line were characterised before 1966 by the range from 0.14 to 1.00 ug-at PO_4-P/L. This range indicate restricted seaward flow of the mixed Nile-sea water mass in the nearshore regions.

During autumn 1966, a significant decrease in the phosphate concentrations attained by the nearshore surface waters was detected from the frequent observed values 0.03-0.05 ug-at PO_4-P/L.

The recorded concentrations from 0.16 to 0.60 ug-at PO_4-P/L in the regions adjacent to Damietta mouth during 1964 before the recent reservation of the flood waters were changed in autumn 1966 to range from 0.06 to 0.12 ug-at PO_4-P/L. Before 1965 the offshore waters in the regions north east to Port-Said were of highest chlorinity values and poor inorganic phosphate. Further increase in these water chlorinity and decrease in its incrganic phosphate content were observed during autumn 1966. The chlorinity reached 22.03‰ with about 0.07 ug-at PO_4-P/L. The shallow waters show some increase in the phosphate content to about 0.12 ug-at PO_4-P/L in the upper layer.

In case of simple mixing conditions, the Nile and sea water types may follow a linear phosphate-chlorinity relationship which before the reservation of the flood waters was approximately :

$$PO_4\text{-P (ug-at/L)} = 6.4977 - 0.2978 \text{ Cl ‰}$$

This equation was found changed after the construction of the High Dam to :

$$PO_4\text{-P (ug-at/L)} = 0.8453 - 0.03596 \text{ Cl ‰}$$

These relationship help in the calculation of the anomalous properties of the coastal surface waters. The deduced anomalies could also be used as a water mass tracer.

Generally, the surface water anomalies of inorganic phosphate in 1964, 1966 and 1970 suggested the existance of the following three water masses which were interacting in the upper 0-10 m layer of the coastal Mediterranean waters of Egypt.

a) The transformed water of Atlantic origin flowing along the coastal line west to Alexandria. Its properties faded significantly in the regions north to the Delta coasts under the influence of the outfollowing Nile flood waters before 1965.

b) The Nile delta nearshore water mass. These waters were formed through the high rate of dilution of the sea water by the outflowing fresh water volumes from the Nile mouths. The low chlorinity, high phosphate properties and high negative anomalies of these waters which covered the northern nearshore to the delta regions, have been founed changed after the construction of the High Dam. High positive phosphate anomalies were recently found in the surface waters and still suggests some specifity of this near shore surface waters after the construction of the High Dam.

c) The coastal south eastern surface waters of the Levantine basin. It is characterised by its relatively high chlorinity and low phosphate values with the exception of some shallow coastal water. It attains low positive anomalies of inorganic phosphate.

In addition, the frequent appearance of complex distribution of phosphate anomalies in the surface waters of the offshore regions north to Damietta coastal line, suggests the existence of a field of interaction between the eastward current and westward counter-current waters.

SUMMARY

1. Regional differences appear in the phosphate content of the surface water of the south east Mediterranean.

2. The concentration 0.09-0.16 ug-at PO_4-P/L in the surface waters west to Alexandria are frequently observed and found independent from the influence of the change in the discharged flood waters of the Nile.

3. The coastal regions north to Alexandria were the field of discontinuity in the properties of the surface water. It attained maximum values 0.17-0.57 ug-at PO_4-P/L during autumn 1964 and lowered to 0.08-0.09 ug-at PO_4-P/L in 1966.

4. The discharged phosphorus ions from the Nile outlets during autumn 1964 were esimated about 8200.0 ton (PO_4-P) ions.

5. The discharge of 41·5 km^3 flood waters during autumn 1964 were associated with the formation of mixed Nile-sea surface water mass attaining 1.60-0.14 ug-at PO_4P/L in the nearshore regions north to the delta.

6. The decrease of the outflowing flood waters to about 6.4 km^3 in autumn 1966 was estimated to distribute about 160.2 ton (PO_4-P/L) ions in the shallow regions.

7. The observed phosphate concentrations in the surface water of the shallow regions north to Rosetta outlet after 1965 varied between 0·08 and 1.16 ug-at PO_4-P/L.

8. The waters of minimum phosphate concentrations which ranged from 0.0 to 0.09 ug-at PO_4-P/L were detected in autumn 1964 beyond Lat. 33°00. N, while in autumn 1966 it covered the regions north to Rosetta mouth beyond Lat. 32° 00' N.

9. The phosphate concentrations in the nearshore regions north to El-Brullus-Damietta coasts ranged from 0.14 to 1·00 ug-at PO_4-P/L in 1964 and from 0.03 to 0.05 ug-at PO.P/L in 1966.

10 - The surface water mass of the coastal regions east to Port-Said was of relatively high chlorinity reaching 22.03‰ and low inorganic phosphate content of less than 0.07 ug-at PO_4-P/L

11 - In autumn 1966, an increase in the phosphate concentrations with depth was observed in the shallow regions north to Rosetta outlet and east to Port-Said and may probably be due to diffusion of desorbed phosphate ions from the bottom sediments.

12 - The formula

$$PO_4\text{-}P \text{ (ug-at/L)} = 6.4977 - 0.2978 \text{ Cl‰}$$

is suggested to explain the phosphate-chlorinity relationship in the water kinds resulting from the simply mixing Nile and the proper sea waters before the construction of Aswan High Dam, while the formula

$$PO_4\text{-}P \text{ (ug-at/L)} = 0.8453 - 0.03596 \text{ Cl‰}$$

explain it after the construction of the High Dam.

13 -The calculated anomalies confirm the regional distribution of properties as a result of the interaction between three water masses in the coastal regions of the south eastern part of the Mediterranean.

14 - The interacting three water masses in the coastal regions are:

a) The transformed current water mass of Atlantic origin along the western coasts of Alexandria. It attains maximum positive anomalies 0.16 - 0.20 ug-at PO_4-P/L..

b) The Nile delta nearshore mixed water mass. It appeared before the construction of Aswan High Dam with high negative anomalies reaching 1.48 ug-at PO_4-P/L. Since 1966, it changed to attain positive anomalies of maximum 0.08 - 0.18 ug-at PO_4-P/L

c) The coastal south eastern surface water mass of the Levantine basin. It aquired low positive anomalies of 0.02 -0.04 ug-at PO_4-P/L. Slight variations in these values may appear in restricted areas of the shallow nearshore regions.

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