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Observations on the Status of the Creek Waters of the United Arab Emirates. 1-Nutrients

By

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Abstract

Water samples were collected from 42 sampling sites including all seven major creeks in the United Arab Emirates and nearby coastal areas. In situ measurements were made for salinity, temperature and pH, while collected samples were analyzed for phosphate, nitrate, nitrite, ammonia and dissolved oxygen. Results indicated that the waters of Dubai and Sharjah creeks are polluted as they contained unusually high nutrient concentrations, unusual pH values and low oxygen relative to other creeks. The concentrations varied widely with location and sampling date. Variations are partly attributable to the presence of intermittent sources of wastewaters, distances from these sources, and differences in the intensities of boat and human activities near each site. Results are discussed and possible adverse effects are pointed out.

Introduction

During the past few decades marine coastal areas all over the Arabian Gulf have been exposed to many environmental hazards. Significaent anthropogenic input is mainly due to heavy oil production, ship activities, town developments, increased industrial and agricultural activities, sewage dumping and increased number of power and desalination plants.

The United Arab Emirates (U.A.E.) has more than 700 km of coast along the Arabian Gulf and the Gulf of Oman. In addition, U.A.E has many other creeks that extend from the Arabian Gulf into the land in Abu-Dhabi, Dubbai, Sharjah, Ajman, Umm Al Quwain, Ras Al Khimah and from the Gulf of Oman forming Kalba creek. These creeks are important bodies of water because of their significant relation with the daily life of people. The banks of these creeks are heavily populated if compared with other areas. Consequently, they are used intensively for many purposes including boat mooring, and sewage, surface water and wastewater dumping. The most potentially threatening pollutants originated form the above human stresses are the hydrocarbons, chlorinated hydrocarbons, heavy metals and nutrients.

The accumulation of these pollutants in any restricted body of water such as these semi-closed creeks usually lead to many environmental and health problems. Of interest is the accumulation of nutrients which usually lead to eutrophication and many related consequences including increased biochemical oxygen demand, particularly in

the bottom waters, bringing about the elimination of aerobic organisms. (Dwivedi and Padmakumar, 1983).

As there was no information about the above pollutants in the United Arab Emirates waters, a study was undertaken to collect reference data about the marine environment of the whole country, investigate the effect of potential sources of pollution on the concentration of nutrients and other pollutants, assess the state and quality of the creek waters and develop a rational programme of measures and improvements of the waste disposal means in creek and coastal waters.

This paper reports summarized data on the hydrography and nutrients obtained for four creeks within the framework of the study.

Material and Methods

The observations are based on data obtained from field measurements and analyses of surface water samples collected from 42 stations along major creeks in the United Arab Emirates and nearshore coastal waters.

Samples were collected by the use of a clean plastic sampling bottles. After collection, 100-250 ml water aliquots were transferred to a pre-cleaned labelled polypropylene containers. Samples for nutrient analysis were stored immediatly after sampling in a deep freezer until analysis.

Temperature, salinity and conductivity were measured in-situ by the use of precalibrated LabComp Ananlyzer Model SCT-100; a microprocessor-based, digital instrument. The pH of water was measured in-situ by the use of a portable HACH One pH meter Model 43800, equipped with Model 44200 combintion electrode, and a temperature sensor.

Ammonia was determined by Solorzano method (1969) as described by Strikland and Parsons (1972) and Grasshoff (1976). Nitrite was determined according to Parsons et al. (1984), Phosphate by the method of Murphy and Riley (1962) as described by Parsons et al. (1984), Nitrate by the copper-coated cadmium reduction column as modified by Grasshoff (1976). All spectrophotometric measurements were made on a HACH spectrophotometer Model DR/2000. Dissolved oxygen was determined by the Winkler titration method given by Strickland and Parsons (1972).

Results and Discussion

The results obtained from Abu-Dhabi, Dubai, Sharjah and Kalba creeks will be presented and discussed in this paper. Those obtained from the other three creeks (Ajman, Umm AlQuwain and Ras Alkhaimah) will be the subject of a later report.

Abu-Dhabi Creek

Figure 1 shows the locations of 14 sampling stations and the major wastewater outlets around Abu-Dhabi Island. Stations 1 and 2 are within the industrial Musaffah area,

while stations 4 and 5 are within an area with some mangrove vegetation. Stations 6, 7, 8, and 9 are located within a coastal area protected by a series of break waters. Station 10 is a control sampling site, not protected by any construction. Stations 12, 13 and 14 are within a semi-enclosed channel-like body of water.

Fig 1

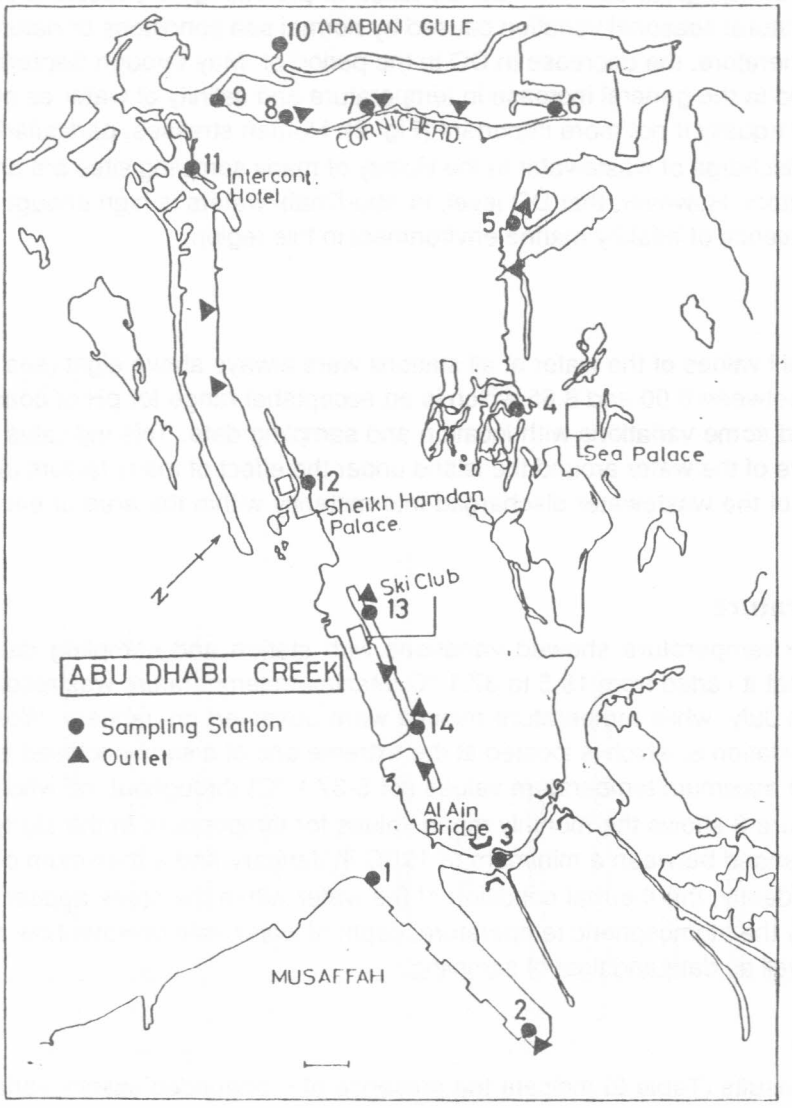

Fig. (1)

Locations of sampling stations and major sewage outlets in Abu Dhabi Creek.

Dissolved oxygen

Table 1 shows the range of values for dissolved oxygen (DO) in samples colleced from Abu-Dhabi creek. Examination of the detailed data indicates the presence of variations in DO contents at each station during the study period. The values ranged between a minimum of 5.85 mg/l and a maximum of 7.11 mg/l. At one station (station 1) it fluctuated between 5.87 and 7.11 mg/l. Figure 2 indicates some variations in the monthly overall mean values of DO in the whole study area. However, considering this time variability, great caution must be taken in predicting its causes. It cannot be a merely natural seasonal variation caused by normal sea conditions or natural processes and therefore, the decrease in DO in the period of May through September cannot be related to the general increase in temperature and salinity of water as other factors could be equally if not more important (Fig. 2). Human stresses, particularly the intermittent discharge of wastewater in the vicinity of many sampling sites are among these other factors. However, that DO level, in Abu-Dhabi waters is high enough to indicate the prevalence of healthy marine environment in this region.

pH

The pH values of the water at all stations were always above eight (see Table 1). It ranged between 8.00 and 8.65 which is an acceptabel range for pH of coastal waters. It showed some variations with location and sampling date. This indicates the changing nature of the water around the island under the effect of many factors including the quantity of the wastewater discharged intermittently within the area of each sampling site.

Temperature

Water temperature showed variations with station and sampling date. Table 2 shows that it varied from 18.5 to 37.1 °C. Maximum temperature was recorded at station 6 on July, while temperature minima were observed on January. Worthmentioning, that station 6, which is located at the extreme end of a semi-enclosed embayment, recorded maximum temperature values (21.5-37.1 °C) throughout the whole study period. Figure 3 shows the monthly mean values for temperature in the study area. The values ranged between a minimum of 19 °C in January and a maximum of 34.8 °C in July. Evidently, the thermal condition of the water within the creek appear to be influenced by the atomospheric temperature, depth of water, rate of water flow at each station as well as date and time of sampling.

Salinity

The results (Table 2) indicate the presence of pronounced salinity variations at all sampling stations within Abu-Dhabi creek. The lowest salinity (35.53%) was recorded at station 8 on October and was correlated with strong wastewater discharge at the time of sampling. The calculated standard deviation for the observed salinity values

Fig 2

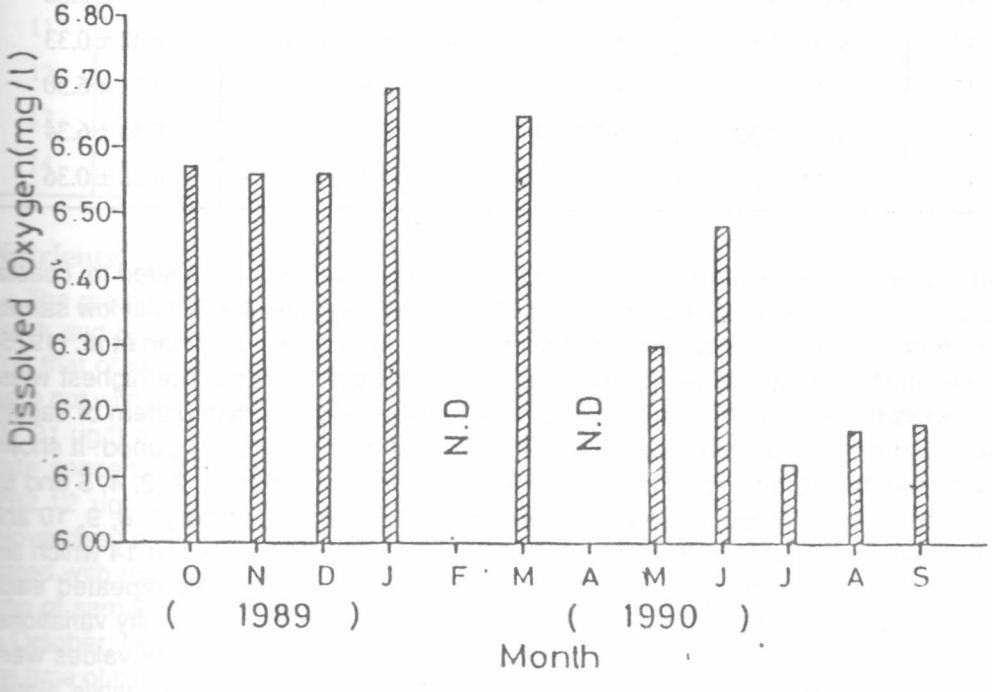

Fig. (2)

Monthly overall mean values of dissolved oxygen in Abu Dhabi Creek and coastal waters

Table (1) : Range values, mean and standard deviation (SD) for pH and dissolved oxygen (mg/1) in the surface water of Abu-Dhabi creek

Sation	pH		Dissolved Oxygen	
	Range	Mean ± SD	Range	Mean ± SD
1	8.01 - 8.52	8.23 ± 0.21	5.87 - 7.11	6.50 ± 0.35
2	8.04 - 8.63	8.26 ± 0.23	6.31 - 6.83	6.53 ± 0.21
3	8.01 - 8.50	8.23 ± 0.21	6.13 - 6.70	6.36 ± 0.21
4	8.00 - 8.53	8.23 ± 0.23	5.85 - 6.92	6.38 ± 0.39
5	8.00 - 8.53	8.26 ± 0.22	5.98 - 6.99	6.46 ± 0.35
6	8.00 - 8.49	8.22 ± 0.19	6.05 - 6.73	6.45 ± 0.22
7	8.00 - 8.42	8.19 ± 0.20	6.15 - 6.80	6.45 ± 0.24
8	8.00 - 8.47	8.19 ± 0.18	5.98 - 6.87	6.35 ± 0.32
9	8.02 - 8.52	8.21 ± 0.22	5.85 - 6.99	6.48 ± 0.36
10	8.03 - 8.48	8.23 ± 0.19	6.01 - 6.83	6.56 ± 0.32
11	8.00 - 8.54	8.22 ± 0.25	5.85 - 6.80	6.42 ± 0.33
12	8.01 - 8.54	8.24 ± 0.24	5.85 - 6.80	6.31 ± 6.30
13	8.01 - 8.52	8.23 ± 0.22	5.85 - 6.88	6.38 ± 6.34
14	8.00 - 8.65	0.22 ± 0.26	5.85 - 6.80	6.28 ± 0.36

was biggest (2.45) for station 8 indicating larger salinity variation compared to coastal stations 7, 9, 10 an 11 (SD:0.39, 0.40, 0.29 and 0.27 respectively). Similar low salinity conditions at areas of sewage discharge have been reported by Unnithan **et al.** (1975). However, the salinity values in Abu-Dhabi creek were in all cases the highest when compared to those of other creeks. Figure 4 represents a common pattern of salinity (mean values) distribution around Abu-Dhabi Island during the study period. It shows that higher salinities occured at the semi-enclosed inner stations (1, 2, 3, 4, 5 and 6), the salinities tend to decrease at the more exposed coastal stations (7, 8, 9, 10 and 11), but increase again in the waters of the creek at stations 12, 13 and 14 which are located on the eastern side of Abu-Dhabi Island. This pattern was repeated each month almost without any significant change. Considering seasonal salinity variations, the examination of the detailed data indicates that relatively low salinity values were observed at all stations in October, November, December and January; while higher values were found in June, July, August and September. This was also true for the monthly mean values as calculated for the entire study area.

Table (2) : Range values, mean and standard deviation (SD) for temperature (°C) and salinity in the surface water of Abu-Dhabi creek.

Station	Temperature		Salinity	
	Range	Mean ± SD	Range	Mean ± SD
1	18.5 - 34.3	28.5 ± 5.46	44.16 - 47.86	46.09 ± 1.13
2	19.0 - 34.6	28.8 ± 5.71	43.12 - 48.74	46.70 ± 1.74
3	18.8 - 35.1	28.9 ± 5.62	43.41 - 48.45	46.63 ± 1.38
4	18.5 - 34.7	28.6 ± 5.64	44.23 - 46.98	45.69 ± 1.04
5	18.8 - 34.7	29.0 ± 5.58	43.31 - 45.07	44.32 ± 0.62
6	21.5 - 37.1	31.0 ± 5.82	44.52 - 48.06	45.62 ± 1.17
7	18.5 - 35.7	28.6 ± 6.23	42.57 - 43.60	43.46 ± 0.39
8	18.5 - 35.7	29.1 ± 6.18	35.53 - 43.75	42.23 ± 2.45
9	18.5 - 35.3	28.6 ± 5.93	42.97 - 44.19	43.59 ± 0.40
10	18.5 - 34.5	28.4 ± 5.50	43.16 - 44.23	43.52 ± 0.29
11	19.0 - 33.9	28.6 ± 5.25	43.31 - 44.19	43.61 ± 0.27
12	19.5 - 33.7	28.6 ± 4.87	44.63 - 46.10	45.15 ± 0.45
13	19.0 - 33.6	28.6 ± 5.16	45.28 - 47.42	46.37 ± 0.67
14	19.0 - 33.6	28.3 ± 5.42	44.92 - 46.83	46.02 ± 0.59

Nutrients

The results listed in Table 3 indicate that the nutrient concentrations in Abu-Dhabi creek and nearshore coastal waters are low if compared with waters of other creeks and that of station 10 which is considered as a control. However, those low results were not without exceptions. For example high values of ammonia (143.11 ug/l), nitrite (37.21 ug/l) and nitrate (204.38 ug/l) were obtained at station 8 in October. High nitrate concentrations were also obtained at station 4 in May (243.35 ug/l) and July (262.12 ug/l). Other examples are the high ammonia (53.85 ug/l) at station 8 (November) and station 5 (53.16 ug/l) in March. Evidently, these high values are associated with the discharge of wastewater occasionally observed before and during the time of sampling. Accordingly, it can be stated that the high ammonia concentrations in October, November, and March indicate the recent nature of the pollution events at the time of sampling, while the high nitrate and nitrite indicate that the prevaling hydrometeorological conditions are supporting strong and propably fast oxidation of a rather high load of amonia in the dumped wastewater. The fluctuation in the

Fig.3

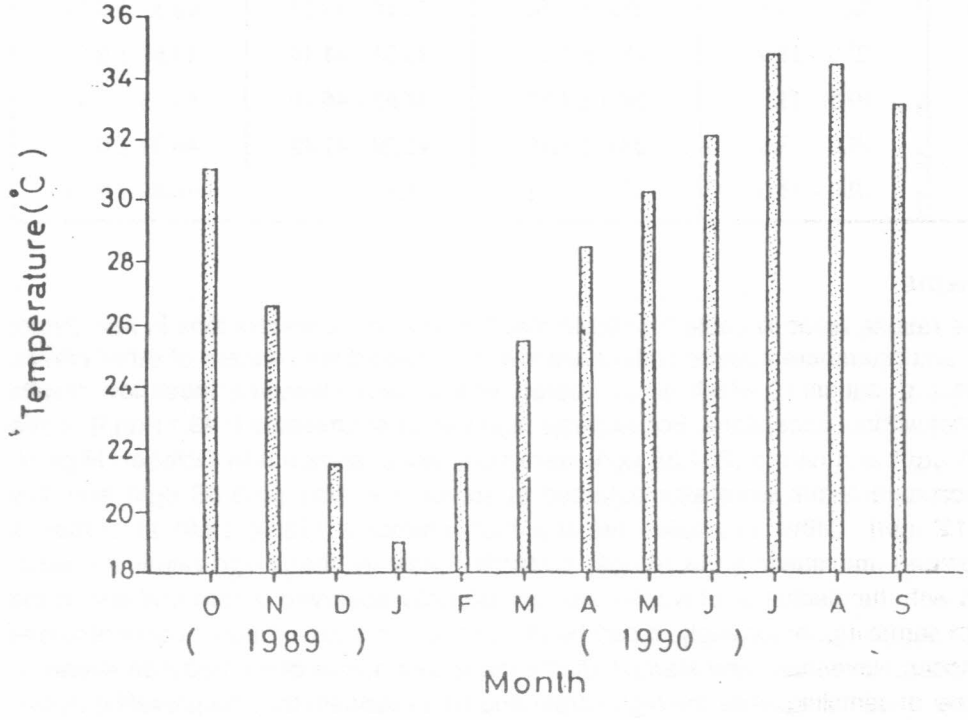

Fig. (3)

Monthly mean values of temperature in Abu Dhabi Creek and coastal waters.

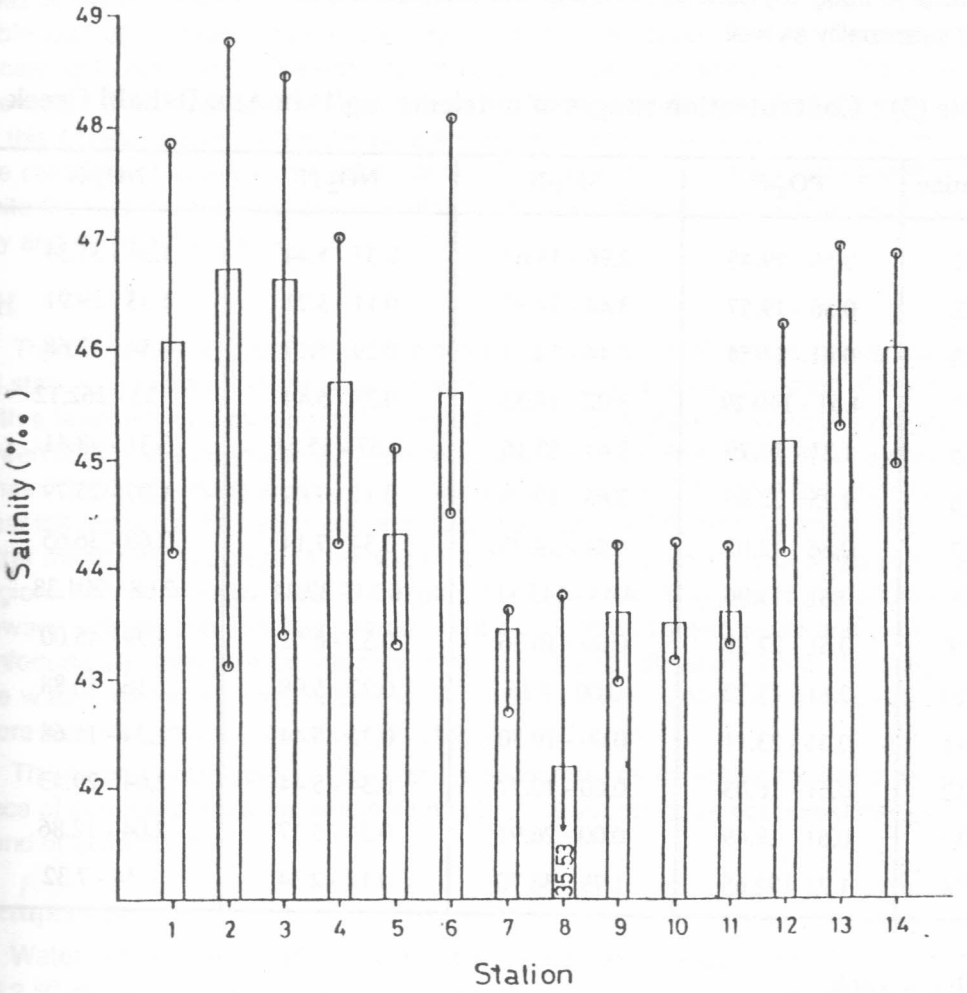

Fig. (4)

Range andd mean values of salinity in Abu Dhabi Creek and coastal waters.

nutrient concentrations with time at each station indicates the significant effect of the intermittent sources of pollution located in the vicinity of the sampling sites. This marked but mainly localized effect is confirmed by the low salinity values (35.53 - 43.755) observed at station 8 in October, November, June, July and August. Noteworthy, the 35.53 was the lowest salinity measured over the entire region throughout the study period. Phossphate ranged between 0.56-140.29 ug/l, ammonia 0.00 - 143.11 ug/l, nitrite 0.11-37.24 ug/l and nitrate 0.54-262.12 ug/l. (see Table 3). The presence of these fluctuations with unusual values in many sites during many occasions makes it difficult to trace any general trend from the obtained results which do not display any clear seasonality as well.

Table (3) : Concentration ranges of nutrients (ug/1) in Abu Dahabi Creek

Station	PO_4-P	NH_3-N	NO_2-N	NO_3-N
1	0.56 - 19.45	2.96 - 18.67	0.33 - 5.44	1.34 - 31.34
2	0.56 - 19.57	3.44 - 37.33	0.11 - 5.71	1.33 - 39.91
3	0.61 - 14.54	3.14 - 12.51	0.29 - 5.17	0.54 - 32.68
4	4.51 - 140.29	3.02 - 14.55	0.33 - 5.44	1.53 - 262.12
5	1.21 - 14.79	3.44 - 53.16	0.67 - 15.51	3.31 - 48.41
6	2.25 - 22.65	2.68 - 10.18	0.11 - 7.07	1.07 - 25.79
7	0.56 - 12.02	4.04 - 14.95	0.34 - 7.14	2.68 - 36.65
8	0.61 - 17.96	4.43 - 143.11	0.33 - 37.24	2.68 - 204.38
9	0.61 - 27.28	0.00 - 16.36	0.33 - 6.52	3.99 - 45.00
10	0.61 - 13.72	0.00 - 9.16	0.22 - 5.98	1.16 - 16.88
11	0.61 - 23.11	0.00 - 19.30	0.22 - 5.44	1.34 - 15.68
12	0.61 - 16.03	0.00 - 10.77	0.34 - 5.44	2.04 - 29.43
13	0.61 - 18.49	0.00 - 26.91	0.34 - 5.17	2.04 - 12.86
14	1.21 - 72.65	1.79 - 36.70	0.11 - 2.34	1.34 - 7.32

Dubai Creek

Figure 5 shows the locations of the four sampling stations and major wastewater outlets within Dubai Creek. Station 1 is located at the far end of the Creek, near Dubai Docking Yard. Stations 2 and 3 are located in the middle of the Creek where major wastewater discharges take place from major outlets. Station 4 is located near the mouth of the Creek.

Dissolved oxygen

Table 4 and Fig. 6 show the range and mean values of DO in water samples collected from the Creek during the study period. Wide variations were observed with locality and date of sampling at each station.The values ranged between 4.32 and 6.27 mg/l. The minimum and maximum concentrations were observed at station 1. However, more or less similar low values and considerable variations were obtained at other stations which indicate the marked influence of pollution sources particularly the intermittent wastewater discharged from the sewage outlets located near the smapling sites at stations 2 and 3. It is likely that the properties of these discharges and its variable load of oxidizable matter are major factors in affecting DO concentration in the receiving Creek water. The occurrence of low oxygen concentrations in the water of the whole Creek indicates the prevalence of unusual conditions within the main body of this Creek. Clearly, while the data are subjected to considerable spatial variation, the calculated monthly mean values of DO do not exhibit clear seasonal variations, inspite the fact that the maximum monthly mean value 5.73 mg/l was obtained in January and minimum value (4.93 mg/l) in july.

pH

The pH values of Dubai waters are comparatively high, with noticeabel varaiation at all stations. (Table 4). Highest values were obseved at the inner portion of the Creek with a tendency of outwards dicline (Fig. 6). Thus, at station 1, pH values ranged between 8.14 and 9.25 (mean 8.58) while at station 2 it ranged between 8.18 and 9.02 (mean 8.47). By comparison, it decreased at station 3 (mean 8.29) and station 4 near the mouth of the Creek where it ranged berween 8.04 and 8.58 (mean 8.21). The latter mean value is close to the values obtained from many coastal stations in other regions within the study area. The high pH values are mainly due to the effect of the sewage effluent and possible interaction of its constituents with water and sediments. Unfortunately, available facilities were not suitable for obtaining water samples from the water column, or near-bottom waters, the results of which are expected to give more indicative information about the status of the Creek.

The careful examination of the calculated monthly mean values indicates the presence of considerable range of variations (8.13 - 8.90) but does not reveal any general trend or seasonality.

Temperature

Water temperature (Table 4) at the time of sampling ranged between 20 °C and 35.2 °C during the study period that extended from January to December 1990. However, variations with station visited on the same day were not as wide as those for Abu Dhabi Creek; a finding that can be explained on the basis of the fact that depth differences among Dubai stations were smaller. By comparison, in Abu Dhabi Creek most of the inner sampling sites were within small channels of shallow water, while other sites were relatively deeper. Variations with sampling dates were also observed. Thus

temperature minima were recored in January (20 - 22 °C) while maxima were in July (33.8 - 34.4 °C) and August (34.6 - 35.2 °C). These variations are caused by many factors including differences in atmospheric temperature, depth of water, tide level and flow rate of in-going and out-going water within the Creek. Figure 7, shows a well defined seasonal variations for the water of the Creek. February was the month of the lowest mean temperature (20.6 °C), while August showed the maximum (34.8 °C).

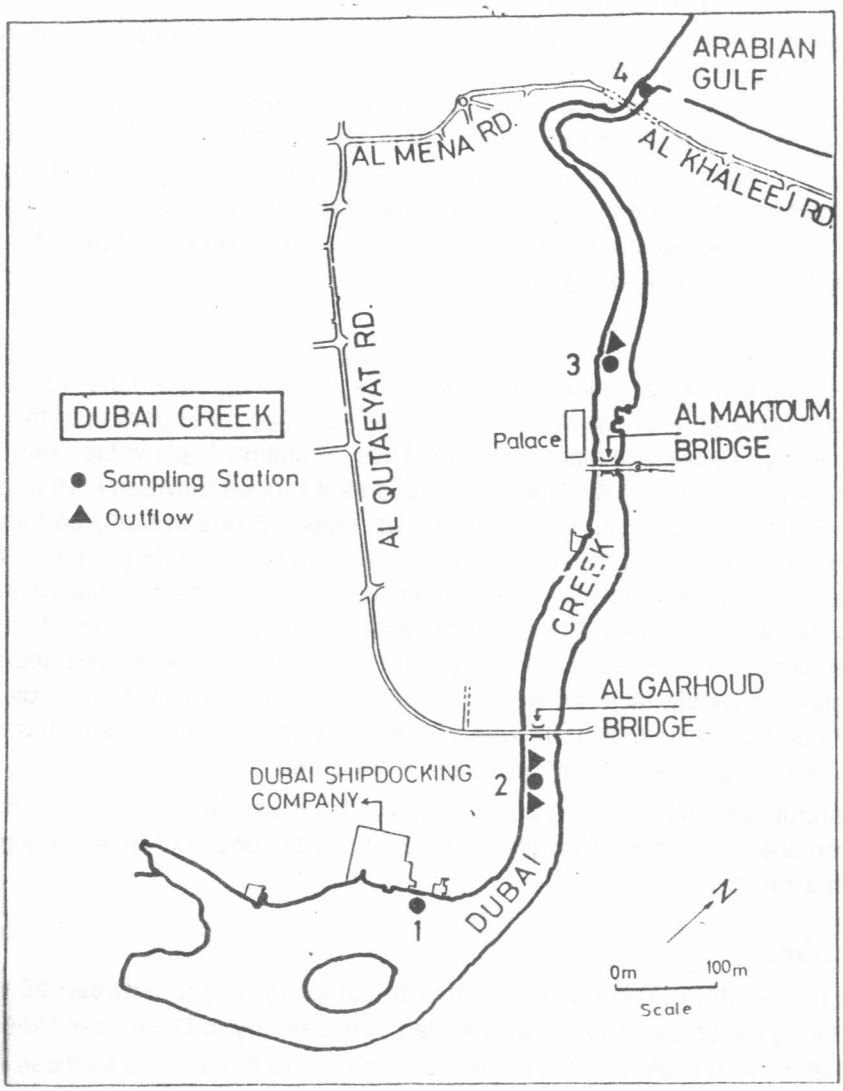

Fig. (5)

Locations of sampling stations and major sewage outlets in Dubai Creek

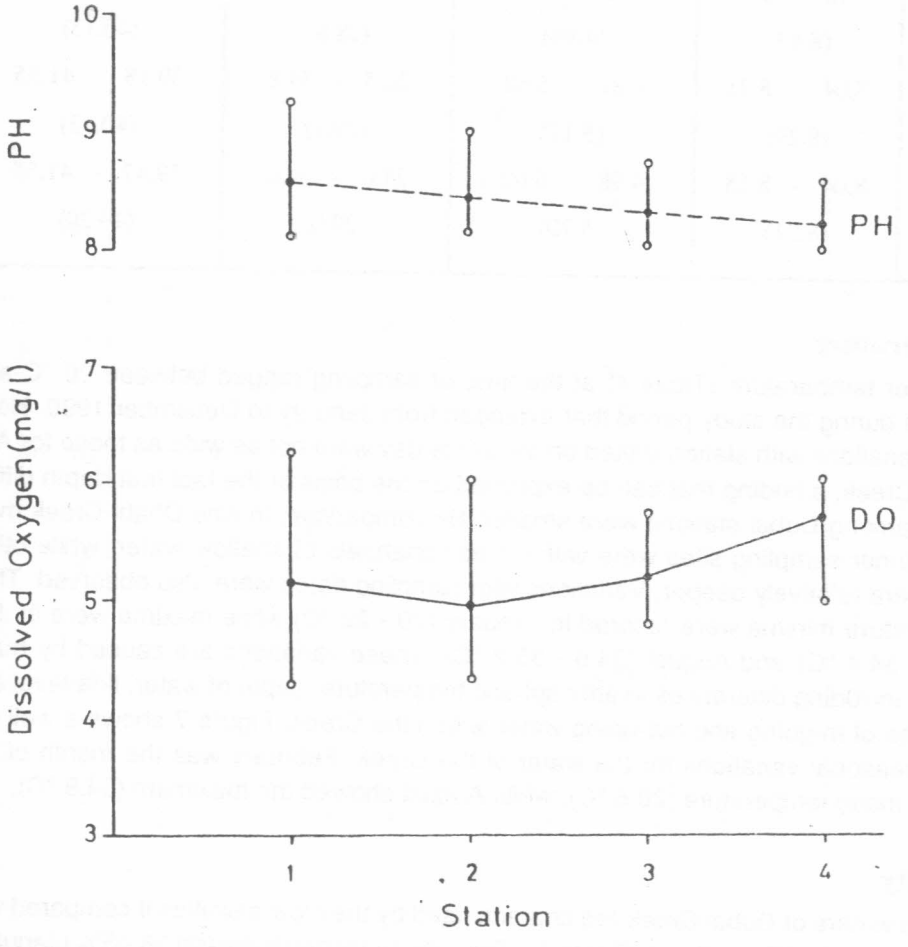

Fig. (6)

Range and mean values of pH and dissolved oxygen in Dubai Creek and coastal waters

Table (4) : Range and mean values of pH, dissolved oxygen (mg/1), temperature (°C), and salinity in the surface waters of Dubai Creek.

Station	pH	Dissolved Oxyen	Temperature	Salinity
1	8.14 - 9.25	4.32 - 6.27	20.0 - 35.2	38.45 - 42.28
	(8.58)	(5.13)	(28.5)	(40.17)
2	8.18 - 9.02	4.33 - 6.02	20.5 - 34.7	36.16 - 42.13
	(8.47)	(4.96)	(28.8)	(40.13)
3	8.04 - 8.73	4.81 - 5.68	20.5 - 34.8	39.18 - 41.55
	(8.29)	(5.17)	(29.1)	(40.13)
4	8.04 - 8.58	4.98 - 6.02	21.0 - 34.6	39.47 - 41.55
	(8.21)	(5.70)	(29.0)	(40.20)

Temperature

Water temperature (Table 4) at the time of sampling ranged between 20 °C and 35.2 °C during the study period that extended from January to December 1990. However, variations with station visited on the same day were not as wide as those for Abu Dhabi Creek; a finding that can be explained on the basis of the fact that depth differences among Dubai stations were smaller. By comparison, in Abu Dhabi Creek most of the inner sampling sites were within small channels of shallow water, while other sites were relatively deeper. Variations with sampling dates were also observed. Thus temperature minima were recored in January (20 - 22 °C) while maxima were in July (33.8 - 34.4 °C) and August (34.6 - 35.2 °C). These variations are caused by many factors including differences in atmospheric temperature, depth of water, tide level and flow rate of in-going and out-going water within the Creek. Figure 7 shows a well defined seasonal variations for the water of the Creek. February was the month of the lowest mean temperature (20.6 °C), while August showed the maximum (34.8 °C).

Salinity

The waters of Dubai Creek are characterised by their low salinities if compared with those from Abu Dhabi Creek (Table 4). The salinity ranged between 38.45% (January) and 42.28% (july), and showed a general distribution pattern from that observed in Abu Dhabi Creek. In the colder months (January - March) salinity values in each month were relatively low near the far end of the Creek at station 1 and in the middle sector at station 2, and tended to show little increase near the mouth of the Creek at station 4 which is exposed to a more stable coastal sea condition (Fig. 8). The

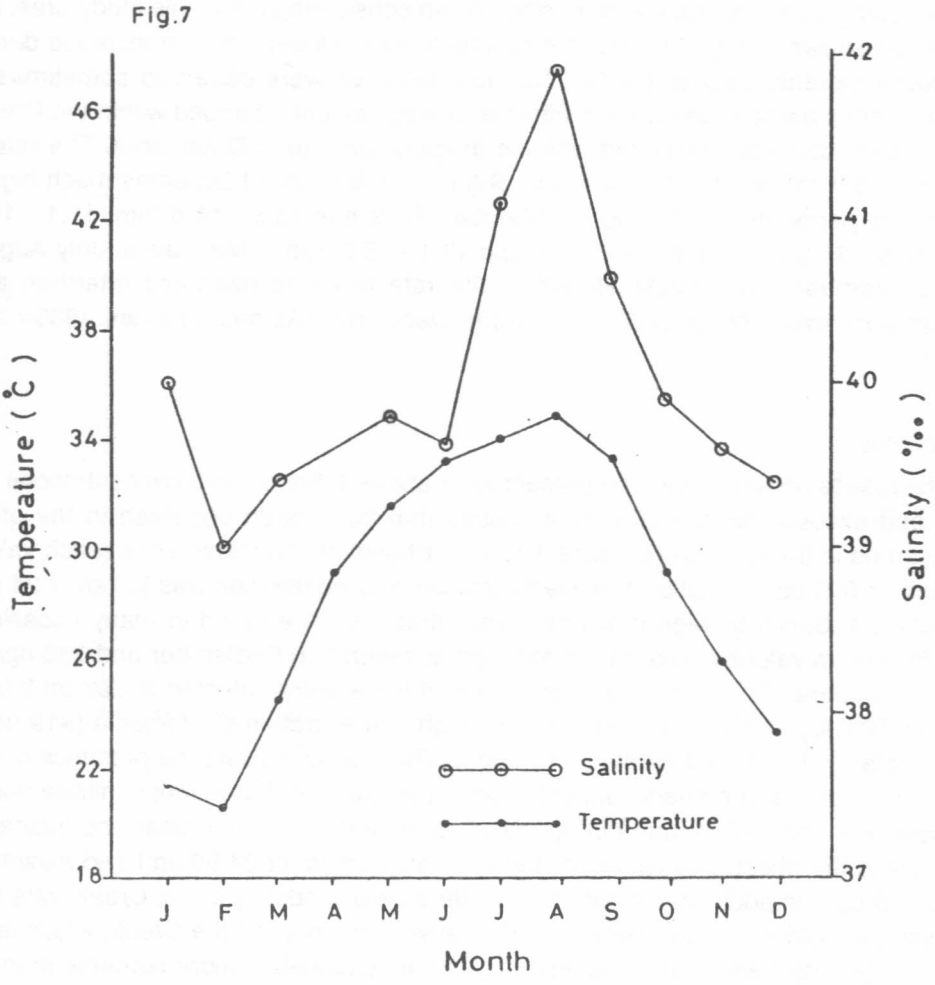

Fig. (7)

Monthly mean values of salinity and temperature in Dubai Creek

factors behind this pattern of distribution are the greater amount of sewage, discharged through three major outlets located in the middle sector fo the Creek (stations 2 and 3), and the higher mixing rate with the in-going coastal water at station 4 near the mouth of the Creek. However, the pattern became completely different in the warm months when higher salinity values were recorded in the inner part at stations 1 and 2, and relatively lower values were observed at stations 3 and 4 (Fig. 8). A possible reason is the high evaporation rate in the middle and inner parts of the Creek compared to the outer part during the warm months. When considering the whole study area, the results as shown in Fig. 7 incate that salinity (mean values) tends to increase during the warm months, despite the fact that low salinities were observed sometimes at some stations owing to the dilution effect of sewage effluent dumped within the Creek. This pattern could be correlated with the evaporation rate in Dubai area. The rate is only 8.7 - 9.4 mm in January, and 9.5 - 9.6 mm in April, but it becomes much higher during the period of May through September. Thus it is 13.8 - 14.6 mm, 11.1 - 14.0 mm, 12.9 - 16.3 mm, 13.4 - 14.8 mm, and 13.1 - 15.2 mm in May, June, July August and September respectively. However, the rate tends to decrease afterthen and reachs a minimum range (7.3 - 7.6 mm) in December (Ali and Cherian, 1983a and 1983b).

Nutrients

The results obtained from the present work showed that nutrient concentrations are high and exceed the normal natural values that have been observed in the other Creeks and in the Arabian Gulf (see Table 5). Phosphate concentrations reach values as high as 893 ug/l at station 1, while the minimum concentration was just over 24 ug/l at station 4. Similarly, high ammonia concentrations were found in many occasions with maximum values of more than 498 ug/l at sation 1 in September and 238 ug/l at station 2 in June. The highest concentrations of nitrite were detected at Station 2 (>54 ug/l) in January and was accompanied by high concentration of ammonia (>19 ug/l), phosphate (707 ug/l) and nitrate (~ 121 ug/l). The results indicate the presence of signigicant variations in nutrient concentrations at all stations. For example nitrate varied between 6.7 and 333.12 ug/l during the study period. The other clear and indicative example is the phosphate variations between a minimum of 24.90 ug/l and maximum of 892.68 ug/l. In addition, the results indicate a clear tendency of the Creek waters to accumulate nutrients above background level with the inner of the Creek, which is influenced by major wastewater outlets, appears to accumulate more nutrients than the other sectors. However, the concentrations tend to decrease from the inner sector of the Creek towards its mouth. Mixing and dilution processes with coastal waters near the mouth are partly but significantly responsible for this general decline.

As a general conclusion, it can be stated that the quality of receiving waters, with respect to nutrients, in this Creek is far from normal and needs more detailed works to include the analysis of deeper and near-bottom water samples as well as bottom sediment samples.

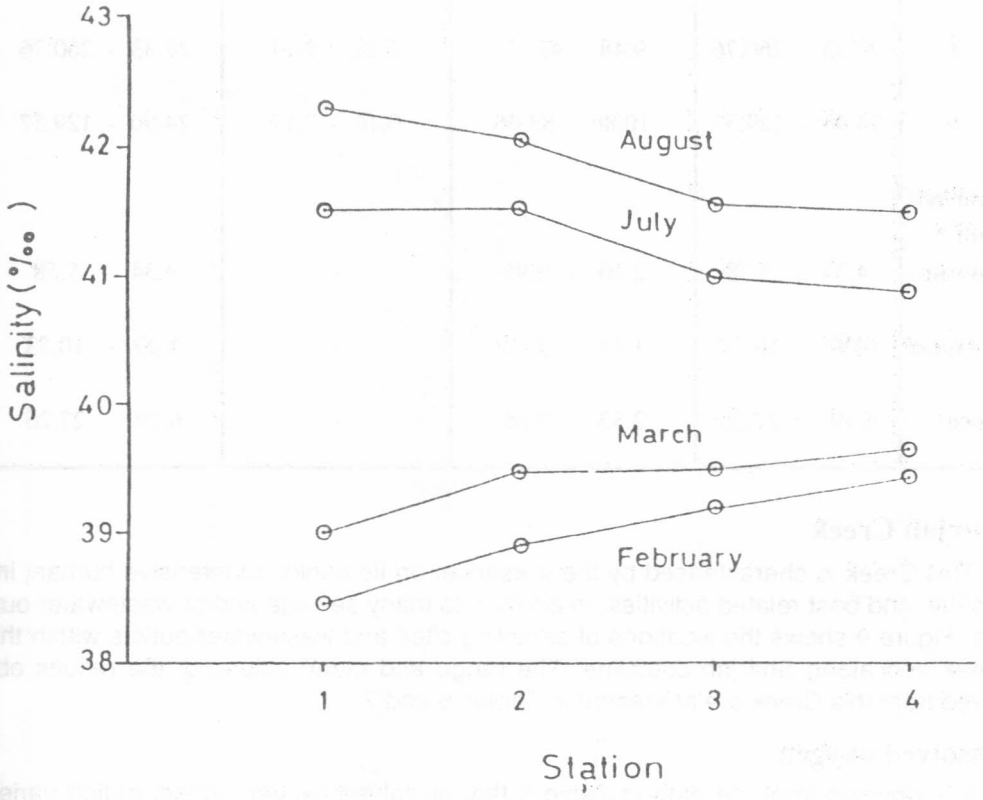

Fig. (8)

Pattern of salinity distribution in Dubai Creek during cold and warm months

Table (5) : Range of nutrient concentrations (ug/1) in Dubai Creek and the Arabian Gulf.

Station	PO_4-P	NH_3-N	NO_2-N	NO_3-N
1	50.42 - 892.68	11.47 - 498.29	3.14 - 32.98	50.42 - 892.68
2	107.00 - 707.36	19.31 - 238.47	2.58 - 54.29	107.00 - 707.36
3	27.33 - 260.76	9.48 - 43.77	2.13 - 9.14	27.33 - 260.76
4	24.90 - 129.57	10.86 - 83.06	0.16 - 7.17	24.90 - 129.57
Arabian Gulf *				
Kuwait	4.34 - 5.58	2.10 - 0.95	-	4.34 - 5.58
S.Arabia	0.00 - 10.53	1.12 - 3.10	-	0.00 - 10.53
Qatar	6.19 - 27.26	2.52 - 2.66	-	6.19 - 27.26

Sharjah Creek

This Creek is characterised by the presence, on its banks, of intensive human, industrial, and boat related activities, in addition to many sewage and/or wastewater outlets. Figure 9 shows the locations of sampling sites and wastewater outlets within the Creek and along Sharjah coastline. The range and mean values of the results obtained from this Creek are presented in Tables 6 and 7.

Dissolved oxygen

It is obvious from the data in Table 6 that dissolved oxygen concentration varied widely with stations and time within this Creek. The values ranged between 3.90 and 6.80 mg/l. The lowest values (3.90 and 3.98 mg/l) were obtained at stations 2 and 3 in September and May respectively. It was noticed from the detailed data that oxygen contents were relatively high during January (5.65-6.80 mg/l) and February (5.44-6.80 mg/l), but tend to decrease afterthen. Evidently, this decline conicided with an increase during March, of seawater temperature by 3-6 °C over that recorded in January and February at the time of sampling. Generally, the distribution pattern of DO exhibited in Sharjah Creek and coastal water is more or less similar to that exhibited in Dubai; oxygen is generally low in the inner of the Creek and tend to increase towards its mouth at station 5 and coastal waters at stations 1 and 6. In addition dissolved oxygen in Sharjah waters appear to be low, particularly in the inner stations (2, 3, 4 and 5) compared to that observed at all Abu Dhabi stations.

Fig. (9)

Locations of sampling stations and major sewage outlets in Sharjah Creek

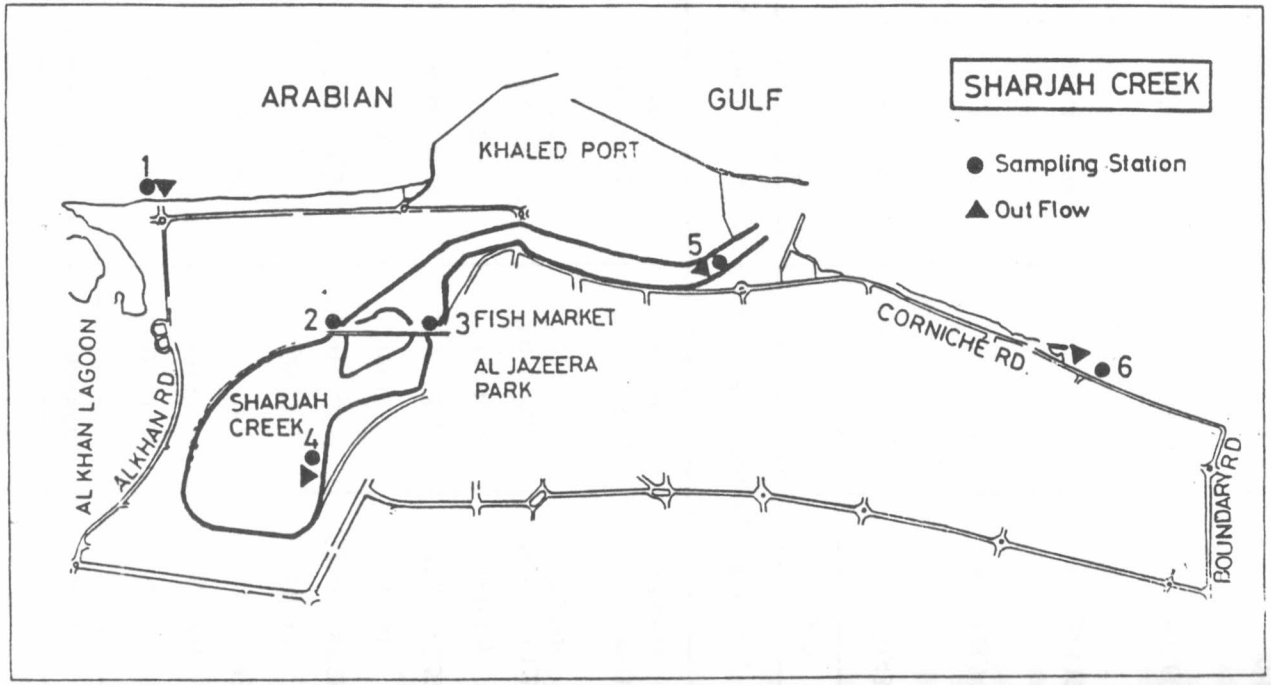

Table (6) : Range and mean values of pH, dissolved oxygen (mg/1), temperature (°C), and salinity in the surface waters of Sharjah Creek.

Station	pH	Dissolvedd Oxygen	Temperature	Salinity
1	8.03 - 8.57 (8.20)	5.37 - 6.80 (6.07)	21.0 - 33.8 (28.9)	39.62 - 41.11 (39.97)
2	8.10 - 9.01 (8.40)	3.90 - 5.85 (5.17)	21.0 - 34.6 (29.0)	38.74 - 24.43 (40.43)
3	8.10 - 8.82 (8.35)	3.98 - 6.24 (4.89)	21.0 - 34.6 (29.0)	39.33 - 42.28 (40.44)
4	8.16 - 9.00 (8.46)	4.55 - 6.24 (5.29)	21.2 - 35.3 (29.4)	37.58 - 42.57 (40.23)
5	8.00 - 8.68 (8.22)	4.65 - 6.27 (5.31)	22.0 - 34.6 (29.4)	39.34 - 41.23 (39.70)
6	8.00 - 8.66 (8.18)	5.53 - 6.80 (6.13)	22.0 - 34.6 (29.4)	35.82 - 40.37 (38.88)

Table (7) : Range of nutrient concentrations (ug/1) in Sharjah Creek .

Station	$P0_4$-P	NH_3-N	NO_2-N	NO_3-N
1	3.64 - 27.26	5.87 - 19.08	0.22 - 3.70	4.99 - 70.43
2	13.52 - 210.33	10.39 - 85.63	1.01 - 7.14	1.60 - 238.94
3	10.93 - 779.39	10.33 - 105.23	1.12 - 6.00	1.60 - 246.17
4	14.58 - 398.69	10.70 - 64.92	1.79 - 40.10	1.60 - 803.60
5	6.07 - 109.49	19.57 - 568.62	1.77 - 95.87	14.73 - 230.10
6	8.45 - 427.44	5.87 - 39.64	2.31 - 132.83	74.47 - 2340

pH

The pH, values of the water in Sharjah Creek appear to be high in some stations with noticeable variation at all stations (Table 6). The values ranged between a minimum of 8.0 at the coastal stations 1 and 6 and maximum of 9.0 at stations 2 and 4. The pH values indicate the presence of a common trend similar to that observed for Dubai waters; the values were relatively high (8.10-9.01) in the inner waters of the Creek at stations 2, 3 adn 4 and tend to be low near its mouth .

at station 5 (8.00-8.68) and at the coastal station 1 (9.03-8.57). The wide differences between the observed values indicate the presence of important anthropogenic sources enough to create unusual conditions inside the Creek. Noteworthy, is the close similarity between this trend and that observed for Dubai waters which could indicate the similarity of factors causing this trend in the two Creeks.

Temperature

The water temperature ranged between 21 and 36.3 °C (Table 6). The minimum temperature (21 °C) was recorded in January and February, while the maximum of 35.3 °C was observed during July. Like other parameters, variations in water temperature with time and locations were also observed. However temperature differences were small among sampling stations in the cold months. Thus narrow temperature ranges were observed in January (21-23 °C) and February (21-22 °C) respectively. But the temperature incresed steadily during the following months (see Fig. 10) and reached a maximum during July when it ranged between 33.7 and 35.3 °C compared to a range of 33.8-34.5 °C during August. This indicates an expected wide and significant temperature difference (14 °C) between cold and warm months.

Salinity

Figure 10 shows salinity distribution (mean values) in Sharjah Creek and nearby coastal waters. The salinity ranged between 35.82 (at station 6) in January and 42.57 (at station 4) in August (see Table 6). This indicates a salinity difference of more than 7 between cold and warm months. Similar to Dubai Creek, variations with time and stations were observed at the time of sampling. Generally water salinities in the inner stations were lower than salinities in coastal waters of stations 1 and 6 during the colder months (January, February and March). Once again, this pattern is almost similar to that observed in Dubai Creek, and is attributed to the discharge of waste waters from many outlets along the Creek. However, the pattern was distorted during the warmer months as salinities in the inner stations became higher than those obtained from coastal stations. This reversed pattern of salinity distribution observed during the warm months was caused mainly by the increase in the evaporation rates at the inner stations as air temperature increased. By comparison, the effect of the evaporation rate at the coastal stations is expected to be less due to the higher mixing rate with waters of the Arabian Gulf and therefore salinity is not affected to the same extent as

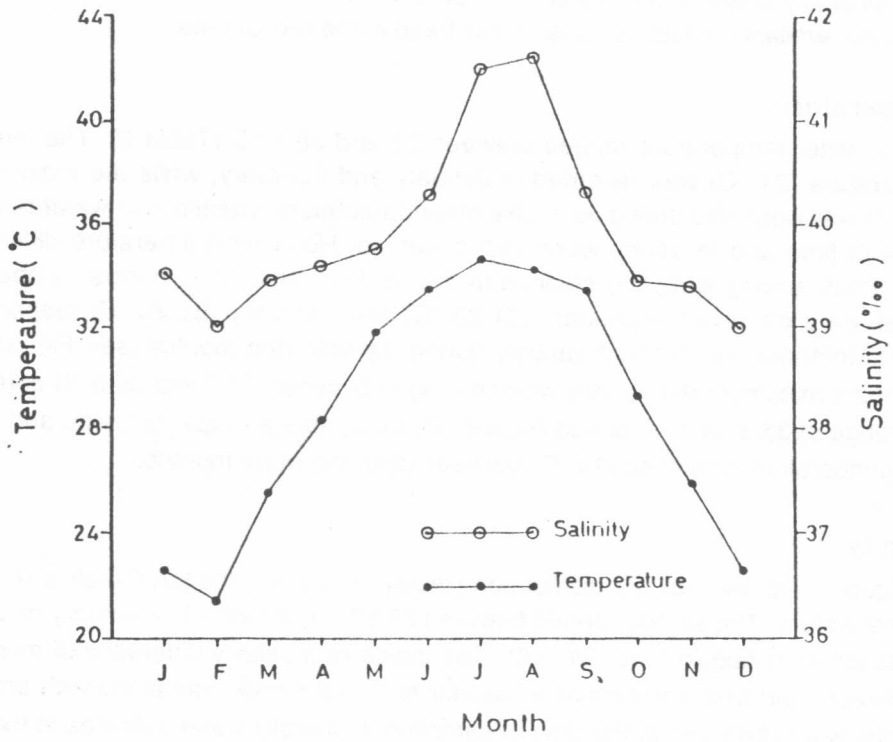

Fig. (10)

Monthly overall mean values of temperature and salinity in Sharjah Creek and coastal waters

that in the inner stations. Another feature for salinity in this area is the difference in salinity between the two coastal stations 1 and 6. It was noticed that salinity of water at station 6 was always lower than taht at station 1. The more expected reason for this is the discharge of wastewater from a major outlet located in the vicinity of station 6. Confirming this effect is the unusual low salinity (35.82) that was recorded in October accompanied with considerably high concentrations of nitrate (2340 ug/l), ammonia (30.20 ug/l), nitrite (47.38 ug/l) and phosphate (427.44 ug/l).

Nutrients

Table 7 shows the range of nutrients concentrations in Sharjah Creek and nearby coastal waters. It shows that variations were significant with time and locations for all nutrients. Phosphate ranged between 3.64 and 779 ug/l, ammonia 5.9-568.6 ug/l, nitrite 0.22-132.8 ug/l and nitrate 1.6-2340 ug/l. It was noticed that nutrients were always low at station 1 compared to all other stations. For example, phosphate concentrations did not exceed 23 ug/l at station 1, while it was more than 779 ug/l at station 3 in January, 283.8 ug/l, 398.7 ug/l and 306.8 ug/l at station 4 in January, February and March respectively. Maximum ammonia concentration (568.6 ug/l) was recorded at station 5 near the mouth of the Creek, where the water receives an intermittent wastewater discharge from one of the main outlets. High nitrate concentrations were also measured at station 4 in January (803.6 ug/l) February (696.7 ug/l) and March (724.6 ug/l). Maximum nitrite concentration (132.82 ug/l) and highest nitrate (2340 ug/l) were measured at station 6 in October. In general, the results indicate similar spatial distribution patterns for all nutrients within Sharjah Creek; with high concentrations in the inner sites and lower concentrations outside the Creek, paritcularly at station 1. This pattern is almost similar to that found in Dubai Creek. However, the pattern was not without exceptions as high concentrations were measured more than once at station 6. Of particular importance are the high nitrate (2340 ug/l), nitrite)132.82 ug/l), ammonia (30.20 ug/l) and phosphate (327.44 ug/l) measured in October 1990, when samples were taken from a closer position to a sewage outlet.

Kalba Creek

Figure 11 shows the locations of sampling station in Kalba Creek (stations 1, 2 and 3) and along the eastern coast of the United Arab Emirates on the Gulf of Oman (stations 4, 5 and 6). This Creek differs from other Creeks in its geographical location, topographical features and environmental conditions. It can be divided into two sections with respect to its depth. The comparatively deeper section starts from the entrance of the Creek and extends to the bridge near the University Marine Station just before the location of station 2. The shallow section starts from the site of station 2 (Fig. 11) and extends south and southeast. To the west of this shallow section is a tidal swamp area rich in mangrove vegetation dominated by **Avicenna marina** which grow at the upper tidal level and along the southwest margins of the Creek. This area becomes covered with water during high tides b ut exposed widely during low tides

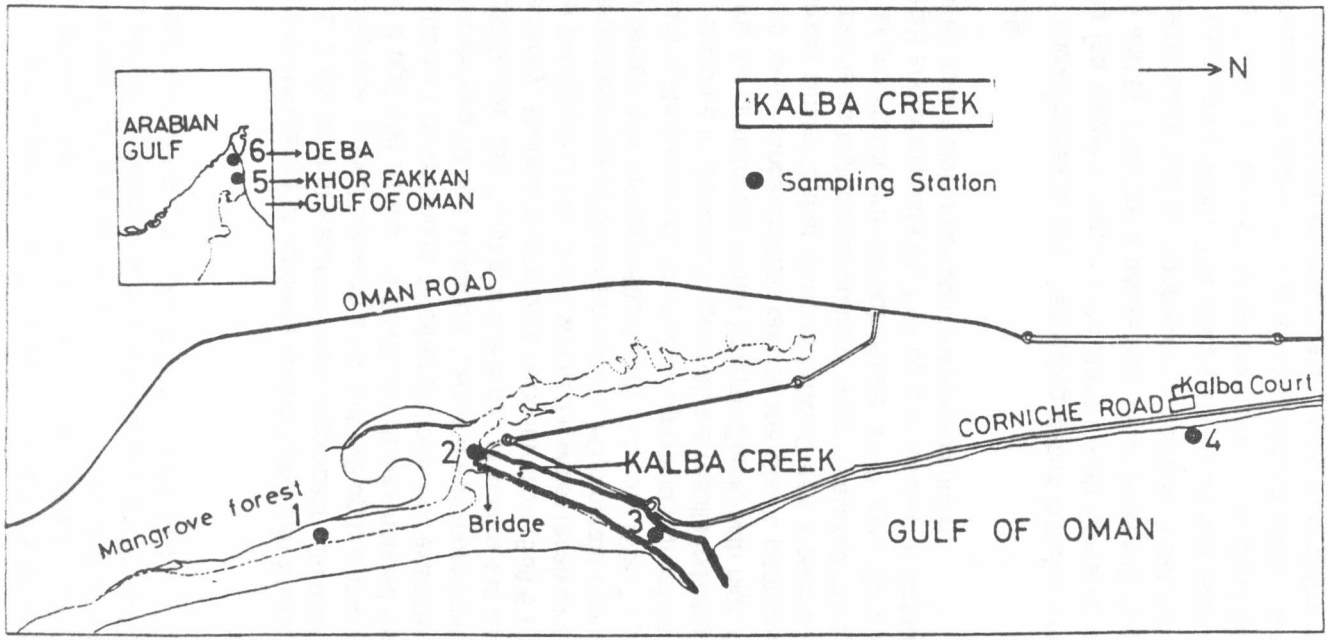

Fig. (11)

Locations of sampling stations in Kalba Creek and Gulf of Oman costal waters

when water flow back to the deeper section of the Creek with increasing speed during the progress of the low tide. All these features, in addition to the climatological conditions, are anticipated to affect the physical and chemical properties of the water of the Creek and the nearby coastal waters.

Dissolved Oxygen

It is obvious from Table 8 that DO inside Kalba Creek ranged between 3.74 and 6.80 mg/l, while it ranged between 5.69 and 6.90 mg/l in the waters of the Gulf of Oman outside the Creek. In addition to the wide variations, the table shows that the lowest values were measured at stations 1 (3.74 mg/1), 2 (4.96 mg/1) and 3 (5.20 mg/l) respectively. This gradual increase in DO content continued outside the Creek but the differences between the lowest values recorded at stations 4 (5.69 mg/l), 5 (5.78 mg/l) and 6 (5.85 mg/l), became smaller than those for stations 1, 2 and 3 inside the Creek. The calculated overall mean values of DO for each station (Table 8) indicate a distinct and recognizable pattern of distribution and gradual but significant increase from the inner of the Creek towards the Gulf of Oman resulting in a common pattern fairly similar to that of pH and opposite to that of salinity (Table 8). It seems that the occurrence of the mangrove forest in the vicinity of this Creek has a great impact on the properties of water inside and probably outside its body. However, more detailed and thorough investigations should be made at the mangrove area before drawing final and exclusive conclusions about its effects on the chemical and physical characteristics of water and sediments in this area.

pH

The pH values of water in this regoin ranged between 7.67 at station 1 in April, 1990 and 8.29 at station 6 in June, which indicate the presence of pH differences among all stations (Table 8). Examination of the mean values in the table indicate a clear tendency for a gradual increase in pH from the inner of the Creek towards its entrance. Inside the Creek the minimum values were always less than 8.0 and ranged between 7.67 and 7.98. In contrast, the measured pH values outside the Creek were 8.0 or higher and ranged between 8.0 and 8.29. The low pH values inside the Creek, are attributable to many factors including tidal conditions and sampling time which seem to be major factors. Sampling from stations in the inner of the Creek was made during early mornings which happened to be the time of low tide and it was easy to notice the outflow of water from the mangrove swamps towards the mouth of the Creek. Consequently the measured low pH value would reflect the prevailing conditions and properties of waters flowing back from the mangrove swamp. These waters are likely to have high load of organic matter and low concentration of DO.

Temperature

Table 8 shows the range and mean values of surface water temperature during the study period (March - December, 1990). It shows that the temperature of the water

within the body of Kalba Creek (stations 1, 2 and 3), ranged between 22.5 °C (April. 1990) and 35.8 °C (July, 1990) by comparison the temperature of surface water at coastal stations 4, 5 and 6 ranged between 23. °C at station 4 in April and 36 °C in July at the same station. This indicates the presence of considerable differences between cold and warm months. The difference is 12.4 °C for coastal stations, 13.3 °C for stations located within the Creek, and 12.9 °C (mean value) for both Creek and coastal stations (Fig. 12). The original and detailed data indicate also the presence of some temperature differences among stations during each sampling date. These differences are mainly attributable to the chages in meteorological conditions, particularly changes in air temperature during the same day, as the lower temperatures were recorded at stations occupied during early morning, while higher readings were obtained at stations occupied at later times (mid day and early afternoon).

Table (8) : Range and mean values of pH, dissolved oxygen (mg/1), temperature (°C), and salinity (%) in Kalba Creek and Gulf of Oman ccoastal waters.

Station	pH	Dissolved Oxygen	Temperature	Salinity
1	7.67 - 8.26	3.74 - 6.80	22.5 - 35.8	38.46 - 44.92
	(8.03)	(5.00)	(28.6)	(40.05)
2	7.72 - 8.22	4.96 - 5.98	22.6 - 35.4	38.01 - 44.63
	(8.06)	(5.46)	(29.1)	(39.32)
3	7.98 - 8.28	5.20 - 6.24	23.5 - 35.2	37.27 - 39.78
	(8.10)	(5.78)	(29.7)	(38.12)
4	8.08 - 8.26	5.69 - 6.67	23.6 - 36.0	36.98 - 40.08
	(8.17)	(6.14)	(29.4)	(37.76)
5	8.00 - 8.26	5.78 - 6.67	23.8 - 33.5	36.10 - 37.74
	(8.14)	(6.17)	(29.8)	(37.17)
6	8.07 - 8.29	5.85 - 6.80	24.4 - 33.8	36.10 - 37.43
	(8.20)	(6.43)	(29.4)	(37.02)

Salinity

Table 8 shows also the salinity range and mean values at all station within Kalba Creek and along the coast of the Gulf of Oman. The values inside the Creek ranged between 37.27 at station 3 in April and 44.92 at station 1 near the far end of the Creek in March. By comparison, salinity values outside the Creek were always lower

and ranged between 36.10 at stations 5 and 6 in April and 38.02 at station 4 in july. The salinity value (40.08) measured at station 4 in March is unusually high compared to all other values measured from the other two stations (5 and 6) along the coast fo the Gulf of Oman. A possible reason for this could be the mixing of the high salinity water flowing back from the inside of the Creek towards station 4 during the low tide. The relatively high salinity of shallow water inside the Creek is attributable to the fact that this water is affected more than the deeper water outside its body (in the Gulf Oman) by many factors including tide level and evaporation rate. Inside the Creek highest salinity values were always measured at station 1 near the far end of the Creek in the mangrove area. However, the salinity tends to decrease in an outward direction towards the middle of the Creek (station 2) and near its mouth (station 3). Figure 12 shows another feature or the salinity of the coastal stations outside the Creek; a general but gradual increase from the colder months to the warmer months. This trend is in general agreement with the increase in the evaporation rate reported from the region by Ali and Cherian, (1979). Moreover, the trend is more or less sinilar to that observed for temperature. Concequently, highest salinity (37.74) and temperature (35 °C) were recorded at station 4 in July; the month of the maximum evaporation rate (11.4 mm).

Nutrients

Table 9 shows the range of nutrient concentrations for Kalba Creek and the reference stations on t he Gulf of Oman. In addition to the variations in nutrient concentrations, the table shows many facts with respect to nutrient distribution and the magnitude of its variations. With regard to the distribution, the data indicate clearly that the concentrations are relatively low inside the Creek with a general tendency to increase in the coastal waters. This is particularly clear for nitrate and total nitrogen (ammonia, nitrite, and nitrate). Inside the Creek nutrients seem to be low at stations 1, located within the mangrove area, compared to station 3, near the mouth of the Creek, which showed relatively higher concentrations of ammonia, nitrite and nitrate in many occasions. Apparently human stresses represented mainly by fishermen boats and a land based hotel seem to be the reason for the higher values measured at this latter station. When considering the magnitude of variations in nutrient concentrations, Table 9 indicates significant spatial variations for all nutrients while the detailled data signal the occurrence of temporal variations as well. It was evident from the examination of the results that highest concentrations occurred during March and April at the begenning of our sampling programme in this region. It is important to note taht this period was reported by Thangaraja, (1990) to be the time of marked phytoplankton bloom in more than one region in the Gulf of Oman accompannied by high mortality of marine life and low oxygen content. He observed that the intensity of the blooms which was consisted mainly of dinoflagellates and yellow green algae started to decline on the second half of April. this observation could account for the change

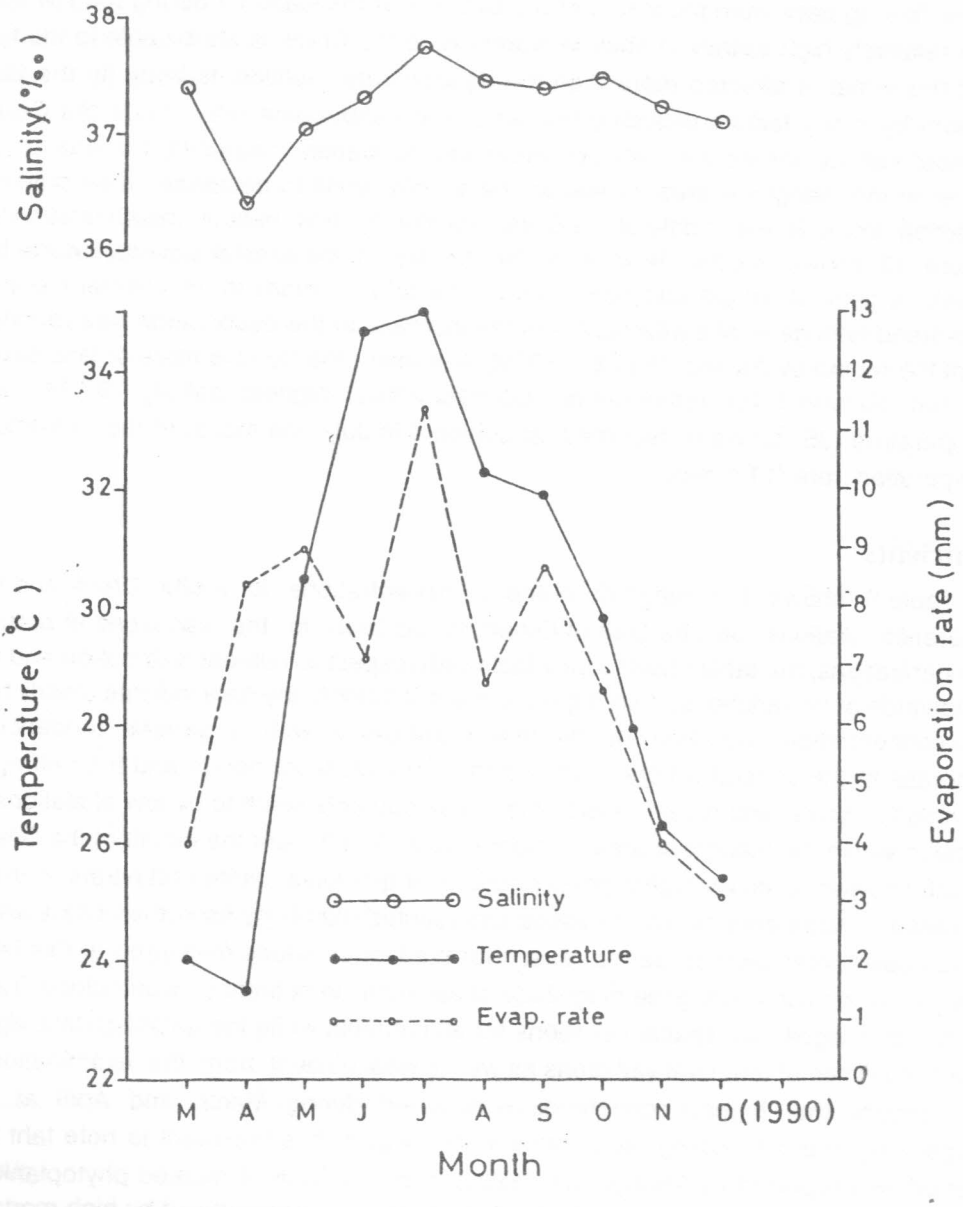

Fig. (12)

Monthly overall mean of temperature, salinity and evaporation rate in Kalba Creek and Gulf of Oman coastal waters

in nutrient concentrations occurred after April and thus resulted in wide concentration variations. The ratio of the highest to lowest concentrations was 320, 63, 74 and 214 for phosphate, ammonia, nitrite and nitrate respectively, indicating the magnitude of the variations. However, because nutrient measurements in the Creek area were not available before, the natural or background levels cannot be evaluated to compare the present results with it. However, it can be postulated that the high nutrient concentrations measured from the area were generally due to the combined effect of natural and man-made anthropogenic sources. This includes phytoplankton blooms, morphology of the Creek, tidal conditions, circulation of the water, intensive ship and boat activities and some land-based but limited sources of pollution.

Table (9) : Range of nutrient concentrations (ug/1), in Kalba Creek and Gulf of Oman coastal waters.

Station	PO_4-P	NH_3-N	NO_2-N	NO_3-N
1	3.04 - 20.65	2.83 - 32.35	0.34 - 2.75	1.18 - 7.98
2	2.43 - 210.33	1.26 - 24.22	0.45 - 1.66	2.75 - 9.31
3	3.97 - 779.39	4.67 - 38.06	0.44 - 4.39	1.10 - 116.52
4	6.28 - 398.69	2.92 - 32.85	0.22 - 5.49	2.95 - 120.40
5	13.88 - 109.49	3.21 - 79.03	0.66 - 8.09	14.33 - 113.04
6	7.90 - 63.39	2.92 - 28.06	0.11 - 5.49	5.60 - 235.72

finally, the presence of mangrove vegetation in this area is important but needs more refined and extensive investigation to assess its role and effect on the environmental conditions prevailing within the Creek.

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