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INORGANIC NITROGEN FORMS AS INDICATOR OF SEWAGE POLLUTION IN THE COASTAL WATER OFF JEDDAH, RED SEA

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ABSTRACT

The distribution of inorganic nitrogen forms: ammonia, nitrite and nitrate was studied in order to evaluate the state of pollution of the coastal waters off Jeddah Centre. Salinity, pH, transparency and dissolved oxygen or hydrogen sulphide were also measured.

The degree of variation from natural Red Sea water conditions was highly manifisted in: lower salinity and transparency, depletion of dissolved oxygen, high levels of hydrogen sulphide and the reduced form of inorganic nitrogen, i.e. ammonia. This indicates the disposal of fresh water, highly turbid and with high organic nitrogen content. The concentration of inorganic nitrogen forms and total nitrogen in the southeastern part of the area investigated was high that it amounted to the concentration existed in raw sewage but with slight dilution. Slow mixing due to limited exchange with the open sea water, as a result of partial isolation by barrier reef, hinders the rapid dilution and oxidation of the disposed organic water.

INTRODUCTION

An extensive industrial and population activities were recorded in the past few years along the Saudi Coast of the Red Sea. Harbour development and land extension have required extensive dredging, and construction of breakwaters, beaches and other structures to protect shipping. The demand for coastal land had led to the filling of large areas of the coast and to the distruction of natural coral reef structures in the shallow coastal zone.

The waste products of dense population and of industries have been discharged into the coastal water without any pretreatment with no appreciation of the possible harmful effects on shore environment and its fauna and flora.

Thomas and Carsola (1980) suggested that ammonia may be a useful tracer for the discharge of sewage in sea water. Frilligos (1979) and (1982) used the nutrients in general and especially the inorganic nitrogen forms as tracers of sewage disposal into the sea in Greece. He pointed out also that the chemical ratio of ammonia to the total inorganic nitrogen and nitrate to phosphate are good indicators for sewage pollution.

The aim of this investigation is to evaluate the changes in some properties of sea water under the influence of waste disposal from Jeddah City during the period between October 1981 and January 1982. It is aimed also to evaluate the effect of sewage disposal on the variation of concentration of different forms of nitrogen and also to trace the hydrographic changes as a result of waste disposal.

MATERIALS AND METHODS

The sampling scheme was planned to cover the area of coastal water off Jeddah Centre. This area is surrounded by reef barrier to the west Fig. (1). This barrier restricts free exchange of water with the open sea. Surface and subsurface samples were collected from 13 stations during the period from October 1981 to January 1982. Additional station, No. (14) was sampled once during the fourth trip in January to represent the open sea water away from the barrier reef Fig. (2). Surface water samples were collected 10 cm below the surface to avoid contamination from floating materials. Subsurface samples were collected by a 5-liter Niskin bottles. Samples for dissolved oxygen or hydrogen sulphide were fixed and pH was measured by a pocket pH meter directly in the field. The samples were filtered immediately after reaching the laboratory using millipore 0.45 um membrane filters. Ammonia was determined directly and samples for nitrate, nitrite and total nitrogen were deep freezed at - 20° C till analysis. Ammonia, nitrite nitrate and total nitrogen were determined according to the method described by Koroleff (1976). Salinity was measured for the filtered samples using an inductive salinometer. Dissolved oxygen and hydrogen sulphide were measured by titremetric methods according to Strickland and Parsons (1968) and Johnson et al., (1960) respectively.

RESULTS AND DISCUSSION

Temperature :

The maximum water temperature was about 30°C during the third trip in November 1981, and the minimum surface water temperature was 18.5°C during January 1982. No significant differences were measured for the surface and bottom water temperatures since most of the area was shallow (Table 1).

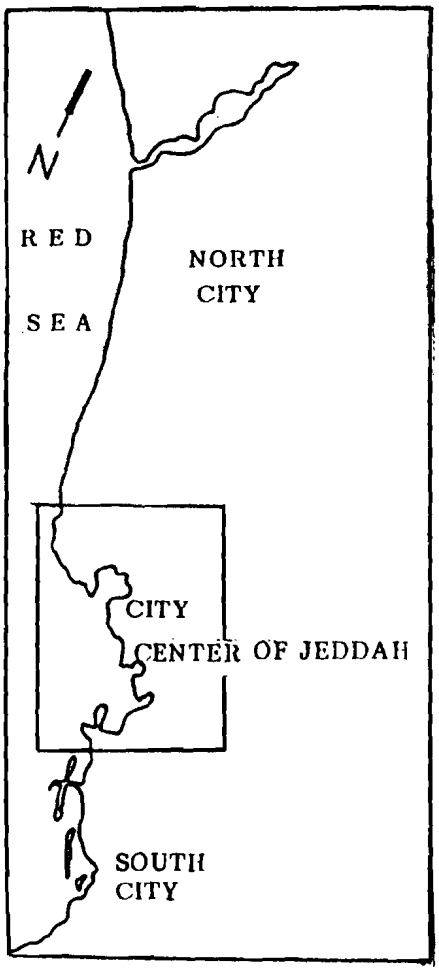

Fig. (1) Map of Jeddah City.

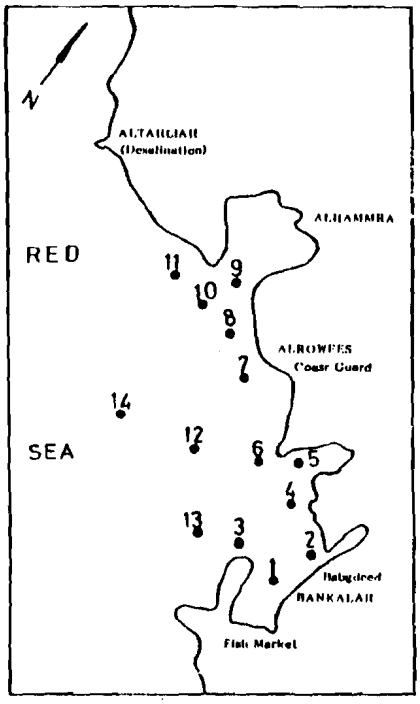

Fig. (2) Locations of stations.

TABLE (1)

Showing surface temperature, transparency and H_2S during the 1 st , 3 rd , and 4 th trips

St. No.	Temp. °C Trip			Transparency (m) Trip			H_2S Trip		
	1 st	2 nd	3 rd	1 st	2 nd	3 rd	1 st	2 nd	3 rd
1	28.3	27	18.5	0.1	0.1	0.1	9.46	3.83	16.239
2	30.0	26.9	20.5	0.2	0.25	0.15	4.16	3.84	6.801
3	28.2	26.4	21.0	0.45	0.9	0.5	-	-	-
4	29.5	26.8	21.8	1.1	2.15	2.0	-	-	-
5	29.3	26.6	21.0	2.1	1.6	1.5	-	-	-
6	29.9	26.4	23.0	1.9	3.30	2.5	-	-	-
7	30.2	26.8	30.2	1.8	2.5	1.8	-	-	-
8	30.2	26.6	24.0	3.0	3.0	4.0	-	-	-
9	29.7	26.4	24.0	1.9	2.5	2.0	-	-	-
10	30.5	27.0	22.5	4.0	3.0	4.5	-	-	-
11	30.4	27.4	22.5	4.2	12.0	13.0	-	-	-
12	28.4	27.5	23.0	4.5	3.5	5.0	-	-	-
13	30.4	27.5	24.8	7.5	5.0	6.0	-	-	-
14	-	-	24.0	-	-	15.0	-	-	-

Transparency :

The area was characterized by very turbid water that in some instances, the light penetration did not exceed 0.1 m especially near the waste disposal site at station (1). The transparency in other stations was considerably different. It reached 15 m at station (14) during the fourth trip in January 1982. In some cases a great part of the investigated area was covered by thick pinkis suspended material that prevented light penetration completely, and in some cases the suspended material was olive-green in colour, (Table 1).

pH Value :

pH values were measured during the 1st and 3rd trips only due to technical disturbancies in the field. During the 1st trip in October the pH values for most of the stations were greater than 8.0. The lowest pH value of 7.5 was measured at station (6). During the third trip in December 1981, the pH values were less than 8.0 except at station (8) where it reached 8.25. The lowest pH value during this trip was measured at station (6) also, (Figs. 3 & 5).

Salinity :

Salinity distribution during the four trips exhibited wide variations especially in the area between disposal and the other stations. The salinity at station (1) was about 10 ‰ during the 1st and 4th trips. The salinity increased gradually through stations (2) and (3), then reached the normal Red Sea salinity of about 39 $\%_0$ at the other stations. During the third trip the lowest salinity recorded was 33.21 $\%^0$, (Figs. 3 - 6).

Oxygen and Hydrogen Sulphide :

The distribution of dissolved oxygen in the investigated area was characterized by severe fluctuations where high concentration, (higher than 8 ml/l), was detected at station (11) during the 1st trip. Low concentration, lower than 1 ml/l was detected at station (3) during the 4th trip. Most of the oxygen concentration fall around 4 ml/l for most of the stations away from the site of disposal, (Figs. 3 - 6).

On the contrary stations (1) and (2) exhibited a different pattern where they have high concentrations of hydrogen sulphide during the four trips (Table 1). Concentrations of H_2s as high as 16.2 ml/l was detected at station (1) during the 4th trip.

Total Inorganic Nitrogen (TIN) :

The values on TIN were considerably high at the site of disposal near stations (1) and (2). During the third trip the maximum TIN was measured at station (3). A wide range of variations has been observed between

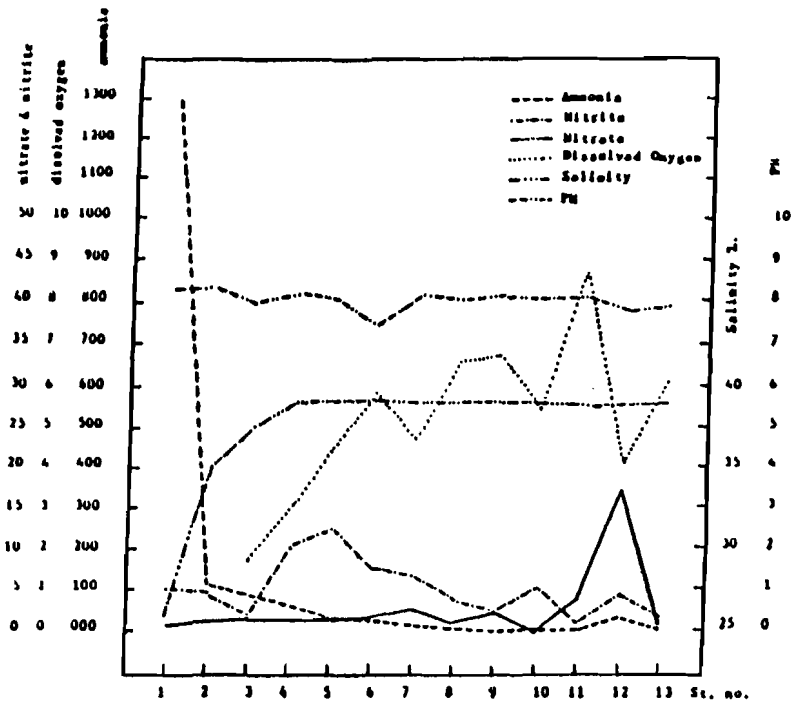

Fig. (3)
The distribution of ammonia, nitrite, nitrate, dissolved oxygen, salinity and pH during the first trip.

the values of TIN between stations (1), (2) and (3) and the other stations (Table 2). Maxima exceeding 1300 ug-at N/l were reported at station (1) during the 1 st and 4 th trips. A maximum of 1179 ug at-N/l was recorded at station (2) during the second trip. The above values can not be compared with those ranged from 7 to 60 ug at N/l for stations (6) to (13). Average values also varied from 900 ug at-N/l at station (1) to as little as 10.4 ug at-N/l at station (10), (Table 2).

Organic Nitrogen (ON):

Organic nitrogen content has the same trend of decrease as that of inorganic nitrogen. The highest value (515.24 µg at-N/l) was measured at station (2) during the first trip, and the lowest value (1.04 µg at-N/l) was measured at station (12) during the second trip (Table 2).

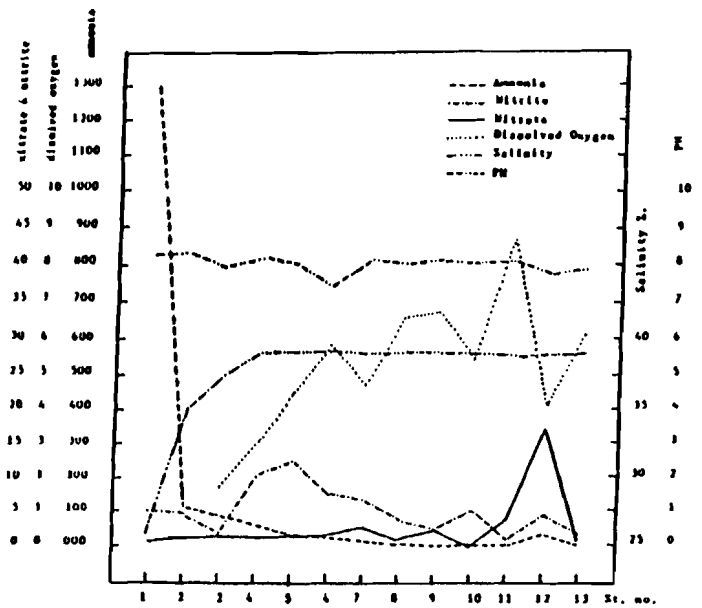

Fig. (4)
Variation of ammonia, nitrite, nitrate and
dissolved oxygen during the second trip.

Ammonia:

A significant diffrence between the values of ammonia in the eastern part of the investigated area and the other parts can be easily detected. Concentrations exceeding 1300 µg at-N/l were measured at stations (1) and (2), except in the third trip where the maximum surface ammonium concentration of only 297.72 µg at-N/l was recorded at station (3). The distribution of ammonia decreased gradually in all directions. Concentrations as low as 1 µg at NH -N/l or less were detected in the northern area. The whole area still had ammonia concentrations greatly exceeded the normal values of the Red Sea water, (Figs. 3 - 6).

Nitrite:

The nitrite distribution exhibited a similar trend during the first and third trips with maxima at stations (4) and (5) in the first trip and at stations (3) and (4) for the third trip. In the second trip, nitrite concentrations were generally lower and a maximum of 14.0 µg at $-NO_2$ -N/l was measured at station (8). The nitrite concentrations in the fourth trip was characterized by severe fluctuation where more than one maximum were found, (Figs.

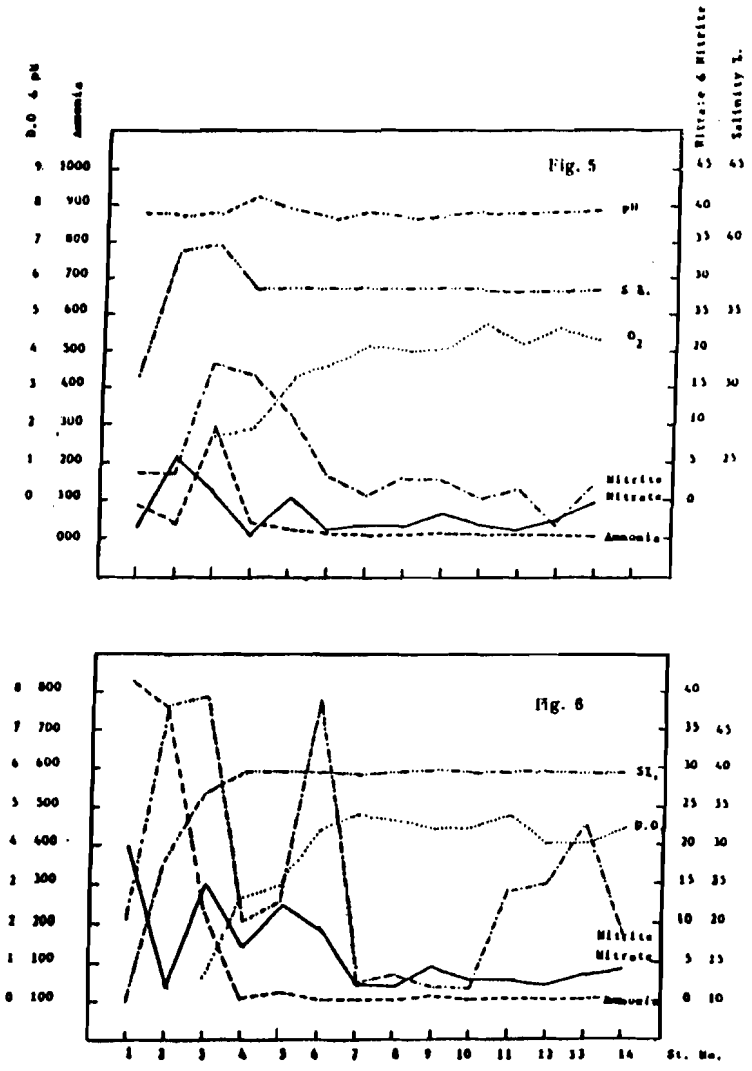

Fig. (5 and 6)
Variations of ammonia, nitrite, nitrate, salinity, dissolved oxygen and pH values during the third and fourth trips, respectively.

TABLE (2)

Inorganic and organic the four trips. (Mg at - N/L).

St. No.	Inorganic nitrogen					Organic nitrogen					Total			
	1st. trip	2nd. trip	3 trip	4 trip	average	1 trip	2 trip	3 trip	4 trip	average	1 trip	2 trip	3 trip	4 trip
1	1309.97	1365.61	98.75	860.85	908.8	-	-	328.35	-	328.3	-	-	427.1	-
2	114.28	1179.06	59.76	797.94	537.8	515.24	-	200.77	-	558.0	630.0	-	260.53	-
3	98.03	213.99	327.33	298.05	234.3	12.89	52.29	-	-	33.0	110.92	266.24	-	-
4	69.23	20.27	64.053	30.30	46.0	47.23	46.29	93.467	31.76	54.7	116.46	66.56	157.52	62.12
5	50.5	106.43	50.31	48.36	63.9	2.75	16.69	42.87	29.29	22.9	53.25	123.12	93.18	77.65
6	39.45	34.61	15.82	57.95	37.0	40.42	165.06	12.91	-	72.8	79.87	199.67	28.73	-
7	27.96	16.93	16.5	10.09	17.9	121.79	138.95	61.15	23.19	86.3	149.75	155.88	77.65	33.28
8	12.22	25.59	16.35	12.56	16.7	112.02	44.81	-	-	78.4	124.24	70.4	-	-
9	9.98	11.87	22.16	15.14	15.8	31.06	18.5	86.55	6.93	35.7	41.04	30.17	108.71	26.07
10	10.31	11.89	8.71	10.78	10.4	11.87	26.93	37.02	26.93	25.7	22.18	38.82	45.73	37.71
11	9.94	10.18	8.44	25.2	13.44	31.66	50.83	4.16	-	28.9	41.60	61.01	12.6	23.29
12	59.29	57.73	8.17	23.56	37.2	35.0	1.04	39.75	14.03	22.5	94.29	58.77	47.92	37.61
13	7.34	10.46	15.14	31.66	16.2	46.12	3.96	13.7	-	21.9	55.46	14.42	28.84	-

3 - 6). The concentration of nitrite in this trip fluctuated between 48 µg at/l recorded at stations (2), (3) and (B) and about 2 µg at/l at stations (7), (8), (9) and (10).

Nitrate :

The distribution of nitrate was also characterized by fluctuations and the maxima varied from trip to trip, (Figs. 3 - 6). Although nitrate is the high oxidation state of inorganic nitrogen, yet the maximum during the fourth trip was measured at station (1), which is characterized by prevalence of severe anoxic conditions. Generally, the nitrate concentrations ranged betweeen (17.00 - 0.23), (13.00 - 0.55), (10.00 - 1.00) and (21.00 - 2.60) µg at-N/l during the four trips, respectively, (Figs. 3 - 6).

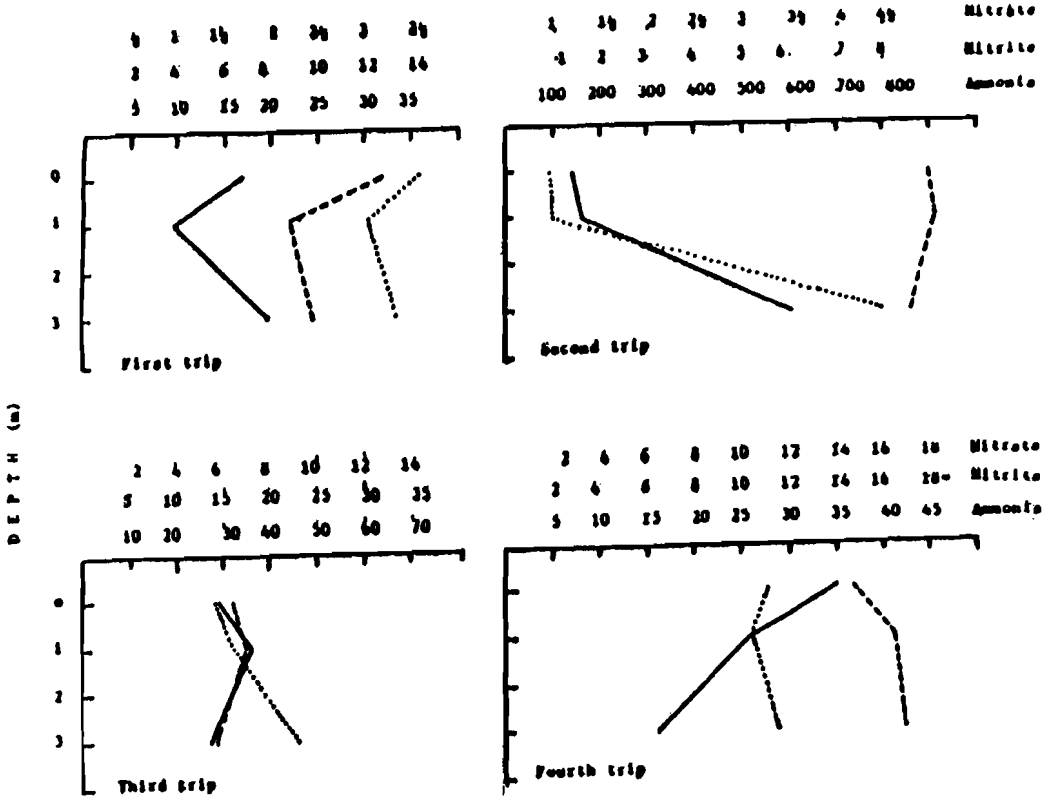

Fig. (7)
Vertical distribution of ammonia, nitrite, and nitrate at station (5) during the fourth trip.
____ Nitrate
----- Nitrite
..... Ammonia.

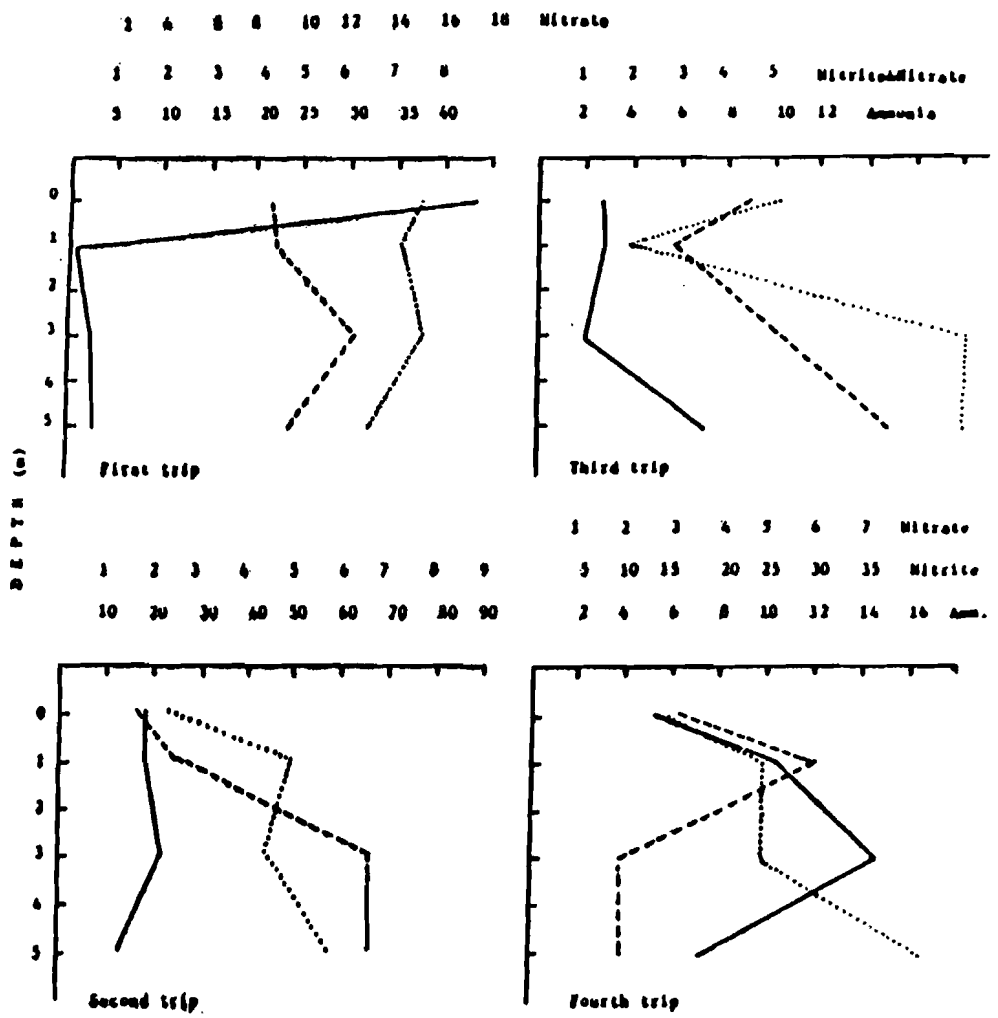

Fig. (8)
Vertical distribution of ammonia, nitrite and nitrate
at station (12) during the fourth trip.

Vertical Distribution:

The vertical distribution of the different parameters are shown in figures (7, 8 and 9). The depth profiles of ammonia, nitrite and nitrate show that ammonia and nitrite exhibited approximately a parallel type of distribution in the vertical section of station 14, (Fig. 9). Both of them increased from surface to reach maximum at a dpth of 5 meters, then decreased to lower values at 10 m depth. On the other hand nitrate exhibited different type of distribution , where a minimum appeared at 3 m, increased at 5 m then again increased at 10 m depth. The vertical distribution of ammonia , nitrite and nitrate at stations 5 and 12 during the four trips are shown in figures 7 and 8. These figures show the complete irregularities in the vertical distribution of the inorganic nitrogen salt components , and then they do not obey a special type of distribution.

The results of this investigation show that the coastal area off Jeddah is subjected to inflow of highly turbid water, low in salinity and with high content of nutrient salts especially inorganic and organic nitrogen forms. This water caused a decrease in salinity in the surface water to values as low as 10.5 ‰ at station (1). Gradual increase of salinity due to mixing raised the value to be about 39 ‰ which is about the normal Red Sea surface water salinity. The waste water also depressed the transparency to less than 10 cm in some cases. This means that the intruded water is highly turbid in contrast to the normal Red Sea water of high transparency. Marszalek (1981), found that the turbidity resulting from fine silty material greatly destroyed coral reef community , and this can be considered as resemblance to what happened in the investigated area.

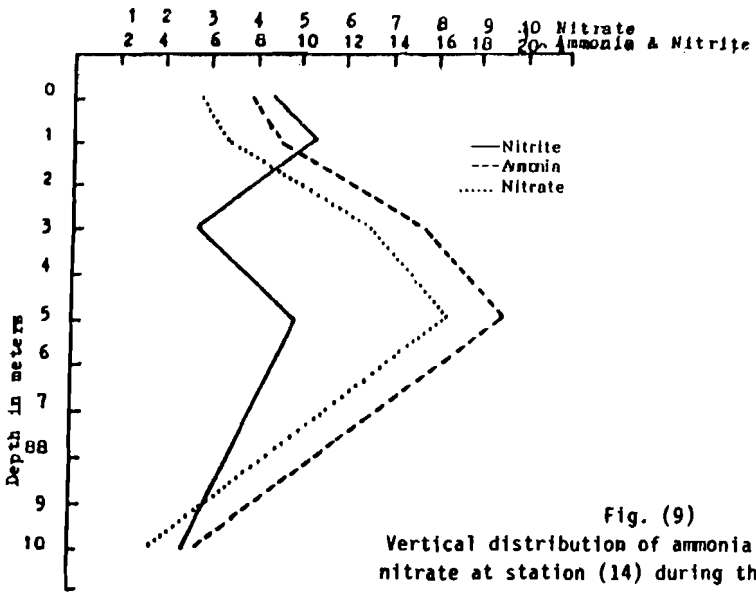

Fig. (9)
Vertical distribution of ammonia, nitrite and nitrate at station (14) during the fourth trip.

The effect of waste water on the oxygen regeme was drastic. Not only complete depletion of dissolved oxygen was measured, but even high concentrations of hydrogen sulphide (16 ml/l) were recorded both in the surface and bottom water. This means that the organic load in the disposed wastes was higher than the capacity of the area for self purification and, therefore, symptoms of eutrophication were detected. These symptoms are represented by the complete depletion of DO, the evolution of H_2S gas indicating the anaerobic decomposition of organic matter. This in addition to the high concentrations of the reduced inorganic nitrogen form, i.e. ammonia, which concentration was extraordinarily high that it reached more than 1300 µg at NH_3-N/l. Also the percentage of ammonia to the total inorganic nitrogen exceeded 90% especiall near the site of disposal, (Table 3). These values of ammonia are not easily found in sea water and amounted to the values of ammonia found raw sewage slightly diluted by water. Frilligos (1981) found that the concentration of ammonia in a composite sewage sample was about 1540 µg at/l. The data of our study show that the oxidation of ammonia was slow. This is indicated from the progression of surface water front, rich in ammonia, which covered most of the coastal area with concentrations of ammonia exceeding 30 µg at/l. This can be attributed to the slow mixing and low rate of dilution resulting from the barrier reef which restricts free exchange with clean uncontaminated sea water. In some instances the decrease of ammonia was not along the coast line, but in the northeast direction. This means that during these trips, except the third, the direction of spreading was toward the west and not along the coast.

In the same time the high temperature accelrated the decomposition of organic nitrogen compounds to the inorganic forms.

The results of this investigation also show that the high nutrient load as well as the dilution effect by water of lower salinity are not restricted only to the inner most part (stations 1-3), but exceeded this to spread to most of the other stations restricted by the reef. Grasshoff, (1969 and 1975) and Morcos (1970), showed that the surface water in the Red Sea, especially in the central area, in common with the tropical seas, is almost completely depleted in nutrients especially nitrogen and phosphorous compounds. Moammar (1981), stated that the Red Sea, in general, is characterized by low biological activity due to lack of nutrients and that the surface layers are supplied with phosphate and nitrate through the flow of shallow water over the Strait of Bab El-Mandab and these nutrients have already been depleted by biological activity. This is not coincide with the condition in the area of investigation where the supply of nutrient is very high.

The present results coincide with those reported by El-Rayis et. al, (1982), for the same area, since the concentrations of phosphate and silicate were also greatly magnified as a result of waste disposal.

TABLE (3)
Percentage of ammonia concentration to the sum of the inorganic nitrogen forms.

Station No.	1st. trip	2 nd. trip	3 ed. trip	4 th. trip	Average
1	99.54	99.5	89.51	96.2	96.187
2	94.85	99.34	67.49	94.8	89.12
3	58.68	97.41	90.95	80.89	81.98
4	83.09	49.09	64.75	40.09	59.25
5	71.19	90.41	57.16	48.04	66.70
6	75.72	54.32	40.52	16.22	46.70
7	65.67	65.32	53.64	49.36	58.50
8	58.84	43.22	41.96	54.62	49.70
9	48.80	75.48	52.39	64.73	60.35
10	48.30	64.17	19.06	51.30	45.10
11	47.89	79.27	11.73	30.71	45.70
12	63.43	90.06	56.79	24.85	58.80
13	60.22	74.00	15.14	15.73	41.30

CONCLUSION AND RECOMMENDATION

In general, the area of investigation is characterized by limited type of exchange with the open sea, therefore, the rapid supply of organic wastes to such an area with limited axchange with the open sea give rise to the accumulation and decomposition of organic wastes and to be mineralized to inorganic nitrogen forms. This mineralization at the expense of limited supply of dissolved oxygen leads to its complete exhaustion with the appearance of symptoms of anaerobic stage represented by the evolution of high concentrations of hydrogen sulphide. This in addition to high turbidity give rise to an anoxic condition which is not suitable for normal sea life in general and the coral reef community specifically.

It is recommended that wastes must be, at least, partially treated before disposal and that the disposal must be done through pipe lines with certain specification away from the coast and in open areas with free exchange with the open sea.

REFERENCES

El-Rayis, O.A., M.M. Abbas and A.A. Qurashi, 1982. Distribution of chemical pollutanta in Jeddah coastal waters, Red Sea. I- Phosphate and silicate. J. Fac. Mar. Sci., 2: 73 - 80.

Frilligos, N., 1981. Influence of various sources of pollution on the distribution of nutrients in the sea-water of the upper Saronikos Gulf (14 th. of November, 1973). Rev. Int. Oceanogr. Med., 62: 47 - 61.

Frilligos, N., 1982. Nutrients distribution around a sewage outfall (May 23rd., 1973). Rev. Int. Oceanogr. Med., 66 - 67, 47 - 59.

Grasshoff, K., 1969. Meteor Forsch. Ergebnisse, Reihe A, No. 6.

Grasshoff, K., 1975. The hydrochemistry of Landlocked Basins and Fjords. In: Chemical Oceanography. 2 nd. Ed. Vol. 2. Ed. J. P. Riley and G. Skirrow. Acad. Press. pp. 455 - 597.

Johnson C.R., P.H. McClelland and R.L. Boster, 1960. Rapid volumetric determination of sulphide in estuarine and sea waters. Analyt. Chem., 36, 300 - 302.

Koroleff, F., 1976. In: Methods of sea water analysis. By: K. Grasshoff. Verlag Chemie, N.Y., 721 p.

Moammar, M.O., 1981. Environmental Aspects of mining in the Red Sea. Sea water / metal sulfide interaction. M. Sc. Thesis, Univ. of California, San Diego, 168 pp.

Morcos, S.A., 1970. Physical and chemical oceanography of the Red Sea. Oceanogr. Mar. Biol. Ann. Rev., 8: 73-202.

Strickland, J.D.H. and T.R. Parsons, 1972. A practical handbook of sea water analysis. Bull. Fish. Res. Board of Canada, 167, 2 nd. ed., 310 pp.

Thomas, W.H. and A.J. Carsola, 1980. Ammonium input to the sea via large sewage outfall. Part 1: Tracing sewage in Southern California waters. Marine Environmental Research, 3: 277-289.