

PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER AND SEDIMENT IN THE VICINITY OF A MAJOR SEWAGE TREATMENT PLANT OUTFALL.

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ABSTRACT

This report presents the results of an ecological survey carried out by The Environmental Protection Technical Secretariat to describe the major physical and chemical characteristics of seawater and sediments of Tubli Bay. Data are presented for temperature, salinity, conductivity, dissolved oxygen, turbidity, pH, nutrients, total suspended solids, alkalinity, chlorophyll-a, hydrocarbons, trace metals and total bacteria for sea water at 6 stations, during May 1990, January and June 1991.

Data are also presented for sediments for total Kjeldhal nitrogen (TKN), total phosphate (PO₄-P), total organic carbon (TOC), and trace metals.

Physical parameters like temperature, and salinity did not show any abnormal values. But turbidity and suspended matter were high (170.00NTU, 208.00 mg/L respectively). Among the chemical parameters measured, dissolved Oxygen, alkalinity and nitrite levels were normal. But ammonia-N, nitrate-N, phosphate-P, silicate-Si, and hydrocarbons showed high values. Chlorophyll-a concentration was high in this area. Total Coliform bacteria also showed high levels, max.9500 No/100 ml. Trace metals in seawater were within acceptable limits. Trace metals Cd, Cu, Pb, Zn and Hg in sediments were not high when compared to the trace metal levels in other parts of the World.

Even though some water quality variables showed an increase near the Tubli outfall area, water quality at other stations were good when compared to their background values. Reclamation and various sewage outfalls continue to be a major problem.

INTRODUCTION

Tubli Bay is a very important area, as it is a spawning ground for shrimps and other marine life (Vousden, 1988). Tubli Bay has received wastes from man's activities for a very long time and the recent reclamation around it has caused considerable deterioration of the marine environment. A complete study of

The whole of Tubli Bay would be very time consuming; therefore, it was decided to study only the Tubli WPCC effluent outfall area for an overview of the environmental quality of the area. Here the very slightly saline final effluent discharged from WPCC, at most states of the tide, can be seen to fan out from the outfall over the surface of the high salinity seawater. Mixing at the horizontal and vertical boundaries occurs but the rate of mixing is variable and dependent upon many factors which can only be determined by extensive study.

The present study examines the physical, and chemical parameters in water and sediment to determine the status of the outfall area, in relation to pollution load from Tubli WPCC and extensive reclamation of the area.

GENERAL BACKGROUND INFORMATION

Coastal Water Topography:

The coastal waters around the main islands of Bahrain, Muharraq and Sitra are very shallow. The depth in these areas is normally less than 10 meters and in large areas between zero and two meters. The main habitats in these shallow waters consist of sand, rock and coral reefs which form a barrier to tidal water movements and wind driven wave action (Linden, 1982). In the coastal province of Bahrain, three major critical marine habitats are recognized - mangroves, sea grass beds and coral reefs. Mangroves are represented by a single species, *Avicennia marina* and is found near Sanad on Tubli bay. This area displays the typical high productivity associated with mangrove communities with, for example, concentration of molluscs > 500 per m² (UNEP, 1985).

At present, critical marine habitats, especially mangroves and the intertidal flats with which they are associated, are disappearing as a result of coastal in

filling.

General seawater quality:

General seawater quality along the East Coast is different from the west coast. Salinity in the waters along the East coast of Bahrain are 43-55 ‰ and at west coast 50-57 ‰. This is partly a result of the geographic position of Bahrain with only a shallow, relatively narrow stretch of water separating the west coast from the Arabian mainland (UNEP, 1985). Suspended solids, nitrate-N, nitrite-N, ammonia-N, phosphate-P, and chlorophyll-a at the East coast waters usually vary from 16.0-19.0 mg/L, 3.5-30.0 ug/L, 0.0-5.0 ug/L, 2.5-9.0 ug/L, 5.0-40.0 ug/L, and 0.5-1.0 ug/L respectively (Atkins, 1985).

Status of Tubli bay:

Tubli Bay comprises a total area of approximately 12.56 km², as shown in Figure-1. Northern part of the bay is normally polluted from discharge from WPCC and from reclamation activities. (WPCC = Water Pollution Control Center).

The emergency outfall from pumping station A1 terminates at the coastline of the bay, but reclamation is in progress along the northern coast and even near the outfall of the WPCC. The bay is used as an anchorage for small fishing vessels and other craft. Generally very little water movement normally occurs within this local area other than slow filling and emptying with each tidal cycle.

A part from pollution loads at present being discharged into the bay via the Tubli Sewage Treatment works outfall comprising 125000 m³/day of treated effluent, the following much smaller inputs to the bay are also taking place.

- Effluent from Nuwaydrat oxidation ponds (800 m³/d) at the southern end of the Bay (having no apparent impact upon the northern part of the Bay because most of the flow seems to be blocked off at the main channel due to land reclamation by the Eastern Asphalt and ready made concrete company).
- Several discharges from isolated houses and groups of properties scattered around the Bay.
- Several discharges of muddy water from sand washing plants.

- Several land drainages from farms around the Bay.

Pollution from reclamation:

As building rubble is used as fill material in the reclamation around Tubli Bay, several places around the Bay are densely littered with debris, mostly wood, plastic and other floating matter.

MATERIALS AND METHODS:

Sample collection:

The sampling stations are shown in Figure-1. Seawater samples were taken from a depth of 0.4 meters at all the stations, following procedures outlined in *MOOPAM* (1989). Briefly

A weighted 2L amber colored glass bottle was quickly lowered by hand line to a 0.4-meter and allowed to fill with seawater. For the determination of trace metals, samples were collected in acid cleaned polyethylene bottles. Samples for total hydrocarbons were collected in specially cleaned glass bottles. For the determination of phosphate samples were collected in 100ml glass bottles. Samples for bacteriology were collected in sterilized glass bottles.

All sediment samples were obtained by 0.25 m² stainless steel Van Veen grab sampler. Samples were collected in plastic bags, sealed and transported to the Laboratory. Sediment samples were air-dried and various analyses carried out as per *MOOPAM* (1985).

Water analysis:

Temperature, pH, D.O, conductivity and salinity were measured in situ using a Hydrolab Surveyor-11. Turbidity was measured by use of H.F.Instruments DRT Turbidimeter. A R.W. Munro hand held anemometer checked wind speed.

Water samples for nutrient analysis were filtered through a 0.45 um filter using a vacuum pump set, then transferred into polyethylene bottles and analyzed immediately. Nitrate-N, nitrite-N, phosphate-P and ammonia-N were analyzed by Tecator Aquatec 5200 Auto Analyzer using Standard Methods (1985). Silicate-Si was determined as per Grasshoff et al, (1972). All values

were expressed as ug/L. Chlorophyll-a, total coliform bacteria, alkalinity and petroleum hydrocarbons were determined as per methods outlined in MOOPAM, 1989. Petroleum hydrocarbons were measured using Shimadzu RF-540 Fluorescence Spectrophotometer. Trace metals in seawater were analysed using Metrohm Anodic Stripping Voltmeter (646 VA Processor with Dosimat and 675 VA Sample Changer). Mercury was determined by a Mercury Monitor (Model 1235, LDC Milton Roy, U.S.A).

Sediment analysis :

Sediment samples collected were washed with distilled water to remove all possible salts, and dried at 60 C. A portion of the sediment was used for the determination of total organic carbon, total Kjeldhal nitrogen, total phosphate-P (MOOPAM, 1989). A known weight of sediment sample was dispersed in distilled water with the help of a dispersing agent (10% calgon). The dispersed sediment was poured onto a wet 63 µm sieve and washed with water till sediment was free of fine particles. The retained sand fraction was analyzed using standard sieves on a mechanical shaker as per methods outlined in MOOPAM (1989).

The other portion of the sediment was also washed with distilled water to remove salts, and dried at 60 C, sieved to separate < 63 um fraction and then used for the determination of trace metals as per MOOPAM 1988. Trace metals were measured using a Pye-Unicam SP-9-800 Atomic Absorption Spectrophotometer.

Mercury was determined as per methods described in MOOPAM using a Mercury monitor.

RESULTS AND DISCUSSION

Water Quality:

Tables 1-3, give the summary of the water quality data sampled at Tubli Bay during the three sampling periods May 1990, January and June 1991. During the survey wind and sea conditions were light and North Westerly winds persisted. Physico-chemical parameters followed almost the same pattern in all the sampling sites even though there were marked differences in their quantum.

Surface temperature varied from 17.20-29.96 C with an overall average of

25.20 C. The pH values found were within the range of 7.68-8.33 with an average of 7.96 which is consistent with those reported for open ocean water (Skirrow, 1975). Dissolved Oxygen ranged from 4.52-8.10 mg/l in all water samples analyzed with an average of 6.17 mg/l. There were some differences in D.O. values between stations with the highest value shown at location 4. Concentration below 4.0 mg/L in marine or estuarine waters is unacceptable and it is generally expected to have a D.O. Levels above 6.0 mg/L, except when temporary natural phenomena cause this value to decrease. During the period of study, D.O. concentrations were within permissible limits (> 4.0 mg/L)(Sharkawi, 1988). Salinity varied from 39.70-44.80 % with an average of 42.29 % . This salinity is slightly lower than the usual reported value for east coast of Bahrain. In general, salinity values in Tubli Bay showed only a slight variation between locations. As samples were collected at high tide, it shows that slightly saline WPCC effluent entering this Bay near location I is well circulated by the tidal flow. Salinity near the Tubli outfall can vary depending on the sampling location, as slightly saline water (2.5 %) is discharged to the sea.

Turbidity varied from 1.95-170.00 NTU with an average of 22.40 NTU. This is quite high compared to the usual value of <1 in offshore areas. In general, the least turbid water occurred in the center of the bay, near Nuwaidirat Island. The highest turbidity was recorded near the Tubli out fall at location 2. (170.00 NTU). The consistently high turbidity values in the bay are indicative of both the shallowness of the area and of the inflow of suspended sediments from the indiscriminate reclamation along the coast. Turbidity is an expression of the optical

Property that causes light to be scattered and absorbed rather than transmitted straight through the sample. Correlation of turbidity with the weight concentration of suspended matter is difficult because the size, shape and refractive index of the particulates also affect the light scattering properties of the suspension.

TSS varied from 2.00-208.00 mg/l with an average of 20.06 mg/l. Compared to other offshore values this value is very high (1-5 mg/l usually). TSS includes both organic and inorganic materials; suspended solids adversely affect fisheries by covering the bottom of the sea with a blanket of material that destroys the fish-food bottom fauna or the spawns of fish. Solids in suspension can cause adverse condition to aquatic life by reducing transmittance of light, by choking the gills of fish and smothering benthic organisms (Al-Madany et al, 1991).

Alkalinity as CaCO_3 at the surface ranged from 116.00-142.00 mg/l with an average of 124.60 mg/l. Alkalinity is related to waters buffering capacity and the values are quite normal for the seawater.

Chlorophyll-a varied from 0.80-12.55 ug/l with an average value of 5.76 ug/l. Our study revealed that chlorophyll-a concentration in the seawater in Tubli bay is high in comparison with many offshore and coastal waters (0.5 ug/L). There is a station-to-station variation in chlorophyll-a content, the highest noted at the Tubli WPCC outfall area decreases towards the south.

Total petroleum hydrocarbon levels measured by fluorescence analysis are given in Table-3. Hydrocarbon content varied from 2.50-655.00 ug/l with an average of 53.12 ug/l. The highest value of 655.00 ug/L was obtained near Station-1, which is just outside the Tubli outfall. Hydrocarbons in this area are relatively high (0.07-1.57 ug/l Askar area) (Fowler, 1985). This is not surprising since the Tubli Bay is near oil terminals and port and at high tide, water from these areas flow into Tubli Bay. Comparison of the values with concentrations in other areas of the world's oceans suggests that current levels of petroleum hydrocarbons at these stations are exceptionally high. For example, based on Kuwait crude as reference oil, reported concentrations throughout the Western Mediterranean ranged from 1-123 ug/l with an average of 9.9 ug/l (Fowler, 1985). Monitoring studies carried out in the North Atlantic off the coast of Canada show average levels of 4.9 ug/l (1.6-10.8 ug/l). A recent baseline study in the relatively pristine Arctic waters under the ice reports concentrations ranging from 0.05-20.0 ug/l (Fowler 1985)

The total annual discharge of 125000 m³ per day (45 Mm³ per year) of slightly saline water from Tubli Treatment Plant (WPCC) causes more nutrient enrichment in this area than other coastal areas in the region. A total of 4.3 tones of Ammonia-N, 104.0 tones of Nitrate-N, 40.5 tones of Phosphate-P, and 1.6 tones of Hydrocarbons per year are discharged to this area.

Ammonia-N values ranged from 0.10-118.80 ug/l with an average of 39.67 ug/l. Ammonia-N concentration showed significant difference between the three sampling periods ($p < 0.01$). The highest value was noticed near the Tubli outfall. This value is quite high for the region as 0.34 ug/L was reported for Qatar and 3.00-40.40 ug/L for Kuwait (Shumbo et al, 1986). This value compares with the earlier reported values of 5.8-172.0 ug/L near Sitra (Al-Alawi, 1980). The European inland Fisheries Advisory Commission (1973) stated that toxic levels of NH_3 for short-term exposure usually lie between 0.6 and 2.0 mg/L.

Unionized ammonia is more toxic. Conc. of unionized ammonia in marine or estuarine waters should not exceed 0.4 mg/L. (Sharkawi, 1988)

Nitrate-N values varied from 1.00-7513.10 ug/l with an average value of 444.34 ug/l. This value is also high compared to the values reported for the Gulf region (18.9 ug/L for Qatar and 3.6 - 19.2 ug/L for Kuwait) (Shumbo et al 1986). Actually high NO₃-N values are expected as Tubli WPCCC discharges effluents containing (0.4 - 2.3 mg/L NO₃-N) (1988). As the sample was taken at high tide, the water may be well mixed, showing a low value. Although nitrates are essential for protein synthesis, high concentrations of nitrates in a body of water may stimulate algal blooms causing oxygen depletion.

Nitrite-N values varied from 0.00-33.00 ug/l with an average value of 3.55 ug/l. Nitrite-N is an oxidation product of Ammonia. Nitrite is rather rapidly and easily converted to nitrates, its presence in higher concentrations usually is indicative of active biological process in water. The levels reported are not unusual as 0 - 36.7 ug/L has been reported in the eastern waters of Bahrain (Al-Alawi, 1980) and 2.76 ug/L near Qatar.

Phosphate-P values varied from 10.28-1331.46 ug/l with an average value of 190.29 ug/l. Phosphate-P showed significant difference between the sampling stations ($p < 0.05$). The highest P level reported was 1331.46 ug/l at the Tubli outfall area which is quite high compared to the values reported for the Gulf region (17.00 ug/L for Qatar, and 1.00 - 41.30 ug/L). Concentration of the elemental phosphorus in excess of 0.10 mg/L in marine and estuarine waters is unacceptable (Sharkawi, 1988). One result of pollutional enrichment of waters by the ions NO₃, PO₄ and other plant nutrients is eutrophication. It has been reported that phosphorus is the main cause of such eutrophication, since even in the absence of combined inorganic nitrogen; nitrogen-fixing algae will continue to flourish, provided that sufficient phosphate is available.

Silicate-Si values varied from 27.07-2102.20 ug/l with an average value of 301.30 ug/l. In Qatar a value of 243.5 ug/L and in Kuwait 24.00 - 965.00 ug/L were reported (Shumbo, 1986).

Because of the limited number of samples taken no clear trends of nutrient distribution from one area to another were revealed.

Total Coliform bacteria ranged from 0-9500 No/100ml the highest being near the outfall. Coliform bacteria in seawater undergo 90% reduction in 6 - 8 hours compared with 20 - 100 hour in fresh water (Shepherd, 1982). The

coliform count exceeded the max. Allowed limit of 3000 No/100 ml for marine water in certain cases (Kuwait EPC, 1979).

Trace metals:

Results of trace metals Cd, Pb, Cu, Zn and Hg are shown in Table-3. Table-4 shows a comparison of trace metals in seawater with the levels in other parts of the World. Mean levels of each metal in ug/l were as follows: Cd 0.27, Pb 11.97, Cu 3.35, Zn 6.48 and Hg 0.05. Copper and Zinc showed significant variation between the three sampling periods ($p < 0.01$). The maximum acceptable limits of the metals in seawater are as follows: Cd 0.01 mg/l, Pb 0.05 mg/l, Cu 0.05 mg/l, Zn 0.1 mg/l and Hg 1.0 mg/l (Sharkawi, 1988). Natural concentrations of cadmium, mercury, lead, zinc and copper in sea water are usually 0.02, 0.1, 0.03, 4.9 and 2.0 ug/l respectively (UNEP, 1982).

TABLE- 4
Trace metals in sea water (ug/l)
as compared to the levels in other parts of the world

Location	Cd	Cu	Pb	Zn	Hg	source
Bahrain	0.27	3.35	11.97	6.48	0.05	Present Study
Northern North Sea	16.0	140.0	31.0	-	-	Balls, P.W 1985
Atlantic Water	8.0	70.0	30.0	10.0	-	Balls, P.W 1985 Goldbere,1965
Kuwait	0.04-3.4	0.7-16.0	0.6-27.5	-	0.01-0.73	(Shumbo,1985)

As no accepted quality standards for Bahrain marine waters are available, an overview of critical levels of toxics was made based on EPA standards (Train, 1979), Japanese Standards and EC Directive. A comparison between these assessment levels (Table-5) shows that none of the metals showed an average value exceeding the EPA Standards except for Copper. When compared to other standards, all the trace metals remained within the specified limits.

TABLE-5

Critical concentration for trace metals (ug/l) as per EPA, Japan and EC Directive.

Pollutant	EPA Std	Japanese Std	EC Directive (Mance, 1986)
Cd	5	10	2.5 (annual ave)
Cu	1.4	30	5
Hg	0.1	0.5	0.3
Pb	-	100	25
Zn	250	500	40

SEDIMENT QUALITY:

Sediment characteristics such as TKN, PO₄-P, TOC and trace metals are shown in Table- 3. Grain size and grain size distribution of sediments not only have importance on sediment transport and deposition, but also significantly affects the distribution and concentration of various pollutants. Sediments at locations near the outfall showed high content of < 63 um fraction. Very high silt fraction at the surface layer in almost all the locations shows the effects of reclamation on siltation.

TKN values ranged from 560.00-2212.00 ug/g, the highest being at location-1 near the Tubli outfall. The high values of total nitrogen shows that nitrogen mainly in organic forms are input into this area from various sources.

Total phosphate-P ranged from 100.00-1050.00 ug/g with an average of 475.83 ug/g. Phosphate in sediments comes from various sources from land drainages and from Tubli WPCC discharge. Phosphorous is essential to the growth of organisms and can be the nutrient that limits the primary productivity of a body of water. Under conditions where soluble phosphates are in short supply, algae may utilize phosphates in sediments.

Total organic carbon ranged from 0.26 % - 2.22 % with an average of 1.08 %. TOC is a measure of organic matter in sediments and shows that near the Tubli outfall area sediments are rich in organic matter and it decreases with distance. Usually a value of <1.0 % is considered a background value and the highest value of 2.22 % was obtained near the effluent outfall area in conformity with earlier studies in the region (Khalaf et al, 1986).

Trace metals:

The results of the analysis of all 18 samples are presented in Table-3. The elements Cd and Pb appear to have similar distributions with relatively minor variations. Copper and Zinc showed significant variation between stations (p<0.05). The metals followed the following order, Zn > Cu > Pb > Cd > Hg. The highest concentrations of metals were observed near Tubli WPCC outfall area and it decreased with distance from the outfall.

The data suggest that similar levels were earlier reported in Askar area (Fowler, 1985). More likely the elevated Hg and Cd levels are due to the areas proximity to the densely populated and industrialized northern sector of Bahrain. Compared to the trace metal levels in other parts of the World (Table- 6), the levels of metals exhibited in this study are not high.

TABLE-6

Trace metal levels in sediments in Bahrain and other areas of the World

Location	Cd	Cu	Pb	Zn	Hg	Source
Bahrain	3.38	11.37	5.99	36.42	0.59	Present study
Scotland (Firth of Clyde control area)	1.60	16.00	42.00	85.00	-	Halcrow et al
South West England (Avon Estuary control area)	0.10	44.00	50.00	102.00	-	Bryan 1976.
Japan shallow water						

sediments	0.22	27.00	55.00	51.00	-	Yamamoto, 1968
Kuwait	1.46	20.73	22.72	44.63	0.04-3.3	KISR, 1979
Crustal rocks	0.20	55.00	13.00	70.00	-	Mason 1960

Source : Annual research report of KISR, 1979.

CONCLUSION

Although it is difficult to make any firm conclusions from this small survey, some trends have emerged. Trace metal pollution is confined to areas adjacent to the Tubli effluent Treatment Plant due to heavy input. Reclamation and discharge from various sewage outfalls also contributes to the above problem.

Incoming tide velocity in Tubli bay was reported reaching 1.2 m/sec and the outgoing 0.8 m/sec (Watson Hawksley, 1984). Indiscriminate reclamation may reduce the velocity of flow in the future. Sedimentation to the north of the Bay is possible to increase with the low current velocities prevalent in this area. The reduction in water exchange rates can be expected to result in the buildup of pollutants and even increase the salinity in summer, with stagnation most evident in the mangrove swamp area.

Water quality has shown that whilst seawater quality is relatively good, turbidity and nutrients such as PO₄-P are high, which are the cause for algal growth during July-Dec every year in this area. Decaying algae accumulates in the sediment along with other organic matter. This results in mud flats which, except for a thin surface layer, are mostly anaerobic, containing free hydrogen sulfide. This algal detritus contributes considerably to the accumulation of phosphates, nitrates and organic carbon in the sediments. If the reclamation continues like this, the process of recovery of the benthic community is impossible.

The dumping of large quantities of fine material in the sea can blanket the bottom and kill off all marine life. These operations though not directly toxic, may lead to increased turbidity and reduced primary productivity. In addition, important spawning, feeding or nursery grounds may be damaged or lost. If this reclamation is allowed to continue, the loss of Tubli Bay will be a great loss to Bahrain.

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