POLLUTION STUDIES OFF BOMBAY

ABSTRACT

Preliminary studies on the Biological Oxygen Demand (BOD_5) in the nearshore waters off Bombay indicate a rate of discharge of sewage of about 2000×10^6 m^3 per year. From the hydrographical data it is possible to conclude that if a submarine pipeline is proposed to be laid for the discharge of sewage into the sea, the ideal site would be at a distance of 25-30 km off the northern part of the city at a depth of about 15–20 m. A comparison with chemical observations made 15 years ago for the same area showed that an increase in inorganic phosphate in the inshore waters off Bombay has definitely occurred during the last 15 years.

Bombay is the second most-populated city in India and a very large number of industries are located in and around the city. The easiest place where sewage and industrial effluents from the city could be discharged is the adjacent sea. No proper study on the capacity of the marine areas adjoining the city as a recipient of sewage is on record. Some studies, however, have been carried out earlier by the scientists of the National Institute of Oceanography (Anonymous, 1971 a, b), and a check on the sewage discharged from the city is also being made by the National Environmental Engineering Research Institute. Recently, a proposal has been accepted by the Bombay Municipal Corporation to lay an underwater pipeline for the disposal of sewage far out into the sea. Availing the opportunity of the Oceanographic Expedition of I. N. S. *Darshak* (1973–74) the conditions of an area of the sea which is a recipient of sewage were examined and the changes in the environment that have taken place through the years were also studied.

Three stations, near the coast (Fig. 1) were located along the transect 51 of the ship's track. Another station (special station), located south of the Bombay harbour (Fig. 1) close to the shore, was studied only once.

The factors studied using standard procedures (Anonymous, 1972) were : salinity, dissolved oxygen, inorganic phosphate, nitrate–nitrogen and pH. The values of all the parameters have been presented in Table I. Biological Oxygen Demand for five days (BOD_5) was determined at station 51–01 and at the special station.

The average value of BOD_5 at station 51–01 was 0.46 ml/l and at the special station 0.29 ml/l. Current measurements indicated that the movement of the water mass off Bombay was northward during the rising tide and southward during the falling tide with very strong onshore

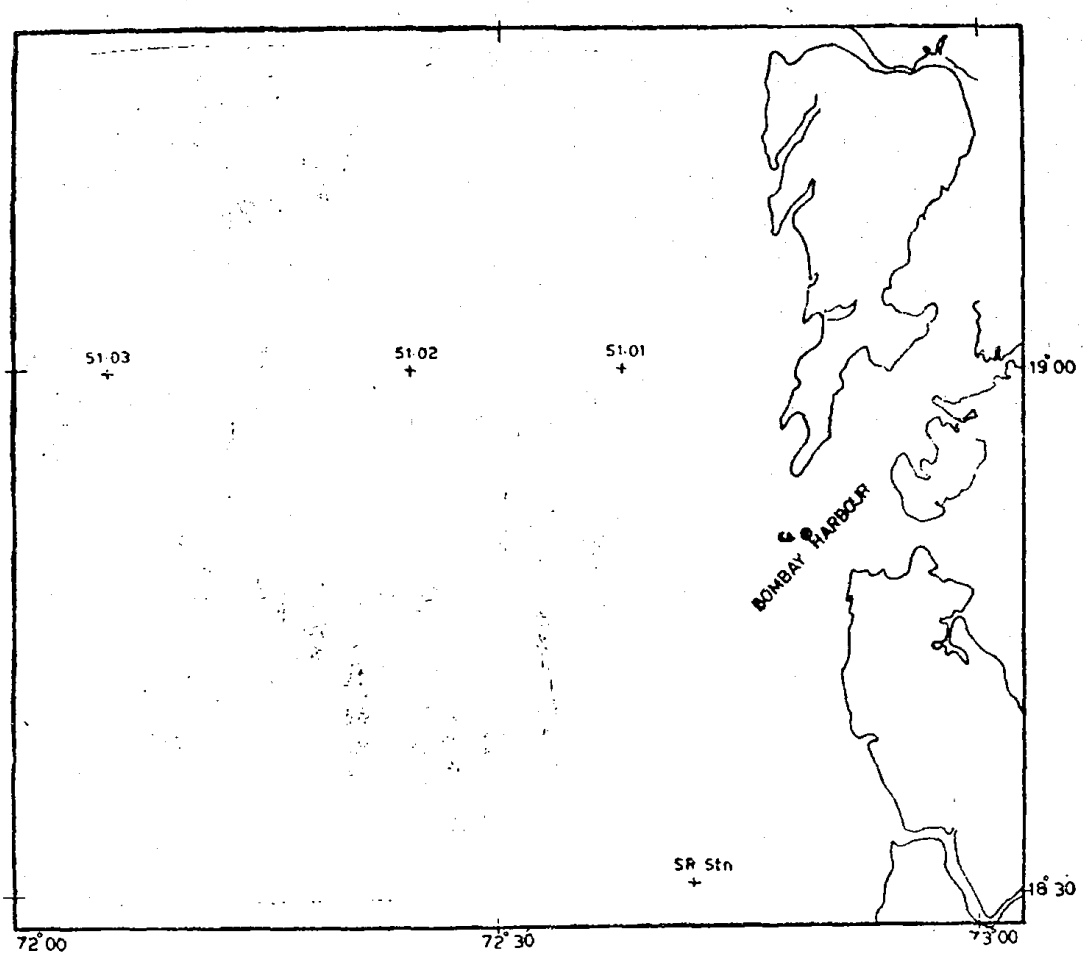

Fig. 1 Location of observation stations occupied by I. N. S. "Darshak". Station GS, location of the light ship, was studied in 1959 by S. S. Gogate.

and offshore components south of the harbour, within the 10 m isobath (Anonymous, 1971a). Beyond the 10 m isobath and north of the harbour, the shoreward components of the currents were less marked as compared to the general pattern of water circulation in the area (Anonymous, 1971a). It was, therefore, preferred to introduce the BOD_5 values at station 51-01 in the calculation as this would indicate a general picture of the pattern of oxidation of organic matter added to the sea as a result of sewage disposal at a place where the shoreward components of tidal currents are not very strong.

The values of Biological Oxygen Demand indicate the amount of oxygen used up for the oxidation of organic matter during a given period. We could not measure the chemical oxygen demand on board the vessel. However, from the BOD_5 values it was possible

to make a rough estimate of the total sewage discharge from the city of Bombay as follows :

Gross production of BOD_5 form Bombay is between 45 and 50 g per capita per day (Professor V. Raman, National Environmental Engineering Research Institute – personal communication), as compared to 80 g per capita per day in industrial countries (Engwall, 1972). Thus taking the average BOD_5 from Bombay as 48 g per capita per day the average value would be $(48 \times 365 \times 6 \times 10^6)/10^6$ or about 100,000 tonnes O_2/year from the community discharges, assuming that the total population of Bombay is 6 million.

The BOD_5 values at station 51–10 give 48 mg oxygen consumption per litre per year. Working with this value we get $(10^5 \times 10^3)/48$ or about 2000×10^6 m^3 as the annual sewage discharge from the city of Bombay to account for the BOD values, assuming that the change in BOD is because of sewage only and the entire quantity of sewage is discharged into the sea. Our value determined from the above procedure is much higher than what has been given by official sources, *i.e.*, 1000×10^6 m^3 per year (Dr. B. N. Desai–personal communication). The difference may be due to the following reasons :

(i) It is known that at present the sewage from Bombay is discharged along the beaches and a considerable portion of this is washed ashore due to the shoreward influx of tidal currents. The accumulated sewage near the shore gets decomposed in nearshore areas causing a considerable depletion of the oxygen content of the water. The low values of oxygen at our special station (Table I), which agree well with the values reported from a study within the 10 m isobath (Anonymous, 1972b), may be due to this. Evidently, the low BOD_5 value at the special station (30 mg O_2 per litre per year) is the effect of the low initial oxygen content of water. Our BOD_5 values may be higher as a result of the oxidation of that portion of the sewage which is carried beyond the 10 m isobath.

(ii) The values, probably include only the part of the sewage which finally reaches the sea. In our study, we have assumed that all the sewage goes into the sea, which may not be entirely correct.

It has been observed that the rate of oxidation of organic matter is greater at depths between 5 and 15 metres than at the surface and lower values of oxidation rate were recorded near the bottom. Further, the difference between BOD_2 and BOD_5 values was not very significant. This suggests that the rate of oxidation in this region is quite fast and most of the organic matter decomposes during the first two days.

The rate of flow of the industrial effluents from Bombay is about 75×10^6 m^3 per year (Professor V. Raman – personal communication) which is insignificant when compared to the total amount of sewage discharged annually. Therefore, the measurement of Chemical Oxygen Demand may be not of much value in this region.

One of our observation stations (51–01) was located about 17 km off

TABLE I

Variations of chemical constituents at Station 51–01

Date	Depth (m)	s* ‰	O_2 ml/l	O_2 saturation%	PO_4^{3-}-P µg-at/l	NO_3^--N µg-at/l	NO_2^--N µg-at/l	pH
29-1-74	1	35.52	4.52	95	0.40	2.06	0.54	—
	5	35.52	4.91	103	0.88	2.21	0.59	—
	10	35.53	4.62	97	0.80	1.24	0.46	—
	20	35.52	5.42	115	1.30	2.28	0.32	—
5-2-74	1	35.34	4.49	95	0.51	2.17	0.44	—
	5	35.33	4.42	93	0.70	2.13	0.44	—
	10	35.28	4.47	95	0.70	2.54	0.	—
	18	35.30	4.46	94	0.57	1.75	0.66	—
1-3-74	1	35.45	5.02	109	0.38	1.72	0.46	—
	5	35.43	5.00	106	0.32	1.34	0.48	—
	10	35.43	4.71	100	0.63	2.44	0.64	—
	15	35.43	4.70	100	0.82	2.38	0.57	—
	20	35.45	4.74	101	0.57	1.97	0.31	—
16-3-74	1	35.31	4.98	109	2.43	2.02	0.31	8.52
	5	35.31	4.86	106	2.43	1.66	0.22	8.58
	10	35.39	4.52	98	2.56	3.17	0.59	8.55
	15	35.38	4.73	102	2.73	3.38	0.68	8.53
	20	35.38	4.92	107	2.43	4.06	0.79	8.50
3-5-74	1	35.43	3.78	83	0.94	1.24	0.47	8.17
	5	35.50	3.64	80	1.17	1.46	0.29	8.16
	10	35.40	3.64	80	1.17	1.71	0.25	8.19
	13	35.41	3.80	83	1.28	1.97	0.38	8.19

* By courtesy of Naval Physical & Oceanographic Laboratory, Cochin

the Bombay coast. This area is considerably affected by the tidal variations and hence it is very well aerated. No depletion of oxygen, therefore, can be expected to occur here as a result of sewage discharge.

Combining our observations with the physical characteristics of the area, it would appear that the safest place to lay the sewage pipeline would be at a distance of about 25-30 km off the coast and beyond the 10 m isobath. It should normally be clear of shipping channels. The appropriate depth would be around 15–20 metres at high water and the location somewhere off the northern shores of Bombay. This would help the total oxidation of the decomposable organic matter without polluting the beaches.

Gogate (1960) carried out hydrographic observations at the light ship and at the light house off the Bombay coast in 1958–59. The light ship was anchored at about 13 km from the harbour at approximately Lat. 18°50'N and Long. 72°42'E (station GS shown in Figure 1). The station 51–01 is located

along Lat. 18°58'N and Long 72°38' E, and is approximately 17 km away from the coastline. A comparison between our values and those of Gogate will indicate any change in the chemical characteristics of water in this region that might have occurred during the interval of 15 years. From Gogate's data we have taken the values pertaining to January, February and March 1959. For the same months our values have also been given in Table II. Gogate in his study applied the phosphomolybdenum blue method for the determination of the phosphate content of water and used stannous chloride as the reducing agent. He measured the colour intensity in Nessler cylinders. We applied the same basic principle for our phosphate estimations but used potassium antimonyl tartrate as a catalyser for the reaction and ascorbic acid to reduce the complex. The colour intensity thus developed was measured on a spectrocolorimeter.

The relative error in the former method compared to the latter, which is a more sensitive method, is not well established. But surely the error cannot be as much as the difference obtained between the two sets of values (ca. 20-50%) given in Table II. Moreover, the range of concentration in our observations is larger than that of Gogate. Nevertheless, from the comparison it is evident that some changes have definitely taken place in this region during the last 15 years. Fig. 2 presents the average values for dissolved oxygen and inorganic phosphate at the two stations in 1959 and 1974 respectively. It is evident that phosphate concentration has increased during the period while concentration of dissolved oxygen remained more or less unaltered or varied insignificantly. Phosphate concentration have increased probably due to a greater

TABLE II

Range and mean values of oxygen and phosphate at station 51-01 (Jan Mar 1974) and at the Light ship station (Jan-Mar 1959)

Depth (m)	Jan-Mar 1974 O_2 (ml/l)	PO_4^{3-}-P µg-at/l	Depth (m)	Jan-Mar 1959 O_2 (ml/l)	PO_4^{3-}-P µg-at/l
0	4.75	0.93	0	4.4	0.69
	(4.49–5.02)	(0.38–2.43)		(4.2–4.6)	(0.46–1.11)
5	4.80	1.08	5	4.4	0.75
	(4.42–5.00)	(0.32-2.43)		(4.1–4.7)	(0.51–1.08)
10	4.58	1.17	10	4.4	0.95
	(4.47–4.73)	(0.63–2.56)		(4.2–4.5)	(0.62–1.38)
15–20	4.71	1.35	15	4.3	0.89
	(4.46–4.92)	(0.57–2.43)		(3.4–4.6)	(0.57–1.56)

Range is in brackets;

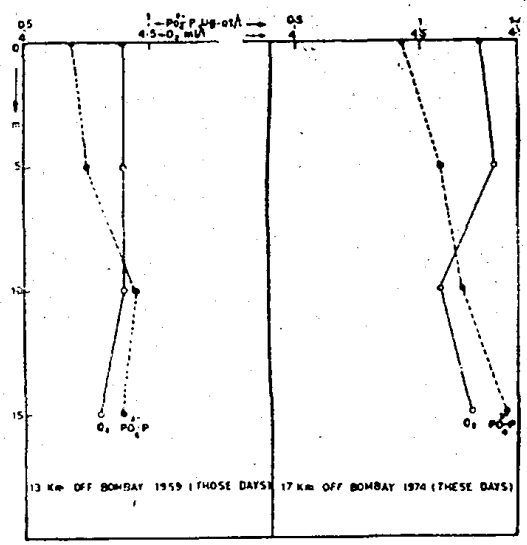

Fig. 2. Vertical distribtion of dissolved oxy gen and inorganic phosphate at station GS in 1959 and at station 51-01 in 1974.

sewage load. An increase in the use of synthetic detergents which are known to contain about 30% organic poly-phosphates may be another reason for the increase in phosphate concentration.

The population of Bombay has increased several times over the years and this has led to a considerable increase in the sewage discharge and the use of detergents.

We, therefore, conclude that the total amount of inorganic phosphate in the inshore waters off Bombay has increased considerably during the last 15 years, but because of the tidal influence and fast circulation of the water the situation has not yet become alarming.

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