

WASTE WATER DISCHARGE AND ITS EFFECT ON THE QUALITY OF WATER OF MAHIM CREEK AND BAY

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ABSTRACT

Coastal environment around Mahim was monitored to evaluate the effects of domestic and industrial waste water discharge in Mahim Creek. Vertical salinity and DO gradient occasionally observed in the Mahim Bay during postmonsoon period arises from the partial mixing of the contaminated creek water and bay water during the ebb tide. DO, BOD, $\text{PO}_4^{3-} - \text{P}$ and $\text{NO}_3^- - \text{N}$ vary considerably over each tidal cycle with DO levels often falling below 2 mg/l in the bay water and below 1 mg/l in the creek water during the ebb tide. Consequently, the BOD is very high and exceeds 100 mg/l in the creek. Levels of $\text{PO}_4^{3-} - \text{P}$ and $\text{NO}_3^- - \text{N}$ are also abnormally high.

INTRODUCTION

Large quantities of liquid waste of domestic and industrial origin are being released in the bays and creeks in and around Bombay (Lat. $18^\circ 55' \text{N}$, Long. $72^\circ 49' \text{E}$), thus deteriorating the quality of receiving water (Zingde, Trivedi and Desai, in Press). Mahim Creek which forms the upper extension of Mahim Bay is perhaps the worst affected area in this region. Some sewage treatment plants and pumping stations around the region, discharge about 160 mld (million litres per day) of domestic waste water in the creek, most of which is untreated since the existing combined capacity of the treatment plants is only 80 mld. In addition, several industrial establishments release about 25 mld of liquid waste in the narrow meandering Mahim River which ultimately joins the Mahim Creek. Proposal to convert the area around Mahim Creek into a Nature Park is being considered in view of the shortage of greenery and open spaces in the city. The present survey was undertaken to evaluate the extent of pollution and existing water quality of the creek and bay regions and the findings of this survey are reported here.

MATERIALS AND METHODS

Water samples were collected from the sites indicated in Fig. 1. Surface samples were obtained with a clean polyethylene bucket, while, non-metallic Niskin sampler was used for collecting sub-surface samples at the stations 1, 2 and 3. Regions being shallow (0.2-1 m), only surface sampling was done at the stations 4 and 5. Hourly collection at station 3 was done over the ebb and flood cycles once every month from July 1976 to December 1977. For the purpose of representing the data, the values obtained

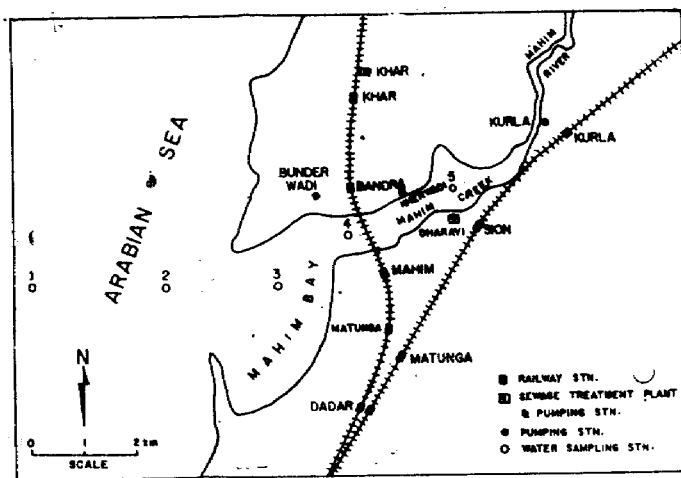


Fig. 1. Map showing sampling locations.

during a particular period have been averaged. Stations 1, 2, 4 and 5 were operated every two months for collecting flood and ebb samples. Diurnal variations at the stations 3 and 4 were measured over complete tidal cycles during November and weekly at the station 4 during August. Tide level measurements were made by installing self recording tide gauge at station 4. Current measurements at stations 3 and 4 over half tidal cycles were made during August and May. Currents over complete tidal cycle were measured at station 4 during February.

Salinity, nitrate, total nitrogen, reactive phosphorus and total phosphorus were determined by standard procedures (New Baltic Manual, 1972). Dissolved oxygen (DO) was determined by modified Winkler's method (APHA, 1978). For the determination of BOD, direct method was used for samples having BOD less than 3 mg/l, while for the samples having higher BOD, unseeded dilution method was employed (Martin, 1970). pH was measured by a calibrated Philips pp 9040 portable pH meter.

RESULTS AND DISCUSSION

Tides and currents

Water level changes near station 4 recorded during spring (20/21-1-77) and neap (28-2-77 and 1-3-77) tides were compared with the data obtained from the recording station at Apollo Bunder. The tide attained a range of about 2.1 m during spring period and decreased to 1.1 m during the neap period. The corresponding levels at Apollo Bunder were 4.7 and 1.7 m respectively.

The currents measured at station 3 during May were weak and predominantly tide induced with the maximum speed of 40 cm/sec for the spring tide when the water was ebbing. During August, however, the monsoon fresh water flow strongly influenced the currents. The maximum speed recorded during the spring ebb tide was 160 cm/sec.

Salinity

High salinity of the order of 36‰ during April–May in the coastal region of Bombay (station 1) decreased considerably accompanied with the development of lateral salinity gradient across shoreline into the creek under the influence of monsoon fresh water flow during July–August (Table I). Salinity increased from 25–27‰ during August to 32–34‰ during September and attained maximum (35.5–36.5‰) during May at station 1. Within the bay the salinity minimum was observed in September and though general increase was noticed from October onwards (Fig. 2), the actual value was dependant on state of the tide. Unlike in the coastal region, vertical salinity gradient was observed during August–September due to the incomplete mixing of fresh water with the underlying saline water. The influence of monsoonal flow is considerably reduced (Fig. 2) after September and the salinity increased to 32.8‰ during October from 8.1‰ observed during September. At station 3, the water was well mixed vertically during many observations in the postmonsoon period though lateral gradient due to the waste water discharges from station 5 to station 1 was observed (Table II). Appreciable vertical salinity gradient was sometimes observed as is evident from Fig. 3 which represents data obtained during November. The difference in the salinity of the surface and bottom water was considerable during the ebbing tide and decreased as the ebb slack approached. The water was fairly mixed at the flood slack with the increase in salinity of the surface water from 31.4 at the ebb slack to 34.3‰ at the flood slack. As the level of water decreased during the ebb tide at the bay entrance, less saline water from the creek region advanced in the bay and the mixing being slow due to salinity differences and weaker currents, the gradient was observed.

Diurnal observations at station 4 during November revealed that the salinity ranged from about 20 at the ebb slack to about 34‰ at the flood slack indicating the influence of waste water discharges. The data collected during August under different tidal conditions are shown in Fig. 4. From the curves (a) to (d) which represent spring and neap

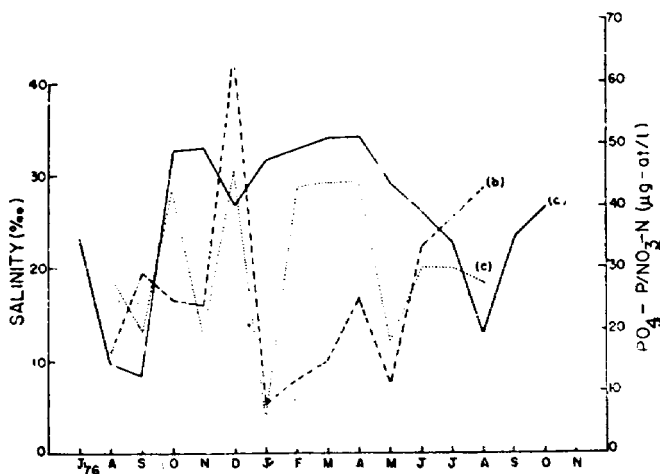


Fig. 2. Monthly variation of (a) salinity, (b) phosphate-phosphorus (total), (c) nitrate-nitrogen at station 3.

tidal conditions, it is evident that significant intrusion of sea water into the creek region occurs even during the period of high freshwater discharge and that during low tide the creek flow had some sea water component. The variations at the stations 1 and 2 were in line with the observations made for the coastal region of Bombay (Zingde, Trivedi and Desai, in press). At station 5, the intrusion of saline water was observed during spring as well as neap tides and the salinity varied according to the nature of tide (Tables I & II).

Table I. Physico-chemical parameters observed at different stations during August 1977.

Stn.	Tide	Sam dep (m)	SS	Sal	DO	BOD	TP	RP	NO ₃ ⁻ - N
1	Eb	0	185	26.5	6.7	1.2	2.3	1.4	3.1
		8	92	26.7	6.3	1.6	2.0	1.7	3.6
	Fl	0	75	25.3	6.9	1.5	1.7	0.9	2.6
		12	82	26.5	6.0	—	2.8	2.4	3.8
2	Eb	0	132	15.8	5.9	1.9	3.6	2.8	8.0
	Fl	0	108	22.9	6.3	—	3.6	1.5	2.8
3	Eb	0	210	3.6	1.8	13	55	32	52
		1	320	10.0	2.0	10	68	28	—
	Fl	0	410	17.7	5.5	4.6	30	24	12
		2	503	20.8	5.0	6.2	12	10	18
4	Eb	0	393	2.8	2.8	38	132	—	—
	Fl	0	289	16.5	0.5	45	92	—	—
5	Eb	0	247	1.0	0.0	190	205	—	—
	Fl	0	591	4.6	1.0	—	214	—	—

Sam dep - Sampling depth (m) SS - Suspended solids (mg/l) TP - Total phosphorus ($\mu\text{g-at P/l}$)
 RP - Reactive phosphorus ($\mu\text{g-at PO}_4^{3-} - \text{P/l}$) Sal - Salinity (‰)
 NO₃⁻ - N - Nitrate-nitrogen ($\mu\text{g-at NO}_3^{--} - \text{N/l}$) DO - Dissolved oxygen (mg/l)
 BOD - Biochemical oxygen demand (mg/l) TN - Total nitrogen ($\mu\text{g-at N/l}$)

Table II. Physico-chemical parameters observed at different stations during the postmonsoon period.

Stn.	Tide	Sam dep (m)	SS	pH	Sal	DO	BOD	TP	RP	NO ₃ ⁻ - N	TN
1	Eb	0	21	7.9	35.0	6.1	1.8	2.8	2.5	3.3	4.8
		10	18	7.9	35.8	6.1	2.0	2.2	1.8	2.2	5.1
	Fl	0	29	8.0	36.1	6.2	1.5	1.8	1.3	2.8	—
		10	32	8.1	36.4	5.9	1.9	2.7	1.8	2.9	—
2	Eb	0	50	7.9	33.9	4.8	4.5	4.9	3.0	6.9	—
		4	41	8.1	34.6	5.0	1.7	3.6	3.2	5.1	—
	Fl	0	55	8.1	35.0	5.2	2.8	3.5	2.7	4.0	—
		5	62	8.0	35.9	5.0	3.0	2.9	2.2	5.2	—
3	Eb	1	57	7.8	30.7	1.8	18	32	25	42	86
	Fl	0	39	7.9	31.2	3.3	6.2	16	13	23	80
		2	48	8.0	32.2	3.6	4.0	15	14	28	—
4	Eb	0	52	6.8	16.8	0.5	65	95	—	—	113
	Fl	0	40	7.7	32.0	1.5	22	20	—	—	121
5	Eb	0	230	6.6	16.5	0.0	122	181	—	—	205
	Fl	0	232	6.7	28.0	1.0	169	175	—	—	136

Suspended solids

The suspended load at the station 3 fluctuated in the range 18 to 52 mg/l during the dry season and varied irregularly (Fig. 5). Marked increase during June to August may result from the high load associated with the fresh water runoff.

Samples from the sewage treatment plants and pumping stations discharging in the creek region were analysed thrice during February. The suspended load varied in the range of 252 to 430 mg/l with an average of 373 mg/l. The creek region, therefore, receives about 60 tonnes of suspended solids per day which would be reflected on the suspended load in the creek region. At the station 4 it varied in the range 22 to 108 mg/l with an average of 50 mg/l during the dry season. This is almost of the same order as observed at the bay station 3 (Table II). Some fraction of the externally added load, therefore, settles during the passage of the water in the creek region. In line with the station 3 substantial increase was observed during the monsoon period (Table I).

During February, measurements were made at the mean tide to have an idea about the water flowing across the station 4. Hourly current measurements in the mid-channel at station 4 over a complete tidal cycle gave an average flood current speed of 72 cm/sec and an average ebb current speed of 70 cm/sec. Cross-section near station 4 was measured by actual depth and width measurements during high and low water slack periods. The average cross-sectional area was then calculated to be 143 m². Samples were also collected hourly for suspended solids and the average values during the flood and ebb tide were 43 and 46 mg/l respectively. The sea water entering the creek during the flood tide was calculated to be 1.95×10^6 m³ and the water leaving the creek during the ebb tide was 2.10×10^6 m³. Since the creek receives negligible fresh water during the postmonsoon period the greater flow during the ebb tide is mainly due to the waste water discharges. The transport of suspended solids from the creek to the bay is about 97 tonnes as against 114 tonnes received by the creek. It is, therefore, surmised that the creek acts as a sink for the suspended solids.

Dissolved oxygen

Dissolved oxygen profiles for the coastal region of Bombay are characterised by maxima in July–August and January–February throughout the water column. The former is associated with the monsoonal influence and increased turbulence and the later is due to the fall in temperature and increased photosynthesis (Zingde, Trivedi and Desai, in press). Also, the water being well mixed, the difference between the surface and bottom levels was not appreciable, and did not vary much over the tidal cycle. From Fig. 5, however, it is obvious that the bay water behaved differently. The variation was quite irregular and the difference between the maximum and minimum concentrations was quite appreciable. On several occasions the minimum level fell to zero and rarely exceeded 2 mg/l. Variation of DO over a tidal cycle measured during November gave a pattern (Fig. 3) which clearly indicate the pronounced influence of waste water discharge on DO levels in the bay. The surface DO decreased sharply from 3.2 mg/l to about 0.5 mg/l at the ebb slack and then increased to 5.1 mg/l as the flood slack approached. Except during the flood tide, when surface and bottom levels were comparable, the concentration at the surface was lower as compared to that at the bottom with an appreciable gradient. This supports the earlier conclusion that during ebb tide the creek water flowing into

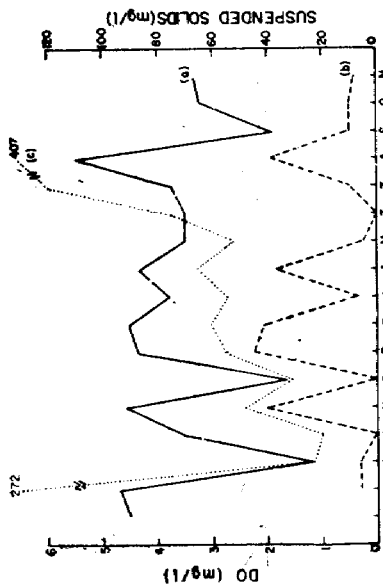


Fig. 5. Monthly variation of DO and suspended solids (c) at station 3. (a) maximum DO, (b) minimum DO.

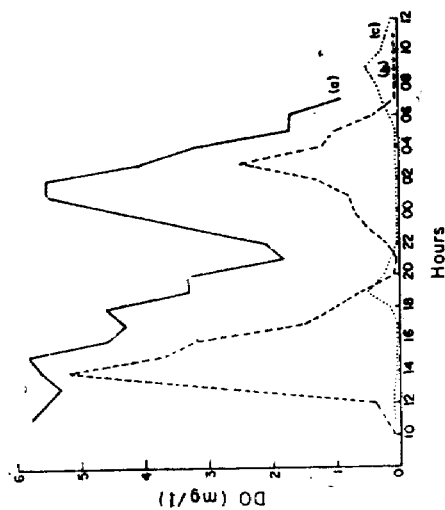


Fig. 6. Variation of DO at station 4 during August 77. (a) 1/2.8.77, (b) 17/18.8.77, (c) 23/24.8.77.

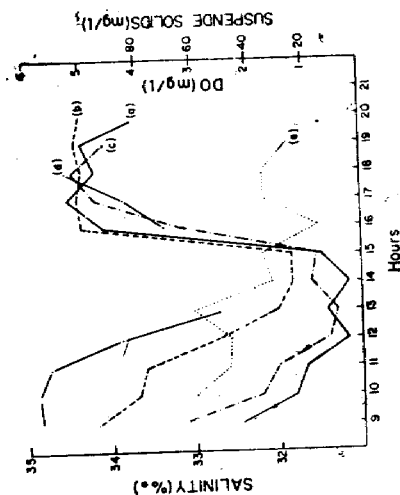


Fig. 3. Variation of salinity, DO and suspended solids at station 3 on 30.11.76 (a) surface salinity, (b) bottom salinity, (c) surface DO, (d) bottom DO, (e) surface suspended solids.

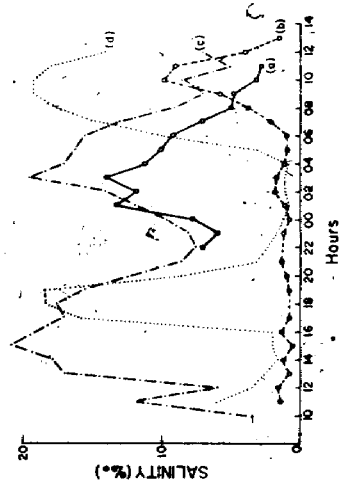


Fig. 4. Variation of salinity at station 4 during August 77. (a) 1/2.8.77, (b) 9/10.8.77, (c) 17/18.8.77, (d) 23/24.8.77.

the bay predominantly remained at the surface and hence had lower DO as compared to the bottom layer unlike in the coastal region.

DO profiles obtained during spring and neap tides in August at the station 4 are represented in Fig. 6. Comparing the curves (a) and (b) (Fig. 6) with the curves (a) and (b) (Fig. 4) obtained during spring tide, it is clear that the DO levels at station 4 were dominated by the tidal state as well as the fresh water flow during the period of measurement. The influence of waste water discharge in the creek was still predominant and levels decreased from 5.5 mg/l to less than 1 mg/l with the corresponding decrease in salinity from 14‰ to 2.8‰ during the first week. Decrease in DO during the third week (Fig. 6, curve b) is perhaps mainly due to the decreased fresh water flow as indicated by increase in salinity (Fig. 4, curve c). During the fourth week, the fresh water flow decreased still further and for 2 full tide cycles the DO rarely exceeded 0.5 mg/l (Fig. 6, curve c).

At station 5, DO was below 1 mg/l even during the monsoon period (Table I) indicating the severity of pollution resulting from the waste water inputs. It is, therefore, not surprising to find the absence of marine fauna in the creek region except for highly resistant intertidal animals like polychaetes, hermit-crabs, barnacles etc. (Govindan and Desai, unpublished results).

A water body with a BOD of 8 mg/l is considered to be moderately polluted (Martin, 1970). Examination of the Tables I and II immediately reveal the severity of pollution in the creek region (station 5) where values exceeding 100 mg/l were commonly observed. At station 4, the levels were considerably reduced due to better tidal flushing but still exceeded 20 mg/l. BOD at station 3 was tide dependant and increased to 18 mg/l at the

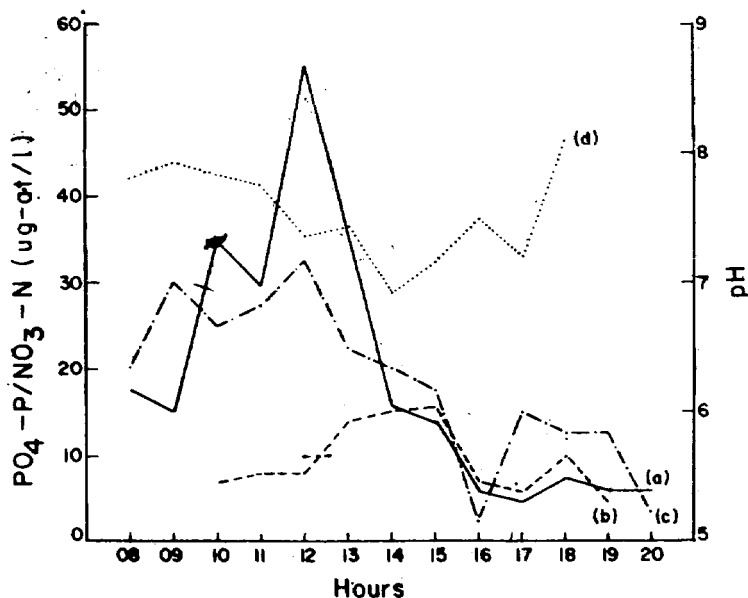


Fig. 7. Variation of phosphate-phosphorus (total), nitrate-nitrogen and pH at station 3; (a) surface phosphorus, (b) bottom phosphorus, (c) surface nitrate, (d) pH.

ebb tide from the flood value of about 5 mg/l during the postmonsoon period. Evidently, the creek region presents the sight of a smelly swamp emitting H_2S like odour.

Influence of waste water discharge is noticeable even at station 2 (Table II) though the effect is considerably reduced here due to high dilution. The movement of water in the coastal region is towards northeast at an angle of 30° during the flood tide and southwest at 210° during the ebb tide. The overall circulation pattern is elliptical with the major axis of the ellipse parallel to the coast line. Upto a distance of about 6 km from the shoreline, the currents have appreciable onshore component (NIO, 1978). The possibility of built-up of pollutants in the coastal water, therefore, cannot be ruled out and in the long run the conditions are likely to deteriorate even at the stations 1 and 2, if the present discharge continues. DO and BOD variations at station 1 are comparable to those observed at other coastal stations (NIO, 1978) and indicate a better water quality at this location.

Nutrients

The lateral gradient of phosphate and nitrate increasing from station 2 to station 5 is evident from the Tables I and II. Monthly variation of these components is quite irregular (Fig. 2) like other parameters in the bay region and the values fluctuated widely from

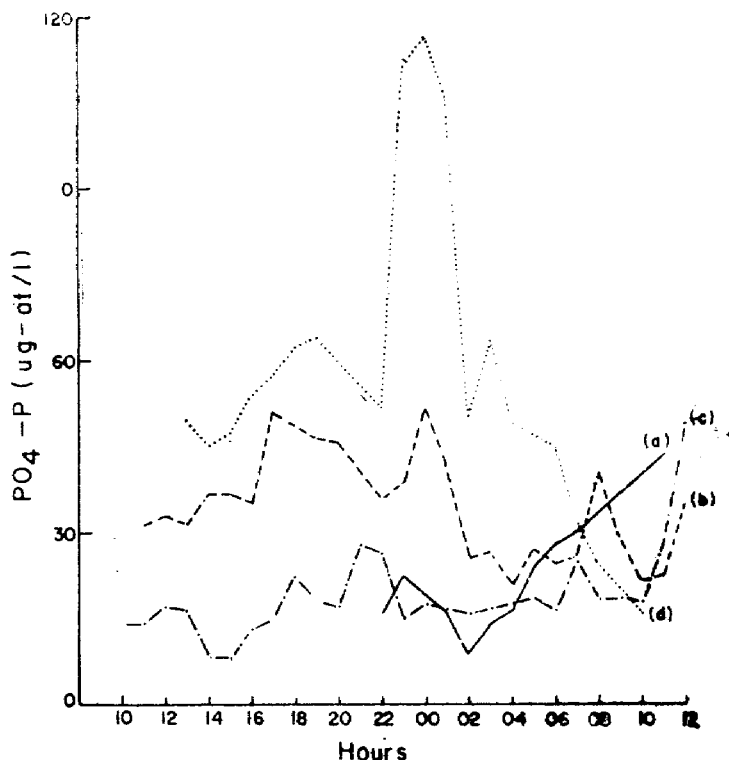


Fig. 8. Variation of phosphate-phosphorus (total) at station 4 during August 77 (a) 1/2.8.77, (b) 9/10.8.77, (c) 17/18.8.77 and (d) 23.24.8.77.

65 μg at $\text{PO}_4^{3-}\text{-P/l}$ to 8 μg at $\text{PO}_4^{3-}\text{-P/l}$ for total phosphorus and from 46 μg at $\text{NO}_3^-\text{-N/l}$ to 6 μg at $\text{NO}_3^-\text{-N/l}$ for nitrate. These levels are many folds higher as compared to the coastal region of Bombay where the values seldom exceeded 3 μg at $\text{PO}_4^{3-}\text{-P/l}$ and 4 μg at $\text{NO}_3^-\text{-N/l}$. It is quite interesting to note from Fig. 2 that a sudden drop in salinity observed during December sampling coincided with the highest nitrate and phosphate levels observed during the study period indicating pronounced influence of waste water during the period of December measurements. Variation of phosphate concentration over a tidal cycle conducted during November (Fig. 7) again supports the earlier conclusion that the contaminated water flowing into the bay predominantly forms the surface layer.

The nutrient level at station 4 is very high and tide dependant and increases during the ebb tide. Also, the levels are higher during neap tide than during spring tide (Fig. 8).

From the foregoing discussion it is quite clear that nutrients are abundantly available in the bay region and their levels are much higher than observed at less polluted stations in the coastal region (NIO, 1978). Primary productivity estimated on the basis of chlorophyll levels is, however, markedly lower around Mahim upto the station 2 (Jiyalal Ram and Desai, unpublished). It is possible that lower oxygen levels and other pollutants present in the waste are hampering the productivity. Studies on zooplankton revealed that the biomass was generally low but the numerical abundance of certain more resistant species like copepods was high and species diversification, observed at the less polluted stations, was low. Lesser diversity in the number of families of fish larvae has also been noticed in Mahim area (Gajbiye, 1979). Study of Mahim Bay has revealed that macroanimals except the barnacles, littorinids, hermit-crabs and polychaetes were normally absent in the interior of the bay and the representative fauna was observed only at the bay mouth (Govindan and Desai, unpublished).

These results clearly indicate that the waste water discharges are far in excess than the receiving water can assimilate and the quality of creek and bay water is quite unsuitable for the healthy growth of marine fauna. Immediate attention should, therefore, be given to stop or regulate the discharges into the creek and bay region to make it cleaner and healthier.

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