

Flushing characteristics of Mahim River estuary (Bombay)

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Strong tidal influence prevailing in Mahim Bay reduced considerably in the estuary due to abrupt bed elevation and sudden narrowing of the channel cross-section. The calculated and observed tidal excursions varied in some instances perhaps due to the influence of wastewater. Flushing time of 19 tidal cycles was estimated by applying modified tidal prism method. After a large number of tidal cycles the estuary would retain $9.3 \times 10^4 \text{ m}^3$ of wastewater which was over 15 per cent of the spring high tide and 40 per cent of the low tide volume of the estuary.

KEY WORDS : Flushing time, pollution, Mahim estuary.

INTRODUCTION

Mahim River estuary and the adjacent bay are under extreme environmental stress due to the indiscriminate release of domestic and industrial wastewaters into the system through point discharges. Abnormally high levels of $\text{PO}_4^{3-}\text{-P}$, $\text{NO}_3\text{-N}$ and BOD have been reported in the bay with wide temporal variations (Zingde and Desai, 1980). Dissolved oxygen (DO) varied considerably and often reduced to zero particularly around low tide. The estuary on the contrary was totally devoid of DO with the presence of sulphide in the water column (Sabnis, 1984). Markedly low diversity of fish larvae and low mean biomass of zooplankton with the dominance of *Paracalanus*, *Oithona* and *Acartia* has been observed off Mahim (Gajbhiye, *et al.*, 1981 and 1982). The benthic fauna though abundant

at the entrance to the Mahim Bay was either absent or sparse in the inner regions (Govindan and Desai, 1980-81). Although it has been recognised that the degradation of the estuary is due to its limited waste assimilation capacity, little is known regarding the tides and the associated flushing potential.

MATERIAL AND METHODS

Water level changes over complete tidal cycles at sts 2 to 5 (Fig. 1) were measured by installing graduated staff gauges during spring and neap tides for comparison with the tidal data recorded continuously at st 2 during 1977-78 (NIO, 1978). Surveyor shallow-water echosounder was used for charting the bottom topography of the bay by using sextant for position fixing. The cross-sectional profiles at nonnavigable sections of the estuary were obtained by actual depth and breadth measurements. Detailed survey drawing obtained from the Bombay Matropolilan Regional Development Authority was used for obtaining longitudinal distances along the estuary.

Spatial and temporal changes in salinity were measured at all the stations during spring and neap tides. Salinity was determined by argentometric titration. Currents across the cross-section at st 6 were measured periodically during the salinity measurement to estimate the riverine freshwater flow in the estuary.

RESULTS AND DISCUSSION

Study area

Mahim Bay which forms a semi-enclosed basin on the west coast of Bombay is connected to Mahim River terminating at the base of Vihar and Powai Lakes. The lower portion of the river popularly called Mahim Creek, harbours extensive growth of mangroves forming a major green belt in the city. A portion of the green belt is being developed into the Mahim National Park by the World Wildlife Fund of India.

The narrow and meandering Mahim River passes through the industrial zone receiving voluminous wastes from domestic and industrial sectors. The river experiences pronounced cycle of freshwater discharge mainly through the overflow from the lakes during July-August which becomes negligible after September and nearly stagnant conditions exist in the river and the upper estuary during the dry season.

Tides and tidal excursion

The tides experienced in the region are generally mixed semi-diurnal type

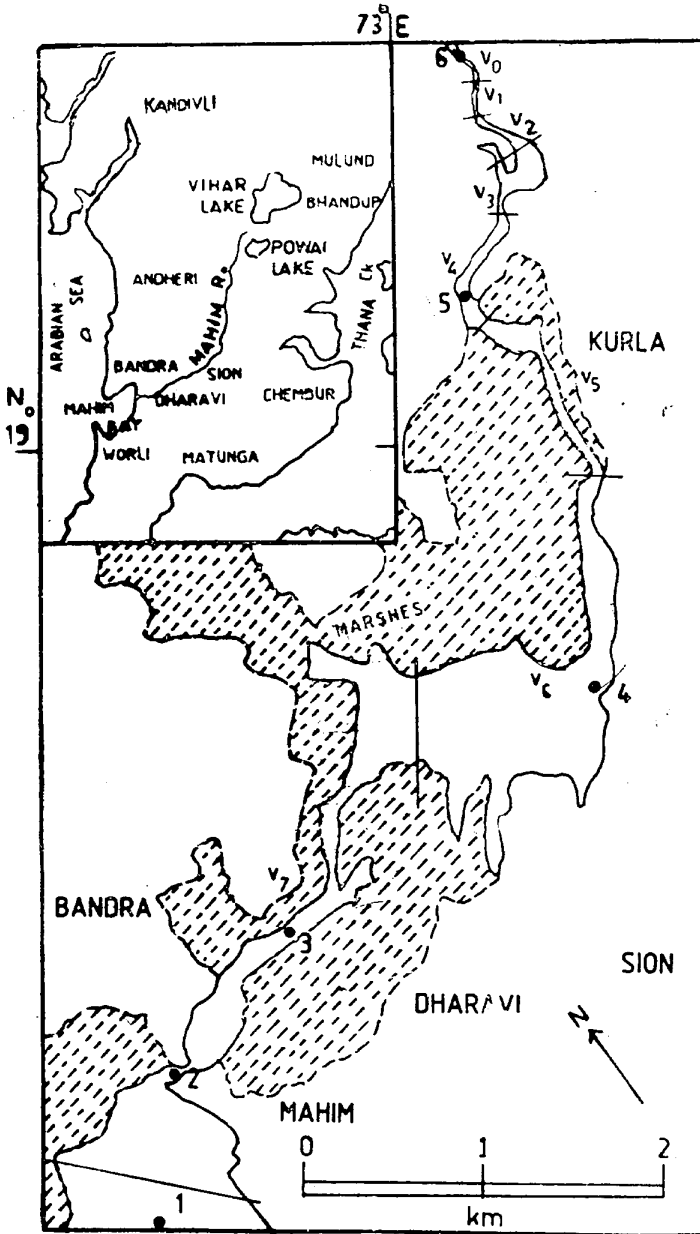


Fig. 1

Fig. 1 Study area and locations of stations.

with two unequal high and low waters occurring each tidal day. An abrupt bed elevation just beyond st 2 and considerable narrowing of the channel cross-section, markedly decreased the tidal flow into the estuary. Thus for instance, the spring rise of 3 m in the bay decreased to only 0.9 m in the creek and the influence was negligible beyond st 6. This influence was only just beyond st 3 during neap with a water level rise of 0.15 m. Although the flood and the ebb were approximately of the same duration of 6 h at the mouth of the bay, the flood period decreased to 3.4 h and the ebb extended over a period of 8-9 h in the inner bay and the regions upstream.

The volumes of the different segments of the estuary were calculated from the bathymetry and the tidal data. Expected tidal excursion was then estimated by drawing a horizontal line between the low tide and the high tide curves (Fig. 2) in the absence of displacement by freshwater (HMS, 1964). The excursion length during spring tide decreased from about 3.5 km at the estuary mouth to 1.5 km

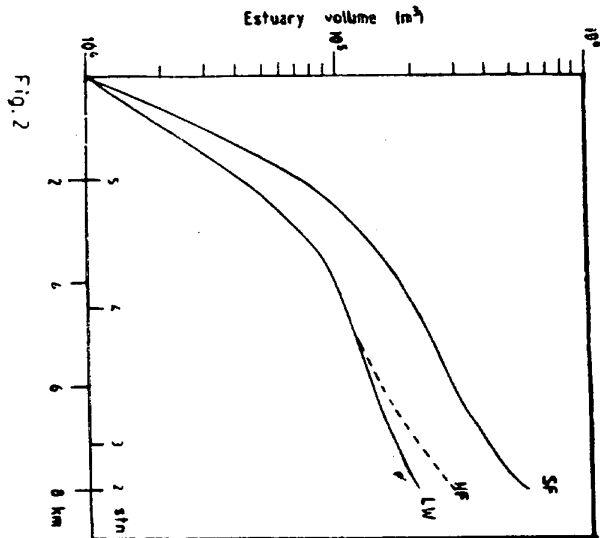


Fig. 2 Volume of water in the estuary under different tidal conditions. LW-Low water; NP-Neap flood; Sp-Spring flood.

Mahim River estuary

Table 1. Mahim estuary segment volumes, exchange ratios and flushing time based on modified tidal prism method.

Segment	Segment volume x 10 ⁶ (m ³) Low water	Tidal prism	Exchange ratio, E _n	Flushing Time (Tidal cycles)	Freshwater in the segment x 10 ⁶ (m ³)	Salinity (‰)	
						Calculated	Observed
V ₀	3.13	1.8	0.365	2.7	4.93	—	—
V ₁	4.93	2.82	0.364	2.7	4.94	12.6	0.3
V ₂	7.75	4.45	0.365	2.7	4.93	20.8	0.4
V ₃	12.2	7.0	0.365	2.7	4.93	25.9	—
V ₄	19.21	11.03	0.365	2.7	4.93	29.2	2.5
V ₅	30.23	26.52	0.467	2.1	3.85	32.5	4.5
V ₆	56.76	71.47	0.557	1.8	3.23	33.9	31.6
V ₇	128.22	563.74	0.815	1.2	2.21	34.8	34.0

at st 4 and the displacement was only about 0.5 km at st 5. The excursion length was barely 1 km at the estuary mouth and was insignificant upstream of st 3 during neap tide.

The trajectories obtained during spring tide by releasing neutrally buoyant floats at st 2 at the commencement of the flood indicated an excursion length of 3.5 to 4 km in fair agreement with the calculated value. On the following ebb, however, the floats reached st 2 in just 2.3–3 h indicating a tidal excursion of 6–8 km. This discrepancy was probably due to the voluminous discharge of wastewater which would favour preferential seaward movement during ebb tide.

Flushing time

Spring tidal conditions were considered for estimating the flushing time since the tidal influence was only upto the st 3 during neaps. The spring tidal prism for the Mahim River estuary (between sts 2 to 6) was estimated at 3.25×10^5 m³ with the low tide volume of 2.09×10^5 m³. The application of the tidal prism method (Dyer, 1973) gave a flushing time of 1.6 tidal cycles. The portion of well-mixed water removed from the estuary is then calculated to be 60 per cent. After an infinite number of tidal cycles under a continuous flow of pollutants in the estuary, the load fraction L calculated by using the relation

$$L = \frac{y}{1-y}$$

worked out to be 0.7 (y being the fraction remaining after one tidal cycle). This method of calculating flushing time, however, assumes complete mixing within the estuary which is rarely justified.

The flushing time was also calculated by applying the modified tidal prism method (Dyer, 1973). In this approach the estuary is divided into several segments in such a manner that each segment at high tide contain the volume of water contained in the next seaward segment at the low tide. The innermost segment is that above which the intertidal volume is supplied by the river flow R . The exchange ratio r_n for any segment 'n' can then be calculated by using the relation

$$r_n = \frac{P_n}{P_n + V_n}$$

where P_n is the intertidal volume and V_n is the low tide volume of the segment. The flushing time T in tidal cycles will then be

$$T = \frac{1}{r_n}$$

It is evident from the Table 1 that the cumulative flushing time of the estuary is around 19 tidal cycles. The load L retained in the estuary worked out to be 11

times the load introduced from tide cycle. The Mahim River estuary was estimated to receive $1.6 \times 10^5 \text{ m}^3 \text{ day}^{-1}$ of wastewater (Sabnis, 1984) of which over 95 per cent is domestic waste released downstream of segment V_5 . The load L retained in the estuary after a large number of tidal cycles was therefore $9.3 \times 10^4 \text{ m}^3$ which forms 16 per cent of the spring high tide and 40 per cent of the low tide volume of the estuary. The observed and calculated salinities differed considerably except for the segments V_6 and V_7 (Table 1). This was perhaps because the mid-estuarine region received $1.6 \times 10^5 \text{ m}^3 \text{ day}^{-1}$ of wastewater which would considerably dilute the sea water resulting in low salinities in the inner estuary. It is, therefore, not surprising that the Mahim River estuary is highly polluted and cannot sustain diversified fauna.

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