

A Study of the Probable Movement and Mixing of Contaminants in a Tidal Estuary

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The probable movement and mixing of contaminants within and through the Amba river estuary, a tidal estuary along the westcoast of India are studied. Neutrally buoyant biplane drogues, floats and dye were tracked at different stages of the tide for the qualitative assessment of the flow pattern and possible behaviour of the contaminants released in the estuary. The studies have shown that contaminants if released in the inner estuary tend to accumulate in the upstream regions and would not be flushed out effectively. The region downstream of Dharamtar experienced larger tidal displacements with wider float trajectories revealing better dispersion and transport over a larger area.

INTRODUCTION

With the urbanization and industrial growth, our estuaries have become receptacles of wastes from coastal cities and towns. The frequent use of estuaries to transport industrial and domestic wastes to the sea has made mixing and dispersion in estuarine flows, the subject of much study. An excellent review of the subject has been prepared (Fischer, 1976). Contaminants, untreated or partly treated or introduced into estuaries in aqueous solution or suspension. Initial concentration of the contaminant in the immediate vicinity of the point of discharge is the concentration of the undiluted effluent. Practically, this initial concentration does not occur over any significant time of space interval, since the process of the contaminant into the receiving waters will result in some mechanical mixing. After this, the contaminated volume will be transported by currents in the estuary and will spread both vertically and horizontally. Tidal currents will carry the contaminated volume back and forth over the tidal excursion and the contaminant will participate in the net nontidal motion. The movement and dispersion of waterborne contaminants within and through a tidal estuary are presented based on studies conducted in the Amba river estuary along the westcoast of India (Figure 1).

Amba river originated in the western Ghats follows a narrow and meandering course along its length of over 140 km before opening into the Bombay Harbour. Practically so far no detailed information is available to assess the hydrographic conditions prevailing in these waters. An indepth field study was carried out

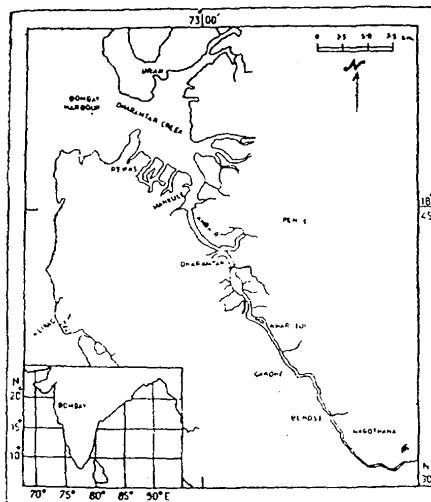


Figure 1. Location map

in 1986 so as to get an overall picture of the hydrographic conditions prevailing during different seasons (NIO Report, 1987). This paper deals with the salient features of the flow patterns studied. Although, at present the estuary does not receive any pollutants through direct discharges, the estuary which is predominantly tide dominant during non monsoon months opens into the Bombay Harbour, its water quality is expected to be largely influenced by the harbour water which receives an estimated $4 \times 10^5 \text{ m}^3/\text{day}$ of domestic wastewater and over $2 \times 10^5 \text{ m}^3/\text{day}$ of industrial wastewater. In addition Patalganga river which recei-

ves a variety of pollutants through industrial inputs discharges in the mouth of Amba river can also influence the water quality.

Amba river which is narrow, broadens into a wide estuary with the width exceeding 260 m in the mouth region during spring tides. The width decreases to about 65 m at 40 km inland. The estuary is shallow with the channel depth generally less than 5 m during low tides. The lower reaches of the river often referred to as Dharamtar creek is navigable upto Dharamtar jetty for medium size crafts under all tidal conditions. Though the region downstream of Bandhara is known to experience significant seawater incursion during dry season, no information is available about the hydrography.

MATERIAL AND METHOD

Fiva locations, namely Nagothana, Bendse, Khar Jui, Dharamtar and Mankule located in the lower to the upstream zones of the estuary were selected for the present study. These were located at about 39 km, 35 km, 25 km, 17 km and 8 km from the estuary mouth respectively. During the spring and neap tides, flow patterns were studied using biplane metallic drogues of

size 3' x 2' fitted with flags for convenient tracking and identification. These current crosses were adjusted to register the flow at the required depth using suitable floats, weights and shaft ropes. The floats were suitably adjusted to minimise the effect of wind stress and drag. The tracking was generally possible only during the day time mainly due to the navigational difficulties. However, in certain deeper regions, battery powered lights were fitted on the drogue mast during night for easy tracking and position fixing. Rhodamine - B dye patches were also used to assess the movement of water bodies. The drogues and dye patches were followed by a boat and locations were fixed at regular intervals using sextant and the trajectories plotted.

RESULT AND DISCUSSION

The water movements in the area under study are mainly tide induced and closely associated with the tidal patterns. The tides experienced in the region are generally mixed semidiurnal type with two unequal high and low waters occurring each tidal day. The tidal data is summarised in table 1. The tidal ranges for Appolo Bundar is based on the predicted tide for the survey period (Anon, 1986). The drogue and dye patch studies revealed the possible behaviour of the contami-

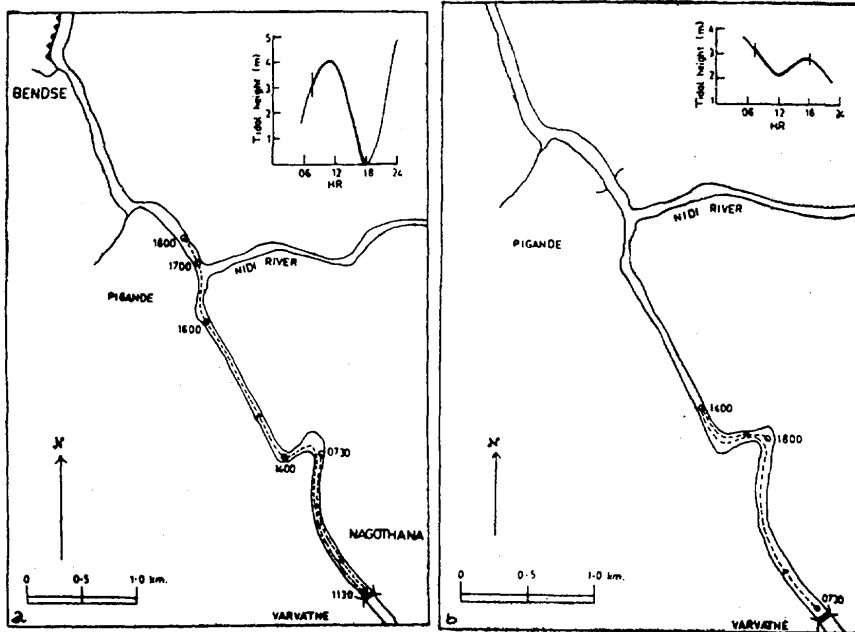


Figure 2. Drogue/dye path during : (a) 1-12-86, (b) 24-11-86

nants, its further movement and dilution. During pre-monsoon time, the region downstream of Bandhara was predominantly under tidal influence with practically no visible river discharge. Hence these observations could be taken as representing the flow conditions for non-monsoon period, that is from mid-October to late June when the riverine discharge was nil or insignificant.

Table 1. Tidal ranges along Amba river estuary, in m

Location	Distance from Nagothane, km	Tidal range (pre-monsoon)		Tidal range (post-monsoon)	
		Spring	Neap	Spring	Neap
Nagothane	—	3.35	1.90	4.08	1.56
Bendse	4	3.72	1.48	4.25	1.52
Gandhe	8	4.08	1.62	4.59	1.44
Khar Juli	14	4.80	1.38	5.07	1.42
Dharamtar	22	5.20	1.15	5.30	1.16

Mankule	31	5.00	1.16	5.32	1.06
Revas	39	5.08	1.04	5.20	0.96
Apollo	55	5.11	1.17	5.10	0.84
Bandar*					

*Based on predicted tide for the survey period

The floats released near Nagothane at spring high water (Figure 2a) moved slowly over the first 1.5 hr moving a distance of only 1 km downstream. The speed however increased considerably during the third hour and the floats crossed the Nidi river point. The floats generally went ashore near Bendse around the end of ebb tide and crossed this point only on two occasions. During neaps, the floats barely reached Bendse. The floats released near Nagothane at spring ebb slack registered very slow movement over the entire flood period perhaps because of the Bandhara upstream. Although the neap ebb tide trajectories revealed reduction in distance as compared to springs, the distances covered during neap floods were almost the same (Figure 2b). The floats released at flood slack crossed Gandhe - a distance of 4 km by mid-

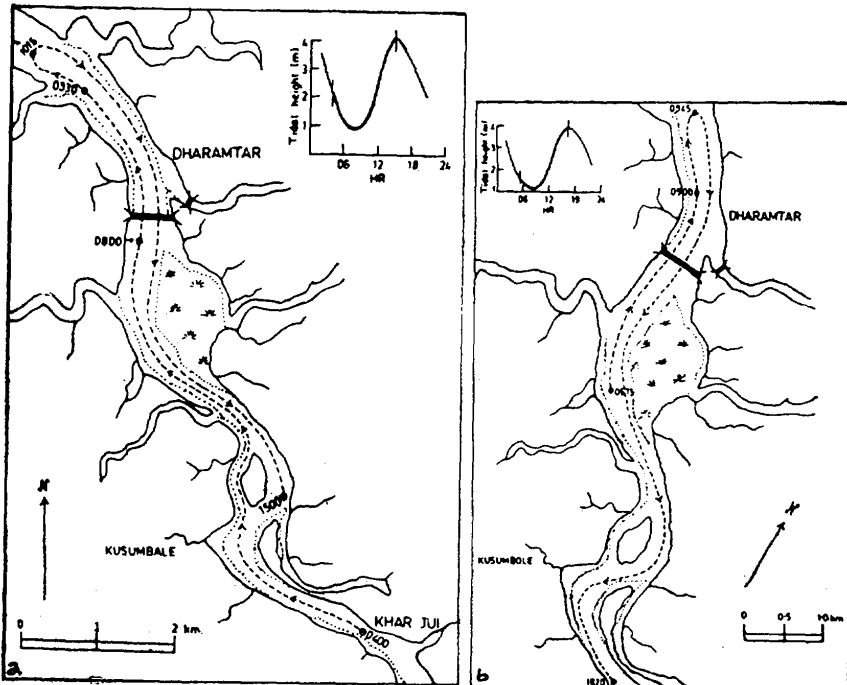


Figure 3. Droguedye path during : (a) 13-5-86, (b) 14-5-86

tide and the maximum distance of 9 km was covered during spring ebbs when released near Bendse at ebb slacks, the floats travelled upto the horseshoe bend (2 km downstream of Nagothane) and more or less remained stagnant. They crossed Nagothane only on 2 occasions. The distance covered during neap ebbs was generally about 2 km less than the corresponding distance during springs. However, this distance remained roughly similar during spring as well as neap floods.

Float trajectories at Khar Jui indicated larger longitudinal displacements in upstream as well as downstream directions compared to those at Nagothane, Bendse and Gandhe. The floats covered a distance of 8 km in just about 3 hr during spring floods. In some cases the distance travelled was about 12 km. This indicated possible transport of contaminants upto at least 10 km upstream if released at Khar Jui. The distance travelled over the spring ebbs was also of the order 12 km. In an isolated case, the distance moved was more than 14 km indicating an average displacement of 65 cm/sec. The longitudinal distance over which the floats were transported during neaps was considerably smaller and was of the order of 5 - 8 km (Figures 3a, 3b).

The estuary upstream of Dharamtar is narrow and

shallow while it is wider and deeper downstream. This abrupt morphological change may be responsible for the marginal piling up of the tidal water during non-monsoon. The floats released in mid channel at spring high tide crossed the high tension powerline by mid tide covering a distance of about 6 km. By the end of ebb tide they crossed Mankule and entered the mouth region of the creek between Rewas and Mankule (Figures 4a, 4b). The average distance covered during spring was 12 - 14 km during floods as well as ebbs. The floats which were at Mankule reached Khar Jui in the subsequent neap floods (Figures 5a, 5b).

The floats released about 4 km downstream of Dharamtar at flood slacks were transported beyond Rewas at the end of the ebb. A few floats released especially during flood slack were carried over towards the mud flats off Karanja. The pattern of float movements markedly changed as the estuary was wider and deeper. Unlike the narrower and shallow upstream regions where the movement was essentially longitudinal the trajectories were over a wider course tending to be elliptical. The floats released at Mankule were transported well beyond Rewas even during neap ebbs (Figures 6a, 6b). When released downstream of Mankule, they were carried beyond Gull Island during spring

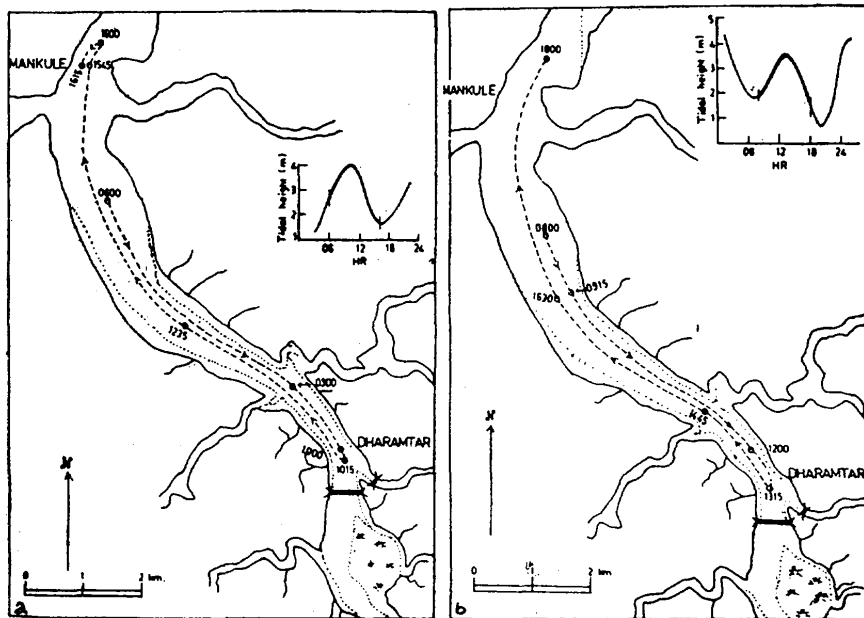


Figure 4. Drogue/dye path during : (a) 30-9-86, (b) 19-11-86

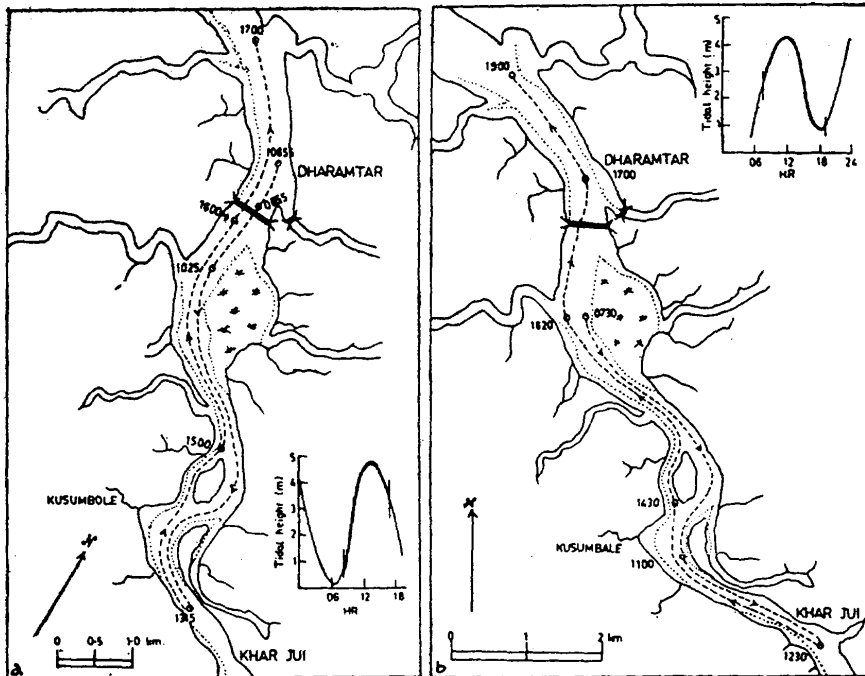


Figure 5. Drogue/dye path during : (a) 22-7-86, (b) 17-9-86

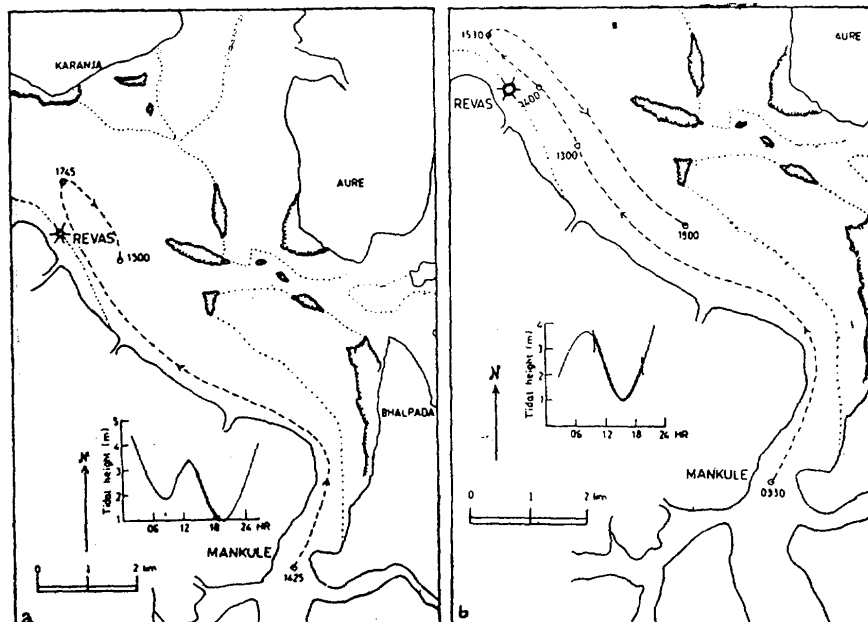


Figure 6. Drogue/dye path during : (a) 20-11-86, (b) 28-11-86

ebbs. The overall movement indicated better dispersion potential.

Weakening of the tidal influence in the region upstream of Dharamtar due to the substantial river discharge during monsoon influenced the movement of floats to a considerable extent. The floats released near Dharamtar at a spring flood tide were transported only upto Khar Jui, a distance of about 7 km while during the ebb they were carried 3 km downstream of Dharamtar, a distance of 10 km in just 3.5 hr showing substantial net seaward displacement. In general, the monsoon conditions were characterized by shorter upstream movements and considerably longer downstream transport (Figures 7, 5b). During post monsoon season, the river discharge decreases considerably and the tidal influence became dominant once again in the inner estuary. Evidently, the float trajectories were similar to those observed during premonsoon.

CONCLUSION

The float trajectories and dye studies revealed that any contaminants if released in the inner estuary oscillate up and down with the tide along the estuarine stretch of about 10 km during springs and 6 km during neaps. The contaminants would therefore tend to accumulate in the upstream regions and would not be flushed out effectively. The region downstream of Dharamtar experienced larger tidal displacements with wider float trajectories revealing better dispersion and transport over a larger area. A significant portion of the estuarine water is flushing out into the mouth region and beyond during spring tides.

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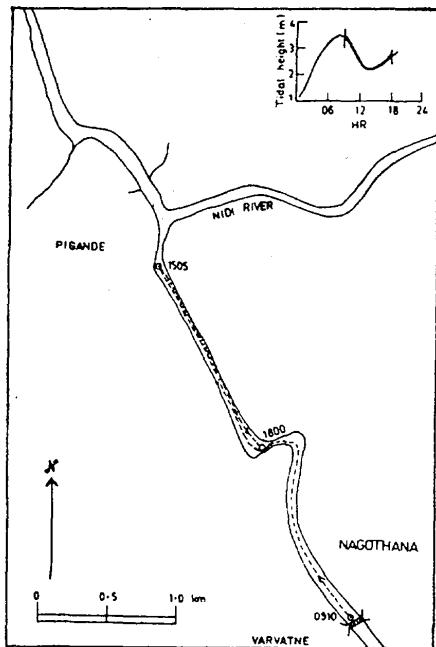


Figure 7. Drogue/dye path during 13-9-89

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