J. Hum. Ecol., 8 (3) : 175-178 (1997)
DOI: 10.31901/24566608.1997/08.03.05

Physical Aspects of Estuarine Pollution - A Case Study in Amba River Estuary

P.K. Dinesh Kumar[1], V. Josanto[1], R.V. Sarma and M.D. Zingde

National Institute of Oceanography, Regional Centre, Bombay 400 061, Maharashtra, India
1. N.I.O. Regional Centre, P.B. No. 1913, Cochin 682 018, Kerala, India

KEY WORDS Estuary. Effluent. Discharge. Dilution.

ABSTRACT Tide dominated Amba river estuary was studied to evaluate it's physical characteristics with a point on application to locate a suitable release point of industrial effluents. It is important to site the outfall in a manner ensuring that the water in the estuary is protected from contamination and will meet the required quality standards which necessitated the study of tides, currents, probable wastewater flow paths, dispersion potential, flushing time and also the propagation characteristics of the wastewater when released. Results are presented for crucial information on these aspects. Accordingly it is suggested to release the treated wastewater in the lower estuary at a convenient site downstream of Dharamtar from where a significant portion of the effluents is flushed out under all tidal conditions.

INTRODUCTION

Amba river rises in the western ghats, follows a meandering course of over 140 km and finally meets the Arabian sea at Bombay Harbour (Fig.1). A large petrochemical complex being established at Nagothana on the right bank of the river at about 45 km south of Bombay, planned to release the treated wastewater estimated about 750 m^3/hr into the estuary. Detailed surveys were carried out in the estuarine region for evaluating it's environmental status(Anonymous, 1987). Results of some investigations with a thrust to select a suitable site for releasing the wastewater are reported in this paper.

INVESTIGATION PROCEDURE

Physical oceanographic investigations are inevitable for a wastewater disposal installation, as the obvious function of this is to convey the waste, treat it to a suitable level before final disposal so that it's effect on the receiving waters will be minimum even at the point of initial mixing(Fischer, 1979).

For the present purpose, detailed studies were undertaken with respect to tides, currents, circulation and dispersion. The field investigations were planned in such a way as to get an overall picture of the extreme hydrographic conditions prevailing during different seasons. Stations were fixed in the lower, mid and inner estuarine zone for effective sampling and monitoring.

RESULTS AND DISCUSSION

Tides

Tides were measured simultaneously for 15 days using graduated staffs whose levels were corrected to the local datum mark. The tides experienced in the region were mixed semi-diurnal type with two unequal high and low waters occurring each day. The spring tidal range of 5.08 m at Rewas decreased to 3.35 m at Nagothana. The neap tidal range however increased from 1.04 m at Rewas to 1.09 m at Nagothana. About 30 cm increase in the tidal range at Dharamtar during spring tide as compared to that at Rewas was perhaps due to the piling up of water due to an abrupt narrowing of the estuary channel upstream of Dharamtar. The high tide at Rewas preceded Apollo Bunder by 2 to 3 min while the high tide at Nagothana lagged by 65 to 70 minutes.

Currents

Field observations on currents made using rotor induction current meter (make: N.I.O, Goa. Accuracy for velocity ± 1 cm/sec; direction ± 2.68°). The currents were purely tide

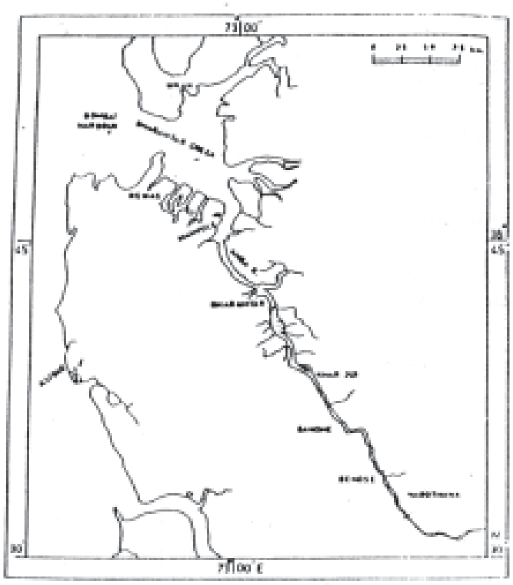

Fig. 1. Amba estuary

induced and reversing with the tide during the dry season. The nature of the current profile did not vary appreciably. The speeds decreased gradually in the upstream direction. Thus the maximum current speed of 111 cm/sec at Rewas decreased to 38 cm/sec at Nagothana. During monsoon, the flood current velocities and periods were reduced considerably while the ebb velocities and periods increased substantially. Continuous ebb was noticed in the upstream region as the flood tidal flow was suppressed by the river discharge. Thus for instance, at Dharamtar, the maximum flood current velocity was 42 cm/sec whereas the ebb velocity was 105 cm/sec. Towards the end of monsoon, as the freshwater discharge reduced, the flood currents once again became dominant.

Excursion

Tidal excursion was estimated by tracking biplane drogues over complete tidal cycles for different segments of the estuary, and this provided an insight for charting the currents transporting the effluent away from the point of discharge under different tidal conditions. The tracking was generally possible only during day time mainly due to navigational difficulties. However, in certain deeper regions drogues with indicator lights were used. In certain cases, hypothetical trajectories were drawn using the current meter data.

The tidal excursion during neap tide (dry season) increased from 2.5 km at Nagothana to 7 km at Mankule. During spring (dry season) this increase was from 4 km at Nagothana to 10 km at Mankule. It was assessed from the tidal excursion that (i) any material released upstream of Dharamtar (inner estuary) would be transported upto a maximum distance of 10 km in the inner estuary during spring flood tide which would not be flushed out during the following ebb, (ii) net transport of material to the Bombay harbour would be much better if the release was downstream of Dharamtar (lower estuary), and (iv) the riverine flow during monsoon considerably suppressed the upstream transport and build-up of pollutants during this period was unlikely even if the wastewater was released in the inner estuary.

Flushing Time

Flushing time was calculated using the modified tidal prism method in which, the estuary was subdivided into several segments, the length of which is determined by the excursion of the water particles during the tide. From the fraction remaining after one tidal cycle, the load retained in the estuary after infinite number of tidal cycles under a continuous flow of pollutants is also estimated. The results of calculations of the flushing time are given in table 1. It was quite evident that the cumulative flushing time of the estuary was around 6 to 7 tidal cycles during spring tide for both freshwater flow conditions revealing the dominance of tidal influence over the river discharge during springs. However during neaps when the sea water incursion greatly reduced, the cumulative flushing time which was 23 tidal cycles when the riverine flow was 4.3×10^6 m^3/tidal cycle increased considerably to 45 tidal cycles when

Table 1: Flushing time of Amba river estuary (modified the prism method) after Dinesh Kumar et al. (1991)

Estuary segment (km)	*Low tide volume X 106(m³)*	*Tidal prism X 106(m³)*	*Exchange ratio*	*Flushing time (tide cycles)*
*Riverrine freshwater flow per tidal cycle 4.3 x $10^6 m^3$**				
0-25.7	8.5	4.3	0.336	3.0
25.7-33.8	12.8	4.1	2.242	4.1
33.8-35.8	16.9	3.2	0.159	6.3
35.8-38.9	20.1	5.6	0.218	4.6
38.9-42.8	25.7	7.2	0.220	4.5
Riverrine freshwater flow per tidal cycle 4.3 x $10^6 m^3$+				
0-15.9	1.2	4.3	0.782	1.3
15.9-27.7	5.6	12.7	0.694	1.4
27.7-37.2	18.2	35.4	0.660	1.5
37.2-44.2	53.7	76.7	0.588	1.7
*Riverrine freshwater flow per tidal cycle 4.3 x $10^6 m^3$**				
0-8.9	0.53	0.43	0.448	2.2
8.9-13.6	0.96	0.67	0.411	2.4
13.6-18.0	1.6	0.98	0.380	2.6
18.0-21.8	2.6	1.1	0.297	3.6
21.8-26.3	3.7	1.4	0.274	3.6
26.3-29.5	5.1	1.6	0.239	4.2
29.5-33.7	6.7	2.1	0.239	4.2
33.7-33.5	8.9	2.5	0.219	4.6
35.5-37.2	11.4	3.2	0.219	4.6
37.2-39.4	14.6	4.1	0.219	4.6
39.4-41.3	18.7	5.2	0.217	4.5
41.3-44.9	23.9	6.7	0.219	4.6
Riverrine freshwater flow per tidal cycle 4.3 x $10^6 m^3$+				
0-49	0.12	0.43	0.782	1.3
4.9-13.1-	0.55	2.3	0.807	1.2
13.1-22.0	2.8	7.0	0.714	1.4
22.0-34.3	9.8	20.4	0.675	1.5
34.3-41.8	30.2	57.2	0.654	1.5

* = *Neap*, + = *Spring*

the flow decreased to 0.43 x 10^6 m^3/tidal cycle. This meant that if the wastewater was released at Nagothana, 45 tidal cycles would be required to get it flushed out of the estuary under neap tidal conditions when the river discharge was 0.43 x 10^6 m^3/tidal cycle (worst scenario). The load retained in the estuary after an infinite number of tidal cycles would be 33 times the load introduced per tidal cycles during neaps at river discharge of 0.43 x 10^6 m^3/tidal cycle. This would be greatly reduced during springs to 2 times. The actual load in the estuary at any given time would be somewhere between these extremes.

Wastewater Release Location

Considering the tidal characteristics, morphometry, transport, dispersion, flushing time etc., it would be advantageous to release the treated wastewater in the lower estuary at a site downstream of Dharamtar.

If the wastewater was released in Dharamtar-Mankule segment, then it would require about 31 tidal cycles for getting completely flushed out while the same will be achieved within 3 tidal cycles during spring (Table 1). Hence, when the wastewater was released in this region, there would be a tendency for the effluent build-up as the neap approached. This accumulated effluent would be largely flushed outside the mouth of the estuary during springs. Since the load retained was 24 for this segment (worst scenario), the effluent released in the estuary under neap conditions after an infinite number of tidal cycles would be around 2.1 x 10^5 m^3 which would be evenly distributed in the estuary. This wastewater would constitute less than 0.3% of the low tide volume of the estuary.

Rapid and widespread dispersion is a principal objective particularly for liquid waste disposal. This can be achieved by ensuring maximum initial dilution through an appropriate means of disposal. Generally, a diffuser adequately designed to suit the local requirements is preferred. However, release of wastewater at the above site through a sophisticated diffuser would not offer a high advantage because the region was shallow and the water column available above the diffuser was barely 3 m at an average tide. Moreover, the navigational channel being close to the southern shore of the estuary, sufficient area was not available for installing the diffuser. The wastewater could therefore be released through a subsurface outfall into the active zone of the estuary.

Propagation of Wastewater when Released

Jets and Plumes : For a plume discharging vertically in a medium of homogeneous density, plume path and mean dilution can be calculated(Quetin and De Rouville, 1986). The calculations performed for average tide when 3 m water would be available above the release point (Dharamtar-Mankule segment) revealed that the wastewater would surface close to the release point and the plume would have a diameter of around 3 m to 3.5 m as it surfaced. The dilution attained as the plume surfaced would be of the order of 5-7 times. Once the wastewater reached the surface, advection by the prevailing currents would be the major mechanism for the dispersal.

Thickness of the Affected Layer : It should be established whether the surface currents would be capable of transporting away the polluted water brought to the surface by the subsurface outfall. The approximate thickness of the receiving water layer which will be affected by the effluent was calculated(Quetin and De Rouville, 1986). The treated wastewater meeting specifications when released between Dharamtar-Mankule segment would attain initial dilution by 5-7 times as it surfaces through a subsurface outfall. The thickness of the contaminated layer was estimated at 0.6 m prior to transport by advection. Since this thickness was less than the available water depth (3 m), the probability of recirculation of the pollutants released through the wastewater was negligible.

ACKNOWLEDGEMENTS

Authors thank Dr. B.N.Desai, former Director and Dr.E.Desa, Director, N.I.O. for the facilities and support.

REFERENCES

Anonymous : *Hydrographic Studies in Amba River Estuary for Wastewater Disposal from a Petrochemicals Complex* (Part I). Technical Report, National Institute of Oceanography, Goa (1987).

Dinesh Kumar, P.K., Sarma, R.V. and Josanto, V. : *Indian J. Mar. Sci.*, **20** : 212-215 (1991).

Fischer, H.B. : *Mixing in Inland and Coastal Waters*. Academic Press, New York (1979).

Quetin, B. and De Rouville, M. : Submarine sewer outfalls-A design manual, *Mar. Polln. Bulltn.*, **17** : 133-183 (1986).