Simulation Models for the dispersion of sewage outfalls along the west coast of Mumbai, India..

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Abstract: - The island city of Mumbai with an area of 438 sq. kms and supporting a population of over 10 million generates about 2700 million liters per day (mld) of sewage from the seven service areas of the city sewerage network and discharges it into the adjoining west coast and the two creeks in the Arabian Sea. This has resulted in the degradation of coastal water quality, contamination of the adjoining beaches and seafronts. The Municipal Corporation of Greater Mumbai has therefore, undertaken the task of delineating appropriate sewage disposal system to achieve cleaner marine ecosystem through marine outfalls at specific locations. This paper presents the results of the mathematical simulations on the impacts of discharge vis-a-vis the length of the outfall and level of land treatment. The results of the simulation indicate the level of bacterial pollution to be higher near the diffuser locations as compared to nearshore regions. 48 hrs simulation result analysis shows that FC counts near the diffuser location will be in the range of 2000–8000 counts per 100 ml.

Keywords**:** mathematical simulations, Mumbai, sea outfalls

Introduction:

In recent years, there has been significant progress in the development of numerical circulation models that are able to simulate and predict the transport processes that operate in coastal areas. Such models, when properly configured and validated with observational data, are often the best tool for evaluating management scenarios in the coastal ocean. Because of the complexity of driving forces and topography in Mumbai shores, computer models have played a critical role in predicting how sewage effluent released from the new outfall will be transported and diluted.

Rapid growth of the Mumbai City over the past few decades has given rise to pollution problems of significant dimensions. A major aspect of these problems is deterioration of water quality in creeks and the coastal zone around the city due to less restricted disposal of large volumes of domestic and industrial wastewater. The island city of Mumbai generates about more than 2700 mld of untreated sewage from seven municipal service areas of the city. It is discharged daily into the adjoining west coast area and two creeks the Arabian Sea.

Wastewater originates mainly from a)domestic, b)industrial, c)groundwater and d)meteorological sources. a)Domestic sewage result from people's day to day activities such as bathing, body elimination, food preparation and recreation averaging to 150 lts per capita dialy. b) The quantity and character of industrial wastewater is highly varied, depending on the type of industry, waste management of its water usage and the degree of treatment before the wastewater in discharged. A steel mill for example may discharge anywhere from 5700 to 151.000 lts per ton of steel manufactured. c&d)The amount of storm water drainage to be carried away depends on the amount of rainfall as well as runoff.

The composition of waste water is characterised by the presence of suspended solids, dissolved solids, organic matter which is measured by BOD (biochemical oxygen demand) and COD(chemical oxygen demand) analysis, pH and faecal matter (FC counts-colilform). Till about a couple of years ago the wastewater was flushed into the sea without any treatment.

The Brihmumbai Muncipal Corporation has undertaken the task of management of wastewatee discharges by appropriate sewage disposal practice and aims to achieve the objective of cleaner marine ecosystem in an around Mumbai's coastal areas. For successful implementation Mumbai region is divided into seven drainage areas namely Colaba, Worli, Bandra, Versova, Malad, Bhandup and Ghatkaoper. (Fig no. 1)

Attempts are made in this paper to simulate the sewage outfall spread at four locations- Worli, Bandra, Versova and Malad using microstation geographics and descartes. It is an experimental study. The variety of hydrodynamic data constraints the simulation at all oceanic conditions. This paper focuses the simulation of sewage outfalls into the Arabian Sea for the monsoon season during spring and neap tide condition at a distance of 3 kms, 5 kms and 8 kms after primary and secondary treatment. The other variables that affect wastewater spread includes minimum dilution, maximum dilution, tidal conditions, bathymetry of the sea and wind directions.

The Study Area:

The study area is the west coast of Mumbai covering 15 kms x 25 kms into the sea from the Mumbai Coast Offshore. This area is thus bound by the 18.56' N to 19.16' N and 72.39 E up to the shores of Mumabi.

Database:

The variables used in the study are extremely dynamic and indepth data collection was required for bathymetry, ocean surface current, depth current profile, tidal elevations and wind directions. The database was made available by NEERI (National Environment and Engineerint Institute, Nagpur). Hydrographic charts are used for bathymetry. (Data was collected by NEERI and BMC susing very sophisticated equipment like S4 Current Meter, Tide Guages WTG904, Ocean surface Current Radar(OSCR). The data is both quantitative and qualitative pertaining to flood and ebb of Spring and Neap tides, wind directions, sea sound measurements, current movement and bathymetry.

Methodology:

The obtained data on hydrodynamics was input into the Bentley tool systems as point data and customised applets were built to trace isolines. Whenever the data could not be modified, the graphics data was scanned and 'descartes' was used to construct polygons. The system allows data models to be incorporated if desired. The qualitative data is transformed into cartographic form. For getting the desired results the mathematical model developed by NEERI and BARC is used. This model is being presented in a cartographic form using GIS - microstation geogaphics and Descartes.

1. The direction of the wind was determined for monsoon and non monsoon period. It was found that the general direction of wind during October-February was NNW with a speed of 10-15 km/hr. During other months the direction of the wind was West and Southwest with an average velocity of 15-30 km/hr. Consequently the current pattern (diagram 1) and drift of water was a net northerly drift during spring

tide and net southerly drift during neap tides.

2. The bathygraphy of the west coast off Mumbai was determined using hydrographical charts and it was found that the depth increased gradually upto 15 kms (Fig no. 3) It was also found that the seabed is covered with clay sediments and underlain by rock.
3. Three options of the length of marine outfalls were decided at a distance of 3 kms, 5 kms and 8 kms into the sea from the shore to find how the dispersion of water varies with increasing distance from the coast.
4. Each outfall was simulated for a period of 48 hours to find out the concentration of FC and coliform and its spread and implications with regard to service areas.
5. These variations have been plotted to bring out the effect of the dilution, tidal fluctuations, length of outfalls and levels of treatment for monsoon and non monsoon period to trace the FC counts in a spatio-temporal variation within defined area.

Objectives:

To test: a) At which distance the outfall will have minimum FC counts so as to be economically viable

b) How the outfalls spread after primary and secondary treatment and which one is more economically viable.

c) To find the mode of dispersion of sewage in spring and neap tide conditions.

d) to merge all the outfalls simultaneously to get total picture of the sewage outfalls spread along the west coast.

e) To find the main direction of dispersion of FC coliform whether from north to south or west to east.

Analysis:

The monsoon simulation results are presented in series of maps for Worli, Bandra, Versova and Malad. These diagrms are representative of the whole scenario and allows delineation of bacterial wastefield and FC coliform-count, their movement and distance from the shore. All the simulation results have 48 hours run.

Worli and Bandra:

Fig 2 shows the simulation results for Worli and Bandra during Spring Tide conditions at 3kms distance from the shore. The simulation shows that a wastefield patch of 1.4kms x 0.8 kms of FC counts above 200/100 mls at a distance of 1.2 kms from the shore is visible. FC count of over 800/100 ml is always present. Fig 3 depicts the simulations of Spring tidal conditions at a distance of 5 kms from shore and Fig 5 depicts simulation results at 8kms distance from shore. It is found that bacterial patch of 1.8 kms x 1.0 kms of FC count 200/100 ml is observed at distance of 1.6 kms from the shore. There is not much difference in the mode of dispersion of sewage at 3 kms, 5 ms and 8 kms. At all distances the dispersion is north-south with a little amount of inshore drift during spring tides. A 8 kms the waste patch is slightly reduced due to the larger water column available for dispersion.. When secondary treatment is given to the effluents, it is observed that the waster-field patch is significantly reduced and in Worli, it is hardly traced. Fig.6.

Fig 7 shows the dispersion of sewage during Neap Tide conditions. The diagram shows that the waste field is larger and FC count is also larger covering a compact area of 1 km x 1 km at a distance of 1.5 kms from the sea shore. The dispersion at 5 kms outfall and 8 kms outfall does not show much difference due to the shallow seas suring neap tides. The higher concentration of FC is due to the shallow sea during neap tides and dilution is minimum.

Versova and Malad:

Fig 8 shows the monsoon simulation results of Versova and Malad during Spring and Neap Tide conditions. It is observed that the sewage dispersion is north-south with a much longer and wider wastefield. The FC count patch is comparatively less and the sewage outfalls of Versova and Malad merge to get one complete north-south drift with two FC waste patches. The dilution in this section of coast is more due to the changes in the bathymetry. Fig 9 shows the simulation result of Neap tide condition. The dispersion of sewage is much larger and elongated than Worli and Bandra. This is due to the larger of column of water available for dilution. The pattern is north-south with two FC count patch. The volume of sewage handled is also greater than Worli and Bandra.

Fig 10 shows the simulation of all the four locations Worli, Bandra, Malad and Versova. It is observed that the waster water patch of Worli is the smallest and the patch size increases to the north. However the degree of dilution is minimum near Worli and increases toward north. It is likely that although dispersion direction is north-south, there is a strong west-east inshore drift present, which may carry the faecal matter and leave it floating near the shores at all times of the day.

Conclusions:

a)The spead of waste filed is higher during Spring and FC concentration are higher at the diffuser location during neap tide.

b) FC patch at Worli reduces uniformly upto 5 kms length of the outfall and further away does not change significantly.

c) FC patch at Bandra does not reduce upto 5 kms length after which a sharp decrease is noticed.

d) Malad and Versova discharges if combined and discharged into the sea at 3 kms length will always result in FC patch near the shore. So the Malad and Versova outfalls are separate although they merge to reduce two FC patch of small size away from the shore.

e) There is marked improvement in the ranges of FC concentrations when the level of treatment is from primary to secondary.

If all the wastewater is discharged into the sea after primaryt treamtment, the overall impact on the marine ecosystem will be minimum and water quality will be as per the standard fixed by CPCB and MPCB. But about 30% to 40% of crude sewage discharged into the adjoining sea is through slums at diffused sources, degrading the near shore water quality in terms of dissolved oxygen and high bacterial density. This is one of major problem in Mumbai where large % of people reside in slums. The slum redevelopment scheme and slum sanitation plans have already reduced such degradation of coastal water in certain sections.

The reports of the Department of Ocean Development(DOD) point out that except Mumbai, the water quality in all the other coasts are as per standard set by CPCB at a distance of 2 kms from the shore. In case of Mumbai clean water is found at an alarmingly long distance of 5 kms from the shore. Currently all the seven plants are working and had already provided the much needed relief to coastal water.

Recommondations:

For future water management possibility of reuse and recycling of wasterwater after primary treatment should be explored and secondary treatment option should be considered.

Sr. No.	Zone	Average dry weather flow capacities
1	Colaba	41.10 mld,
2	Worli	756.90 mld,
3	Bandra	796.80 mld
4	Versova	131.30 mld
5	Malad	280.40 mld
6	Ghatkopar	386.10 mld
7	Bhandup	176.10 mld

Source:BMC

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Only four diagrams have been added here.

FIG. NO. 1 STUDY AREA

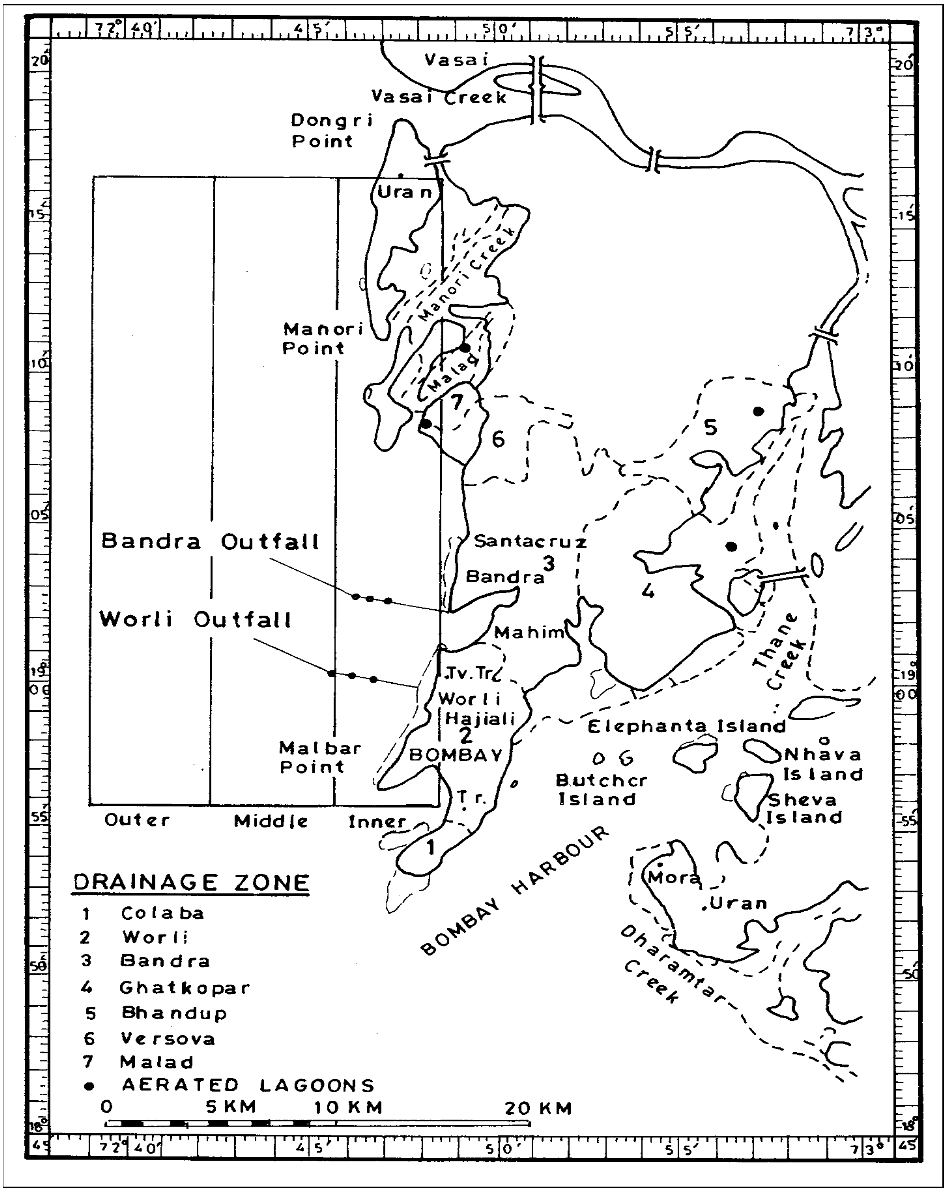

FIG NO. 2. Simulations for Bandra and Worli (Spring tide)

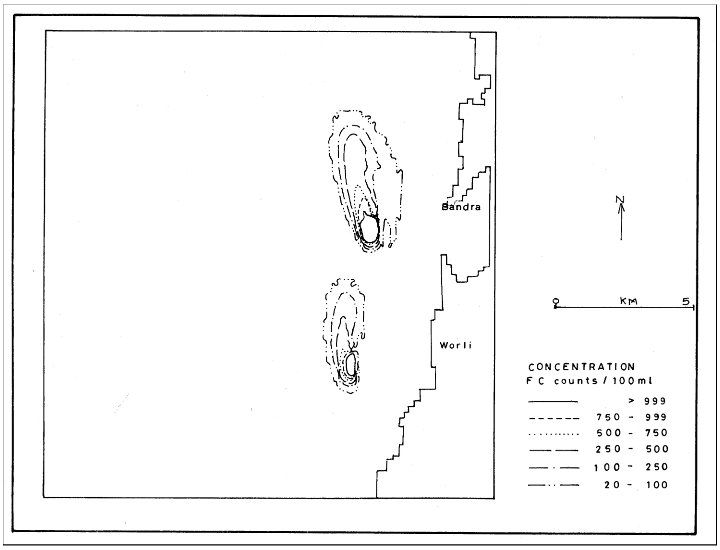

FIG NO. 7. Simulations at Bandra and Worli (Neap Tide Conditions)

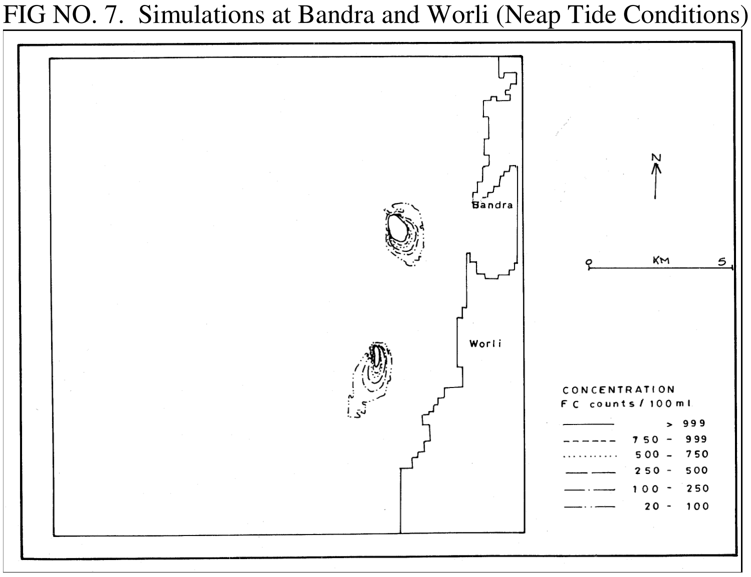

FIG NO. 8 Simulations at Bandra & Worli at 3, 5, & 8 kms. Spring Tide.