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# HEALTH STATUS OF THE COASTAL WATERS OF MUMBAI AND REGIONS AROUND

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## ABSTRACT

*The coastal marine environment of Mumbai and regions around receives the domestic wastewater generated of around 1800 million litres per day (mld), mostly untreated. In addition, a large number of industries established in the drainage zones also contribute to pollution loads. These inputs have affected the water quality, sediment quality and biological characteristics of receiving waters to varying degrees. BOD in coastal water is often high and water is enriched in dissolved nitrogen and phosphorous compounds. Although the concentrations of Petroleum hydrocarbons (PHC) and phenols are high particularly in Thane creek, they are not alarming. The levels of heavy metals such as Cr, Cu, Zn, Pb, Cd and Hg have enhanced, though marginally. The degraded water quality of coastal waters is also reflected in very high counts of pathogenic bacteria with their populations markedly decrease as the flood tide progresses. Adsorption and transfer of pollutants to bed sediment by suspended particulate matter has increased the sediment burden of several pollutants in some areas. Degradation in water quality has induced marked alterations in community structure and population of phytoplankton, zooplankton and macrobenthos. The impact of anthropogenic pollutants decreases considerably from creek to offshore areas and is insignificant beyond 5 km from the shoreline.*

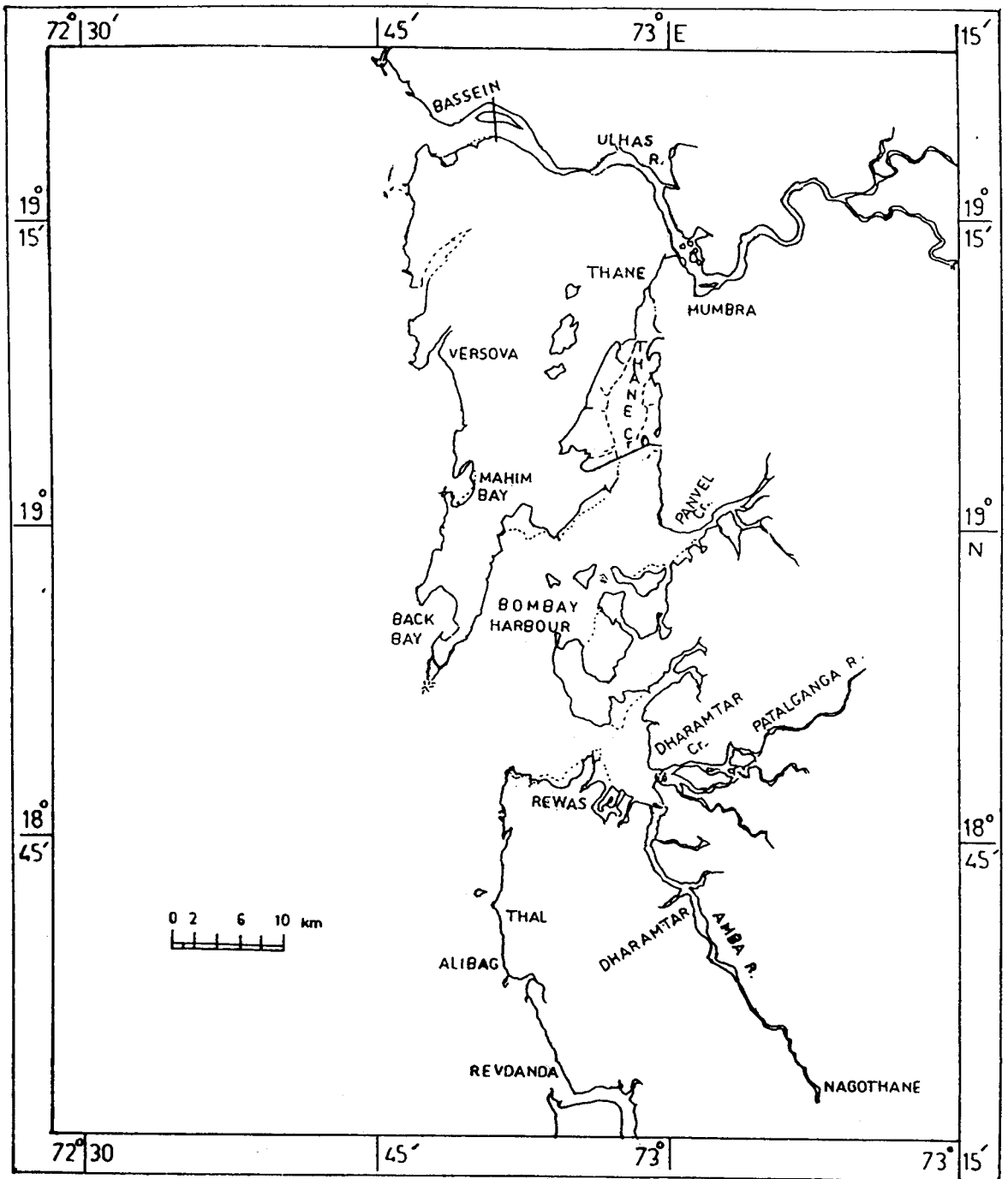
## INTRODUCTION

The coastal marine environment of Mumbai and regions around, comprising of Arabian Sea to the west and a number of tidal inlets such as Thane creek, Back bay, Mahim creek, Versova creek, Ulhas estuary and Bassein creek (Figure 10.1), is the recipient of a variety of pollutants emanating from domestic and industrial sources. Of these, Thane creek receives wastewaters from heavily industrialised Thane-Belapur belt stretching along its eastern shores, a group of industries largely concentrated around Chembur and domestic wastewater through several point sources stretching between Colaba and Thane. In addition, the industries located around Rasayani release the effluents into Patalganga estuary while those at Nagothane use Amba estuary for effluent disposal. Both these estuaries open into Dharamtar creek which is an inlet of Thane creek. Loading and unloading operations at Mumbai and Jawaharlal Nehru ports and ship-generated wastes including bilge also expected to contribute to the environmental degradation of Thane creek. Back bay, Mahim bay and Versova creek are the recipients of large volumes of domestic wastewaters apart from industries located within their drainage zones.

Several industrial complexes and estates located in Mumbra-Ambarnath segment release wastewater in the Ulhas estuary, directly or indirectly, which opens in the Arabian Sea through the Bassein creek. Salient features of the prevailing water quality, sediment quality and biological characteristics of the coastal marine environment of Mumbai is discussed in this chapter.

## WASTEWATER FLUXES

Reliable estimates of quantities of wastewaters entering coastal waters of Mumbai are not available. Guesstimates vary between  $1.5 \times 10^6$  and  $1.8 \times 10^6$  m<sup>3</sup>/day for domestic wastewater released often untreated or partially treated through point discharges in Thane, Mahim and Versova creeks, Back bay and directly into the Arabian Sea off Worli. The fluxes of various contaminants entering marine zone through domestic wastewater are presented in Table 10.1 based on the flow of  $1.8 \times 10^6$  m<sup>3</sup>/d (Zingde, 1989). These loads are quite significant since they are largely confined to inshore creeks and bays, which due to restricted water exchange, have limited capacity to assimilate pollutants. Thus, for instance though tidal range of 2-4 m generally occurs along the open coast, a spring tide rise of 3 m in Mahim bay decreases to 0.9 m in the outer Mahim creek and becomes negligible a few kilometers inland. Hence, the wastewater released in Mahim creek tends to stagnate and tidal flushing is slow.



**Figure 10.1: Coastal Environment of Mumbai**

**Table 10.1: Wastewater Characteristics and Loads of Contaminants Entering Marine Waters**

Parameter	Average Concentration (mg/l)	Load (kg/d)
Dissolved solids	1500	$2.7 \times 10^6$
Suspended solids	235	$4.2 \times 10^5$
pH	7.0	-
BOD	250	$4.5 \times 10^5$
COD	350	$6.3 \times 10^5$
Total nitrogen	35	$6.3 \times 10^5$
Total phosphorus	6	$1.1 \times 10^4$
Oil and grease	7	$1.3 \times 10^4$
Phenols	0.4	720
Chromium	0.02	36
Manganese	0.6	1080
Iron	2.0	3600
Cobalt	0.03	54
Nickel	0.05	90
Copper	0.08	144
Zinc	0.2	360
Lead	0.05	90
Cadmium	0.01	18

## WATER QUALITY

### Salinity

The salinity of the coastal water is under the influence of land drainage during monsoon though the impact is small beyond 10 m depth contour. During periods of high monsoon precipitation salinities as low as 1 ppt can occur in interior Thane creek, Mahim creek and Ulhas estuary. The high freshwater flow in these creeks enhances the flushing and the environmental quality improves considerably during monsoon. During dry season, however, the fluctuations in salinity in these waters are largely due to wastewater discharges. Thus, in Mahim bay the seawater salinity of 35 ppt intruding the creek during high tide falls below 15 ppt during low tide due to the influences of wastewater. The incomplete mixing of low saline, contaminated creek water and high saline sea water often results in appreciable vertical salinity gradient in some of these creeks. The offshore water however, is generally well-mixed vertically as well as laterally during the dry season.

## **Suspended solids**

The strong tidal currents sweeping the shallow creeks disperse the fine grained and poorly sorted bed and shore sediments into the water column resulting in high suspended solids in water. The load though variable, is generally below 100 mg/l during dry season and increases substantially during monsoon (Zingde *et al* 1989). Off the open coast, the suspended load is generally below 50 mg/l (dry season) and is largely inorganic in nature with organic carbon content of less than 3%. It appears that the load of  $4.3 \times 10^5$  kg/d of BOD associated with domestic wastewater does not contribute substantially to the suspended load in the coastal water though its contribution in Mahim and Versova creeks is high.

## **pH**

Although the pH of openshore water (8.0-8.3) is close to that expected for seawater, a marked decrease occurs in the interior Thane, Mahim and Versova creeks and Ulhas estuary where the fluctuating pH often decreases to less than 7.5 around low tide under the influence of microbial oxidation of organic matter.

## **DO and BOD**

DO in a water body is an important parameter since the existence of aquatic life including fishery is intimately linked with its availability. The sources of DO in water are photosynthesis and dissolution from the atmosphere across the air-water interface. However, the DO is consumed during microbial oxidation of organic detritus which is measured in terms of BOD. Some fraction of DO is also utilized by higher organisms through respiration. Although considerable controversy exists over the levels of DO required for a healthy ecosystem, it is considered that the DO should not fall below 2.5 mg/l for prolonged periods.

Release of large volumes of organic wastes influence DO levels in the creeks substantially as evident from Table 10.2. Generally DO increases with the incursion of tidal water and attains maximum around high tide followed by decrease during ebb with very low values around low tide. Extreme low values in Mahim and Versova creek throughout a tide cycle indicate the severity of pollution in these creeks. Even in Mahim bay where the tidal flushing is appreciable during spring tide, complete depletion occasionally occurs at low tide. The incomplete mixing of contaminated low saline creek water draining into Mahim bay with seawater, often results in steep vertical DO gradient

and it is not surprising to observe bottom DO of as high as 2.5 ml/l when the DO at the surface is close to zero (DOD, 1992). DO in the open-shore water is generally above 3 mg/l but substantially undersaturated even upto 10 km from the shoreline indicating the influence of organic matter even in the offshore region (DOD, 1992). Unpolluted seawater has low BOD of generally less than 3 mg/l. The BOD in the creeks around Mumbai is variable and tide dependent and the values can exceed 20 mg/l in Mahim and Versova creeks. The open-shore water has considerable lower BOD though values as high as 4 mg/l are sometimes encountered.

**Table 10.2: Typical DO at Selected Locations in Coastal Water of Mumbai During Premonsoon**

Location	DO
Thane creek (Bhandup)	0.5-3
Thane creek (Colaba)	2-3
5 km off (Harbour mouth)	2-5
10 km off (Harbour mouth)	3-5
Mahim creek	0-0.5
Mahim bay	0-3
Versova creek (Inner)	0-1.5
Versova creek (Outer)	0-3
Ulhas estuary (Mumbra)	0.5-3
Ulhas estuary (Kasheli)	1.5-3.5
Ulhas estuary (Bassein)	2.5-4
5 km off Ulhas estuary mouth	2-5
10 km off Ulhas estuary mouth	3-5

### Nutrients

Concentrations of  $PO_4\text{-P}$ ,  $NO_3\text{-N}$ ,  $NO_2\text{-N}$ ,  $NH_4\text{-N}$  have increased considerably (DOD, 1992) in the creeks and the levels are often abnormal as compared to the concentrations in the offshore as evident from Table 10.3. The low levels of  $NO_3\text{-N}$  in Mahim creek and Versova creek can be explained on the basis of general mechanism of decomposition of organic matter. When the DO is depleted, the oxidation of organic matter proceeds utilising nitrate; the most efficient oxidant after DO. Hence, in the absence or in presence of low levels of DO, the nitrate entering the creeks during the high tide is consumed after the depletion of DO, leading to low  $NO_3\text{-N}$ . In the absence of DO, nitrate and nitrite, the

oxidation of organic matter proceeds through the utilization of sulphate which is the abundantly available in seawater resulting in the liberation of sulphide and ammonia in Mahim and Versova creeks (Inner). Most marine organisms cannot survive under these conditions (Zingde and Sabnis, 1994).

Nitrite occurs in surface seawater in low concentrations as an intermediate product during the oxidation of ammonia to nitrate. It is evident from Table 10.3 that abnormally high  $\text{NO}_2\text{-N}$  occurs in the interior Thane creek and inner Ulhas estuary. This accumulation of  $\text{NO}_2\text{-N}$  in the system is indicative of an environment under high pollution stress.

**Table 10.3: Typical Levels of Nutrients ( $\mu\text{ mol/l}$ ) at Selected Locations in Coastal Water of Mumbai During Premonsoon.**

Location	$\text{NO}_3\text{-N}$	$\text{NO}_2\text{-N}$	$\text{NH}_4\text{-N}$	$\text{PO}_4^{3-}\text{-P}$
Thane creek (Bhandup)	5-40	3-15	5-10	5-10
Thane creek (Colaba)	2-15	0.2-3	0.2-5	1.5-5
5 km off (Harbour mouth)	3-15	0.2-2	0.2-1	0.5-4
10 km off (Harbour mouth)	1-10	0.1-1.5	0.1-1	0.5-3
Mahim creek	0-5	0-10	10-80	5-25
Mahim bay	0.5-20	0.5-3	3-30	3-15
Versova creek (Inner)	0-2	0-5	15-50	10-70
Versova creek (Outer)	0.1-15	0.1-10	5-30	5-40
Ulhas estuary (Mumbra)	25-40	5-20	3-15	5-20
Ulhas estuary (Kasheli)	15-30	5-15	0.5-10	5-15
Ulhas estuary (Bassein)	10-25	0.5-3	0.1-3	3-10
5 km off Ulhas estuary mouth	5-15	0.1-1	0.1-2	0.5-2
10 km off Ulhas estuary mouth	1-10	0.1-1	0.1-1	0.5-2

### Heavy metals

The available information indicates that the levels of dissolved Co, Ni, Cu, Zn, Pb and Hg are highly variable. The trends, however, suggest probable marginal increase in inshore waters as compared to that along the openshore (Sahu and Bhosale, 1991).

### Petroleum Hydrocarbons

Although the inshore waters, particularly Thane creek receives high fluxes of petroleum contaminating wastes from refineries, tanker washings, loading and unloading operations

of crude oil and petroleum products, the levels in water (1 m below surface) are relatively low ( $< 10 \mu\text{g/l}$ ). It is possible that the PHC entering the water is scavenged by the high suspended load and removed from the water column.

## **SEDIMENT QUALITY**

Pollutants such as trace metals, some organics, phosphorus etc. get adsorbed on the particulate suspended matter and transferred to the bed sediment on settling. Hence, the character of the bed sediment has changed considerably in inshore water bodies with considerable enrichment of certain pollutants in the surficial sediment. This is clearly evident from Figure 10.2 in which depthwise variation of trace metals, organic carbon (OC) and total phosphorus (TP) in a core from Mahim creek is illustrated. The surface concentration of Cu is as high as 800 ppm and that of Zn exceeds 2500 ppm as against 180 and 400 ppm respectively associated with the bottom segment of the core probably since the bottom sediment would have deposited when the creek was relatively free from pollution. Organic carbon, Total phosphorous and Pb also reveal high accumulation. Similar trends have also been observed in cores obtained from certain locations from Thane creek though the metal accumulation is not to the extent expected considering the fluxes entering the system (Sharma *et al* 1994). It has been estimated that the top 20 cm sediment in Mahim creek contains 1.3 t Ni, 37 t Cu, 100 t Zn and 4.6 t Pb in excess over the expected background (Sabnis, 1984). Surficial sediment from Ulhas estuary also have higher burden of Cr, Zn, Pb and Hg (Bhosale and Sahu, 1991).

In Thane creek, the total Hg concentration in the surface sediment varies from 0.17 to 8.21 ppm with definite enrichment in the inner creek. An excess of 14 t Hg over the natural background has been estimated to be trapped in these sediments (Zingde and Desai, 1981). The sediment from Thane creek also reveal marked enrichment of PHC in surficial layers and values exceeding  $3 \mu\text{g/g}$  (wet wt) are common. The contamination of open-shore sediment, however, is low.

## **BIOLOGICAL CHARACTERISTICS**

### **Microbiology**

Microbiological results (Table 10.4) indicate very high total viable count (TVC) in the creek systems of Versova, Mahim and Thane as compared to openshore waters (DOD, 1992). The population of total coliforms (TC) and many of the pathogens in these creeks



exceed the required water quality standards and the bacterial contamination of the sea food is a distinct possibility since, these creeks serve as recognised landing centres for fish. Indiscriminate release of domestic wastewater is largely responsible for the prevailing microbial contamination of the coastal water.

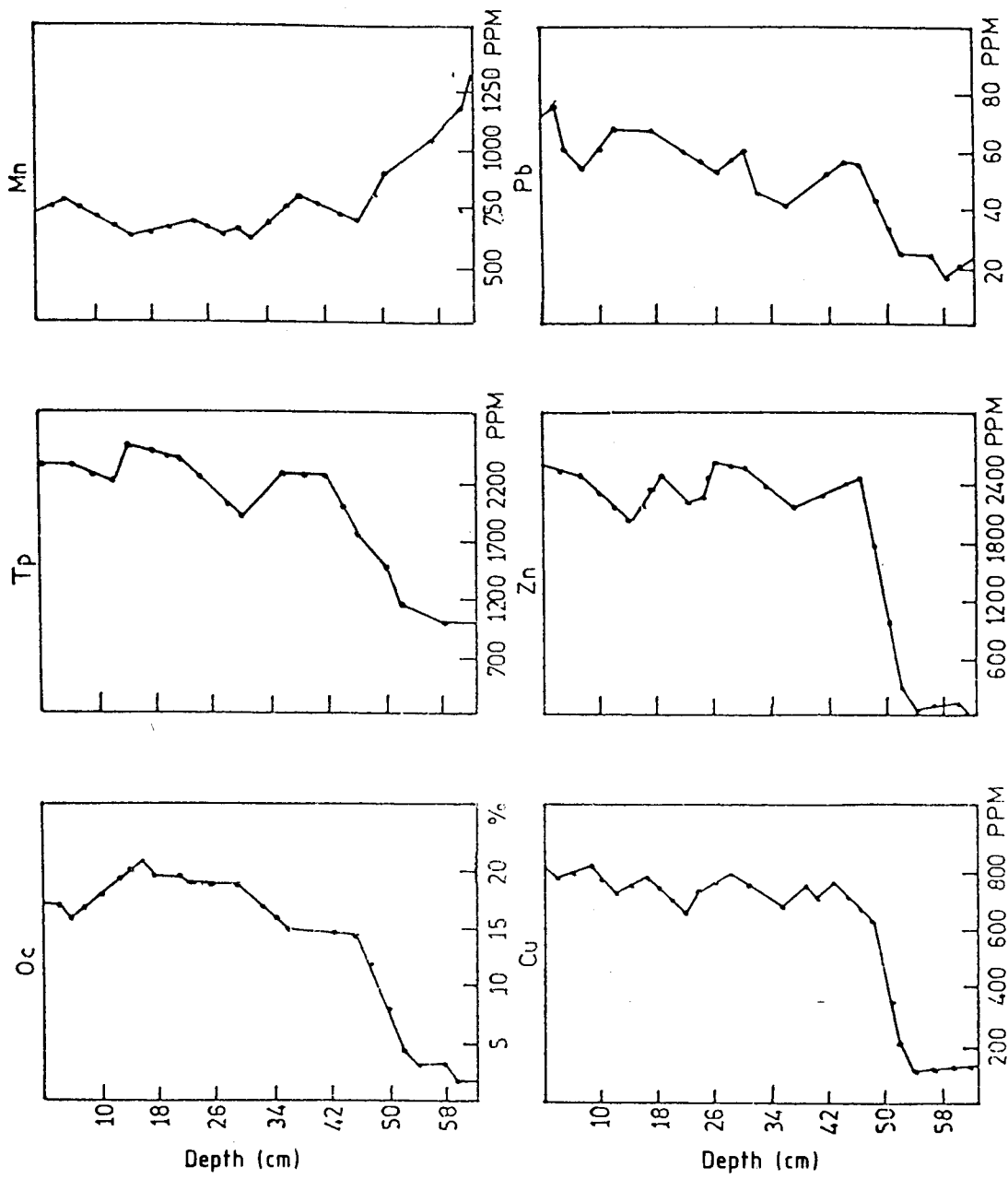
**Table 10.4: Populations (no/ml) of Some Microorganisms in Seawater Around Mumbai (Flood Tide Value in Parenthesis).**

Bacteria type	Thane creek	Mahim bay	Versvova creek	Offshore
TVC	228000 (5600)	800000 (2900)	290000 (69000)	39
TC	9800 (210)	11000 (72)	9000 (79000)	6
ECLO	3200 (60)	6000 (26)	5600 (3600)	1
SHLO	2800 (110)	2000 (32)	3100 (400)	1
SLO	300 (-)	1000 (2)	600 (100)	-
PKLO	100 (40)	12000 (28)	1600 (-)	1
VLO	7600 (240)	1000 (56)	8200 (2300)	4
VPLO	2900 (30)	- (-)	400 (200)	-
VCLO	3900 (110)	200 (34)	5400 (1400)	-
PALO	4200 (70)	-- (21)	6600 (4200)	1
SFLO	6400 (70)	6000 (150)	8100 (7300)	2

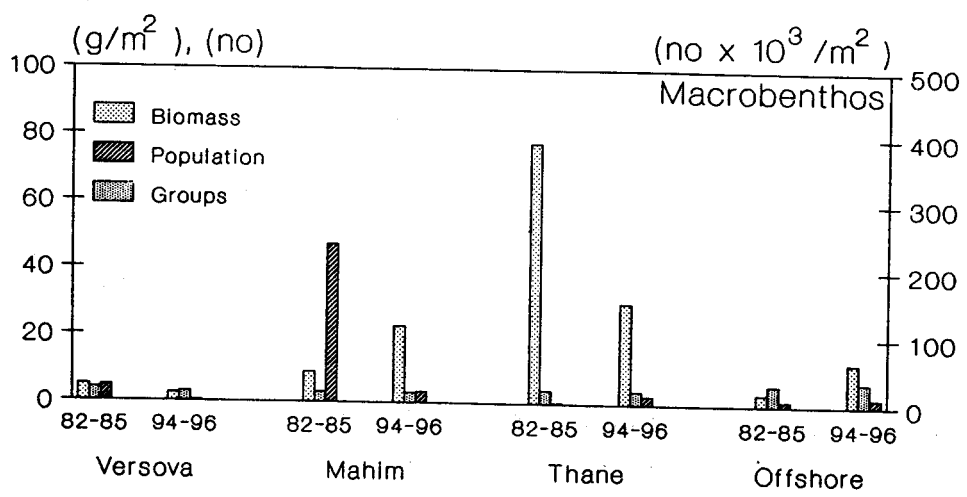
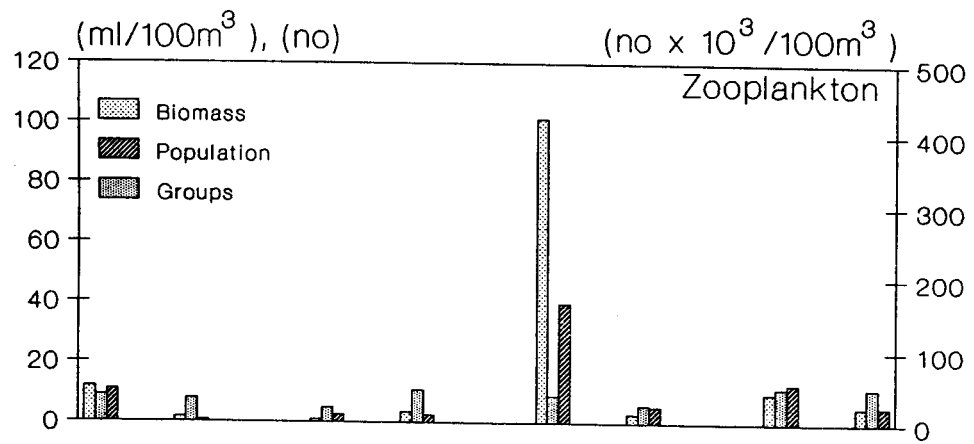
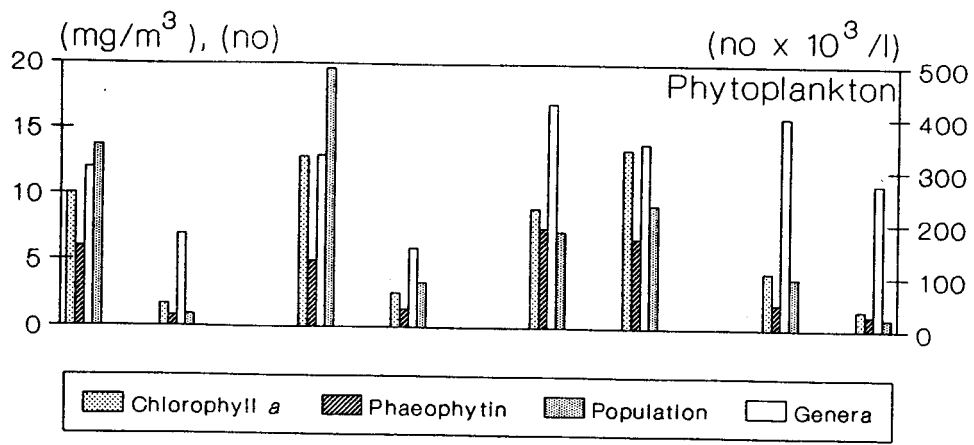
TVC - Total viable counts; TC - Total coliforms; ECLO - *Escherichia coli* like organisms; SHLO - *Shigella* like organisms; SLO - *Salmonella* like organisms; PKLO - *Proteus klebsiella* like organisms; VLO - *Vibrio* like organisms; VPLO - *Vibrio parahaemolyticus* like organisms; VCLO - *Vibrio cholerae* like organisms; PALO - *Pseudomonas aeruginosa* like organisms; SFLO - *Streptococcus faecalis* like organisms.

### Phytoplankton and phaeopigments

The creek systems, in general, reveal higher concentration of phaeopigments and phytoplankton counts as compared to openshore (Figure 10.3) due to higher nutrients availability associated with sewage pollution. However, the diversity of phytoplankton is relatively low as compared to the offshore coastal system. Mahim and Versova creeks



**Figure 10.2: Depth Distribution of Organic C, P, Mn, Cu, Zn and Pb in the Core from Interior of Mahim Creek**



**Figure 10.3: Comparison of Phaeopigments, Phytoplankton, Zooplankton and Macrobenthos between 1982-85 and 1995-96.**

sustain relatively less diversity as compared to Thane creek. The trends indicate a reduction in the concentration of phaeopigments and phytoplankton counts and diversity, especially in Versova and Mahim creeks in recent years when compared with the past results (Figure 10.3). A change in generic dominance of phytoplankton (Table 10.5) between 1982 and 1996 is also evident (Ram, 1985; DOD, 1996). This could be due to the response of tolerant species to the change in pollution stress. However, Thane creek shows an increasing trend in phaeopigment values and phytoplankton counts during recent years than the past.

**Table 10.5: Composition of Phytoplankton in Versova and Mahim Creeks**

Versova		Mahim	
1982	1996	1982	1996
<i>Nitzschia</i>	<i>Oscillatoria</i>	<i>Oscillatoria</i>	<i>Skeletonema</i>
<i>Thalassiosira</i>	<i>Skeletonema</i>	<i>Nitzschia</i>	<i>Nitzschia</i>
<i>Oscillatoria</i>	<i>Nitzschia</i>	<i>Thalassiosira</i>	
<i>Chaetoceros</i>		<i>Navicula</i>	
<i>Navicula</i>			

### Zooplankton

The creek systems are characterised by wide fluctuations in the standing stock of zooplankton (Figure 10.3) with lower faunal diversity as compared to openshore. Unlike polluted creeks, openshore water reveals higher incidence of siphonophores, lamellibranchs, appendicularians and fish larvae (Nair and Govindan, 1986). Abundance of carnivores like medusae, ctenophores, mysids and polychaetes are the characteristic of polluted creeks. A reduction in zooplankton standing stock of Versova and Thane creeks during 1995-96 as compared to 1982-85 is evident from Figure 10.3. A marginal increase in zooplankton biomass at Mahim during 1995-96 (DOD, 1996) than 1982-85 could be due to the dominance of carnivores like medusea and ctenophores which are abundant in the polluted creek systems (Nair and Govindan, 1986).

### Macrobenthos

The standing stock of macrobenthos in terms of population reveals wide fluctuations in the polluted creek systems around Mumbai. The macrobenthic biomass however, is relatively higher in Mahim and Thane creeks as compared to Versova creek (Figure

10.3). Benthic biomass is moderate in the openshore regions though the faunal group diversity shows improvement. The high standing stock of benthos usually encountered in the polluted creeks could be due to the enrichment of sediments with high detrital materials through high primary productivity of the water column, and the particulate matter rich in organic matter associated with domestic wastewater settling on the bed. The benthic filter feeders and deposit feeders conveniently make use of the rich carbon availability through the food chain. Hence, in many instances (Varshsney, 1982) the enhancement of primary production subsequently increases the benthic faunal potential. However, inspite of enhanced benthic faunal potential of selected pollution tolerant groups, a decrease in species diversity (H) of polychaetes at Thane (0.67) as compared to coastal waters (1.84) away from the creek, is evident (Annie and Govindan, 1995). Species composition of polychaetes in general is inhibited at the zones which are under severe pollution stress which can be attributed to the signs of ecological imbalance of the ecosystem (Armstrong *et al* 1981).

Pollution leads to a lower growth rate condition index and percentage edibility of intertidal molluscs from Mumbai (Krishnakumari *et al.*, 1990; Fernandes 1991). Higher levels of bioaccumulation of trace metals and PHC in the tissues of intertidal gastropods from highly polluted regions like Worli as compared to Madh and Colaba have also been reported (Fernandes 1991).

### **Fishery**

The openshore waters (DOD, 1992) sustain moderate fishery potential (5.25 kg/h). The abundance of fish eggs and larvae increases towards the offshore from the coastal inshore and creek regions. Higher productivity at the primary and secondary levels is expected to increase the pelagic fishery potential especially within the creek systems. However, the high productivity at the primary and secondary levels in the creek systems is mainly induced by pollution and supported by proliferation of pollution tolerant species which need not necessarily end up with high tertiary production. In other words, the high productivity in lower trophic levels due to pollution is not entirely utilized at tertiary level to induce the expected fishery potential. Since most of the tertiary producers are highly mobile and sensitive to environmental stress, they can easily avoid such polluted systems which cause under utilization of prevailing high biomass at the lower trophic level resulting in low ecological efficiency (Varshney *et al.* 1982-83) in terms of transfer coefficient values (Table 10.6). Hence, these polluted creek systems with poor fishery

potential should be classified as special ecosystem where the normal trophic conversion factor of 10% is not applicable.

**Table 10.6: Observed and Estimated Biological Productivity in Different Creeks.**

Station	Observed PP (tc/km <sup>2</sup> /y)	Estimated SP (tc/km <sup>2</sup> /y)	Observed SP (tc/km <sup>2</sup> /y)	TC (%)	Estimated fishery potential (tc/km <sup>2</sup> /y)		
					Based on PP	Based on SP	Mean PP& SP
Versova creek	172.6	17.3	7.9	4.6	12.9	5.9	9.4
Versova offshore	138.9	13.9	10.6	7.6	10.4	8.0	9.2
Mahim creek	120.9	12.1	7.2	5.9	9.0	5.4	7.2
Thane creek	194.3	19.4	17.2	8.9	14.5	12.8	13.7

*Note:* PP- Primary Productivity; SP- Secondary Productivity; TC- Transfer Coefficient

### Bioaccumulation of trace metals

Marine organisms at different trophic level indicate bioaccumulation of selected trace metals like Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb and Hg through the marine food chain. Zooplankton like copepods and chaetognaths from various creek systems around Mumbai shows (Nair and Govindan, 1986) different levels of body burden of trace metals (Figure 10.4). Higher body burden of metals like Cu and Mn at Mahim, and Co and Ni at Thane is evident. Copepods concentrate higher levels of many of these trace metals as compared to chaetognaths indicating regional and species differences in bioconcentration. In case of benthic invertebrates, the concentration of metals is relatively more in polychaetes than decapods (Figure 10.5).

Bioaccumulation of Fe, Zn and Pb in polychaetes is more in Thane creek as compared to Mahim and Versova creeks. The decapods concentrate higher levels of Cd and Pb in Thane creek as compared to other creek systems. The bioaccumulation of metals at the higher level of food chain, viz. the fishes, shrimps (crabs and prawns) and molluscs in Thane creek also occur. Bioconcentration of metals in molluscs is relatively more as compared to shrimps and fishes. In general, the concentration of various trace metals in fishes and shrimps is considerably low as compared to marine organisms at the

lower trophic levels like zooplankton and benthos. However, bioconcentration of metals like Cu, Zn, Cd, Pb and Hg in fishes from Thane creek, though low, pollution induced metal burden at the tertiary level of the food chain is quite clear. The increase in pollution load is likely to cause increase in body burden of metals in marine organisms of the creek system which is not desirable. Proper pollution control and monitoring of various creek systems around Mumbai are become imminent.

## **CONCLUSIONS**

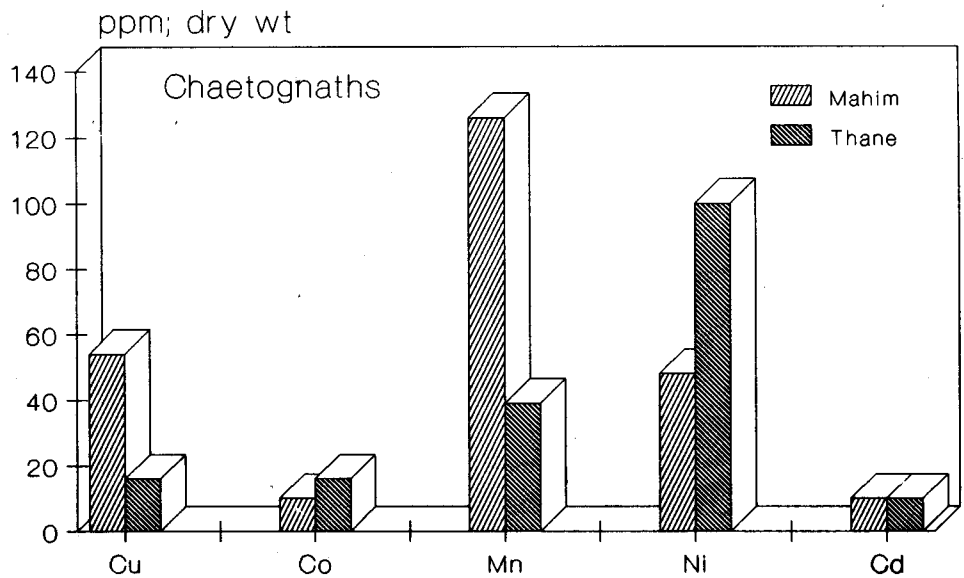
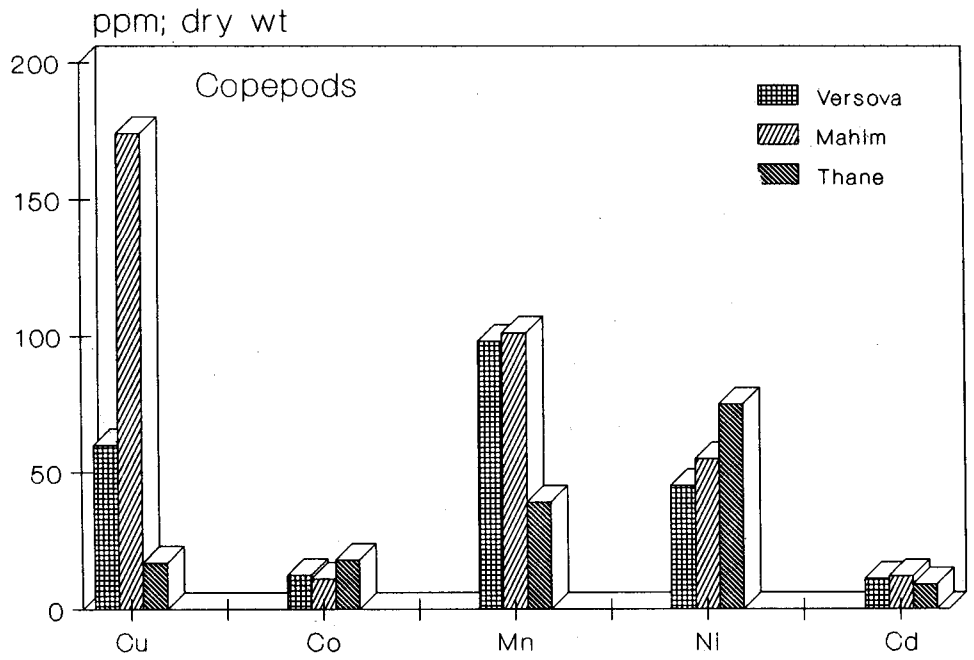
Domestic and industrial wastewater released indiscriminately have severely deteriorated the water quality of Mahim, Versova and inner Thane creeks and Ulhas estuary. Intermittent or total depletion of DO, active denitrification and liberation of hydrogen sulphide in onshore waters indicate the severity of pollution due to the fluxes of organic loads which far exceed the assimilation capacity of these creeks. The openshore waters though sustain the signatures of contaminants drained through the creeks, bays and estuaries are relatively clean.

Transport of pollutants from the water column to the bed has modified the sediment character to a marked extent in the inshore waters with high levels of trace metal, OC and TP and sometimes PHC in the surficial sediment.

The biotic features indicate very high bacterial contamination, enhanced concentration of phaeopigments and phytoplankton counts with low generic diversity, wide fluctuations in zooplankton standing stock with higher abundance of carnivores and low faunal diversity, increased abundance of macrobenthos with reduced diversity and lower fishery potential especially of the polluted creek as compared to offshore coastal system. Bioaccumulation of selected trace metals in zooplankton, benthos and fishes especially in the creek systems reveals slow build up of metal burden through the food chain. Hence, alternate mode of waste disposals with strict pollution control measures to ensure the health of the creek systems around Mumbai is warranted.

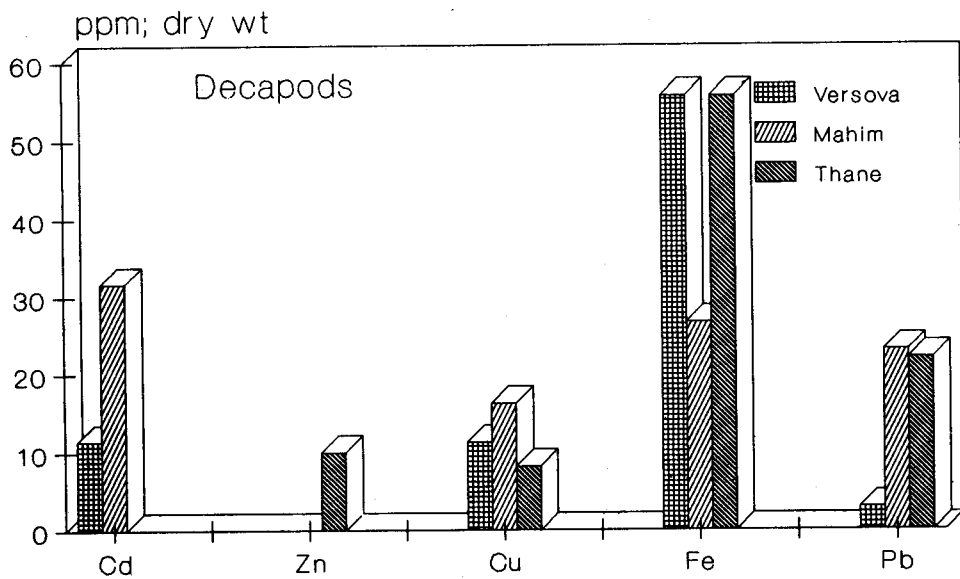
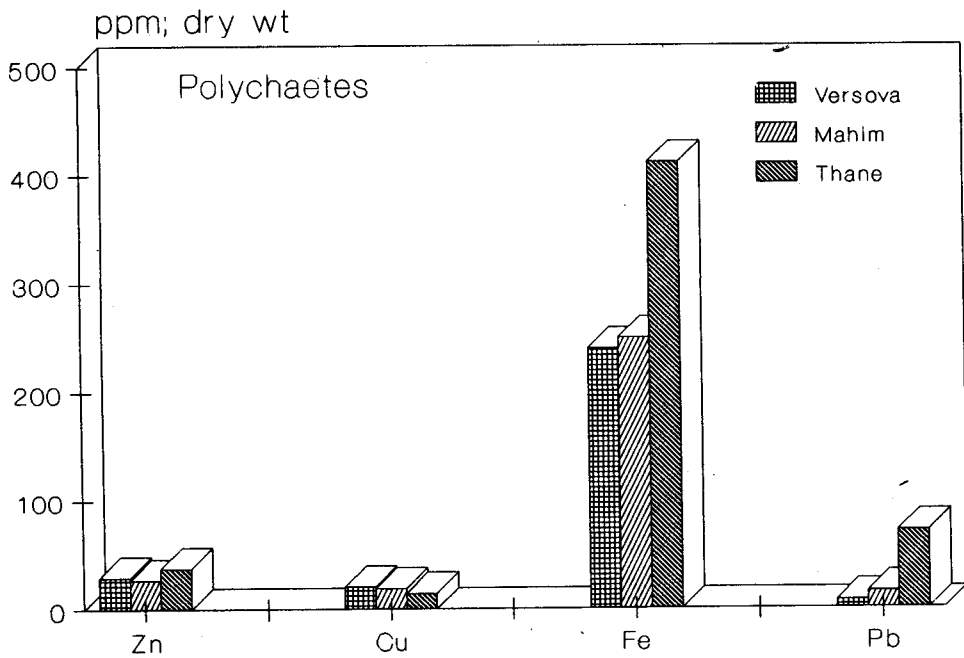
## **ACKNOWLEDGEMENT**

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**Figure 10.4: Average Concentration of Trade Metals in Zooplankton of the Creek Systems.**





**Figure 10.5: Average Bioaccumulation of Trace Metals in Benthic Organisms of Mumbai (Varshney 1982).**

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