

5.1 *Environmental Pollution in Coastal Areas of India*

R. SEN GUPTA, SUGANDHINI NAIK AND V. V. R. VARADACHARI

5.1.1 ADDITIONS FROM LAND

The chemistry and biology of coastal waters are very vulnerable to additions of biodegradable and stable compounds from land. It has been estimated (Qasim and Sen Gupta, 1983) that in 1984, 5 million tonnes of fertilizers, 55 000 tonnes of pesticides, and 125 000 tonnes of synthetic detergents were used in India (Table 5.1.1). Roughly about 25% of all these can be expected to ultimately end up in the sea every year. Some of these substances are biodegradable while others are persistent. Their cumulative effect over a long period could be quite harmful to the coastal marine environment. These effects are, as yet, not very perceptible over all the Indian coast. But near a few big cities and industrial conglomerates the effects are, indeed, becoming near disastrous. In the 15 years from 1959 to 1974 phosphate-phosphorus concentration in the nearshore waters of Bombay increased from 0.82 to 1.13 $\mu\text{mol/l}$, i.e. by about 40% (Sen Gupta and Sankaranarayanan, 1975). The present concentration (1984) is around 2 $\mu\text{mol/l}$ (Zingde, 1985). The dissolved oxygen concentration decreased from 4.71 ml/l to near zero in 1983 (Parulekar *et al.*, 1986). High values of phosphate-phosphorus have also been observed at nearshore Madras (Sen Gupta, unpublished data).

Similar situations can be expected to have taken place with regard to some toxic heavy metals. Indian rivers annually add about 1600 million tonnes of sediment to the seas around (Holeman, 1968), a major portion of which can be expected to settle in the nearshore regions. Most of the heavy metals are transported to the sea this way. This can be illustrated by our observations in the estuarine regions of River Hooghly. These were carried out in September when the freshwater runoff, and consequently suspended solids, can be expected to be maximum. Several heavy metals were analysed in suspended sediments, collected by filtering a large volume of water, from two stations every three hours over two tidal cycles in the final 125 km stretch of the river. The mean concentration of metals came to 2.14% of suspended solids on a wet weight basis.

Table 5.1.1 Population, related data, and some estimates of pollutants entering the sea around India (as of 1984)

Population	720 million
Coastal population (25% of total)	130 million
Area of the country	3.276 million km ²
Agricultural area	1.65 million km ²
Exclusive economic zone	2.015 million km ²
River runoff (annual mean)	1645 km ³
Rainfall per year (on land)	3500 thousand million m ³
Rainfall per year (on Bay of Bengal)	6500 thousand million m ³
Rainfall per year (on Arabian Sea)	6100 thousand million m ³
Domestic sewage added to the sea by coastal population per year (at 60 l per head per day)	3900 million m ³
Industrial effluents added to the sea by coastal industries per year	390 million m ³
Sewage and effluents added by the rivers to the sea per year	50 million m ³
Solid waste and garbage generated by coastal population per year (at 0.8 kg per head per day)	53 million tonnes
Fertilizer used per year (at 30.5 kg/ha/year)	5 million tonnes*
Pesticides used per year (at 336 g/ha/year)	55 000 tonnes*
Synthetic detergents used per year	125 000 tonnes*
Oil transported across the Arabian Sea in 1983	513 million tonnes
Oil transported to Western Hemisphere in 1983	291 million tonnes
Oil transported to Far East and Japan in 1983	222 million tonnes
Tar deposition on beaches along the west coast of India per year	750-1000 tonnes

*Approximately 25% of this amount is expected to end up in the sea

Another set of similar observations was carried out at three stations, spread over a distance of about 80 km, in the region of the river mouth. The mean concentration of metals at the westernmost station, which is in the direction of the main outflow from the river, was 1.91% of suspended solids. However, if the mean value of observation at all the three stations is taken the concentration of metals comes to 1.45% of suspended solids. This would mean that approximately 11-32% of the metals in suspended form can be expected to settle to the bottom at the confluence of the River Hooghly and the Bay of Bengal.

5.1.2 SEWAGE AND EFFLUENTS

Domestic sewage and industrial effluents are discharged in the water courses in and around India in untreated or partially treated form. These, naturally, add

a variety of pollutants which include, among others, certain toxic heavy metals and metalloids. The total volume of all discharges from the environs of Bombay is around 365 million tonnes (MT) per year (Sabnis, 1984). Similar discharges from the environs of Calcutta are around 350 MT every year (Ghose *et al.*, 1973). These figures would, perhaps, help towards ascertaining the total volume of domestic sewage and industrial effluents generated and released in India.

The expected composition of such discharges is presented in Table 5.1.2. The data are from the annual releases to the Mahim River bay and creek in the city of Bombay (Sabnis, 1984). The Bay occupies an area of 64 km² and is influenced by semi-diurnal tide with a maximum height of 3 m. It once had good fisheries and an oyster bed, and its fringing mangroves used to be visited by migratory birds. Today it is one of the most industrialized and densely populated areas of Bombay. Birds hardly flock there and the fisheries are dead, as no fauna can survive in the toxic environment. The Bay receives 64 MT domestic sewage and 0.9 MT industrial effluents every year. These discharges were initially untreated, but are now partially treated. The resulting concentration of H₂S-S in waters of the Bay ranges from 1.5 to 98.4 μmol/l, depending on the stages of the tide. The release of effluents of hydrocarbon origin has so heavily contaminated the creek that it has become common practice to recover the oil by soaking sorbents. Geochronology of sediments using ²¹⁰Pb gave the maximum period since deterioration started as 54 years, which is roughly about the time when pumping of untreated sewage into the river started.

5.1.3 TOXIC METALS IN MARINE BIOTA

It may be assumed, perhaps, that due to the discharge of such a large volume of contaminants, concentrations of heavy metals in the marine biota around India

Table 5.1.2 Pollutants discharged into Mahim Bay (Bombay) every year (in tonnes). From Sabnis (1984)

Dissolved solids	92 619
Chlorides	37 495
BOD	16 480
Suspended solids	15 649
Sulphates	4 791
Nitrogen	2 236
Phosphorus	383
Iron	162
Manganese	32
Zinc	16
Copper	7
Nickel	5
Cobalt	2
Lead	0.7

will be fairly high. That such is not yet the case can be seen from the values presented in Table 5.1.3, which presents the concentrations of heavy metals in zooplankton and in muscles of fishes of commercial importance, including sharks. It can be seen from the table that concentrations of almost all of the metals, particularly the toxic metals Pb, Cd, and Hg, are within the permissible limits for human consumption. It has also been observed that concentrations of all these metals in the livers of the dolphin, barracuda, shark, skipjack tuna, and yellowfin tuna are significantly higher than in their muscles. This indicates that most of these metals are assimilated by these fishes in a fat-soluble form. Acceptable correlation with their sex, size, and stage of maturity was observed in the different fish tissues.

The absence of mercury in zooplankton indicates that the metal is assimilated by fishes, probably by other pathways of the marine food chain. Mercury concentrations in the muscles of sharks and skipjack tuna are the highest of all the values (Table 5.1.3). Concentrations of the toxic heavy metals, Hg, Cd, and Pb, in different tissues of the fishes (Table 5.1.4) indicate that their highest occurrence is in the liver and the kidney. However, the highest concentrations of mercury, observed in muscles, are still much lower than the internationally permissible maximum of 0.5 ppm for human consumption. Analyses of mercury in the muscles of several commercially important fishes from the inshore regions and from a polluted creek in and around Bombay in 1975 gave values ranging from 0.04 to 0.57 ppm on a fresh weight basis (Tejam and Haldar, 1975). A high concentration of mercury, 0.2–7.3 ppm on a fresh weight basis, was observed in muscles of crab from the same area in 1980 (Ganeshan *et al.*, 1980).

5.1.4 PESTICIDES RESIDUES

India is predominantly an agricultural country. Large quantities of pesticides, herbicides, fungicides, etc. are used in agriculture and disease-vector control. Their residues will ultimately find their way into the sea. Organophosphorus pesticides will undergo biodegradation, but the organochlorines and polychlorinated biphenyls are persistent in the marine environment. Their main transport route to the sea is through the atmosphere, while a part may also be transported with sewage and effluents.

A few measurements of DDT and its isomers (expressed as t-DDT) have been conducted in zooplankton and water from the eastern part of the Arabian Sea and from the air over it. During a series of observations in 1978, concentrations of t-DDT were found to vary from 0.05 to 3.21 ppm wet weight in zooplankton samples from the eastern Arabian Sea (Kureishy *et al.*, 1978). A recent observation from the same area (Kannan and Sen Gupta, 1987) in a few zooplankton samples indicated values from 0.379 to 1.63 ppm wet weight. Both the sets of values, however, indicated a relatively decreasing trend from nearshore to offshore regions (Figure 5.1.1). Concentrations of t-DDT in the waters of

Table 5.1.3 Concentration ranges of a few essential and non-essential heavy metals (ppm wet weight) in zooplankton, crustaceans, bivalves and muscles of certain fishes from the northern Indian Ocean. ND = not detectable. Sources: Kureishy *et al.* (1979, 1981, 1983)

	Essential heavy metals							Non-essential heavy metals						
	Cu	Fe	Mn	Zn	Ni	Co	Pb	Cd	Hg					
Zooplankton	2.0-5.0	35.0-94.0	3.0-7.0	8.0-31.0	0.2-3.0	ND-4.0	1.0-12.6	0.02-5.99	ND					
Prawns (6 spp.)	3.5-24.0	-	-	-	-	ND-4.0	1.0	<0.2-2.5	ND-0.17					
Crabs	0.7-13.5	-	-	-	-	-	<1.0	0.61-1.12	0.004-0.01					
Clams	-	-	-	-	-	-	1.28	1.66	0.06					
Oysters	45.0	-	-	-	-	-	<1.0	1.36	0.02					
Mussels	-	-	-	-	-	-	1.31	1.38	0.09					
Flying fish	0.1-0.7	4.0-62.0	ND-3.7	4.0-21.0	ND-0.9	0.2-1.3	1.8-5.76	ND-0.65	ND-0.07					
Silver bellies	1.0-1.6	-	-	-	-	-	<1-3.21	0.58-2.11	0.0001-0.01					
Malabar anchovies	4.4	-	-	-	-	-	<1	0.7	0.01					
Sardines (2 spp.)	0.03	8.0-10.0	0.2	4.5-6.3	-	0.7-1.1	<1	ND-0.62	ND-0.01					
Mackerel (2 spp.)	1.0-1.3	12.0	0.01	6.0	ND	1.8	<1	0.22-1.62	0.01-0.02					
Jew fish (2 spp.)	ND-0.8	6.0-8.0	0.3-10.0	4.0-4.8	ND	0.7-1.1	<1-1.14	0.19-0.42	0.006-0.01					
Perch (3 spp.)	0.2-0.7	6.0-29.0	ND-0.1	3.4-6.1	0.3-0.5	ND	<1	ND-1.47	0.007-0.1					
Pilot fish	0.1-4.9	-	-	-	-	-	<1-2.95	ND-0.83	ND-0.02					
Scianid (2 spp.)	0.1-0.3	-	-	-	-	-	<1	0.86-1.36	ND-0.02					
Sole	-	-	-	-	-	-	<1	0.35	0.01					
Pomfret	-	-	-	-	-	-	<1	0.73	0.01					
Catfish	-	-	-	-	-	-	<1.02	0.92	0.06					
Trevally (2 spp.)	ND-0.7	5.0-11.0	0.1-9.0	2.0-5.0	ND-0.6	ND-1.2	<1	ND-0.62	0.018-0.08					
Grunter	0.36	-	-	-	-	-	2.7	ND	0.24					
Talang	0.4	-	-	-	-	-	<1	ND	0.36					
Tuna (4 spp.)	0.3-3.0	7.0-164	-	-	-	-	<1	ND	0.06					
Dolphin	0.2-1.7	0	0.1-7.5	4.0-12.0	ND-4.0	ND-3.2	<1-3.3	ND-2.00	0.004-0.22					
Seer fish	0.4	13.0-39.0	ND-3.1	5.0-9.0	0.1-1.2	ND-1.9	<1-2.95	ND-0.95	0.01-0.14					
Barracuda	0.1-0.5	4.0-17.0	0.2-3.1	3.3-5.8	0.1-0.3	0.6-1.9	<1	0.25-0.66	0.09-0.11					
Sea pike	-	-	-	-	-	-	1.46	ND	0.06-0.2					
Sharks (4 spp.)	0.14-1.1	10.0-57.0	ND-2.0	4.5-12.0	ND-0.3	ND-3.8	<1-6.02	ND-0.81	0.02-0.21					

Table 5.1.4 Ranges and average concentrations of a few toxic heavy metals (ppm wet weight) in different body parts of fishes from the northern Indian Ocean. ND = not detectable. Source: Kureishy *et al.* (1979, 1981, 1983)

Body parts	Mercury		Cadmium		Lead	
	Range	Average	Range	Average	Range	Average
Muscle	ND-0.36	0.07	ND-3.24	0.59	1-3.43	1.11
Liver	ND-0.04	0.01	1.2-87.3	20.18	1-17.62	3.8
Gill	ND-0.03	0.016	ND-0.76	0.42	1-7.0	3.14
Heart	ND-0.08	0.026	ND-1.91	0.54	1-3.4	1.36
Kidney	ND-0.04	0.015	0.38-36.69	9.02	1-69.46	8.61
Gonads	ND-0.03	0.015	ND-8.06	1.25	1-4.76	1.36

the eastern Arabian Sea were from 0.06 to 0.16 ng/l while those in the air over the same area varied from 0.93 to 10.9 ng/m³ (Tanabe and Tatsukawa, 1980). These observations would clearly indicate that residues of organochlorines in the marine environment of the Arabian Sea are cause for concern.

5.1.5 PETROLEUM HYDROCARBONS

In 1983 the global marine transport of oil was 1206 MT, of which 513 MT (42.5% of the total) was shipped from the Gulf countries (British Petroleum, 1984; Sen Gupta and Qasim, 1985). The main routes of marine transport of oil from the Gulf countries are across the Arabian Sea. One of these is through the Mozambique Channel around South Africa to the Western Hemisphere; while the other is along the west coast of India, around Sri Lanka, across the southern Bay of Bengal, through the Malacca Strait to the Far East, including Japan. In 1983, 291 MT of oil was shipped to the Western Hemisphere and 222 MT to the Far East, including Japan, from the Gulf countries. This, coupled with increasing emphasis on offshore oil exploration in many countries in the area, makes the northern Indian Ocean very vulnerable to oil pollution.

Oil pollution is caused both by accidents and by operational discharges, e.g. tanker disasters, ballast water, and bilge washings. The presence of about 75% of oil in the marine environment is due to operational discharges. Fortunately, only a few tanker disasters have occurred along these routes so far.

The effects of oil pollution on the sea are: presence of oil slicks; dissolved/dispersed petroleum hydrocarbons; floating petroleum residues (tar balls); and tar on beaches. A total of 6689 observations on oil slicks and other floating pollutants revealed positive results for oil slicks on 5582 or 83.5% of the total (Sen Gupta and Kureishy, 1981).

A summary of observations on floating petroleum residues (tar balls) from the surface of the Arabian Sea is presented in Table 5.1.5. The concentrations vary in time and space; they are occasionally very high along the tanker routes. In the Arabian Sea the concentrations range from 0 to 6.0 mg/m² with a mean

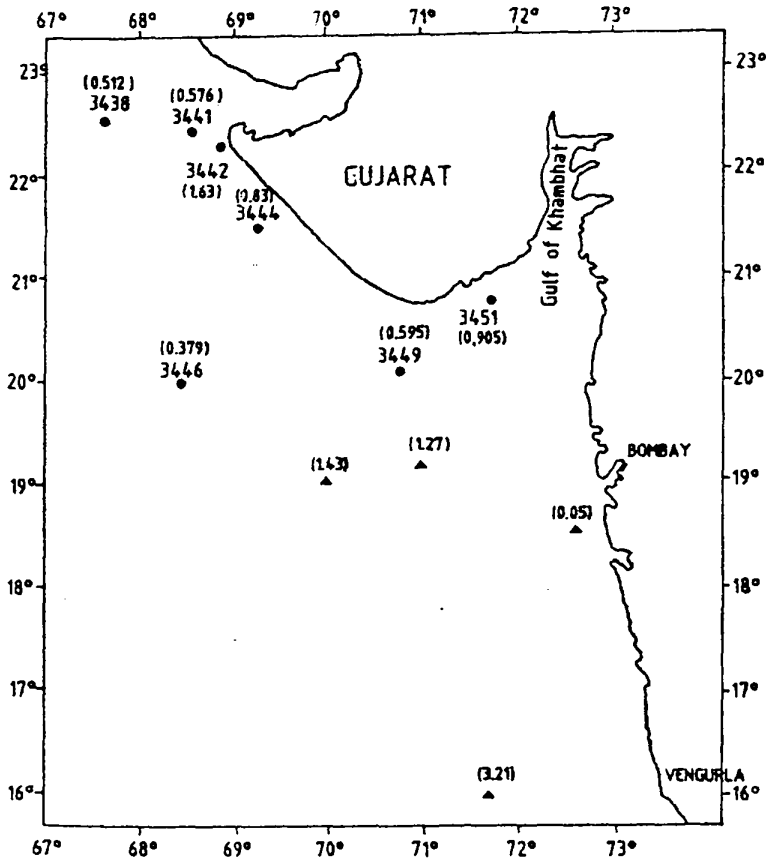


Figure 5.1.1 Points of observation for t-DDT in zooplankton. Numbers in parentheses are concentrations in ppm wet weight

of 0.59 mg/m². The range on the Bay of Bengal tanker route varies from 0 to 69.75 mg/m², with a mean of 1.52 mg/m². This would indicate that the tanker route across the southern Bay of Bengal is relatively more polluted than those across the Arabian Sea.

A number of observations were taken along the western-bound tanker route across the Arabian Sea during June–September 1983 (Table 5.1.5). Near absence of floating tar particles in this area during this period was expected, as the surface currents of the Arabian Sea normally flow towards the Indian west coast during the southwest monsoon months (June–September).

Table 5.1.5 Dissolved/dispersed hydrocarbons, particulate petroleum residues (tar balls) in, and transport of oil across the Arabian Sea. ND = not detectable; PI = presence indicated

Month/year	Dissolved/dispersed hydrocarbons ($\mu\text{g/l}$)			Tar balls (mg/m^2)
	0 m	10 m	20 m	
March 1978	0.6-22.9	0.9-18.1	25-28	0.02-0.32
June 1978	-	-	-	1.26-3.46
December 1978	21.5-42.8	16.8-42.5	28.6-37.5	0-0.54
May 1979	-	-	-	0.09-6.0
December 1979	18.6-41.6	16.9-34.15	10.4-24.9	-
February 1980	6.4-9.0	3.1-6.3	2.4-4.5	0-0.53
October 1980	47-230	77-210	-	-
November 1980	2.6-55.6	1.9-36.0	-	-
January 1981	4.0-9.5	ND-2.5	-	-
March 1981	200-305	130-277	-	0.30-112.2
February 1982	-	-	-	0-0.06
January 1983	9.7-24.2	6.7-13.2	2.2-7.2	0-0.06
July 1983*	3.0-8.9	ND-1.2	ND-1.0	0-PI
September 1983*	7.4-16.2	3.4-8.5	ND-1.2	0-PI
October 1983*	5.7-10.6	2.1-5.4	ND-1.1	0-PI
November 1983*	5.1-12.4	1.4-6.1	ND-1.6	-
May 1984	22.9-114.6	18.6-62.2	18.9-72.0	0-0.06

Transport of Oil	
Year	Volume (million tonnes)
1977	1024.4
1978	974.9
1979	1009.6
1980	869.3
1981	725.4
1982	578.7
1983	512.9

* Indicates data from the west-bound tanker route. The rest are from the east bound tanker route

The concentrations of dissolved and dispersed petroleum hydrocarbons in the upper 20 m of the tanker routes across the Arabian Sea are also presented in Table 5.1.5. The ranges are almost uniform, excepting some occasional high values. However, some seasonal variations can be observed which are due to varying intensities of tanker traffic and changes in meteorological factors. The quantum of oil pollution in the northern Indian Ocean due to this, as of end 1983, is presented in Figure 5.1.2.

One very interesting factor can be observed from the values in Table 5.1.5. The ranges did neither vary nor change appreciably from 1978 to 1984. Marine transport of oil and its products from the Middle East countries, however,

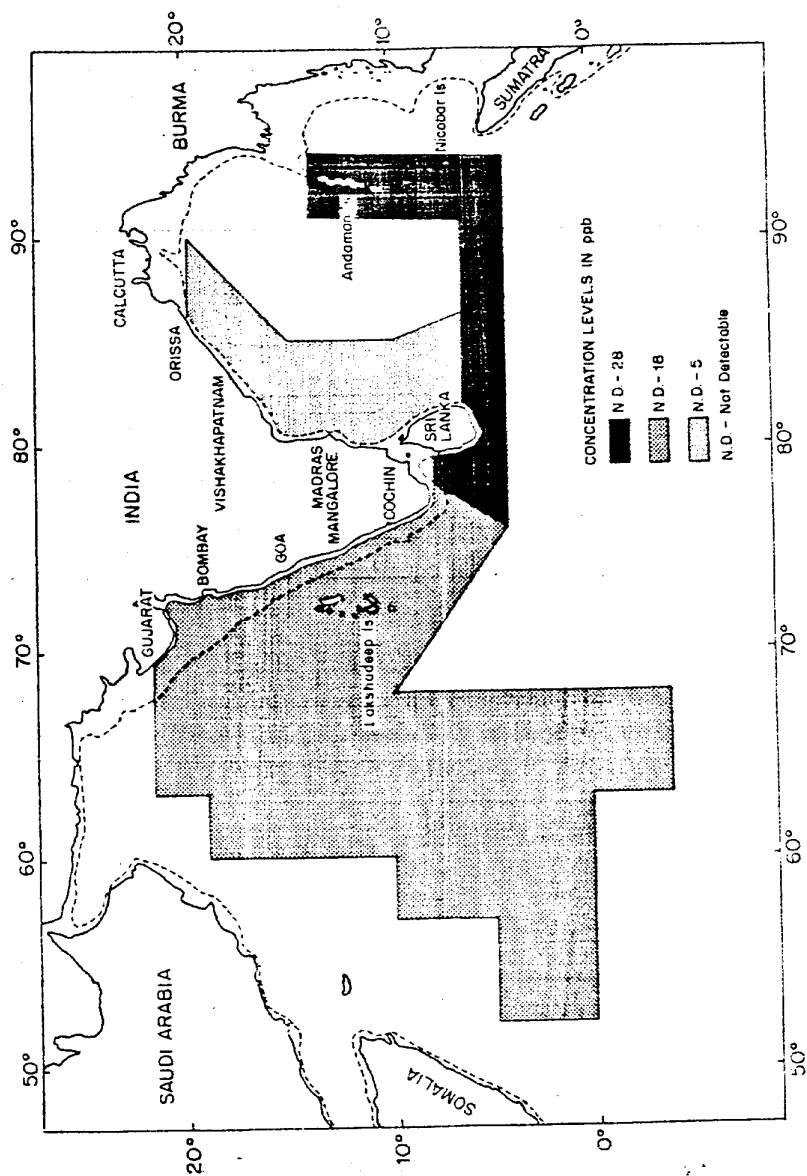


Figure 5.1.2 Dissolved petroleum residues in Indian Ocean

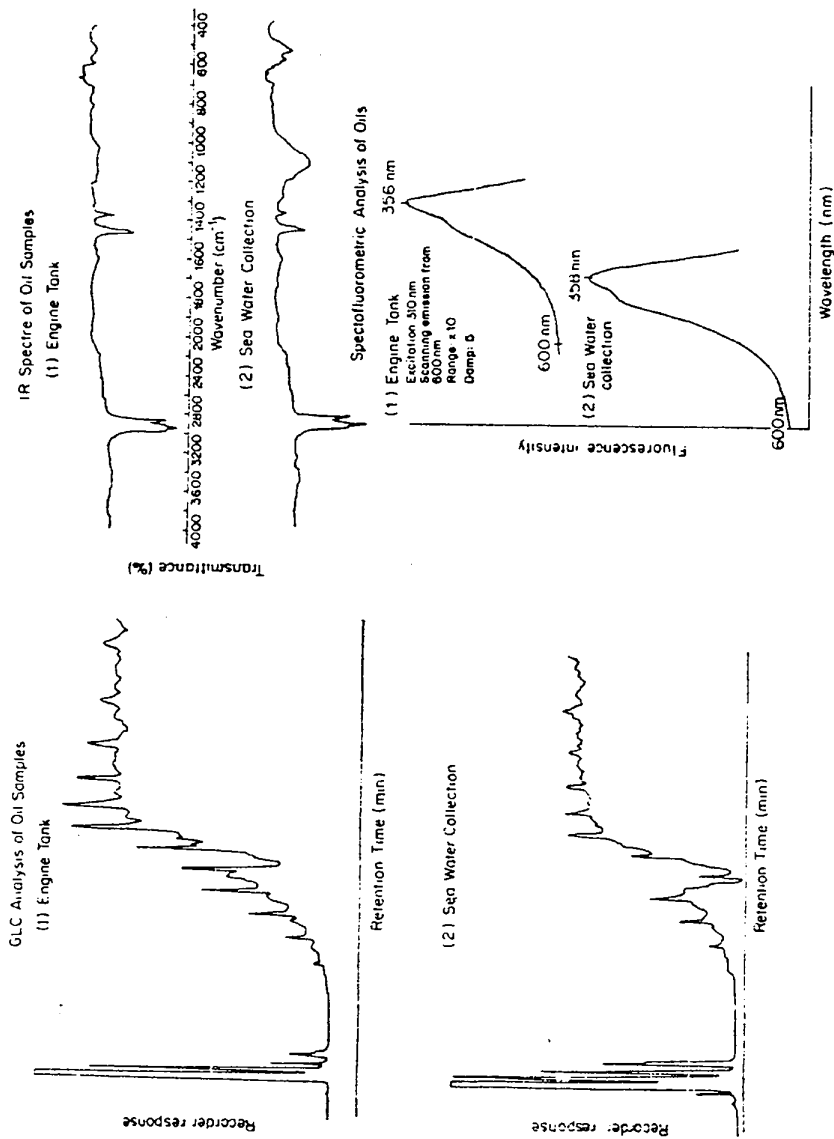


Figure S.1.3 A case study of an oil pollution incident in an Indian harbour

decreased significantly over the same period (Table 5.1.5). This leads us to two conclusions. Oil pollution in the surface waters of the Arabian Sea did not undergo much quantitative alteration over the years and is not directly related to the volume transported. The pollution is mainly due to operational discharges of bilge and bunker washings of the tankers on their way to the Gulf ports for loading the cargo of oil.

Deposition of tar-like residues on the beaches is a chronic problem along the west coast of India. However, this is a seasonal phenomenon depending on the pattern of coastal circulation, largely regulated by the monsoons. Records from the west coast of India during the years 1975 and 1976 indicate a range from 22 to 448 mg/m², with a peak value on one occasion of 1386 g/m². The computed total deposits on beaches along the west coast of India are 1000 and 750 tonnes for 1975 and 1976 respectively (Table 5.1.1).

In the nearshore area of Bombay high concentrations of dissolved/dispersed hydrocarbons ranged from 2 to 46 µg/l in water and from 4 to 32 µg/g dry weight in sediments. In the Bombay harbour region the concentrations, after a tanker fire accident, ranged from 27 to 105 µg/l at the surface and from 36 to 59 µg/l at 5 m. The concentrations in sediments increased from 1–26 µg/g to 40–512 µg/g after the accident. In a polluted creek in Bombay concentrations in sediments were in the high range of 142–393 µg/g.

Cargo ships and oil tankers, visiting Indian ports, may cause oil pollution in harbour waters by operational or accidental discharges of oil and oily ballasts. According to MARPOL 1973/1978 (Convention of the International Maritime Organization) such spills are highly irregular and the owners of the ships are liable to pay compensation to the harbour authorities for clean-up operations. It is difficult, however, to identify the source of pollution and to match it to oil in harbour waters. The analytical techniques for such matching are: UV/spectrofluorometry, IR-spectrometry, and gas chromatography. A case study of one such incident in an Indian harbour (Bhosle *et al.*, 1987) is presented in Figure 5.1.3.

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