

VIEWPOINT

Viewpoint is a column which allows authors to express their own opinions about current events.

Some Problems of Coastal Pollution in India

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Studies on the hydrographic and chemical characteristics of the coast surrounding the Indian subcontinent and the offshore regions of the Arabian Sea and the Bay of Bengal began during the International Indian Ocean Expedition (IIOE) 1962-65. After the IIOE, extensive investigations on these environmental features were continued till this date during the cruises of INS *Darshak*, R.V. *Gaveshani* and O.R.V. *Sagar Kanya*. The present report deals with some of the problems related to pollution of coastal waters of India.

Hydrography

Considering the criteria of river runoff, tidal currents, coastal upwelling, the configuration of the shoreline and the bottom contours, the coastal waters of India have been very broadly defined in this paper as a body of sea water surrounding the land up to a distance of about 12 nautical miles from the shore.

India has a coastline of about 7000 km. The Arabian Sea is an area of negative water balance, i.e. the removal of water by evaporation in this sea exceeds the addition by rainfall and land runoff. The massive addition of freshwater to the Bay of Bengal, on the other hand, by a number of rivers all along the east coast makes it an area of positive water balance with a net annual addition of about 3000 km³ of freshwater from precipitation and runoff (Sen Gupta & Naqvi, 1984). Rivers from the Indian subcontinent alone contribute 1645 km³ of freshwater annually of which about 1300 km³ comes from the drainage of the rivers on the east coast of India. The Northern Indian Ocean is influenced by another unique feature of this region, the monsoons. The south-west monsoon lasts from June to September and this is very predominant in the Arabian Sea. The north-east monsoon extends from October to January and becomes dominant in the Bay of Bengal. The coastal waters are thus subjected to seasonal variations in the environmental features.

Environmental features

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 (Table 1) that approximately, 5 × 10⁶ t of fertilizers, 55 000 t of pesticides and 125 000 t of synthetic detergents are used annually in India. A considerable quantity of these substances are biodegradable while others are not. Their cumulative effect over a long period could be quite harmful to the coastal marine environment. These effects are, as yet, not very perceptible generally on the Indian coast, but in the vicinity of metropolitan cities and industrial conglomerates, the effects are indeed alarming. During the period 1959-1974, phosphate-phosphorus concentration in the nearshore waters of

TABLE 1

Human population and related data together with some estimates of waste material (pollutants) entering the sea around India (figures pertain to 1986).

Population	750 million
Coastal population (25% of the total)	188 million
Area of the country	3.276 × 10 ⁶ km ²
Agricultural area	1.65 × 10 ⁶ km ²
Exclusive economic zone	2.015 × 10 ⁶ km ²
River runoff (annual mean)	1645 km ³
Rainfall per year (on land)	3.5 × 10 ¹² m ³
Rainfall per year (entering the Bay of Bengal)	6.5 × 10 ¹² m ³
Rainfall per year (entering the Arabian Sea)	6.1 × 10 ¹² m ³
Domestic sewage added to the sea by coastal population per year (at 60 l. per head day ⁻¹)	4.1 × 10 ⁹ m ³
Industrial waste added to the sea by coastal industries yr ⁻¹	0.41 × 10 ⁹ m ³
Sewage and effluents added by the rivers to the sea yr ⁻¹	50 × 10 ⁶ m ³
Solid waste and garbage generated by coastal population yr ⁻¹ (at 0.5 kg per head day ⁻¹)	34 × 10 ⁶ t
Fertilisers used per year (at 30.5 kg ha ⁻¹ yr ⁻¹)	5 × 10 ⁶
Pesticides used per year (at 336 g ha ⁻¹ yr ⁻¹)	55 000 t
Synthetic detergents used yr ⁻¹	125 000 t
Tar deposition on beaches along the west coast of India yr ⁻¹	750-1000 t

Bombay increased from $0.82 \mu\text{mol}\cdot\text{dm}^{-3}$ to $1.13 \mu\text{mol}\cdot\text{dm}^{-3}$, that is by about 40% (Sen Gupta & Sankaranarayanan, 1975). The concentration of phosphate-phosphorous in 1984 was found to be about $2 \mu\text{mol}\cdot\text{dm}^{-3}$ (Zingde, 1985). The dissolved oxygen concentration decreased from 4.71 ml dm^{-3} to near zero in 1983 (Parulekar *et al.*, 1985). High values of phosphate-phosphorus have also been observed near the shores of Madras (Sen Gupta, unpublished).

Similar situations can be expected to occur with several toxic heavy metals. The Indian rivers annually add about $16 \times 10^8 \text{ t}$ of sediments to the seas. A major portion of this can be expected to settle in the near-shore regions. Similarly, many of the heavy metals are expected to be transported to the sea. This can be illustrated by our observations in the estuarine system of the river Ganga (Fig. 1). These observations were carried out in September when the freshwater runoff, and consequently the suspended solids, can be expected to be at their maximum, at least at a first approximation. Several heavy metals were analysed in the suspended sediments, collected by filtering large volumes of water, from three stations (Diamond Harbour, Haldia and Sagar Island) every 3 h over two tidal cycles in the final 125 km stretch of the river (NIO, 1986). The data showed that 67% of the dissolved metals settle between Diamond Harbour and Haldia. The mean precipitation within this stretch up to Sandheads (see Fig. 1) is expected to be 85%. Thus, only 15% of the dissolved metals flow into the open sea. An examination of the suspended and particulate metals showed that about 10% settles in the lower estuarine region, 50% at the confluence of the river water with the sea water and 40% finally flows out into the open Bay of Bengal.

Concentrations of pesticides residues in zooplankton in the Arabian Sea decrease away from the shore indicating their terrestrial origin and aerial transport (Kannan & Sen Gupta, 1986). A recent study (Sarkar & Sen Gupta, in press) on the pesticide residues in the coastal sediments of the Bay of Bengal showed that apart from DDT and its isomers, residues of γ -BHC, Aldrine and Dieldrine were also present at a number of places (Fig. 2). Their individual concentrations were, at times, higher than t-DDT. These would indicate that this pollutant comes from land, as it is still being widely used in agricultural practice.

Sewage and effluents

Domestic sewage and industrial effluents are discharged in the rivers, drains and canals or go directly into the seas either untreated or partially treated mostly from the urban and industrial belts. Thus, numerous pollutants are added which include, among others, several toxic heavy metals and metalloids. The total volume of municipal sewage and domestic effluents going into the sea from the city of Bombay is estimated to be about 365 million tonnes (Mt) per year (Sabnis, 1984). Similar discharges from the city of Calcutta is approximately 396 Mt every year (Ghosh *et al.*, 1973). These two examples would perhaps give an idea of the magnitude of domestic sewage and industrial wastes which are generated and finally find their way into the sea.

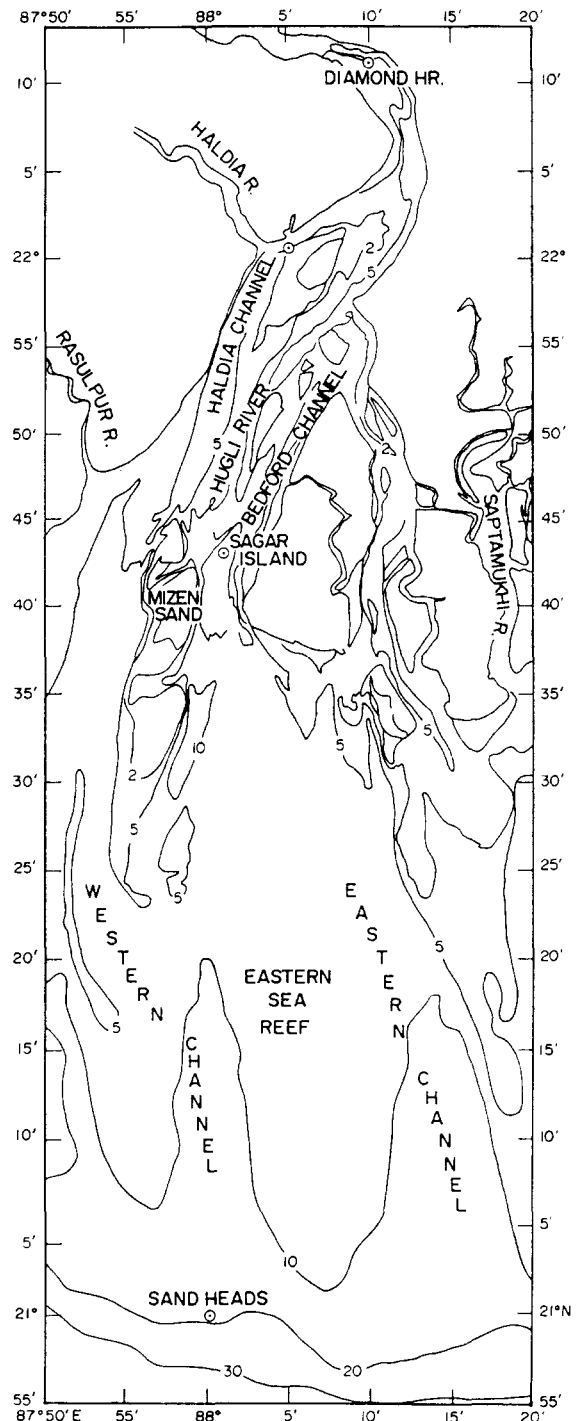


Fig. 1 Ganga estuarine system. Closed circles indicate the position of four stations. Numbers give the depth contour.

An estimate of the various components of the waste material entering at some points of Bombay city is given in Table 2. The data are based on the annual release to the Mahim river, Mahim Bay and creek (Sabnis, 1984). Mahim Bay occupies an area of 64 km^2 and is influenced by semi-diurnal tides with a maximum range of about 3 m. There was a time when this region had good fisheries, flourishing oyster beds, and lush fringing mangroves. The region used to be visited by a number of migratory birds. Today, it is one of the most industrialized and densely populated areas of Bombay. Birds are hardly seen there and the fisheries are non-existent as no fauna can survive in the intense pollution existing there. Mahim Bay receives 64 Mt of municipal sewage and 0.9 Mt of industrial wastes every year. At first,

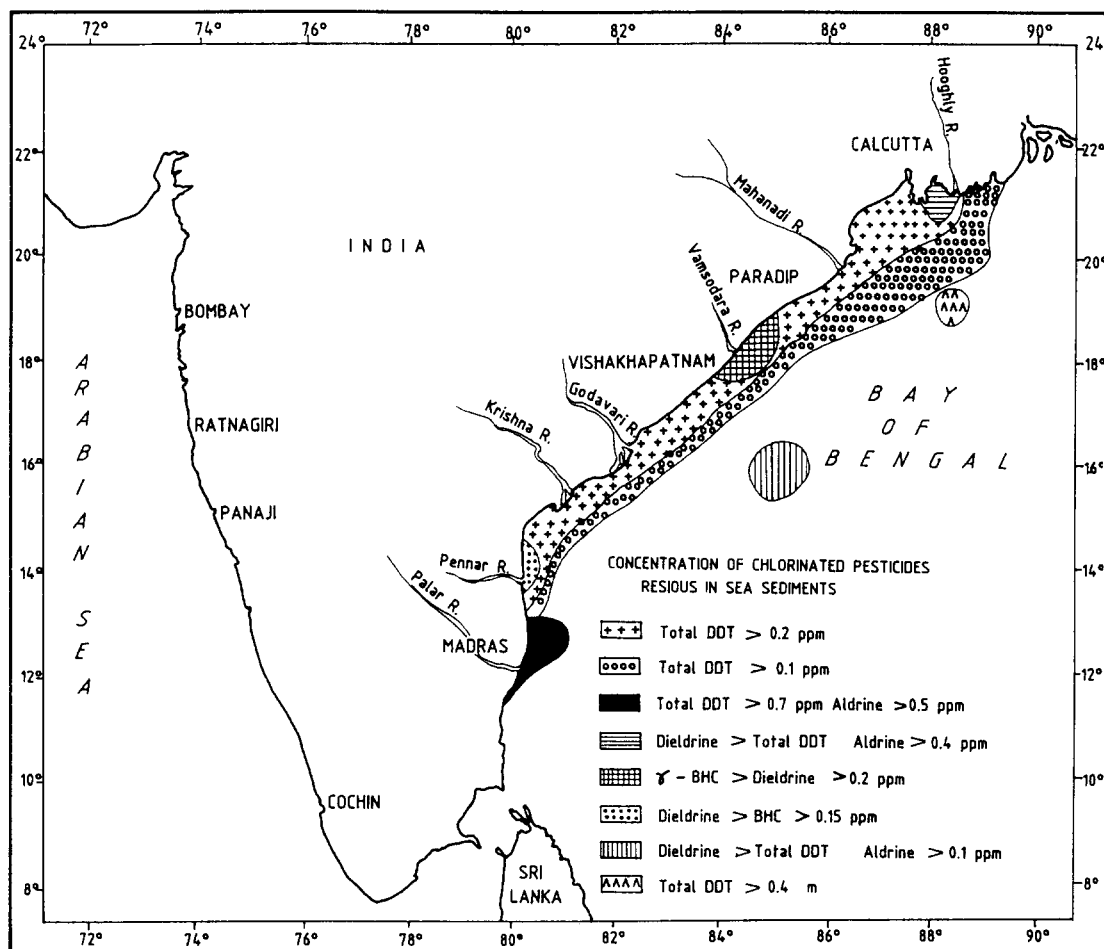


Fig. 2 Residues of persistent pesticides in marine sediments along the east coast of India.

these wastes were totally untreated, but now these are partially treated. The resulting concentration of H_2S -S found in the waters of the Mahim Bay ranges from 1.5–98.4 $\mu\text{mol}\cdot\text{dm}^{-1}$, depending on the stages of the tide. The release of the effluents containing hydrocarbons has so heavily contaminated the creek that it has become a common practice to recover the oil by soaking sorbents. Geochronology of the sediments using ^{210}Pb gave the maximum period since deterioration started as 54 years in 1984 which is roughly about the time when pumping of untreated sewage into the river started. Table 2 also indicates that the contribution from the Mahim River is only about 15% of the total wastes the coastal waters of Bombay receive.

The effect of semi-diurnal tides in the dispersion of pollutants is very significant in coastal marine areas of India. This has both beneficial and deleterious effects. For example, the pollutants discharged from Bombay have hardly any effect beyond a distance of about 4 km from the shores because of dilution, dispersion, and flushing (Zingde, 1985). However, in the tide-dominated estuaries, the pollutants largely oscillate with the tides without easily flowing out. In the estuarine region of the River Ganga, between Diamond Harbour and Sagar Island (see Fig. 1), it has been estimated that about 9% of the pollutants oscillate with the tides (NIO, 1986). Similar estimate for the Mahanadi estuary has been found to be 24%.

TABLE 2

Composition of the total volume of waste entering the coastal waters at two sites of Bombay (t yr^{-1}). Modified from Sabnis (1984) & Zingde (1985).

	Bombay	Mahim Bay	Mahim Bay/Bombay %
Dissolved solids	635 100	92 619	14.6
Suspended solids	105 850	15 643	14.8
BOD	113 150	16 480	14.6
Sulphate	32 850	4 791	14.6
Chloride	255 500	37 495	14.7
Nitrogen	14 600	2 236	15.3
Phosphorus	2 628	383	14.6
Manganese	1 107	162	14.6
Iron	13	2	15.4
Cobalt	35	5	14.3
Nickel	48	7	14.6
Copper	110	16	14.5
Lead	4.7	0.7	14.9
		Mean	14.7

Toxic metals in marine biota

One might assume that such large volumes of pollutants will lead to high concentrations of heavy metals in the marine biota of the coastal waters. However, this is not the case as can be seen from the values of heavy metals given in Table 3, from the tissues of some economically important fishes. It can be seen from the table that the concentrations of metals (Pb, Cd, and Hg) are within the prescribed limits for human consumptions. It can also be observed from Table 4 that the concentrations of all the metals are significantly higher in the liver

than in the muscles. This would indicate that most of these metals are accumulated in fishes in a fat-soluble form. Acceptable correlation was found in the metals as a function of sex, size or stages of maturity.

Highest concentrations of mercury, observed in the muscles, are still lower than the internationally accepted value, of 0.5 ppm. An analysis 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 the values ranging from 0.04–0.57 ppm (fresh wt) (Tejam & Haldar, 1975). A high concentration of mercury, 0.2–7.3 ppm (fresh wt) was observed in the muscles of crab from the same area in 1980 (Ganesan *et al.*, 1980).

Petroleum hydrocarbons

In 1985 the global marine transport of oil was 1264 Mt. Of this, 447 Mt or 35.4% of the total was shipped from the Gulf countries (B.P., 1986).

Sources of oil pollution are, normally, tanker disasters, ballast water, and bilge washings. Fortunately, the total record of accidental oil spills in the Indian Ocean, north of the equator, is 15 tanker disasters and 3 blow outs from 1970 to 1981 (*Times Atlas of the Oceans*, 1983). Therefore, the main source of oil pollution in

this region are the oil tankers and merchant ships sailing along the trade and tanker routes.

A status of oil pollution in the Northern Indian Ocean has been published (Sen Gupta & Kureishy, 1981). Collecting all the data available so far, a summary has been presented in Table 5. The table shows that marine transport of oil from the Gulf countries is on the decline. Consequently the volume of tanker traffic has also decreased considerably. Due to the reduction in traffic an apparent reduction in oil pollution from 1978 to 1985 could be deduced from the data for the tanker routes across the Arabian Sea and the Bay of Bengal.

The reduction in concentration of dissolved petroleum hydrocarbons were sharp from 1979 to 1980 in the Arabian Sea and from 1980 to 1981 in the Bay of Bengal. Thereafter, the conditions appear to have stabilised in both the areas.

Figure 3 depicts a record of observations of oil slicks and other floating pollutants over the entire Indian Ocean down to 40°S latitude. The data have been divided in 5° squares. Numbers at the top indicate the total number of negative observations while those at the bottom are positive observations, that is the number of occasions when oil slicks were sighted. A close examination of the figure will indicate that oil slicks are

TABLE 3

Ranges of concentration of a few essential and non-essential heavy metals (ppm wet wt) in zooplankton, crustaceans, bivalve and muscles of certain fishes from the northern Indian Ocean.

Fish	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	n.d.–4.0	1.0–12.6	0.02–5.99	n.d.
Prawns (6 Spp)	3.5–24.0	-	-	-	-	-	1.0	0.2–2.3	n.d.–0.17
Crabs	0.7–13.5	-	-	-	-	-	<1.0–7.88	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	n.d.–3.7	4.0–21.0	n.d.–0.9	0.2–1.3	1.08–5.76	n.d.–0.65	n.d.–0.07
Silver bellies	1.0–1.6	-	-	-	-	-	<1–3.21	0.58–2.11	0.001–0.01
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	n.d.–0.62	n.d.–0.01
Mackarel (2 Spp)	1.0–1.3	12.0	0.01	6.0	n.d.	1.8	<1	0.22–1.62	0.01–0.02
Jew fish (2 Spp)	n.d.–0.8	6.0–8.0	0.3–10.0	4.0–4.8	n.d.	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	n.d.–0.1	3.4–6.1	0.3–0.5	n.d.	<1	n.d.–1.47	0.007–0.1
Pilot fish	0.1–4.9	-	-	-	-	-	<1–2.95	n.d.–0.83	n.d.–0.02
Scianid (2 Spp)	0.1–0.3	-	-	-	-	-	<1	0.86–1.36	n.d.–0.02
Sole	-	-	-	-	-	-	<1	0.35	0.01
Pomfret	-	-	-	-	-	-	<1	0.73	0.01
Cat fish	-	-	-	-	-	-	1.02	0.92	0.06
Trevally (2 Spp)	n.d.–0.7	5.0–11.0	0.1–9.0	2.0–5.0	n.d.–0.6	n.d.–1.2	<1	n.d.–0.62	0.018–0.08
Grunter	0.36	-	-	-	-	-	2.7	n.d.	0.24
Talang	0.4	-	-	-	-	-	<1	n.d.	0.36
Tuna (4 Spp)	0.3–3.0	7.0–164.0	0.1–7.5	4.0–12.0	n.d.–4.0	n.d.–3.2	<1–3.3	n.d.–2.00	0.004–0.22
Dolphin fish	0.2–1.7	13.0–39.0	n.d.–3.1	5.0–9.0	0.1–1.2	n.d.–1.9	<1–2.95	n.d.–0.95	0.01–0.14
Seer fish	0.4	-	-	-	-	-	<1–1.5	0.25–0.66	0.09–0.11
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	n.d.–0.28	0.06–0.2
Sea Pike	-	-	-	-	-	-	1.46	n.d.	0.11
Sharks (4 Spp)	0.14–1.1	10.0–57.0	n.d.–2.0	4.5–12.0	n.d.–0.3	n.d.–3.8	<1–6.02	n.d.–0.81	0.02–0.21

TABLE 4

Range and average concentration of some heavy metals (ppm wet wt) in different parts of fishes collected from the Northern Indian Ocean. (Sources: Kureishy *et al.*, 1979, 1981, 1985.)

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

n.d.—non-detectable.

frequent mostly along the tanker routes, while south of the equator in the open Indian Ocean there is hardly any visible trace of oil pollution.

In the nearshore area of the Bombay High oilfield; the concentrations of dissolved/dispersed hydrocarbons range from 2–46 $\mu\text{g}\cdot\text{dm}^{-3}$ in the water column

and from 4–32 $\mu\text{g}\cdot\text{g}^{-1}$ (dry wt) in the sediments. In the Bombay harbour region, the concentrations of hydrocarbons after a tanker fire accident, ranged from 27–105 $\mu\text{g}\cdot\text{dm}^{-3}$ at the surface and from 36–59 $\mu\text{g}\cdot\text{dm}^{-3}$ at 5 m depth. The range in concentration in the sediments before the accident was 1–26 $\mu\text{g}\cdot\text{g}^{-1}$. It increased from

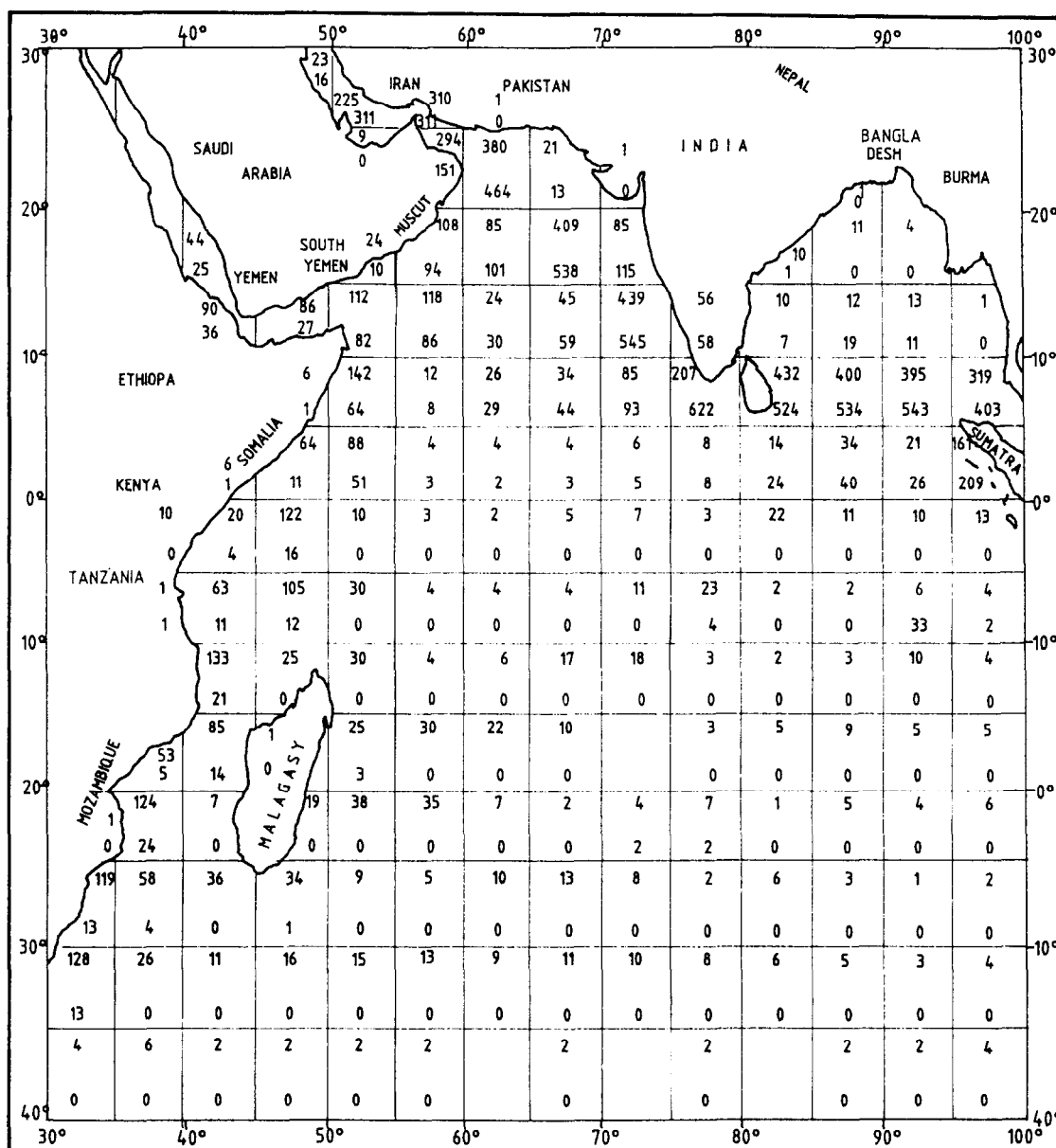


Fig 3 Observations on oil slicks and other floating pollutants every 5° square in the Indian Ocean. Numbers at the top of the squares indicate the occasions of the absence of oil slicks. Numbers at the bottom indicate the occasions when oil slicks were present.

TABLE 5
Dissolved/dispersed hydrocarbons in the upper 20 m of the Arabian Sea and the Bay of Bengal.

Year	Arabian Sea			Bay of Bengal			
	Transport (Mt)	Concentrations ($\mu\text{g}\cdot\text{kg}^{-1}$) Range	Mean	Transport (Mt)	BB/AS (%)	Concentrations ($\mu\text{g}\cdot\text{kg}^{-1}$) Range	Mean
1978	975	0.9–42.5	24.31	323	33	0–28.2	17.14
1979	1010	10.4–41.6	24.48	351	35		
1980	869	2.4–9.0	5.28	308	35	1.2–27.4	12.47
1981	725	–	–	247	43	0–2.8	1.40
1983	513	0–17.7	5.02	222	43	–	–
1984	489	–	–	252	51	0–3.4	1.70
1985	447	0.65–31.0	7.64	232	52	–	–
1986	–	1.0–23.5	7.50	–	–	–	–
Nett decrease (%)	54	–	–	28	–	–	–

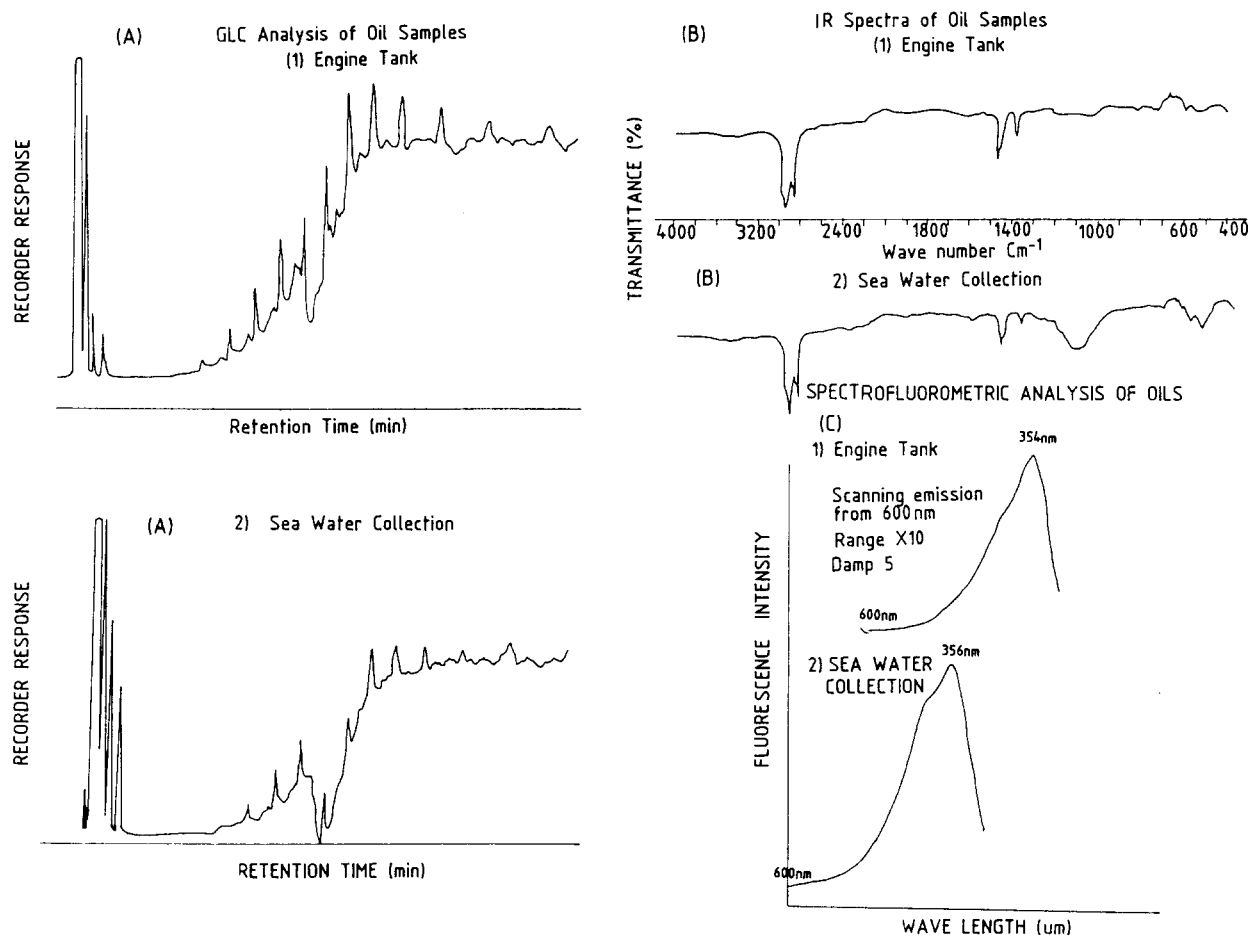


Fig. 4 Qualitative identification of the sources of oil pollution in the harbour. (A). Gas chromatograms of the samples taken from engine tank and harbour water. Similarities in the retention times of the peaks may be noted; (B). Infra-red spectra of the same samples showing identical similarities; and (C). UV-fluorescence showing similar peaks of emission for both the samples.

40–512 $\mu\text{g}\cdot\text{g}^{-1}$ after the accident (Fondekar, in press). Normal values however, were restored in the sediments after some months probably because of biodegradation of oil products.

Cargo ships and oil tankers visiting the Indian ports, cause oil pollution in the harbour waters by operational or accidental discharges of oil and oily ballasts during the unloading process of the oil cargo. According to MARPOL 1973/1978 convention and protocol of the International Maritime Organization (IMO), such spills are highly irregular and the owners of the ships are liable to pay compensation to the harbour authorities for cleanup operations. Nevertheless, it is difficult to identify the source of pollution and match that to the oil occurring in the harbour waters. The analytical techniques generally used for such a matching are: UV-spectrofluorometry, IR-spectrometry, and gas chromatography.

A case study of one such incident at an Indian harbour is presented in Fig. 4. The agreement in the records between the samples from the harbour water and the engine tank in respect of their gas chromatograms, IR spectra, and UV-fluorescence spectra is indeed remarkable. This method for identifying the sources of oil pollution has been recommended recently for adoption by all the Port Trust authorities in India.

Using the same methodology, an attempt has also

been made, to trace the source of discharge which could result in the deposition of tar balls on one of the beaches of Goa (Fig. 5). Although the agreement between the two is reasonably good, the source can only be generalized and cannot be accurately pinpointed. The possibility of several crafts using the same oil and the same bunker complicates the identity of the ship.

Sea surface microlayer

Sea surface microlayer has been defined as the uppermost 30 μm of the sea. This layer is exposed to atmosphere and affects and controls the air-sea interaction processes. Therefore, the layer can be expected to contain a high concentration of pollutants as it is enriched with both air and water. Studies on the sea surface microlayer are at an initial stage at NIO. However, preliminary data indicate a 10–25 times enrichment of the essential nutrients and a few heavy metals of this layer as compared to their concentration in the water just 25 cm below the surface (Singbal) *et al.*, 1987).

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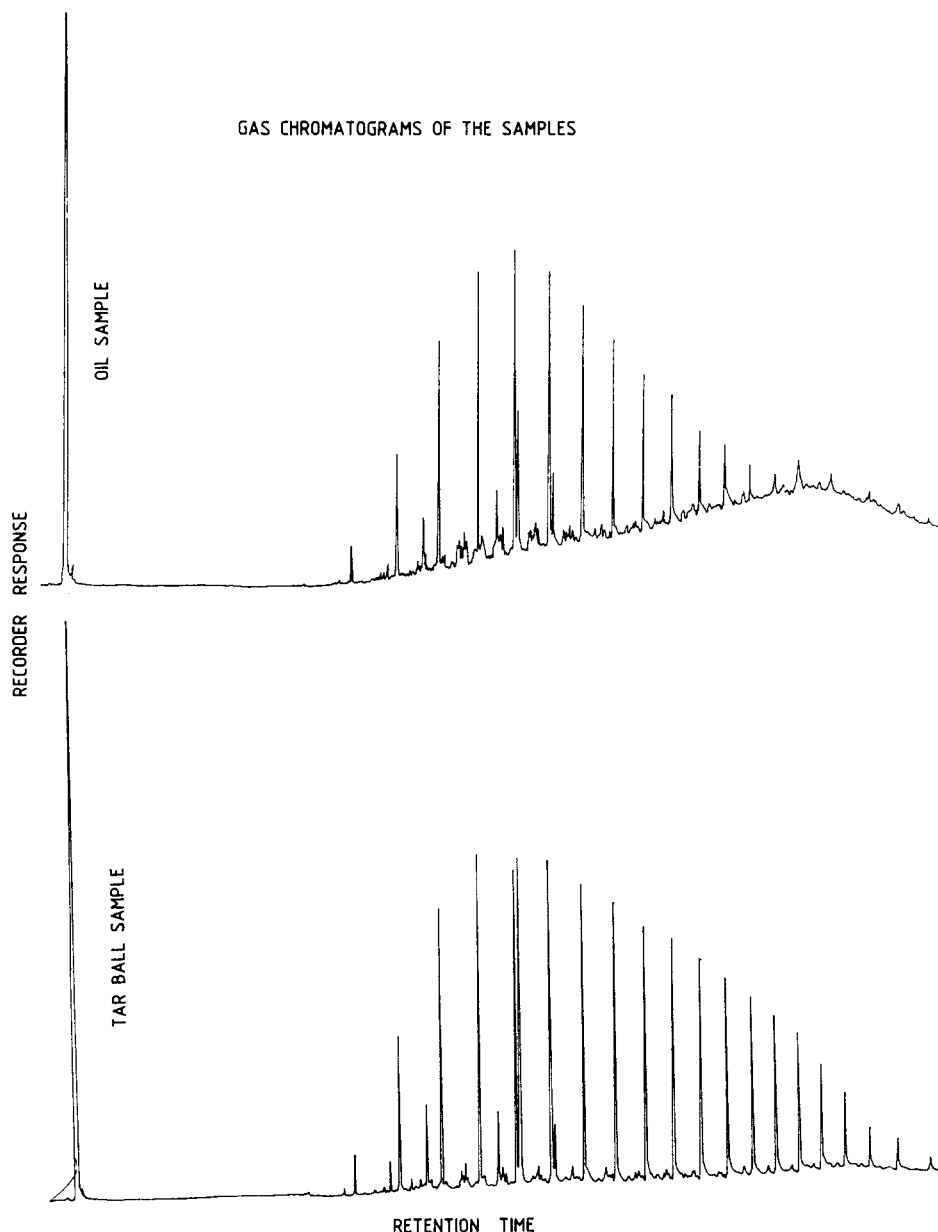


Fig. 5 Gas chromatographs of oil and tar ball samples. From the two records, the possible sources for beach tar can be identified.

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