



***R. Sen Gupta et al.:***  
***State of the marine environment***  
***in the South Asian Seas Region***

***UNEP Regional Seas Reports and Studies No. 123***

***Prepared in co-operation with***



IOC



FAO

## PREFACE

The better understanding of the changing problems facing the marine environment is a continuing goal of UNEP's ocean programme, as it provides the necessary scientific background for shaping UNEP's policy towards the protection of the oceans.

The main sources of factual information used in the assessment of the state of the marine environment are data published in open scientific literature, data available in various reports published as "grey literature" and data generated through numerous research and monitoring programmes sponsored by UNEP and other organizations.

Several procedures are used to evaluate critically the large amount of available data and to prepare consolidated site-specific or contaminant-specific reviews.

GESAMP, the IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on Scientific Aspects of Marine Pollution, is charged by its sponsoring bodies with preparation of global reviews. Reviews dealing with several contaminants have been already published by GESAMP and others are being prepared for publication. The first global review on the state of the marine environment was also published by GESAMP in 1982, and the second global review was published in 1990<sup>1/</sup>.

In parallel with the preparation of global assessments, the preparation of a series of regional assessments, following the general format of the second global review by GESAMP, was initiated by UNEP in 1986, with co-operation of the Food and Agriculture Organization of the United Nations (FAO) and the Intergovernmental Oceanographic Commission of Unesco (IOC). Fifteen task teams of scientists were set up, involving primarily experts from the relevant regions, to prepare the regional reports under the joint overall co-ordination of UNEP, FAO and IOC, and with the collaboration of a number of other organizations.

The present document is the product of the Task Team for the South Asian Seas Region. The final text of the report was prepared by R. Sen Gupta, as Rapporteur of the Task Team for the South Asian Seas Region, with collaboration of M. Ali, A.L. Bhuiyan, M.M. Hossain, P.M. Sivalingam, S. Subasinghe and N.M. Tirmizi, whose contributions are gratefully acknowledged.

The report was edited and prepared for publication by Philip Tortell of Environmental Management Limited, New Zealand.

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<sup>1/</sup> Publications of GESAMP are available from the organizations sponsoring GESAMP.

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ANNEX I : NAMES AND ADDRESSES OF CONTRIBUTORS

## 1. INTRODUCTION

The South Asian Seas region consists of India, Bangladesh, Pakistan, Maldives, Sri Lanka, Burma and western coasts of Thailand and Malaysia (Figure 1).

The total land area covered by these countries is 5.341 million km<sup>2</sup>, having a population of 950 million with a mean of 178 persons per km<sup>2</sup>. The population density varies from 26 per km<sup>2</sup>, in Sri Lanka to 591 per km<sup>2</sup>, in the Maldives. The average growth of population is around 2% per year. It can be assumed, at least at a first approximation, that 25% of the population of these countries is directly or indirectly dependent on the sea for its living. This would mean that roughly about 240 million people will be dependent on the bounties of the sea for their livelihood.

No accurate information is available about the total length of coastline in all the countries. The available information indicates that Pakistan, Bangladesh, Sri Lanka and India have coastlines of 825 km, 768 km, 1,700 km and 7,500 km respectively, making a total of 10,793 km, excepting Maldives. All these countries have wide Exclusive Economic Zones (EEZ), the extent of most have not yet been finally ascertained. Pakistan is estimated to have an EEZ of 196,600 sq.km., which is about 25% of its land area, India has 2.015 million sq.km., which is 61% of the land area, Sri Lanka has 1.2 million sq.km., which is nearly 20 times the land area and Maldives has 90,000 sq.km. (Sen Gupta, 1987; Bhuiyan & Hossain, 1987; Sivalingam, 1987; Subasinghe, 1987; and Tirmizi, 1987).

These countries lie in the equatorial and tropical tidal regions and are influenced mainly by semi-diurnal tides sometimes with large amplitude. All the countries are blessed with perennial rivers. It has been estimated that the total river runoff to the Bay of Bengal and the Arabian Sea is about 3,000 km<sup>3</sup> per year adding 1,600 million tonnes of sediments every year (Sen Gupta & Qasim, 1985). These two marine areas occupy 3% of the world oceans but receive 9% of the global runoff. This means that this region receives three times more river runoff per unit area when compared to the rest of the world (Sen Gupta & Naqvi, 1984).

All the countries in this region are mainly dependent on agriculture for their economy. However, some of the specific economic activities of the countries are: Maldives - fishing and tourism; Pakistan - fishing, oil exploration, agriculture, industries and tourism; Bangladesh - fishing, agriculture, industries; Sri Lanka - fishing, agriculture, industries; Malaysia - fishing, agriculture, industries, tourism, oil exploration and mining; India - fishing, agriculture, industries, tourism, oil exploration. The coastal regions of all the countries are being gradually subjected to urban development.

Marine environmental research is at various stages of development in most of the countries and there is hardly any on-going pollution monitoring programme. It has, however, been stated that "Research in marine pollution has attained significant status in India and a substantial amount of data have been collected in different fields" (UNEP, 1986).

Data and information for this report have been collated from members of the Task Team. The final draft was reviewed at the second meeting of national focal points on the development of an action plan for the protection and management of the South Asian Seas region, Bangkok, 7-11 December 1987 and has been revised accordingly.

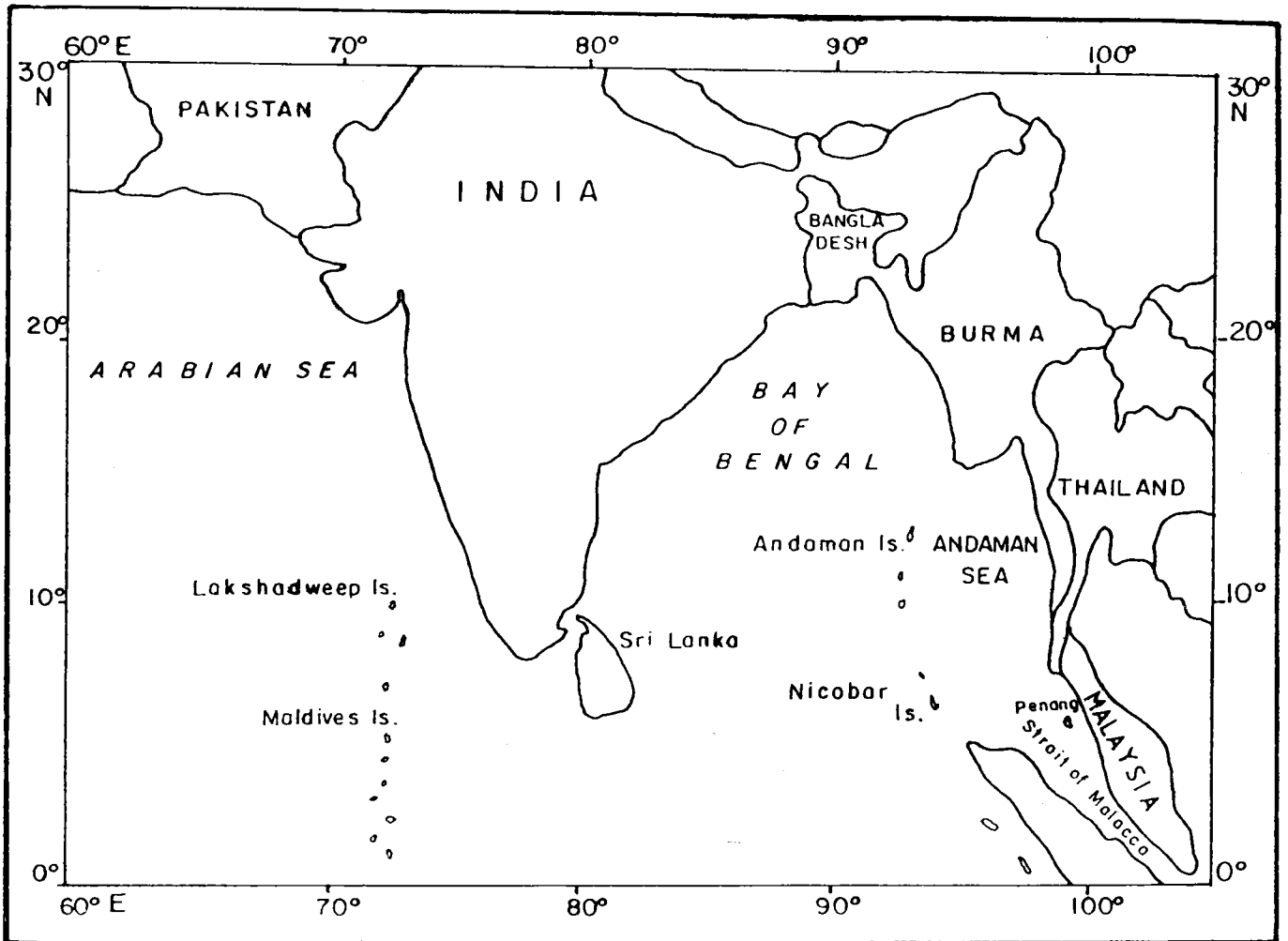


Fig 1 . The South Asian Seas Region

## 2. CHARACTERISTICS OF THE REGION

In relation to the equator, the Indian Ocean has an asymmetric shape largely due to the presence of the Asian continent. The result is that this ocean gets separated from the deep-reaching vertical convection areas of the northern hemisphere. Such an asymmetric configuration leads to a weak circulation and poor renewal at depths of the Northern Indian Ocean (Dietrich, 1973). The Indian Ocean can, broadly speaking, be divided into three regions on the basis of their distinct circulation systems (i) the seasonally changing monsoon gyre; (ii) the southern hemisphere subtropical anticyclonic gyre; and (iii) the Antarctic waters with the circumpolar current (Wyrтки, 1973).

The monsoon gyre, unique to the Indian Ocean, is separated from the subtropical anticyclonic gyre by a front in the hydrochemical structure at about 10° S latitude.

The Indian Ocean, north of the equator, comprising of the Arabian Sea, the Bay of Bengal, the Andaman and Laccadive Seas, in addition to the equatorial region, comes under the monsoon gyre. However, the hydrographical and hydrochemical characteristics are widely different in different parts of this gyre itself owing to the diverse meteorological and geographical factors characteristic of each area.

The Arabian Sea is bordered on the northern, eastern and western sides by the land masses of Asia and Africa. It is connected to the Gulf through the Gulf of Oman by a 50 m deep sill at the Hormuz Strait. Similarly, a 125 m deep sill at the Strait of Bab-el-Mandab separates the Red Sea from the Arabian Sea through the Gulf of Aden. The Arabian Sea is an area of negative water balance where evaporation exceeds precipitation and runoff. The excess of evaporation over precipitation is highest (100-150 cm) off the Arabian coast and decreases steadily towards the southeast (Venkateswaran, 1956). A slight excess of precipitation over evaporation (<20 cm) occurs annually off the southwest coast of India. The high rate of evaporation results in the formation of several high-salinity water masses. The Arabian Sea high salinity water, formed in the northwestern Arabian Sea, flows southward and can be traced as a tongue of high salinity within the surface layer. The high salinity water in the Gulf, characterised by a  $\sigma_t$  (density minus 1)  $\times 10^3$  value of 26.6, flows through the Hormuz Strait and the Gulf of Oman into the Arabian Sea and maintains its density level at about 300 m depth (Wyrтки, 1971). This water mass flows south, mostly east of 63° E longitude (Varma et al, 1980) and loses its characteristics in the southern Arabian Sea (Rameshbabu et al, 1980). The Red Sea water enters the Arabian Sea through the Strait of Bab-el-Mandab and the Gulf of Aden along  $\sigma_t$  27.2 surface (Wyrтки, 1971). This water mass is generally confined to south of about 17° N latitude (Rameshbabu et al, 1980).

Occasionally, the sub-surface high salinity water masses originating in the Gulf and the Red Sea form a thick layer which is of almost uniform vertical salinity, although the individual layers can still be recognized as weak salinity maxima. The whole layer is called the North Indian high-salinity intermediate water (Wyrтки, 1973). The deep and bottom waters are of circumpolar origin, probably transported by a deep western boundary current through a chain of basins (Warren et al, 1966; Warren 1978, 1981). They are called the North Indian Deep Water and North Indian Bottom Water.

Surface circulation in the Arabian Sea undergoes biannual reversal associated with the southwest (SW) and northeast (NE) monsoons. The NE monsoon is weak in this region, but the SW monsoon is very intense. Strong winds blowing with the Somali and the Arabian coasts to the left cause intense upwelling off these coasts during the SW monsoon period. Moderate upwelling also occurs off the southwest coast of India, partly due to the cyclonic motion in the neighbourhood of the Maldives and the Laccadives (Sastry & De Sousa, 1972).

In contrast to the Arabian Sea, the Bay of Bengal is a region of positive water balance. The average annual excess of precipitation is of the order of 70 cm (Venkateswaran, 1956). The total annual river runoff to the Bay of Bengal has been estimated to be about 2,000 cubic kilometres (Sen Gupta et al, 1977). The high excess of precipitation over evaporation and the massive river runoff result in low surface salinities, especially in the northern Bay of Bengal. The salinity, lower at any level in the Bay of Bengal as compared to the Arabian Sea, increases steeply within the thermocline/pycnocline and a weak salinity maximum may be observed at a depth of about 500 m. The salinity thereafter decreases monotonously with depth. The SW monsoon current probably carries the North Indian high salinity intermediate water from the Arabian Sea and fills the Bay of Bengal at intermediate depths, resulting in the salinity maximum (Wyrski, 1973). The deep water is of circumpolar origin probably derived from the central Indian basin.

As in the Arabian Sea, the surface circulation in the Bay of Bengal changes with the monsoonal cycle. The NE monsoon is much more intense here as compared to the Arabian Sea. Induced by favourable currents and winds, moderate upwelling occurs along the coast of India, during the SW monsoon (Murty & Varadachari, 1968; Naqvi et al, 1979), even though the runoff from the rivers may partially compensate for the offshore movement of surface waters (Sen Gupta et al, 1977).

Heat budget computations for the Arabian Sea indicate that about 80% of the changes in the heat content are affected by surface exchange processes prior to the onset of the monsoon. High sea-surface temperature under calm weather conditions, prior to the onset of the southwest monsoon was observed. These surface waters were laden with large quantities of suspended biomass and hydrocarbons causing intense absorption and insolation resulting in a rise in temperature in a thin surface layer.

There is an influx of heat from the Central Indian Ocean region to the Arabian Sea across the eastern boundary before the onset of the monsoon. This is more than the outflux of moisture over the Arabian Sea and is the main source of monsoon activity over the Indian sub-continent (Mohanty et al, 1983).

The most significant chemical observation was the accurate determination of oxygen concentration in the low-oxygenated waters of the northern Indian Ocean by applying a photometric method (Sen Gupta & Naqvi 1984). This real oxygen level was used to compute the original nitrate concentration in water before the onset of denitrification processes. This, combined with the accepted values of diffusion and advection constants, helps to establish a reliable rate of denitrification and the "standing crop" of denitrified nitrogen. Combination of these two, gave a turnover time for the oxygen-poor layer of about 4 years. This short renewal time of intermediate waters and the short-term variability of the denitrification intensity suggests that the oxygen-poor layer is an unstable time-variable feature which may react quickly to any future climatic and/or environmental perturbations. Hence there is an alarming possibility that a slight increase in organic carbon flux due to pollution and/or a climatic change could have a decisive impact on these intermediate waters turning completely anoxic (Naqvi, 1987).

### **3. MARINE CONTAMINANTS: LEVELS AND DISTRIBUTION**

#### **3.1 Concentration in water, sediments and biota**

The most significant contaminants in all the countries of this region are bacteria and viruses arising out of human activities. These have been elaborated under Section 4.

We shall deal here with the concentrations of a few toxic heavy metals and organochlorine residues in different segments of the marine environment.

### 3.1.1 Metals

Regular data on monitoring of metals in water are lacking. Measurements are carried out in zooplankton, fish and sediments in a few countries. The concentrations show a wide range of variation from area to area and between analysts. These differences may be due to errors in sampling, analysis and personal bias. They may also be due to continuous improvement and sophistication of analytical instruments and methodologies.

Zooplankton hauls from different areas are analysed in India for several 'essential' and 'non-essential' heavy metals. The concentration ranges in ppm wet weight are: 2.12 - 31.95 (Cu); 3.01 - 6.99 (Mn); 7.78 - 367.09 (Zn); 36.36 - 426.49 (Fe); 0.23 - 3.12 (Ni); ND (Hg); 0.69 - 5.99 (Cd); and 4.27 - 31.87 (Pb). The most significant observation is the total absence of mercury in all the zooplankton samples (Kureishy et al, 1978, 1981, 1983; Kureishy, 1985).

Available Indian data on the concentrations of Hg, Cd, Pb and Cu in the muscles of several fish from the Northern Indian Ocean are summed up in Table 1. These are very common food fish in India. The fish were caught at different places along the coastline. Wherever ranges of values are stated in the table, they mean concentrations in several fish of varying length, sex and stages of maturity. Higher concentrations were observed in larger fish. In general, the values appear to be well within the maximum permissible limits for the metals. Occurrences of higher values are only occasional.

Examination of data on several metals in dissolved, suspended and particulate forms in the estuarine region of the River Ganges indicates very interesting results. About 85% of the dissolved metals settle within the river leaving only 15% to flow out. 10% of the suspended and particulate metals settle within the estuary, 50% at the confluence of river water with sea water and 40% finally flows out to the open Bay of Bengal (NIO, 1986).

Data from Thailand give mercury concentrations in some of the fish from the Andaman Sea. These were in the range of 0.026 - 0.234 in yellowfin tuna; 0.027 - 0.233 in bigeye tuna, and 0.057 - 0.478 in four shark species all in ppm fresh weight (Menasveta & Siriyong, 1977). These compare well with similar data from India.

Data on concentrations of some metals and metalloids (Khan et al - mss) eg. K, Ca, Mn, Fe, Ni, Cu, Zn, As, Br, Rb and Sr, in a few estuarine fish are available from Bangladesh (Table 2). High concentrations of Zn, Fe and Pb have been observed in water in Pakistan near the Lyari outfall in Manora Channel at Karachi harbour (Beg et al, 1984).

In the sediments near Penang in Malaysia and in the Malacca Straits observed metal concentrations are: none detected - 125 (Cd); 4 - 36 (Co); 2 - 28.5 (Cr); 1 - 26.3 (Cu); 1500 - 18750 (Fe); 12 - 189 (Mn); 1.8 - 29.3 (Ni); 6.5 - 35.3 (Pb); and 8.76 (Zn) all in ppm dry weight.

Levels of these trace metals in water, fin fish, shellfish and marine algae in the environs of Penang and the Straits of Malacca are presented in Table 3 (Sivalingam, 1982; Hamdiah Razak et al, 1984).



Table 1. Concentrations of Hg, Cd, Pb and Cu (ppm wet weight) from 1978 - 1982 in muscles of some fishes from the Northern Indian Ocean. (Modified from Kureishy et al, 1978, 1983; Kureishy, 1985).

Fish	Metal	1978	1979	1980	1981	1982
Skipjack Tuna	Hg	0.160	0.03-0.22	0.04	0.028	0.01
Katsuwonus pelamis (Linnaeus)	Cd	-	ND-0.34	2.0	ND-0.93	0.90
	Pb	-	1.0-1.19	ND	ND-2.63	0.62
	Cu	-	0.28-1.28	2.69	0.47-1.24	0.81
Bluefin Tuna	Hg	0.120	-	0.14	-	-
Kishinoella tonggol (Bleeker)	Cd	-	-	ND	ND	-
	Pb	-	-	ND	ND	-
	Cu	-	-	0.46	0.63	-
Mackerel Tuna	Hg	-	-	0.11-0.13	-	-
Euthunus affinis (Canter)	Cd	-	-	0.75-1.12	-	-
	Pb	-	-	ND-0.25	-	-
	Cu	-	-	0.66-0.70	-	-
Seer fish Acanthocybium	Hg	0.101-0.151	0.89	-	-	-
Solandri (Cuvier)	Cd	-	0.43	-	ND	-
	Pb	-	1.50	-	8.12	-
	Cu	-	0.57	-	0.43	-
Dolphin fish	Hg	0.072-0.140	0.01-0.042	-	0.11	-
Corryphaena hippurus (Linnaeus)	Cd	-	ND-0	-	ND-1.19	-
	Pb	-	1.0-2.09	-	ND-8.54	-
	Cu	-	0.24-1.45	-	0.27-0.74	-

Table 2. Trace elements in muscles of a few estuarine fish from Bangladesh (ppm dry weight) (modified from Khan et al - MSS)

Fish examined: Palaemon carcinus, Wallago attu, Stromateus sinensis, Rita rita, Sillago sihama, Belona strogylurs

Element	Range
K	2,720.0 - 11,693.0
Ca	249.0 - 7,961.0
Mn	1.89 - 7.11
Fe	37.9 - 388.0
Ni	2.7 - 15.2
Cu	0.65 - 58.1
Zn	26.0 - 93.8
As	2.52 - 5.53
Br	18.3 - 122.0
Rb	2.0 - 21.6
Sr	9.06 - 16.0

### 3.1.2 Pesticides

Being predominantly agricultural countries, consumption of pesticides can be expected to be considerable in the region. Recent available figures for the annual consumption of pesticides are 55,000 tonnes in India, 11,000 tonnes in Pakistan, 3,000 tonnes in Bangladesh and 2,800 tonnes in Sri Lanka. It is commonly believed that about 25% of these ultimately end up in the sea. The cumulative effect of non-degradable pesticides over the year can thus be expected to be considerable in the coastal marine environments.

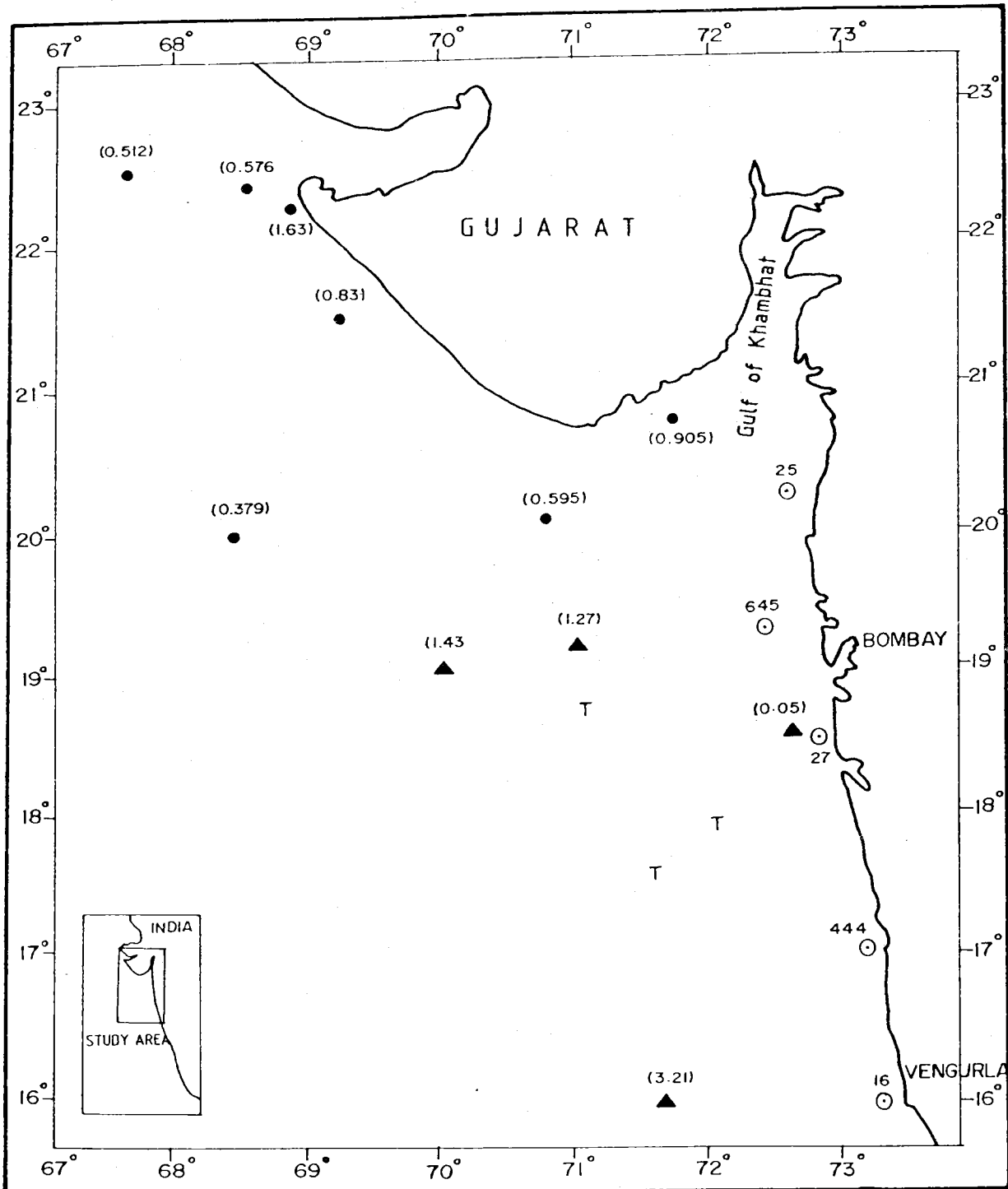
Concentrations of t-DDT in water and zooplankton, from Indian data, are presented in Figure 2 (Kureishy et al, 1978; Sarkar & Sen Gupta, 1989). Over 100 litres of water were filtered in situ, through an ion-exchange column containing Amberlite XAD-2 resin using the Seastar sampler suspended at 20 m. Analyses were carried out by gas chromatography. Concentrations were higher near urban areas whereas they were not significant near agricultural regions. Values of t-DDT in zooplankton decrease seawards. This is possibly due to the effect of river-borne pesticides. Pesticides in the sediments along the Indian coast are presented in Figure 3 (Sarkar & Sen Gupta, 1987, 1988; Qasim & Sen Gupta, 1988). These indicated that apart from DDT and its isomers, residues of Gamma-BHC, Aldrin and Dieldrin were also present at a number of places. Their individual concentrations were, at times, higher than t-DDT. The most interesting feature in Figure 2 is the difference in the order of concentrations between the east and the west coasts of India. All the major rivers in India are east flowing through vast tracts of agricultural land, naturally receiving more organochlorine residues through runoff.

Some data on organochlorine residues are also available from water and marine organisms around Penang Island (Malaysia). Concentration ranges in water in ppm were: Alpha-BHC 0.04 - 0.16; Beta-BHC ND - 1.80; Gamma - BHC 0.15 - 1.37; Aldrin 1.94 - 17.9; Dieldrin 0.25 - 0.86; pp'-DDE ND - 35.81; and PCBs-ND (Sivalingam et al, 1979). Concentrations of pp'-DDE and PCBs in marine organisms are presented in Table 4.

Table 3. Heavy metals in the environs of Penang and the Straits of Malacca (ppm dry weight)

	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg
Coastal waters of Penang	0.056-0.112	0.063-0.375	0.071-0.282	0.065-0.13	0.111-0.554	0.064-0.096	0.178-0.472	0.30-0.50	0.026-0.51	-
Open Waters of Strait of Malacca	0.009-0.014	-	-	0.071-0.107	-	-	-	0.035-0.060	-	ND-0.03
Finfish from Strait of Malacca	ND	ND	ND	D-2.3	2.2-40.1	ND	ND	0.1-4.0	-	-
Shellfish from Malacca	2.08-10.58	ND	ND	ND	144.92-960.86	11.19-38.22	6.47-38.28	7.07-41.29	117.51-2387.15	-
Marine algae from Strait of Malacca	3.74-16.32	-	ND-58.77	ND-49.74	347.84-15473.92	23.7-315.96	-	1.68-58.77	14.22-210.0	-

Sources : Sivalingam, 1982; Hamdiah Razak et al, 1984.



- ▲ t-DDT in Zooplankton in 1978 (ppm)
- t-DDT in Zooplankton in 1987 (ppm)
- ⊙ t-DDT in Water (ng/l)

Fig. 2. Pesticides residue in water and zooplankton in the Arabian Sea (modified from: Kureishi et al, 1978; Sarkar & Sen Gupta - 1989)

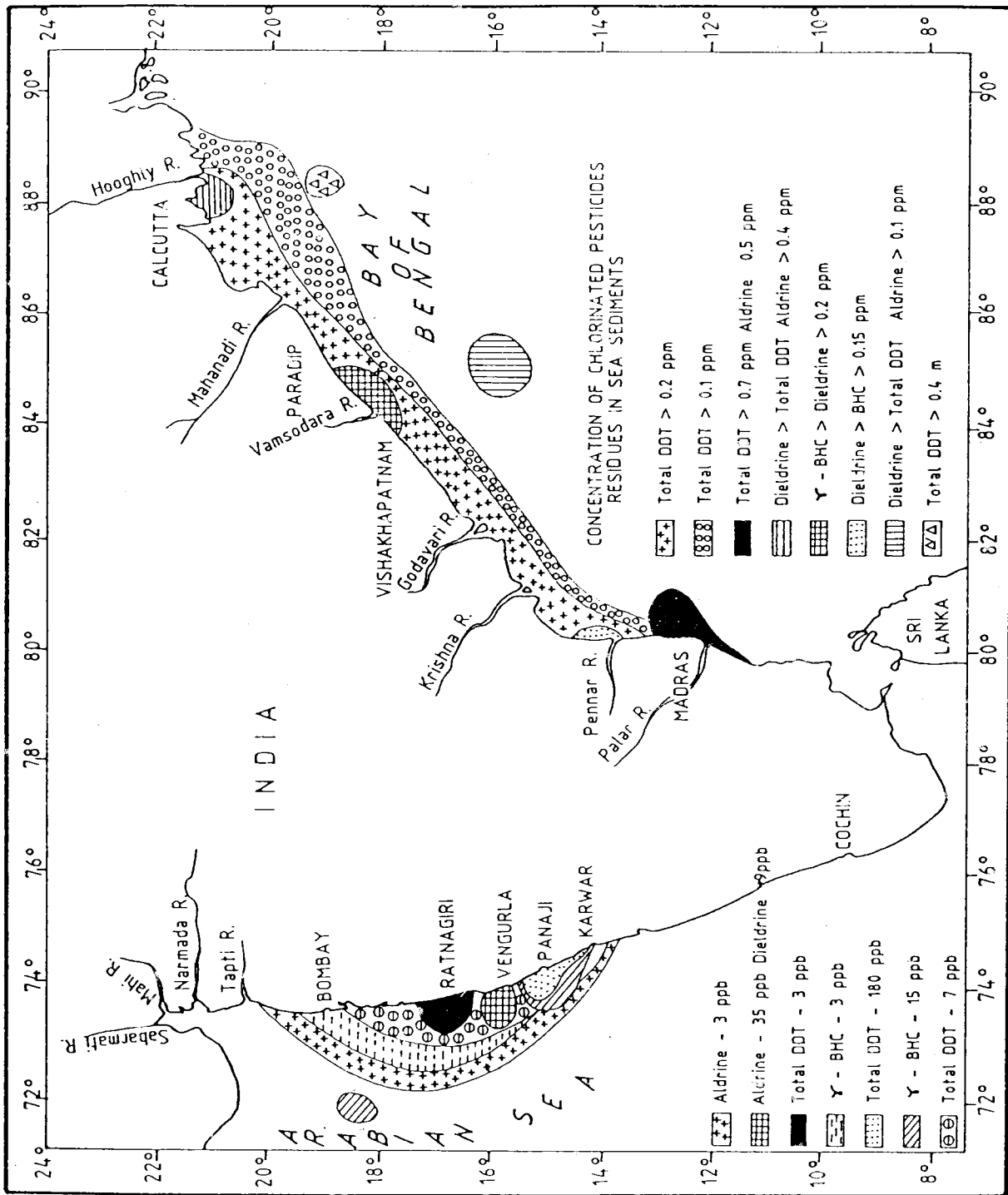


Fig. 3. Concentration of chlorinated pesticides residues in the sea sediments along East and West of India (modified from: Qasim & Sen Gupta, 1988; Sarkar & Sen Gupta, 1987)

Table 4. Levels of pp' - DDE and PCBs in some shellfish off Penang Coast, Malaysia (ppm dry weight)

Shell fish	pp <sup>1</sup> -DDE	PCBs
<u>Perna viridis</u> (Penang)	3.69 - 17.38	99.9 - 599.9
<u>Perna viridis</u> (Singapore)	7.11 - 8.12	139.8 - 256.9
<u>Anadara granosa</u>	ND - 9.24	160.29 - 335.3
<u>Barbatia bicolorata</u>	435.55	ND
<u>Pinctada vulgaris</u>	467.25	ND
<u>Atrina vexillum</u>	519.79	ND
<u>Saccostrea cucullata</u>	461.57	ND

Source: Sivalingam, 1982; Sivalingam et al, 1982.

### 3.1.3 Other contaminants

Being predominantly agricultural countries with a number of agro-based industries in some of them, the dominant contaminants are more or less similar in all of them. Unmitigated and continuous discharges of domestic sewage and industrial effluent with little or no treatment are surely damaging the coastal environment and ecosystems to varying degrees.

The main constituents of all these discharges, directly to the sea or through estuaries, will be the residues of pesticides, insecticides and nitrogenous compounds, PCBs and a few toxic heavy metals.

India, Pakistan, Maldives, Sri Lanka and Western Malaysia lie close to the oil tanker route from the Middle East to the Far East and Japan. The effect of tanker traffic with associated discharges and disasters are almost always visible on shore, in harbours and in coastal areas. The effect of these will be dealt with in detail under Section 4.7.

Disposal of untreated sewage has already created a problem with the presence of large amounts of bacteria and viruses in coastal waters and in sea food. It is not yet fully documented whether microbial contamination has reached an alarming and irreversible stage in places.

The perennial rivers of many of these countries carry a large sediment load of about 1,600 million tonnes per year (Sen Gupta & Qasim, 1985). As a result many of the river mouths are getting shallower with consequent emergence of sand and mud banks. This siltation can be expected to have considerable impact on fish, generally reducing species diversity.

Another important source of contaminants is tourism. All the countries are aggressively promoting tourism and a number of large hotels are coming up on the shoreline. Deleterious effects of such hotels have been noted in many countries in different parts of the world and can be expected here also.

### 3.2 Transport and fluxes across boundaries

Data on these aspects are lacking in almost all the countries. However, the transport and fluxes of pollutants are an emerging field of study in India. Analyses of several potential contaminants have been carried out in rain water, aerosols, water and ocean sediments.

The average annual rainfall over the Indian mainland is 3,500 km<sup>3</sup> and over the surrounding seas it would be about twice as much. The mean concentrations of some elements in rain water from the coastal region are: Na 4.6; Cl 6.8; Ca 1.34; Mg 0.51; K 1.02 all in mg/l; Mn 23.4; Br 33.6; I 13.3; Fe 4.3; Co 0.1; Ni 0.1; Cu 6.8; Zn 13.3; Pb 21.5 all in ug/l (Sadasivan, 1979; Fondekar & Topgi, 1979). Some of these values are influenced by atmospheric contaminants over urban areas along the coast, for example lead concentrations over the city of Bombay.

Aerosol contents over the Indian Ocean decrease from 65.3 µg/m<sup>3</sup> air at 9°N to 1.9 µg/m<sup>3</sup> at 2° S (Sen Gupta & Qasim, 1983). These clearly show that aerosols over the sea are mainly influenced by the air flow from the nearest landmass.

### 3.3 Quality assurance, data validation and management

National intercomparison exercises for quality control of data have been and are being attempted in a few countries.

Attempts at improving the quality of environmental data is an ongoing process in India. So far, the National Institute of Oceanography (NIO) participated in the IOC/GEMS/ICES intercalibration exercise on heavy metals, IOC/ICES intercalibration exercise on petroleum hydrocarbons and IOC/WESTPAC/COBSEA/SPREP intercalibration exercise on heavy metals.

A national intercalibration exercise for nutrients in aqueous solutions and heavy metals in biological and sediment samples was organised by NIO/DOD/SCOR (India) in which 7 marine laboratories in the country participated (NIO, 1987). A second such exercise has also been completed recently with participation from 16 laboratories, and a third one has been initiated recently.

Assessment of the quality of environmental data is in progress in Pakistan. Results of investigations, applying standard methodology, have been presented and published in several international symposia and journals respectively. Much of the available data are provided by the scientists of the Centre of Excellence in Marine Biology, University of Karachi, and by the laboratories of the Pakistan Council of Scientific and Industrial Research.

A national intercalibration exercise among 13 main analytical laboratories is in progress in Sri Lanka. The first phase has been completed and the second phase was expected to be over by the end of 1987.

The School of Biological Sciences of the Universiti Sains Malaysia participated in the IOC/GEMS/ICES and WESTPAC/COBSEA/SPREP intercalibration exercises on heavy metals.

Vast amounts of oceanographic data are now available at the Indian National Oceanographic Data Centre (INODC) at NIO. The data have been collected by research ships from India and a few other countries from the Indian Ocean. The data are variously quality controlled.

#### 4. HUMAN ACTIVITIES AFFECTING THE SEA

##### 4.1 Disposal of urban and industrial waste waters

An estimate of sewage and other effluents added to the seas around India is presented in Table 5. Three of the four Indian major urban areas are located either on or close to the sea with associated industrial belts.

Table 5. Human population and related data together with some estimates of waste material (pollutants) entering the sea around India (as in 1986)

Population	$750 \times 10^6$
Coastal population (25% of the total)	$188 \times 10^6$
Area of the country	$3.276 \times 10^6 \text{ km}^2$
Agricultural area	$1.65 \times 10^6 \text{ km}^2$
Exclusive Economic Zone	$2.015 \times 10^6 \text{ km}^2$
River runoff (annual mean)	$1,645 \text{ km}^3$
Rainfall per year (on land)	$3.5 \times 10^{12} \text{ m}^3$
Rainfall per year (entering the Bay of Bengal)	$6.5 \times 10^{12} \text{ m}^3$
Rainfall per year (entering the Arabian Sea)	$6.1 \times 10^{12} \text{ m}^3$
Domestic sewage added to the sea by coastal population per year (@ 60 litres per head/day)	$4.1 \times 10^9 \text{ m}^3$
Industrial waste added to the sea by coastal industries per year	$0.41 \times 10^9 \text{ m}^3$
Sewage and effluents added by the rivers to the sea per year	$50 \times 10^6 \text{ m}^3$
Solid waste and garbage generated by coastal population per year (@ 0.5 kg per head/day)	$34 \times 10^6 \text{ tonnes}$
Fertilisers used per year (@ 30.5 kg/ha.yr)	$5 \times 10^6 \text{ tonnes}$
Pesticides used per year (@ 336 g/ha.yr)	55,000 tonnes
Synthetic detergents used per year	125,000 tonnes
Tar deposition on beaches along the west coast of India per year	750-1,000 tonnes

Source: Qasim & Sen Gupta, 1988

Currently only 45 cities with a population of 100,000 or more have sewage treatment facilities in India. Many more can be expected to be added to this when projects like the Ganga Action Plan are implemented.

The consequences of the discharges of sewage and effluents are not very perceptible along all the Indian coast. However, in nearshore areas of a few metropolitan cities which have large industrial complexes, the effects are, indeed,



becoming alarming. An increase of about 140% of phosphate-phosphorus concentrations in the nearshore waters off Bombay from 1959 to 1984 ( $0.82$  to  $2.0 \mu\text{mol.l}^{-1}$ ) has been observed (Sen Gupta & Sankaranarayanan, 1975; Zingde, 1985).

Similarly, dissolved oxygen concentration has decreased from  $4.71 \text{ ml.l}^{-1}$  in 1959 to near-zero in 1983 (Parulekar et al, 1985). Higher concentrations of phosphate-phosphorus, as compared to earlier data, have also been observed in the nearshore waters off Madras. This deterioration is evidently the result of uninterrupted discharge of untreated sewage and other effluents. Bombay city discharges about 365 million tonnes (MT) of sewage and effluents to the sea every year. Similar discharges from Calcutta city to the Ganges estuary total about 396 MT. These figures illustrate the environmental stress the coastal waters of India are subjected to.

In Bangladesh, sewage and effluents are usually discharged to the adjacent sea or estuaries. Industrial developments are fast taking place in the Chittagong area, along the river Karnaphuly and in the Khulna industrial zone along Bhairab-Rupsha river. Solid wastes are often released to the aquatic system altering the appearance of water bodies. Quantitative data of total discharges is difficult to compute from available information. Long-term and pre-industrialisation data are not available but the data on the current state of rivers and water-sources close to the coastal area are alarming. Disposal of untreated urban wastes has resulted in Bangladesh having the highest rate of faecal transmitted diseases (Ahmed, 1979). Bangladesh has a good reserve of natural gas and consequently a number of gas-based fertilizer factories have been established. Some of them do not have effluent-treatment plants and untreated effluents occasionally cause fish mortality in receiving water bodies.

In Pakistan, the problems are very similar. There are two large industrial areas in Karachi - Sind Industrial Trading Estate (SITE) and Landhi-Korangi Industrial Trading Estate (LITE). SITE consists of 300 major and 900 minor industries (Beg et al, 1984). Discharges of untreated industrial wastes from SITE and LITE areas create problems with their high load of BOD and suspended matter in the rivers and creeks receiving them. It has been estimated that the Manora channel receives suspended matter at the rate of 30 tonnes per day from SITE area (Beg et al, 1975). The quantity of domestic wastes produced per household varies from 80 - 280 litres per day (Zai-nul-Abidin, 1978). The computed total annual discharge of mostly untreated domestic sewage and industrial effluent from the city of Karachi is 175 MT. The sediment load of the River Indus has come down from 250 MT in 1940 to 50 MT in 1984 as a result of the construction of dams and barrages (Milliman et al, 1984) with a proportional reduction in runoff. This, combined with the increased volume of sewage and effluents, indicates a deterioration in the marine environment.

In the Maldives, Male is the only urban centre. There is, practically, no industry on any of the islands and the major problem is the direct disposal of wastes to the sea from the fish canning factory at Felivaru in Faadippolhu atoll.

In Sri Lanka, there is a major concentration of some 20,000 industrial units around the main urban centre, the city of Colombo. Most industries lack facilities for proper separation of sediments and waste material from the effluents. These waste waters, with high BOD are released to waterways and coastal areas untreated thereby contaminating them. The most damaging industries for such pollution are coconut and rubber-based industries, food processing plants, paper mills and distilleries.

Problems along the Bay of Bengal coasts of Malaysia and Thailand are, in addition to sewage and other effluents, mine tailings. The estimated total annual discharge of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn from raw sewage on the island of Penang alone is 189,000 tonnes (Sivalingam, 1984).

#### 4.2 Development of coastal areas

About 1,600 MT of sediment reaches the Indian Ocean from rivers flowing through the Indian sub-continent. Roughly 500 MT come from Indian rivers, and the rest from rivers of the adjacent countries (Qasim & Sen Gupta, 1983). The greatest amount of sedimentation takes place at the head of the Bay of Bengal which is influenced by outflows from India, Bangladesh and Burma. The visible effects of this are a number of drifting sand bars and islands. This siltation must definitely have a considerable influence on fisheries but no data are available.

Soil erosion, resulting mainly from land reclamation and harbour construction, is quite common in India. Occasional storm surges and tidal waves also cause erosion. Construction of sea walls and groynes to check erosion at one place have resulted in erosion at other parts of the coastline.

Extraction of coralline sand, as a raw material for the cement industry, has resulted in considerable damage to the verdant coral reefs in the Lakshadweeps. Quantitative data are, however, not available.

Construction of hotels along the coast has both negative and beneficial effects. Tourism may spoil aesthetic values by litter and by commercialisation however many hotels strive to keep the nearest beach area clean for their clientele.

Karachi, in Pakistan, has two ports both of which suffer from siltation. As a result, dredging is a regular operation with associated costs and damage to marine life. Harbours are also affected by oil pollution. During construction of a new harbour considerable areas of mangrove were destroyed damaging economically important marine fisheries, particularly prawns.

Bangladesh has a total coastal length of 1,120 km of which 200 km has been assigned for development of tourism, park and recreation facilities. Such developments, though needed for economic reasons, have adverse effects on the natural environment.

In the Maldives, groynes, sea walls and jetties have affected sand movement around many islands causing erosion and deposition. Land reclamation for human habitation, coral mining and sand mining are also damaging some of the reefs and lagoons.

Construction of marine structures without proper environmental impact assessment have created problems in the western, eastern, southwestern and southern coasts of Sri Lanka. Siltation of most of the fishing harbours constructed in the past, has been attributed to the of structures upsetting the littoral drift balance. These and tourism-related activities are damaging the coral ecosystem while land reclamation is destroying habitats for a variety of fish.

#### 4.3 Manipulation of hydrological cycles

The construction of dams and barrages across rivers is quite common in India to provide water for agriculture, power and public water supply. The River Narmada is thought to be the only large river which has, so far, been left without any artificial regulation of its flow.

A fair amount of nutrients and pollutants can be expected to get trapped behind these artificial structures. This is in addition to the quantity which will oscillate with tides in estuaries. It has been calculated that such oscillating tidal entrapments in the estuaries of the rivers Ganges and Mahanadi amount to 9 and 24 per cent respectively (NIO, 1986).

Dams and reservoirs can accumulate silt very fast. As a result of this, their holding capacities are reduced. During heavy rain and consequent high drainage from the catchment areas, water has to be released in large quantities causing floods in downstream areas.

One prominent example of manipulation of the hydrological cycle is the Indus River in Pakistan. Due to the construction of dams and barrages at various places on its course, the annual sediment load at its confluence with the sea has been reduced from 250 MT in 1940 to 50 MT in 1984. The runoff has also been reduced considerably from 174-236 km<sup>3</sup>/year to 57-108 km<sup>3</sup>/year (Milliman et al, 1984). Another example of manipulation of the hydrological cycle concerns the River Ganges giving rise to changes in the water balance of the associated delta and estuarine systems (see e.g. Nandy et al, 1983; Rahman, 1986).

Construction of artificial barriers for shore protection is a common feature both in the Maldives and Sri Lanka. A project on beach nourishment to attempt to reduce the sand transport capacity at a few beaches in Sri Lanka is under way. It has been computed that the net annual loss due to erosion in Sri Lanka is of the order of 300 - 500 x 10<sup>3</sup>m<sup>3</sup>.

#### 4.4 Other land use practices

Near several metropolitan cities land has been reclaimed and is still being reclaimed from the adjacent sea. The material used for such landfills is mostly solid wastes and garbage generated by the urban population. Often, these have resulted in public health problems through leaching.

Another land use practice which is causing concern in India, is the siting of nuclear power generation units along the sea. These plants normally release 50% of their generated heat to the coastal marine environment. Flora and fauna in the warm tropical waters live dangerously close to their upper lethal limits of temperature, particularly during the warm summer months. It does not need a large deviation from this limit to result in an environmental catastrophe. Fisheries near such power plants are receding further and further away from the shore.

About 3,200 ha. of mangrove areas along the Bangladesh coast have been converted to fish farms. Some mangrove areas have also been cleared for the construction of dykes. However, 22,400 ha. of damaged mangrove areas are being replanted with suitable mangrove plants.

Pakistan has problem with thermal pollution from the Karachi nuclear power plant. A reduction in species diversity of marine organisms has been observed near the warm water discharge point of the power plant (Rizvi et al, 1985). Coastal areas are being increasingly used for urbanization. This often results in damage to coastal ecosystems and denudation of mangroves. Increased numbers of automobiles in cities, domestic burning of fuel, power plants and other industries, also contribute considerably to air pollution, part of which ultimately reaches coastal marine areas with associated deleterious consequences.

Flooding of brackish water and lagoon areas by fresh water due to river diversion schemes, the reclamation of marine area by garbage dumping, and construction of dams at upper reaches of rivers resulting in salt water penetration at the lower reaches (e.g. River Mahaveli) are some of the problems in Sri Lanka.

Dynamite blasting of reefs, even if infrequent, could be a problem in the Maldives in the long run.

#### 4.5 Disposal of contaminated sediments, mine tailings and industrial solid wastes

There are 11 major, 16 intermediate and 78 minor ports in India. All these ports have navigation channels which are dredged continuously. The dredge spoils are dumped not very far from shore and may contain material toxic to marine life. During flood tides part of this may be washed back. As a result of this dumping activity, fisheries near several harbours have either been depleted or have disappeared. Monitoring of these areas needs to be undertaken.

In coastal areas of India, occasional deposits of ilmenite placers and monazite sand have been located and are being mined (Siddiquie et al, 1984). Intense mining activity is in progress in some estuarine regions. Depletion of fisheries, particularly shellfish and benthic fauna due to mine tailings and mining rejects and washings, have been observed at places in India, causing irreversible ecosystem instability (Parulekar et al, 1986).

About 500 tonnes of sediments are contributed every year by the Kuala Muda river in Malaysia necessitating regular dredging in Penang Harbour to keep the shipping lanes navigable. Tin mining activities in the offshore waters of Phuket seem to be affecting the northern waters of the Malacca Strait. It is believed that this is harming spawning grounds and rare coral reef areas in the Malacca Strait.

#### 4.6 Disposal of solid waste (litter)

Generation of solid waste and garbage is not very high in India. Calculating at the rate of 0.5 kg per head per day the coastal population of India can be expected to generate  $34 \times 10^6$  tonnes of solid waste per year (Qasim & Sen Gupta, 1988). Near urban and metropolitan areas these are used as landfills and for land reclamation from the sea. The major portion of these wastes is generated in urban areas.

Other solid wastes which pollute Indian coastal waters are: garbage, including plastics, from the tourism industry; scrap material from ship-breaking yards; damaged and rejected fishing nets and other gear; and the disposal of unwanted trash fish by trawlers. Quantitative data on these are, however, lacking.

Wastes from fishing eg. trash fish, rejected gear, and from slaughter houses are problems in Bangladesh. Ship breaking activity is a flourishing business with about 50 companies engaged in such activities. Rejects from these contaminate the beaches and the nearby sea area. Data from a beach quality study are presented in Table 6 (Hossain & Islam, 1986). Bangladesh lies in the cyclone path. Storm surges and cyclones ravage the coastal area almost every year, leaving in their wake devastation and disaster. Human bodies and cattle carcasses together with a large quantity of debris are washed out to sea as a result of these natural catastrophes.

Table 6. Beach quality study in Chittagong, Bangladesh  
(Hossain & Islam, 1986).

	1A	2A	3A	4A	5B	6B
Accumulation of metal fragments (cm depth)	1.0	0.7	1.2	0.6	-	-
pH	8.4	8.1	8.3	8.4	7.4	7.3
EC (us.cm <sup>-1</sup> )	324	296	360	302	500	508
Chloride (mg.l <sup>-1</sup> )	113	110	116	119	213	-
Iron (mg.l <sup>-1</sup> )	2.0	1.8	2.1	1.6	0.6	0.56
Ammonia (mg.l <sup>-1</sup> )	16.1	29.1	21.06	17.22	1.02	0.87

A - Stations in the ship-breaking area.

B - Stations outside the ship-breaking area.

Similar problems exist in Pakistan. Gadani shipbreaking yard located on the outskirts of Karachi is the second largest of its kind in the world and can be expected to contribute a substantial amount of solid wastes to the marine environment. Contamination of channels and backwaters due to dumping of garbage has been observed in Pakistan. Putrefaction of some of this material generates hydrogen sulphide in the fishing harbour of Karachi, turning the colour of the water almost black.

In the Maldives, beach litter consists of dead leaves and other biodegradable material. Recent developments in tourism are posing a threat to the environment. Cans, plastics and empty bottles along with the normal household garbage are increasingly finding their way to the sea. Plastic bags, particularly, pose a serious problem. Disposal of garbage is a problem in Male due to the inefficient incineration system. Incineration is mandatory for the 92 tourist resorts but cans have to be crushed for disposal into the deep sea. It is estimated that 3.1 kg of garbage is generated per head per day.

Solid wastes in Sri Lanka are generally used as landfill in aquatic areas. Fibre wastes, sawdust, wood shavings etc., are dumped in large quantities along river banks and beaches. Litter from industries located along rivers and canals is dumped in these waterways and eventually gets washed to the coast polluting the beaches. In many cases tourist resorts, eg. Hikkaduwa, hotels and guest houses, are the main sources of beach litter. Nearly 75% of the 125 graded hotels in Sri Lanka are located along the coast.

#### 4.7 Marine transport of oil and other hazardous substances

Oil pollution in the Indian Ocean has been reviewed by Sen Gupta & Kureishy (1981). The sources of oil pollution are tanker disasters, discharge of ballast water and bilge washings. The total record of accidental oil spills in the Indian Ocean, north of the equator, is 15 tanker disasters and 3 blow outs between 1970

and 1982 (Couper, 1983). Therefore, the main sources of oil pollution in this region are the oil tankers and merchant ships sailing along the trade and tanker routes.

Monitoring of oil pollution is a regular programme in India. Available data are presented in Table 7. The table shows that marine transport of oil from the Middle East countries is gradually decreasing. Consequently, the volume of tanker traffic has also decreased considerably. As a result of the reduction in traffic an apparent reduction in oil pollution from 1978 to 1985 can be deduced from data for the tanker routes across the Arabian Sea and the Bay of Bengal.

The reduction in concentration of dissolved petroleum hydrocarbons was marked from 1979 to 1980 in the Arabian Sea and from 1980 to 1981 in the Bay of Bengal. Subsequently conditions appear to have stabilised in both areas. All the oil producing countries of this region are signatories to the 1973 MARPOL convention and the 1978 protocol. Many have already ratified them. This has resulted in the establishment of reception facilities for oily bilges, ballasts and sludges at almost all the major ports. With the establishment of such facilities at all the ports, oil pollution in the Arabian Sea and the Bay of Bengal can be expected to decrease further.

Figure 4 summarizes 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 nil observations while those at the bottom are the number of occasions when oil slicks were sighted. A close look at the figures will indicate that oil slicks are 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.

An indication of the effect of oil exploration activities on the marine environment can be obtained from the concentrations of dissolved and dispersed hydrocarbons in the range of 2 - 46 µg/l in the water and 4 - 32 µg/g dry weight in the sediments taken from the vicinity of the Bombay High oilfield. A near catastrophic event took place in the Bombay Harbour region, where, after a tanker fire accident, the concentration of dissolved and dispersed hydrocarbons rose from 27 to 105 µg/l in water and in the sediments it increased from 1 - 26 mg/g dry weight to 40 - 512 µg/g after the accident. The values, however, recovered to background level within a few weeks.

Cargo ships and oil tankers visiting Indian ports often cause oil pollution in harbour waters by operational or accidental discharges of oil and oily ballasts during loading and unloading. These oily discharges may end up as depositions of tarry lumps on nearby beaches. It is extremely difficult to identify the sources of such pollution and match them to the oil in harbour waters unless they are promptly sampled and appropriate analytical methodologies are applied. A technique for such identification using UV-spectrofluorometry, IR-spectrometry and gas chromatography has been perfected at the National Institute of Oceanography, which has been recommended by the Indian Port Management Association for application by all the Port Trusts in India (Bhosle et al, 1987). However, the possibility of several ships using the same oil and the same bunker complicates the identification of the ship.

The oil tanker route from the Middle East to the Far East and Japan, passing through the Arabian Sea, southern Bay of Bengal and Malacca Strait, is of direct concern to Pakistan, India, Sri Lanka, Malaysia and part of Maldives. 232 MT of crude oil and its products were transported along this tanker route in 1985 (British Petroleum, 1986). The effects of this traffic is evident in the form of

Table 7. Dissolved and dispersed hydrocarbons in the upper 20 m of the Arabian Sea and the Bay of Bengal

Year	Transport (M/T)	ARABIAN SEA		Transport (M/T)	BAY OF BENGAL		
		Concentrations (µg/L) Range	Mean		BB/AS %	Concentrations (µg/L) 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	0.0 - 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	-	-	-	-
Net decrease (%)	54	-	-	-	28	-	-

Source : Qasim & Sen Gupta (1988)

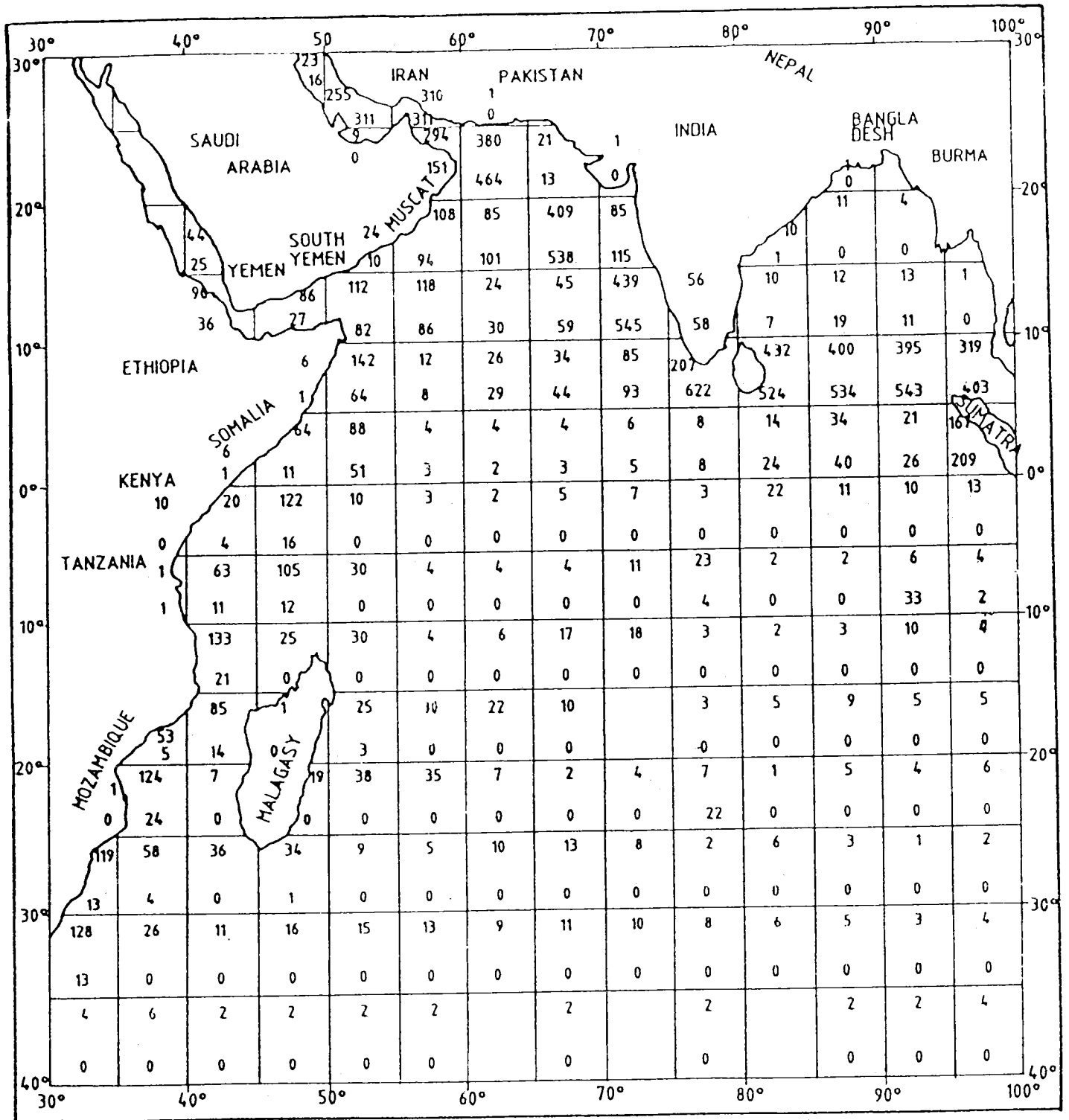


Fig. 4. Observations on oil slicks and other floating pollutants every 5° square in the Indian Ocean. The upper values indicate occasions when oil slicks were absent while lower values indicate occasions when oil slicks were sighted. Data collected 1975-1980, updated to 1984. (Courtesy: Japan Oceanographic Data Centre)



floating tar particles on water and deposits of tar balls on the beaches. All the countries are affected by shipping and tanker operations at their harbours, the most common impacts being occasional mortality and frequent oil-tainting of the benthic fauna, particularly shellfish.

Oil tankers and cargo ships moving in and out of the harbours in Pakistan add a considerable amount of oil to the environment. Manora channel, the site of Karachi harbour, occupying an area of 7.17 km<sup>2</sup> and directly fed by the Arabian Sea, is the worst affected by oil pollution. At some places due to heavy accumulation of oil, the water has turned black. The presence of oil is detected in sediments and the benthic environment. Deposits of tar balls have been found all along the coast. About 20,000 tonnes of oil is believed to leak into Pakistani waters from different sources every year.

#### 4.8 Exploitation of non-living marine resources

##### 4.8.1 Minerals

There are good deposits of ilmenite placers and monazite sand along parts of the coastal stretches of India (Siddiquie et al, 1984). Mining on a commercial scale has only taken place in a few areas. In extracting monazite sand from some of the beaches appropriate care is being taken to prevent erosion.

India has a fast developing exploration and exploitation programme for offshore oil fields. The formation water from such operations is 34,000 barrels/day containing 40 ppm of oil (Anonymous, 1983). The volume of drilling mud and its oil content are not accurately known and their impact on the environment is being evaluated only gradually.

India is also actively engaged in exploration of the seabed in the Central Indian Ocean to assess qualitatively and quantitatively the polymetallic nodule deposits. However, environmental impact studies for eventual deep-sea mining operations are being conducted simultaneously.

Bangladesh has deposits of ilmenite, magnetite, monazite, kyanite, etc., along its southeastern coastline. These are being explored and exploited but no information on the environmental impact of these operations is available.

In Sri Lanka most of the beaches contain a wide range of minerals but only a few are exploited. The beach sand contains ilmenite, zircon, rutile, monazite, silimanite and garnet in varying amounts. Their exploitation is an age-old process in the country.

##### 4.8.2 Coral reefs

Most of the coral reefs in India are fringing and barrier reefs, sea level atolls and elevated reefs. Most of them have been declared as endangered ecosystems and out of bounds for commercial activities. Several coral reefs have almost disappeared because of the collection of coral debris and live corals for use as raw material in the cement industry; while others have died due to their constant exposure to pollutants, particularly oil.

In India the north-west and south-east coasts as well as the Lakshadweep and the Andamans and the Nicobar group of islands possess coral reefs and atolls of great significance. The flora and fauna of the coral reefs are of considerable importance. Ornamental fish have good commercial value while gorgonians, sponges, hard and soft corals can be used as sources of many useful drugs and chemicals for

which an international investigation is in progress. It has been estimated that the lagoons of the Lakshadweep contain up to 2,000 million tonnes of calcareous sands out of which 700 million tonnes are in up to one metre depth and could be exploited without significant change in the steady state of the environment (Siddiquie, 1985). Such investigations, if carried out in all the coral reefs of the South Asian Seas Region, could help the countries economically without causing damage to the environment. However, due to oil pollution from the heavy tanker traffic and the collection for ornamental and decorative purposes, coral reefs in some of the Lakshadweep and Andaman and Nicobar Islands are already damaged. The coral island, Pirotan Island, in the Gulf of Kutch has been declared a nature reserve as part of India's programme for IUCN. Similarly, the islands of the Gulf of Mannar and Palk Bay have also been declared as protected areas. Another coastal area with coral reefs near Malwan on the central west coast of India is also likely to be protected.

So far, 32 genera of corals from the reef adjacent to the Minicoy Island, 34 genera from Palk Bay and Gulf of Mannar, 25 genera from Andaman Islands, 9 genera from Lakshadweep, and 3 genera from Nicobar Islands, have been reported. A total of 342 species belonging to 76 genera from the seas around India have been described. Acanthaster planci, a reef dwelling echinoderm which feeds extensively on coral, has also been reported in the region and is responsible for destroying some of the coral of the Lakshadweep and Andaman and Nicobar Islands.

Primary productivity studies of coral reefs in Indian waters indicated comparable rates with other reef systems. Often the large benthic algal communities and extensive seagrass beds are equally important, since the energy released from them is transferred to higher trophic levels by way of the detrital food chain.

Corals and mangroves occur adjacent to each other at a few places in the Gulf of Kutch and Andaman-Nicobar islands. The mangroves grow in the intertidal region while corals are in near and offshore waters. However, extensive deforestation of mangroves in the Gulf of Kutch has resulted in siltation of the coral reef, destroying part of it. This illustrates the interaction between these two different ecosystems.

Bangladesh has only one coral island viz., St. Martin Island. But corals are exploited from this island for various purposes. Other non-living marine resources which are exploited are dead corals, mollusc shells, dry algal plants, mangrove timber, etc.

In the Maldives, mining of sand has been practised for a long time but extraction of coral and coral sands has only recently reached a critical level. These are used for preparing lime and cement for building purposes. However, alternatives to coral as a raw material for these industries are being looked into, in an attempt to control this unplanned coral mining. Bleaching of corals was noticed around South Male atoll from shallow waters to 30 m. This could be due to temperature increase following a freak tidal surge a month earlier.

Sri Lanka has coral reefs along parts of its southern coast. A number of people are dependent on coral mining for their livelihood. These corals and coral sands are used as raw material for the construction industry. It has been estimated that about 40% of a total of 18,000 tonnes of raw material used by cement kilns, come from coral reefs and debris. Sand mining is also carried out in places in Sri Lanka. However, recently, steps have been taken to regulate sand mining to check beach erosion. Collection of coral and sea shells as souvenirs, ornaments and for export has expanded beyond sustainable levels for most of the species.

In the Malacca Strait, there are only a few coral reefs. These rare coral reefs appear to be affected by offshore mining activities and sedimentation.

#### 4.8.3 Mangroves

In India, the mangrove forests on the east coast start from the westward continuation of the Sunderbans in the Ganges delta and are distributed along estuaries, deltas and backwaters. They are, however, more scattered along the west coast of India. Rhizophora, Avicennia, Bruguiera and Sonneratia are among the most important genera present. Some of them e.g. Acantophora spicifera, Rhizophora mucronata, Sonneratia alba and Kandellia rheedii hold promise as sources of drugs and pharmaceuticals. These mangrove forests are habitats for fish and wildlife. Commercially important species, eg. Mugil cephalus, Hilsa ilisha, Lates calcarifer, Scylla serrata, Meretrix casta, Crassostrea grephoides, Penaeus spp. use mangrove habitats as spawning and breeding grounds. The Sunderbans mangroves area is a part of the IUCN Project Tiger reserve. Land reclamation, deforestation and pollution are the hazards faced by this environment. Industrial effluents have completely decimated the lush mangrove forests along the Mahim Creek, Bombay. Thousands of hectares of mangroves have been reclaimed for agriculture, fish farming, human habitation and industry in the Sunderbans, Cochin Backwaters, Bombay region and the Gulf of Kutch.

Studies on the effect of oil and its products on the seedlings of Rhizophora mucronata and Avicennia officinalis revealed that they cause burning, yellowing and wilting of the leaves associated with root damage (Jagtap & Untawale, 1980). The effect of insecticides and pesticides was also found to be harmful to these plants, though at a slow rate.

Seasonal variation in the concentrations of some heavy metals in the mangrove foliage indicated high concentrations of Fe and Mn without any harmful effect (Untawale et al 1980). Presence of radioactive elements like uranium have also been recorded with no immediate effect on the mangroves.

The mangrove areas in India do not appear to have been properly surveyed. Figures vary widely in the literature and they have been variously estimated as 3,500 and 7,000 km<sup>2</sup> area. The only reliable source of information is satellite imagery and until complete coverage is obtained these figures can be considered as very tentative.

Bangladesh has a total mangrove area of about 41,000 ha. part of which has been denuded for shrimp culture while part has been declared as reserve forest. Afforestation has been and is being undertaken in places as these mangrove plants are very important for the economy of the country. About one-third of the population is dependent upon the mangrove environment for their livelihood with employment for over 300,000 being generated in the Sunderbans region alone (UNEP 1986).

The mangroves which were once well developed along the Sind Coast, are now restricted more or less to the mouth of the Indus. Some 20 hectares along the Makran coast in Baluchistan is occupied by mangroves. Two surveys (Khan, 1966; Mirza et al, 1983) were conducted to estimate the mangrove area in the Indus deltaic region. A comparison of the two surveys shows that mangrove occupied area has decreased from 53.8% in 1960 to 44% in 1978. The present estimated mangrove area is about 1,300 km<sup>2</sup> (Saifullah, 1982).

According to Sneddeker (1984), the mangrove areas of Pakistan ranked fifth or sixth in the world. The mangrove forests of Sind are monospecific in the sense that Avicennia marina occupies about 99.9% of the total mangrove forest area.

In Pakistan, mangroves are threatened largely because they are utilized beyond the sustainable yield limit (Barkati & Tirmizi, 1987). A number of factors have contributed to the over exploitation of mangroves in Pakistan - camel browsing, fodder, firewood, port construction, human settlement, reduction of Indus river flow, siltation, pollution, etc.

Intensive surveys of mangrove fauna have been conducted (Tirmizi, 1983, 1984, 1985). These studies documented juveniles and larvae of a number of commercially important marine species dominated by molluscan and crustacean species. About 131 invertebrate species have been recorded.

Mangrove swamps of Sind support enormous populations of the edible crab, Scylla serrata, and the mud clam, Marcia cor.

Sri Lanka's mangrove area has been variously estimated as between 630 and 1,500 km<sup>2</sup>. The Maldives have scattered, sparse mangrove vegetation of great ecological importance.

The area of mangroves in Malaysia is only 2% of the total land area which is equivalent to 6,500 sq.km. 20% of mangrove on the Malacca Straits has been lost over the last 20 years due to reclamation while in East Malaysia, 5,000 ha. per year has been lost to the wood chip industry.

Mangroves serve the same purpose in all these countries and are facing identical threats of destruction by reclamation, deforestation and pollution.

#### 4.8.4 Marine algae

Marine algae, particularly macrophytes, form an important resource for human food, animal feed, drugs and pharmaceuticals. Their use is so far limited to agar, alginate and as manure. There are about 625 marine algal species in Indian waters and some of them can tolerate a high level of pollution and can be used as 'indicator species'.

Some species eg. Acantophora spicifera, Acanthus illicifolius etc., have promising medicinal properties such as anti-implantation, antiviral, analgesic, etc. Extracts of brown algal species Stoechospermum marginatum and Dictyota dichotoma showed promise as fertilisers.

Seaweed may be considered as an under-utilized marine resource in Pakistan. In spite of the occurrence of about 300 species in Pakistan waters, seaweeds are neither utilized locally nor exported. A recent innovation is the use of seaweed in preparing poultry feed which has recently been initiated.

#### 4.9 Exploitation of living marine resources

Data on total fish catches in the region show a rising trend. However, marine fish landings are decreasing while culture fisheries are increasing.

The decrease in capture fisheries is generally attributed to the effects of pollution. Marine fisheries in all these countries can at best be termed as semi-mechanised. This means that fishing is concentrated mostly in coastal and inshore areas with only a minor effort offshore. As a result, there is stock depletion due to the capture of juveniles. In many places, it is believed, that the maximum sustainable yield has been reached, if not already exceeded. Over-fishing which is an acute problem in this area is bound to affect marine avian life.

Commercially available living resources in the Indian EEZ are being exploited to a depth of about 60 m. Total fish production is rising, the present figure being 1,600 thousand tonnes per annum. However, marine fish landings are decreasing and about 40,000 tonnes are being harvested from culture fisheries per annum.

In the vicinity of busy ports and harbours pollution from ships and dredging reduces the availability of oxygen in bottom waters rendering conditions near-anoxic. Benthic fauna is badly depleted resulting in significant loss of fisheries. Fisheries near the Bombay harbour are, for example receding further and further from shore and fishermen have to go beyond 10 km from shore to catch something worth their effort. Another source of impact on the fish is discharge from thermal power plants. At several places fisheries have receded offshore due to the effect of warm water.

The Government of India has introduced legislation to demarcate zones of operation for non-mechanised traditional boats, small mechanised boats and deep-sea fishing trawlers. While foreign fishing vessels are not permitted within the EEZ, most of the littoral states have enacted legislation which prohibits even small mechanised boats from fishing within 5-10 km from the coastline. This legislation, in addition to safeguarding the interests of the traditional fishermen, will also help to protect ecological values of coastal waters from the ravages of mechanised fishing.

Bangladesh has an average annual fish production of about 187,000 metric tonnes, including production from culture farms. The Bay of Bengal provides 90 commercially important species out of a total of 345 species investigated. There are also 15 species of shrimp or prawn of which 10 species are commercially important. In addition, there is a large quantity of non-conventional marine products such as crabs, turtle etc.

There are about 350 commercially important fish and shrimp species found in Pakistan waters. Of the fish species, 240 are demersal, 50 are small pelagic, 10 medium sized pelagic and 18 are large pelagic fish. Fifty species are exploited for direct human consumption. There are 15 species of commercially important shrimps, 5 of lobsters, and 12 of cephalopods (cuttlefish/squid/octopus). Marine fish landings in Pakistan during the period 1958-85 show a continuous increase, there being no input from culture fisheries in the marine sector at present. Total fish production increased from 46,000 tonnes in 1958 to 333,316 tonnes in 1985. About 26% of total fish production in Pakistan is consumed locally.

Biomass estimates based on acoustic survey showed 60,000 to 62,000 tonnes demersal fish, 408,000 to 538,000 tonnes of small pelagics, and 20,000 tonnes of large pelagics for different time period/area combinations.

It is believed that shrimp resources are overexploited in Pakistan. At present shrimp catches have surpassed the maximum sustainable yield of 15,000 tonnes/year. Landings of the most valuable shrimp category 'jaira' and 'kalri' have declined by 25% (Tirmizi, 1987).

Underutilized resources include lobsters, crabs, bivalves, cephalopods and seaweeds. In spite of the absence of a properly planned fishery, 44 tonnes of lobsters and 27 tonnes of crabs were exported. Crabs are exported to the Middle East, Far East and America. A potential yield of about 2,000 tonnes is expected for recently exploited cephalopod resources which include squid, cuttlefish and octopus. Oyster species are also exported in small quantities. In 1985, 7 tonnes

of oysters were exported. There are several other commercially important marine food resources which are underutilized such as mussels, clams, sea urchins, seaweeds etc.

Both coastal and offshore fisheries are important for Maldives. Fishing is done mostly by pole and line using live bait collected from coral reefs. Spear or dynamite fishing is prohibited. Aquarium fish collection from certain reefs, although controlled by export quotas has virtually depleted the stock. Shells and other coral collections for the flourishing tourist industry is showing environmental depletion. Black coral is being extracted in quantity and in the absence of scientific study it is impossible to gauge the damage. The average annual fish catch is 50,000 tonnes of which 44% is pelagic tuna.

Average annual marine fish catch in Sri Lanka is around 185,000 tonnes engaging about 110,000 people. Fishing is restricted mostly to within 25 nautical miles from shore. Gill netting, beach seining, pole and line, and trawling, are among the methods used for fishing. Beach seining is very damaging to coastal fauna because it picks up immature juveniles. Dynamite and other explosives are also utilised for fishing in some areas. Some rare species of fish have been decimated in a short period of time.

Data from Malaysia indicate that the fish landing from the Malacca Strait has gone up from 200,000 tonnes in 1967 to 440,000 tonnes in 1983. The maximum sustainable yield has been estimated as 250,000 tonnes. This is a clear example of over fishing.

## 5. BIOLOGICAL EFFECTS

Biological effects of pollutants in the marine environment of India are not very well documented mainly because of the nature of the area i.e. sufficiently well mixed waters and the open sea. However, the effects at the population and community levels have been noticed in restricted environments along the coast, estuaries and creeks. This information is, however, very scant and is not in any way representative of the entire coastal area.

The general problem of the area is the discharge of untreated sewage into the coastal environment. Several creeks and estuaries off Bombay and some other parts of India have been affected by sewage and industrial activities to the extent that decline in general fisheries as well as reduction in species diversity of organisms are observed.

### 5.1 Eutrophication

The untreated sewage from the metropolitan cities in India as well as unrestricted industrial discharges have made some water bodies oxygen-deficient. A clear example of this is the Mahim Creek where the diurnal variations of  $H_2S$  - S and dissolved oxygen (DO) are presented in Table 8. Reduction in DO concentrations off Bombay region over the last 15 years has been observed (Parulekar et al 1985). Similar situations are also observed off Cochin and Madras.

The short renewal time of intermediate waters and the related observed short-term temporal variability in denitrification indicate that the oxygen-poor, denitrifying layer in the Arabian Sea is an unstable, time-variable feature. It is not yet very clear if the variability occurs either as a result of productivity or circulation. One or both these controlling factors are probably reflected in the

Table 8. Diurnal variation of H<sub>2</sub>S - S and dissolved oxygen (DO) at Mahim Creek on 5 January 1984

Time (hr)	H <sub>2</sub> S-S (µg-at/l)	DO (mg/l)
0700	33.2	0.0
0800	83.3	0.0
0900	85.4	0.0
1000	93.2	0.0
1100	17.8	0.0
1200	1.5	0.0
1300	0.0	1.8
1400	0.0	2.1
1500	7.8	0.0
1600	12.5	0.0
1700	13.4	0.0

From : Sabnis (1984)

intensity and horizontal extent of denitrification. Thus, there is an alarming possibility that future anthropogenic, climatic or environmental perturbations (global warming resulting from increasing inputs of fossil fuel CO<sub>2</sub> to the atmosphere or an increase in the downward flux of the organic carbon associated with pollution) could disturb the precarious balance between oxygen consumption and its supply, and may well lead to the appearance, or a reappearance, of hydrogen sulphide (Naqvi, 1987).

In Bangladesh, reports about eutrophication are available only from the Karnaphuly river near Chittagong. Eutrophication is caused by the excessive effluent from slaughter houses and the run-off from agricultural land. It is also caused sometimes by the dumping of biodegradable solid wastes and garbage.

In Pakistan near the industrial complexes of Karachi, high BOD loads have been observed. Due to the disposal of untreated domestic sewage, the smell of hydrogen sulphide is present everywhere around Karachi harbour, particularly, near the fishing harbour and premises of sea-food plants.

Sri Lanka data are available only from areas off Colombo where large amounts of sewage and wastes are disposed untreated. This has resulted in eutrophication of parts of the Kelani River and the Wellawatta Canal (NARA, 1985). The BOD and COD levels are much higher than those recommended by the Sri Lanka standards. It has been estimated that the BOD level also goes up due to the discharges from the natural rubber processing plants, coconut husk retting, paper and pulp processing. Some data are available on the water quality of a few places along the west coast of the country which do not indicate any significant deterioration of water quality. However, occasional fish mortality due to indiscriminate discharges has also been observed.

In the Maldives, the absence of facilities and lack of trained personnel, hinders the assessment of the real situation. Observations indicate that part of the marine environment around the principal city of Male, including the semi-

enclosed harbour region where the sewage outfalls are located, do show high levels of BOD and COD.

## 5.2 Public health effects

The most serious public health hazard in India as a result of contamination has been identified as gastro-intestinal diseases resulting from the consumption of contaminated sea food. However, there are no conclusive data to pinpoint the role of the contaminated marine environment in these epidemics.

In Bangladesh an outbreak of diarrhoea caused by Salmonella contamination was noted on St. Martin Island. This contamination was suspected to be from the sun-drying of fish on the beach and the addition of bleaching powder to save them from putrefaction.

Widespread diarrhoeal disease and viral hepatitis do occasionally break out in various parts of Sri Lanka. These were suspected to be due to contamination from human faeces, through the marine food chain or direct contact. An indicator of this is the high value of faecal coliform counts from Beira Lake in the city of Colombo ( $1.2 \times 10^4$  -  $8.4 \times 10^5$  per 100 ml). Fish caught from this lake have often been reported to have an unpleasant odour due to chemical and oil contamination. High faecal coliforms have also been reported from the River Kelani. This river is also contaminated with chemical effluents from nearly 60 industrial units. It is planned to improve the sewerage system in the city of Colombo and in several coastal towns to reduce the bacterial count in the effluent acceptable limits for coastal marine disposal.

A coastal zone management plan has been prepared in Sri Lanka by a committee representing central government agencies. This plan envisages identification of critical habitats of the coastal zone and proposals and guidelines for the management of these habitats. This plan also suggests that for all future developments in the coastal zone, evaluation of ecological and environmental impact is mandatory. As a protection measure, several coastal marine areas have been declared as marine sanctuaries in 1979 for the conservation of endangered fauna and flora.

Reports on microbial contamination of marine organisms, particularly the benthic fauna, indicate fairly high contamination by bacteria and viruses in Pakistan.

In Maldives there is no perceptible public health effect though sewage is disposed of untreated. It is said that the absence of sea organisms like cockles and mussels in the Maldivian diet reduces the health risk.

The whole of Maldives can be considered as a natural marine park but due to unrestrained human interference, many coral reef areas have been damaged. In fact, the introduction of the bait fish, Tilapia, has been reported to have replaced the native species in the southernmost atoll of the country.

## 5.3 Long-term biological impact of contaminants

There are numerous reports about the levels of particular pollutants in marine organisms of India as discussed in the earlier Sections. However, no report deals with the effect these accumulations have on ecological communities or other biological impact. The concentrations generally are quite low in organisms from coastal areas and open seas. Certain areas like the Mahim and Thana Creeks in Bombay show elevated levels of metal contamination leading to a problem from the



human consumption point of view. Effects of mining activities on the clam fisheries and bottom fauna of Goa estuaries indicated that in less than 10 years, mining activity has resulted in more than 70% reduction in clam production, near extinction of resident fauna and the appearance of a low diversity bottom fauna comprising of tolerant but vagrant species (Parulekar et al, 1986). The effect of high organic enrichment on benthic polychaete populations in an estuary has been observed (Ansari et al, 1986). Comparison of zooplankton populations in polluted and unpolluted estuaries showed that the extent of variability in the distribution of zooplankton was in accordance with the intensity of pollution and so was the dominance of various groups (Desai et al, 1983). Copepods were predominant in unpolluted estuaries while in polluted estuaries during ebb tide gastropods, mysids, and polychaetes formed the major part of the zooplankton. The diversity of different groups of zooplankton was relatively low in polluted estuaries of Gujarat. Some indicator organisms have been identified in Cochin backwaters where two different sources of pollution i.e. retting of coconut husks and discharge of municipal wastes occur. Similar situations exist in other parts along the Indian coast where estuaries and enclosed water bodies are under considerable environmental stress.

In Bangladesh observations in the estuarine region indicate a correlation between siltation and fisheries. It has been found that some of the fish and benthic fauna do survive the presence of large amounts of silt, sludge, etc., in water, though, in general, there is a reduction in species diversity (Qadar, 1976).

Data on long-term impacts of contaminants on organisms in estuarine regions of Bangladesh are not available in greater detail. However, some observations using proton-induced x-ray emission, are available and these are presented in Table 9. These data however, do not indicate any significant degree of contamination (Khan & Bhuiyan, 1983).

In Sri Lanka the record of the long-term biological effect of the impact of pollutants on the environment is not directly available. However, it is suspected that due to continuous disposal of various pollutants, damage might have been caused to coral reefs, mangroves and other habitats.

#### 5.4 Damaged habitats and resources and their potential for recovery

The damage of pollutants can be irreversible but at other times the impact is temporary and the affected area can recover to its normal state either through preventive measures or through natural processes. The available information for this region has been summarized in the following paragraphs.

Sewage and wastes from the city of Bombay used to be disposed of to the nearby sea after only primary treatment thereby damaging the coastal marine environment considerably. A programme to establish sewage treatment plants to tertiary level and to lay sea outfalls 3 km away from the shore is under implementation with aid from the World Bank. This will help the recovery of the coastal marine environment from the damages caused earlier.

Petroleum pollution of the beaches and mangroves of India is a significant problem. But this damage is temporary and the environment recovers to its natural state within a short time. The only feature which occurs every year is the regular deposition of tar-like material along the beaches during the southwest monsoon season.

## 5.5 Accidents and episodic events

There has not been any major catastrophic event as such in India but some of the estuarine, backwater and enclosed water body regions can be classified as "grossly polluted" and "polluted" while the majority are at the stage of "enriched zones" fast moving towards the polluted stage.

A few oil spills and damage to coral reefs as a result of shipwrecks are on record.

There is no record of any episodic event in Bangladesh. The only aspect of note is the presence of ship-breaking yards along the coast which do affect the marine area.

There are no records of any major oil spill in Sri Lanka although it lies very close to one of the busiest tanker routes of the world. Submerged rocky reefs scattered around the island have caused several shipwrecks. During the southwest monsoon, cases of coastal erosion are very common and cyclones and storm surges, whenever they develop, do damage the coastal vegetation considerably. Several instances of mass mortality of fish due to eutrophication have been recorded. These are also linked with industrial contamination near Colombo.

In the Malacca Straits there are records of several oil spills. The Strait lies on the busy oil tanker route from the Gulf countries to the Far East and Japan.

## 6. **PREVENTION AND CONTROL STRATEGIES**

Environmental control legislation in force in India includes:

- Indian Ports Act, 1908.
- The Industries Development and Regulation Act, 1951.
- The Insecticides Act, 1968.
- The Water (Prevention and Control of Pollution) Act, 1974.
- The Air (Prevention and Control of Pollution) Act, 1981.
- Merchant Shipping Act with MARPOL Amendments 1985.
- The Environment Protection Act, 1986.

The last two acts have enough provisions for strict punitive measures, as compared to the earlier ones. Ships spilling oil in harbour areas have to pay a fine of Rs.500,000 (US dollars 40,000). Industries polluting air or water can have their licences suspended till they install pollution control devices.

Permissible limits for the discharge and release of pollutants to air, water and soil, have been laid down and are periodically revised and updated by the Bureau of Indian Standards.

India is a signatory to several international conventions and protocols to control marine pollution of the high seas and coastal regions. Some of these are:

- Regulations for the disposal of radioactive wastes, safe transport for radioactive materials etc., of the International Atomic Energy Agency.

Table 9. Trace elements in muscles of different varieties of marine fish in mg/kg (dry weight basis)

Elements	<i>Palaemoncar cinus</i> (Prawn)	<i>Halargu attu</i> (Boal)	<i>Stromateus sinensis</i> (Rupchanda)	<i>Rita rita</i> (Rita)	<i>Sillago siliama</i> (Silver whiting)	<i>Belone strongylus</i> (Gar fish)	Range
K	2720 ± 104	9177 ± 330	11693 ± 311	4912 ± 228	5544 ± 390	10399 ± 715	2720 - 11693
Ca	7961 ± 49	249 ± 16	1907 ± 14	337 ± 8	1011 ± 21	7062 ± 54	249 - 7961
Ti	19.7 ± 1.7	-	-	7.63 ± 0.58	-	-	-
Mn	6.54 ± 0.69	2.02 ± 0.38	7.11 ± 0.60	4.07 ± 0.51	2.29 ± 0.30	1.89 ± 0.48	1.89 - 7.11
Fe	388 ± 2	37.9 ± 0.8	95.4 ± 0.9	182 ± 1	164 ± 2	86.8 ± 1.4	37.9 - 388
Ni	6.03 ± 0.59	8.69 ± 0.41	15.2 ± 0.5	11.4 ± 0.4	3.01 ± 0.47	2.70 ± 0.59	2.70 - 15.2
Cu	58.1 ± 1.1	0.65 ± 0.18	2.00 ± 0.15	1.54 ± 0.23	1.39 ± 0.26	66.0 ± 1.4	0.65 - 58.1
Zn	93.8 ± 2.0	26.0 ± 0.8	51.0 ± 1.0	78.8 ± 1.2	66.0 ± 1.4	47.3 ± 1.4	26.0 - 93.8
As	4.02 ± 0.75	3.50 ± 0.45	2.52 ± 0.41	3.78 ± 0.50	4.00 ± 0.50	5.53 ± 0.69	2.52 - 5.53
Se	-	-	-	3.15 ± 0.44	-	-	-
Br	122 ± 3	45.7 ± 1.8	53.6 ± 1.2	63.5 ± 1.5	18.3 ± 1.4	38.6 ± 2.4	18.3 - 122
Rb	21.6 ± 1.6	16.9 ± 1.2	15.2 ± 1.2	14.7 ± 1.3	2.40 ± 0.57	2.00 ± 0.51	2.00 - 21.6
Sr	160 ± 3	0.06 ± 0.70	76.4 ± 2.3	23.0 ± 1.5	15.4 ± 1.6	166 ± 5	9.06 - 16

Uncertainties are due to counting statistics. Source: Khan & Bhuiyan 1983

- International Convention for the Prevention of Pollution of the Sea by Oil, 1954, as amended up to 1969, of the International Maritime Organisation.
- MARPOL (1973) Convention and Protocol (1978) of the International Maritime Organisation.

Over the last few years the Government of Sri Lanka has taken several positive steps in establishing institutional, legislative and policy frameworks for conservation, protection and management of the environment. The Central Environmental Authority (CEA), which was set up under the National Environmental Act of 1980, has been identified as the principal agency for coordinating activities pertaining to the environment. The National Aquatic Resources Agency (NARA) is the principal national body responsible for carrying out research, development and management activities of the marine environment. Additional protection has been given to the coastal zone through the setting up of a separate department, the Department of Coast Conservation (CCD) under the Ministry of Fisheries. A Coastal Zone Management Plan (CZMP) is now under preparation by a Coast Conservation Advisory Council representatives from CCD, NARA and other relevant agencies. The main aim of the CZMP is to spell out the strategies to be adopted for the protection and management of the coastal environment.

Preventive and control strategies adopted to reduce the degradation of the marine environment are covered by several legislative enactments. From 1 January, 1984, Environmental Impact Assessment (EIA) of all major development projects in the island has become mandatory. The projects are assessed on an EIA report prepared after the critical evaluation of the project on possible environmental implications by a "Scoping Committee" comprising representatives from nine agencies. Nearly 20 organisations have been identified so far as major project approving agencies. As far as the marine environment is concerned, the relevant agencies are National Aquatic Resources Agency, Ministry of Fisheries, Coast Conservation Department and Ceylon Tourist Board.

Provisions under the Fisheries Ordinance cover several areas important in the management of the marine environment. These include,

- (a) restrictions on the export of certain endangered species;
- (b) size and maturity stage specification in the lobster fishery;
- (c) prohibition of the use of explosives in fishing;
- (d) provisions under the Whaling Ordinance.

Under the Fauna and Flora Protection Ordinance the marine mammal Dugong and six species of turtles namely Leather turtle, Green turtle, Loggerhead turtle, Hawksbill turtle, Olive Ridley turtle and Flat-back turtle are protected. In 1980 Cabinet approval was granted to provide provisions under the Fisheries Ordinance to declare several coastal areas as marine sanctuaries. These are now being framed to be included in the amended Fisheries Regulations.

Southwestern and southern coasts of Sri Lanka are highly vulnerable to oil pollution. At an IMO meeting held in Sri Lanka in 1982 it was observed that the country lacks a proper oil spill contingency plan. In this connection the setting up of the Marine Pollution Authority in 1982, the enactment of the Marine Pollution Prevention Act and the steps taken towards the implementation of an IMO traffic routing scheme are important developments aimed at reducing the risk of oil pollution of coastal waters.

The Pakistan Environmental Protection Ordinance was promulgated in 1983. Under this ordinance the National Environmental Policy would be enforced. The Pakistan Environmental Protection Council would approve the National Environmental Policy after it is prepared by the Pakistan Environmental Protection Agency.

In Malaysia and Maldives, there has been some progress in working out anti-pollution strategies. In Bangladesh an Action Plan in this connection is under formulation.

There is adequate legislation existing in all these countries. The problem lies with implementation, the mode of which varies between the countries.

## **7. TRENDS AND FORECASTS**

From the data and information presented in Sections 3 and 4, it can be concluded that the pollution load on the coastal marine environment of India is on the increase. The main reason for this is the increase in population at the rate of about 2 per cent per year. To sustain this growth, agriculture and industry are also growing. The present trend is towards increasing urbanization and industrialization. However, people are becoming more and more aware of the value of a clean environment. It can, therefore be optimistically expected that, though stress on the environment will increase, its quality will not deteriorate.

There is no serious threat, as yet, to the Indian marine environment. The nature and geographical configuration of the Northern Indian Ocean provide a healthy influence on the well being of this region with its arms - the Arabian Sea and the Bay of Bengal - including the Lakshadweep and the Andaman Seas. This area is subjected to the impact of semi-diurnal tides of a large amplitude, the bi-annual reversal of the monsoon winds and the resulting sea currents. These features give this area enough flushing and water exchange to dilute and disperse the incoming pollution loads.

The above comments on India are applicable to all the countries in the region. However, the following may be of some particular significance:

Maldives consider that they may be in a position to manage environmental related problems in future with appropriate inputs.

In Bangladesh, the problem appears to be severe in places and the prospects of any significant short-term improvements are not very good. However, it is anticipated that with the formulation of a proper strategy, the long-term prospects can, perhaps, be better.

In Sri Lanka, a Traffic Separation Scheme has been proposed as an attempt to reduce the risk of oil pollution of its southern beaches.

## **8. ECONOMICS**

India is developing and needs to develop further and faster. Agriculture has to be mechanised, more and more fertilisers and pesticides have to be applied, industries have to be set up and tourism has to be developed. All these are essential for the economy of the country, but will definitely add stress on the environment. Therefore, the necessity is judicious planning. Ways and means have to be found to protect the environment without ignoring development. Environment and development must exist side by side and should go hand in hand.

In Maldives, economic losses could be expected in tourism and fisheries as a result of sewage and garbage pollution of the coastal zone with harmful effects on the coral reef and its associated flora and fauna.

In Sri Lanka, the disposal of sewage has been improved by two sea outfalls with primary treatment. There has been pressure on fisheries in lagoon areas and inland waterways as a result of industrial pollution.

In Bangladesh, only 43% of the total fish catch is utilised commercially. The remaining catch is dumped at sea thereby damaging the environment, affecting the economy and health of the nation by the loss of revenue and protein. However, shrimp farms covering about two-thirds of the mangrove areas, help the country to earn about 14% of its annual foreign exchange inflow.

Siltation in the estuaries is both a curse and a boon. Huge economic loss is incurred due to sedimentation in the river basins, harbours and ports. On the other hand, the land accretion in the coastal region and formation of new islands are blessings for human settlement with associated economic advantages. 25 million people live in the coastal region covering an area of 20,800 sq.km., occupying one-fourth of the total area of Bangladesh. The area of new islands (popularly known as "chars") in the Bay of Bengal is now about 16,000 sq.km., which is being added to Bangladesh as a result of siltation.

## 9. SUMMARY

All the countries in this region have more or less the same way of life and therefore a number of problems are common to all of them.

### 9.1 India

Sewage and other effluent problems are the most important in India. These are at present discharged into coastal marine waters mostly in partially treated form. This, occasionally results in fish kills, damage to coral reefs, destruction of mangrove habitats, etc. A huge amount of silt is added every year by river runoff from India. This silt naturally carries a considerable amount of pollutants from inland. Deleterious effects of tourism are also a significant problem.

### 9.2 Bangladesh

Siltation of estuarine areas, increase in human activity in mangrove areas and in the only coral reef, and sewage and industrial waste disposal, are some of the problems identified as important to Bangladesh. There is no clear national policy for the conservation of the environment as yet. Lack of expertise is the most serious problem in developing a proper picture of the present state of the marine environment around Bangladesh.

### 9.3 Sri Lanka

Sewage, oil, destruction of coral and mangrove habitats and siltation are considered to be the most important problems in Sri Lanka. However, the country is taking appropriate steps to control the contamination of its marine environment. Lack of adequately trained personnel and the non-availability of sophisticated instrumentation hamper the progress of environmental studies.

#### 9.4 Pakistan

Environmental pollution studies are at an early stage because of a lack of trained personnel and infrastructural facilities. There is a recognition that future disposal of garbage and untreated sewage could pose problems.

#### 9.5 Eastern Bay of Bengal (Andaman Sea)

Along the west coasts of Thailand and Malaysia, including the Malacca Strait, sewage and garbage disposal, eutrophication, siltation, mining rejects and industrial effluents, are considered as the main areas of concern.

In all the countries, it thus appears that the state of the marine environment is far from satisfactory. This is mainly because of inadequate measures for treatment of pollutants before release. Lack of expertise and lack of sophisticated instruments due to limited availability of funds are some of the causes standing in the way of a proper assessment of the environment. Common problems of immediate concern for all the countries include:

- petroleum hydrocarbons
- microbial pollution
- sewage and industrial wastes disposal with associated heavy metal pollution
- agricultural wastes including pesticide residues
- siltation changes associated with changes in soil erosion and possibly hydrological cycles; and
- lack of trained personnel and sophisticated instruments to deal with various aspects of the problem.

Pressure on the coastal zone is continuously increasing through population increase with its allied effects. This pressure will continue increasing the potential for detrimental effects unless suitable measures are adopted to mitigate these.

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