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REGIONAL SEAS

Environmental problems of the marine and coastal area of India: National Report

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PREFACE

The Regional Seas Programme was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes eleven regions 1/ and has over 120 coastal States participating in it. It is conceived as an action-oriented programme having concern not only for the consequences but also for the causes of environmental degradation and encompassing a comprehensive approach to controlling environmental problems through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned. It is designed to link assessment of the quality of the marine environment and the causes of its deterioration with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-oriented programme activities 2/.

In May 1982 the UNEP Governing Council adopted decision 10/20 requesting the Executive Director of UNEP "to enter into consultations with the concerned States of the South Asia Co-operative Environment Programme (SACEP) to ascertain their views regarding the conduct of a regional seas programme in the South Asian Seas".

In response to that request the Executive Director appointed a high level consultant to undertake a mission to the coastal States of SACEP in October/November 1982 and February 1983. The report of the consultant on his mission was transmitted to the Governments of the South Asian Seas region in May 1983, and the recommendations of the Executive Director were submitted to the Governing Council at its eleventh session.

By decision 11/7 of 24 May 1983, the UNEP Governing Council noted "the consultations carried out in accordance with Council decision 10/20 of 31 May 1982" and requested "the Executive Director to designate the South Asian Seas as a region to be included in the regional seas programme, in close collaboration with the South Asia Co-operative Environment Programme and Governments in the region, and to assist in the formulation of a plan of action for the environmental protection of the South Asian Seas".

1/ Mediterranean Region, Kuwait Action Plan Region, West and Central African Region, Wider Carribean Region, East Asian Seas Region, South-East Pacific Region, South Pacific Region, Red Sea and Gulf of Aden Region, Eastern African Region, South-West Atlantic Region and South Asian Seas Region.

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies: UNEP Regional Seas Reports and Studies No. 1. UNEP, 1982.

As a first follow-up activity to decision 11/7 of the Governing Council, the Executive Director convened, in co-operation with the South Asia Co-operative Environment Programme (SACEP), a meeting of national focal points of the States of the region in order to seek their views on how to proceed in developing a comprehensive action plan for the protection and management of the marine and coastal environment of the South Asian Seas region (Bangkok, Thailand, 19-21 March 1984).

The meeting discussed the steps leading to the adoption of an action plan and reached a consensus on the items to be considered for further development of the action plan [3/]. This would include a review of the geographic scope, the objectives, the priority areas of regional concern, the institutional arrangements and the financial arrangements.

The meeting recommended that the Governments, with the assistance of UNEP and other organizations as appropriate, should initiate the preparation of country reports reviewing their:

- national environmental problems defined as priority areas of regional concern;

- activities which may usefully be carried out under the action plan to resolve or mitigate these problems; and

- national institutional and manpower resources which are, or may be, involved in dealing with these problems, including the identification of the need to strengthen their capabilities.

It was also recommended that UNEP prepare in cooperation with SACEP, and other organizations as appropriate:

- a draft overview report, based on the country reports, reviewing the environmental problems of the region defined as priority areas;

- a document addressing the essential legislative aspects relevant to the action plan; and

- a draft action plan reflecting the conclusions of the country and regional reports.

The present document is the country report on environmental problems in India prepared by experts designated by the focal point of India for the development of the Action Plan.

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DEFINITION OF THE AREA

In the present review, the Northern Indian Ocean has been defined as the area between 0° and 25°N latitude and between 40° and 98°E longitude. Geographically, it is the area from the equator to the Gulf of Oman and the head of the Bay of Bengal on the north and from the East African coast on the west to the coastlines of Burma, Thailand and Malaysia (excluding the Strait of Malacca) on the east.

The countries, excluding the East African and East Asian states, which are directly dependent on this marine area are: Bangladesh, Burma, India, Maldives, Pakistan and Sri Lanka. These six countries together occupy an area of 4.97 x 10^6 km^2 and are inhabited by 958 million people. However, the geographical limits of the South Asian Seas region have been provisionally defined as the marine and coastal areas of Bangladesh, India, the Maldives, Pakistan and Sri Lanka. The average population density is 193/km^2. Thus, on an average, 22.8 per cent of the world population lives in 11.6 per cent of the total land area.

The Arabian Sea, forming the north-western part of the Indian Ocean, occupies an area of 6.225 x 10^6 km^2 between latitudes 0° and 25°N and longitudes 50° and 80°E. The Bay of Bengal, the north-eastern part of the Indian Ocean, occupies an area of 4.087 x 10^6 km^2 between latitudes 0° and 23°N and longitudes 80° and 100°E.

Rivers from India discharge 1,645 km^3 of freshwater to these two marine areas every year. Rivers from the other countries of the region can also be expected to discharge a considerable amount of freshwater. Literature data indicates that every year runoff from the Brahmaputra, the Irrawaddy and the Indus river systems are 600, 426 and 208 km^3 respectively.

It has been estimated that the Bay of Bengal and the Arabian Sea together occupy only 3 per cent of the world oceanic area but receive 9 per cent of the global river runoff.

HYDROGRAPHIC FEATURES

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.

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 south hemisphere subtropical anticyclonic gyre; and (iii) the Antarctic waters with the circumpolar current.

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 50m deep sill at the Hormuz Strait. Similarly, a 125m 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 maximum (100-150cm) off the Arabian coast and decreases steadily towards the southeast. A slight excess of precipitation over evaporation (<20cm) 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 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 300m depth. This water mass flows south, mostly east of 63°E longitude, and loses its characteristics in the southern Arabian Sea. The Red Sea water enters the Arabian Sea through the Strait of Bal-el-Mandab and the Gulf of Aden along sigma 27.2 at the surface. This water mass is generally confined to south of about 17°N latitude.

Occasionally, the sub-surface high salinity water masses originating in the Gulf and the Red Sea form a thick layer which is vertically of almost uniform 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. The deep and bottom waters are of circumpolar origin, probably transported by a deep western boundary current through a chain of basins. 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.

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 70cm. The total annual river runoff in the Bay of Bengal has been estimated to be about 2,000 km^3. The high excess of precipitation over evaporation and the massive river runnoff 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 500m. 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. 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, even though the runoff from the rivers may partially compensate for the offshore movement of surface waters.

NATURE OF ENVIRONMENTAL PROBLEMS

All the countries in this region of the Indian Ocean are developing countries. Their major source of revenue is agriculture, industry and in some countries also mining. The effects of pollution in the marine environment, largely arising out of the economic activities, began to be felt only recently although the practices have continued over a long period of time. These problems, however, are largely confined to the coastal areas of most countries, although owing to the prevailing wind system, the patterns of water circulation and the nature of bottom topography, the effects can have far-reaching implications.

While a few of the problems are quite chronic in some countries, they are relatively simple in others. In this communication no attempt has been made to differentiate between them and hence it is greatly hoped that most of the problems presented here would be of general interest.

Domestic sewage and industrial effluents

Due to increasing urbanization and industrialization throughout the region, the volume of sewage and industrial waste production is constantly on the increase. Many countries have several large rivers flowing through their landmass, but because of increased human activities around them many of these rivers have become badly polluted. These two human activities also contribute quite substantially to the degradation of the adjoining seas. Sewage and industrial wastes in these countries, either untreated or partially treated, are allowed to be discharged into the rivers and seas. The magnitude of treatment undertaken can, perhaps, be assessed from the fact that in a country like India, only 42 cities, with a population of over 100,000 have arrangements for sewage treatment. Hardly 50 per cent of the total population in the countries bordering the Indian Ocean is provided with proper sanitation arrangements. The result is that high counts of coliform bacteria are often found on the beaches and in coastal waters.

Examination of the concentration of toxic metals, such as, Hg, Cd and Pb, reveals that in plankton and in fishes the levels of these metals are still much lower than the acceptable maximum for them in many industrialized countries.

Agricultural wastes

Fertilizers, pesticides and insecticides are quite abundantly used in the developing countries in agriculture, pest control and vector control. The quantities of pesticides and insecticides used every year vary widely between these countries. In many countries, however, organochlorine pesticides are either prohibited or are gradually being replaced by organophosphorous and carbamate pesticides. Very little study on their accumulation and harmful effects has been carried out. However, a recent survey has shown that plankton in the Arabian Sea, off the west coast of India, has a DDT concentration ranging from 0.05 - 3.21 ppm wet weight.

Use of the organochlorine and organomercurial pesticides has been banned in all the industrial countries of the world. But their total production has not been reduced, rather, a relative increase in their manufacture is taking place. A hypothesis has very recently been put forward that there should be a "southward"

Radioactive and thermal wastes

Although, power generation is mostly thermal in the region, in some countries, nuclear power is also being generated. So far no serious harm has been reported from these sources, but fly ash from thermal power plants invariably creates environmental problems.

Radioactive wastes from nuclear power plants are normally disposed of according to strict international conventions. However, their heat generation poses several problems. Nuclear power plants normally release 50 per cent 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 a environmental catastrophe. Release of the hot salty water, when coupled with the wind system alters the current and mixing patterns from offshore to onshore. This is more probable in tropical areas where the range of the semi-diurnal tides is quite high.

Tourism

In developing countries more and more emphasis is being placed on the promotion of tourism. The result is that too many large hotels are being constructed along the beaches. Wastes from these hotels are very often a serious threat to the adjacent marine habitat. In some countries garbage and other wastes from these hotels have spoilt the beauty of the beaches and led to contamination of the environment and generation of hydrogen sulphide in the water.

Oil spills

In 1983 the global marine transport of oil was 1,206 million tonnes (MT), of which 513 MT or 42.5 per cent of the total was shipped from the Gulf countries (BP, 1982).

The main routes of marine transport of oil from the Gulf countries are across the Arabian Sea. One of these is through the Mozambique Channel around South Africa to the Western Hemisphere, while the other one is around Sri Lanka across the southern Bay of Bengal through the Malacca Strait to the Far East and Japan (figure 1). In 1983, 291 MT of oil was shipped to the Western Hemisphere and 222 MT to the Far East and Japan from the Gulf countries. This coupled with the increasing emphasis on offshore oil exploration in many countries of the region, makes the northern Indian Ocean very vulnerable to oil pollution.

Sources of oil pollution are tanker disasters, ballast water and bilge washings. Fortunately, only a few tanker disasters have occured, so far, along these tanker routes. However, the effect of the oil pollution can be seen on the beaches in the form of deposits of tar-like residue. The frequency and intensity of this residue depend on the current direction along the coastal region. Because of the monsoon winds, the surface currents change direction every six months. Whenever a shoreward component of surface current develops, heavy deposition of tar balls occurs on the beaches.

It has been calculated that at any one time the amount of floating tar in the surface layers of the Arabian Sea would be about 3,700 tonnes while along the tanker route across the southern Bay of Bengal the tar would amount to 1,100 tonnes. This

Coral reefs and mangroves

Coral reefs and mangroves (including macroalgae and seagrasses) occur widely in almost all the Indian Ocean countries. Damages that can occur to these ecosystems as a result of overexploitation of the reefs of mangroves or because of pollution are quite extensive. These can be summarized as follows:

Coral reefs

Coral reefs of the tropical Indian Ocean include, fringing and barrier reefs; sea-level atolls; and elevated reefs. The areas of their occurrences are: NW and SE coasts of India, Laccadive Islands, Andaman and Nicobar Islands and Maldives Islands. Radiocarbon dating of some of the coral reefs has indicated their ages as being more than 2,000 years old. The growth rate of corals in the Atlantic, as determined by use of ^{228}Ra, has been found to be 0.15 - 0.5cm/year. The growth rate of the corals in the Indian Ocean can be assumed to be of a similar order.

Most of the coral reefs in this region have been declared as endangered ecosystems. Several coral reefs have almost disappeared because of the collection of coral debris and live corals for use as a raw material in the cement industry, while others have died due to their constant exposure to pollutants, particularly oil. Examples of this are: the region of Kavaratti reef in the Laccadives; and reefs found in the southern part of the Great Nicobar Island in the Andaman group.

Mangroves

Mangroves constitute an important resource in the region and form spawning grounds, nurseries and feeding grounds for economically important fishes and crustaceans. They act as a buffer zone and offer protection to vulnerable communities like the coral reefs. They also stabilize the bottom sediments, control the local mean water level and the direction of flow. Mangroves constitute a significant portion of the coastal wetland in many countries and a fairly large percentage of the human population is dependent on them. For example, about one-eighth of the Bangladesh wetland is mangrove and one-third of the total population of that country is either directly or indirectly dependent on the mangrove ecosystem.

Due to the ever increasing demand for land and fuel, many mangrove areas of the Indian Ocean region have been and are being destroyed. This has led to heavy siltation in the nearshore region and with no protective cover of mangrove, the devastation of men and material caused during cyclones in coastal areas is immense. Mangroves occur in profusion along the NE coast of India, Bangladesh and Sri Lanka.

Siltation

The Indian Ocean annually receives 34×10^8 tonnes of suspended sediment, half of which or about 16×10^8 tonnes comes from the rivers flowing through the Indian sub-continent. This quantity is on the increase due to human activities, such as, mining on land, clearance of land for agriculture, lumbering, urbanization and industrialization, and dredging to deepen harbour channels and estuaries.

Most of the silt settles near the river mouths and in coastal areas. This probably decreases the productivity of the water and depletes fishery resources. Although these effects have been indicated in many countries, not much direct evidence has been obtained on the influence of siltation on marine and estuarine fisheries.

These then are the potential marine pollution problems, chronic or acute, direct or indirect, in the countries in the Indian Ocean region.

Nearshore coastal water

India has a long coastline. From the EEZ area of 2.02 million km^2 about 40 per cent belongs to the island groups of Andaman & Nicobar and Lakshadweep. With a regard to commercially exploitable living resources the shelf area on the east and west coasts as well as the nearshore waters upto about 40 fathoms are being exploited and most of the current production of 1,600 thousand tonnes is harvested from the nearshore waters.

The quantum jump from 7.2 hundred thousand tonnes during 1981 to the present production occurred mainly due to mechanization. As a result, to date there are about 20,000 mechanized boats and 75 deep sea fishing vessels in the commercial sector operating in the nearshore waters. In addition, under the Government of India policy, until March 1983 there were 38 chartered foreign fishing vessels operating in the nearby offshore areas.

During the 7th plan, the introduction of about 200 additional deep sea fishing trawlers is envisaged in the Indian waters. These activities are of special significance particularly when the fishing operations are concentrating in the productive zones such as off Gujarat, Konkan coast, off Karnataka and Kerala in Wadge Bank and in the south west coast including the waters around Lakshadweep. Similarly, in the east coast the highly productive zone of Sand Heads off Orissa and the waters around the Andaman and Nicobar would be the targets. These productive zones are not only exposed to the dangers of indiscriminate fishing but also exposed to man made stress on the ecosystem through the operation of mechanized boats using fossil fuel.

The Government of India has circulated a model bill to maritime States and UTs for enacting suitable legislation to demarcate zones of operation for non-mechanized traditional boats and small mechanized boats as well as deep-sea fishing trawlers. While foreign fishing vessels are not permitted to fish in the territorial waters within 12 NM (restriction beyond 24 NM under contemplation) most of the maritime States have enacted legislation which prohibits small mechanized boats from fishing in the 10 km area from the coastline. This legislation, in addition to safeguarding the interests of the small fishermen, also help to a certain extent in protecting the ecology of coastal waters from the stress afforded by mechanized boats.

RESEARCH AND MONITORING ACTIVITIES

Monitoring and research on marine pollution are fast developing activities in many countries of the Indian Ocean region. Surveys for the collection of baseline data on almost all of the potential pollutants in the marine environment are under progress and a fairly good data base has been built up. These data are mostly on the environmental conditions in the coastal and nearshore regions and also on some parts of the open areas of the Arabian Sea and the Bay of Bengal including the adjacent areas of the Laccadive and the Andaman group of islands. Several reviews of all these investigations have been published in recent years. The following details have been extracted from these publications and combined with data collected subsequently.

Petroleum hydrocarbons

In all 6,689 observations were made on oil slicks and other floating pollutants along the tanker and trade routes across the northern Indian Ocean. Of these, oil was sighted on 5,582 occasions or on 83.5 per cent of the total number of observations (figure 2). The data were then plotted in 5° squares. The percentage of oil sightings ranged from 51 to 96. The number of oil sightings increased away from the Gulf region. Even in areas away from the tanker and trade routes, the percentage of oil sightings was almost of a similar order. Fortunately so far, the occurrence of tanker disasters has not been very significant along these routes. Therefore, it could be concluded that oil is released in this region mainly from the ballast and bilge washings of the ships and that the northern Indian Ocean is a well known area for the occurrence of oil slicks.

Observations on the floating petroleum residues from the Indian Ocean region, are presented in table 1. As expected, the concentrations show variations in time and are occasionally fairly high along the tanker routes. In the Arabian Sea, the concentrations range from 0 to 6.0 mg/m^2 with a mean of 0.59 mg/m^2. The range in the Bay of Bengal tanker route varied from 0 to 69.75 mg/m^2 with a mean of 1.52 mg/m^2. This probably indicated that the tanker route in the Bay of Bengal is relatively more polluted than that of the Arabian Sea.

A number of observations were taken along the west-going tanker route on the Arabian Sea during June-September 1983 (table 1). Absence of floating tar balls in this region during this period was expected as the surface currents on the Arabian Sea normally flows directly towards the Indian west coast during the SW monsoon months.

Applying the average concentrations of floating tar balls to the areas of the Arabian Sea (6.225 x 10^6 km^2 from 0°-25°N and 50°-80°E) and the tanker route across the southern Bay of Bengal (0.73 x 10^6 km^2 from 5°-7°N and 80°-95°E), the total quantity present comes to 3700 and 1100 tonnes respectively for these two areas.

Accumulation of floating tar is entirely dependent on the surface currents. In the areas of strong surface currents, e.g. the Gulf Stream and Kuroshio, heavy accumulation of tar particles have been observed. The observed concentration in the North Atlantic ranged from 0.12 - 0.64 mg/m^2 with a maximum of 91.8 mg/m^2. Similar accumulation in the Northwestern Pacific ranged from 0.02 - 13.3 mg/m^2. Thus, the oil tanker routes in the northern Indian Ocean appear to be as much polluted as those in the other oceans.

If we assume that the abundance of oil entering any marine area is proportional to the volume transported, and that the average quantity of oil present in the seas around India is 0.36 per cent of the total flow, that 1 per cent of the total input ends up as floating tar and that the volume transported across the Bay of Bengal tanker route is 35 per cent of the total transport across the Arabian Sea, then, the "residence time" of floating tar in the northern Indian Ocean ranges from 33 to 38 days. The average tar concentration on the surface of the North Atlantic has been calculated as 5200 tonnes and its residence time is about 58 days. Thus, it can be concluded that tar found in the sea remains unchanged from 30 to 60 days.

As can be seen from table 1, the concentrations of dissolved and dispersed petroleum hydrocarbons from the surface to 20m were almost uniform, excepting some occasional high values. Some seasonal variations, as seen from table 1, may be due to differences in the intensity of tanker traffic from month to month and because of the changes in the meterological conditions.

The average concentrations of dissolved petroleum hydrocarbons in the upper 20 metres along the tanker routes in the Arabian Sea and the Bay of Bengal were 42.8 and 28.2 µg/kg respectively. Calculating the volumes in the upper 20m from the total areas, mentioned earlier, the quantity of petroleum hydrocarbons present in the uppermost 20m of the water column would be about 5×10^6 tonnes in the entire Arabian Sea and 0.4×10^6 tonnes in the Bay of Bengal tanker route. A summing-up of all the values of table 1, would result in figure 3, depicting the dissolved petroleum residues in the northern Indian Ocean, as at 1983.

Some observations on the concentration of petroleum hydrocarbons in zooplankton and in the sediments of the Arabian Sea off the west coast of India are also available. In zooplankton the concentration was found to range from 19.5 - 83.3 µg/g, while in the sediments the range was 4.8 - 8.5 µg/g, both on a dry weight basis. In some inshore areas of Bombay high, concentrations of petroleum hydrocarbons ranging from 142 - 393 µg/g wet weight, were recorded in sediments.

Deposition of tar-like residues on the beaches is more or less a chronic problem in almost all the countries bordering the Indian Ocean. However, this is a seasonal phenomenon depending on the pattern of coastal circulation largely regulated by the monsoons. Records from the west coast of India during the years 1975 and 1976 indicate a range of 22 to 448 g/m^2 with a peak value, on one occasion, of 1386 g/m^2.

Perhaps, the most important aspect of oil pollution is its ubiquitous and sometimes invisible presence in harbours, coastal regions, along oil tanker routes, and in the offshore oilfields. Sources for such oil are:

(i) Oil spillage during offshore drilling in EEZ (Exclusive Economic Zone):

- in a blow-out situation;
- minor losses during normal drilling and producing operations;
- accidents causing major oil spills of more than 50 barrels.

(ii) Oil discharges by all tankers and cargo ships within EEZ:

- transportation losses from tanker and cargo-ship operations;
- bilge washings;
- tanker and non-tanker accidents;
- floating petroleum residues (tar balls);
- dissolved/dispersed petroleum hydrocarbons.

(iii) Oil discharges in port areas:

- dry docking;
- terminal operations;
- bunkering;
- refinery wastes.

Damages caused by these releases of oil to the marine environment are well known. They are: deposition on beaches as tar-like residues; depletion of gas exchange at the air-sea interface; deposition on benthic fauna, tainting of fish, and damages to mangroves, corals and other coastal ecosystems.

To arrive at a clear picture of the extent of harmful effects due to these sources, reliable data are required from all the countries of this region on the following: (a) oil losses during normal drilling/producing operations and accidents from offshore exploration; (b) number of ships plying the EEZ (loaded and on ballast), including their total dwt, classifying them as LOT and non-LOT tankers and cargo ships; (c) total tonnage handled by ports, number and tonnage of ships dry docked and the volume of oil supplied as bunker; and (d) periodic estimation of oil concentration in harbour waters.

Data on the above are essential in order to delineate a total picture and plan actions for prevention and control.

Heavy metals other than mercury

In water

Some data on the concentrations of heavy metals, in dissolved form, are available from the Indian Ocean region. These are given in table 2, without indicating the horizontal and vertical variations as these samples were collected from different areas and different depths of the Indian Ocean including some areas off the Indian coast. The large ranges seen in the table 2 may be due to different analytical techniques used. The ranges are (all values expressed as µg/l): Cu 0.08 - 49.1; Cd 0.01 - 1.88; Fe 0.10 - 96; Mn 0.07 - 80; Zn 0.3 - 42.4; Pb 0.02 - 7.5; Ni 0 - 16.3; and Co 0 - 7.9. The accuracy and reproducibility of the data on trace metals have always been subjected to statistical treatment and only acceptable values have been reported in all the publications. Excepting copper all the higher value are either from the coastal region of the Indian mainland or off the coasts of oceanic islands. The higher ranges of iron, manganese and nickel are from the seas around the Laccadive islands; high cadmium and lead values are from the sea around the Andaman islands; high zinc concentrations occurred off Bombay and high cobalt ranges off the river mouths in the Bay of Bengal. An exceptionally high value of cadmium, 80 µg/l, was recorded in the polluted coastal waters off the city of Bombay.

In planktons and fishes

Available data on some of the metals in zooplankton from the Arabian Sea and the Bay of Bengal gave the following ranges in ppm fresh weight: Cd 0.7 - 6.0; Cu 2 - 5; Mn 3 - 7; Zn 8 - 31; Fe 35 - 94; Pb 1 - 13; Ni 0.2 - 3; and Co 0 - 4 (table 3). In all these analyses, the recovery was calculated with reference to the standard fishmeal obtained from the International Laboratory of Marine Radioactivity, Monaco, and the values are the mean of at least a triplicate analysis for every sample. Concentrations of all these metals have been analysed in 26 species of fish and crustaceans from both inshore and offshore regions of the northern Indian Ocean and in different parts of their tissues, such as, muscle, liver, gills and heart. Ranges of concentration in the muscles of those fishes of commercial importance, including sharks, are presented in table 3. It can be seen from table 3 that concentrations of almost all of the metals, particularly the toxic metals such as Cd, Pb and Hg, are within the permissible limits for human consumption. It has been observed in the same study, that the concentrations of all these metals in the livers of dolphin fish (Corryphaena hippurus Linnaeus), barracuda (Sphyraena picuda Bloch), sharks (Eulamia ellioti Day), skipjack tuna (Katsuwonus pelamis Linnaeus), and yellowfin tuna (Neothunus macropterus Schlegel) were signifiantly higher than in their muscles. This indicates that most of the metals are assimilated by these fishes in a fat soluble form. An acceptable correlation was, however, observed in the different fish tissues with relation to their sexes, sizes and stages of maturity.

Mercury

Because of its extreme toxicity and very harmful nature to human beings, concentrations of mercury in the water and biota have been treated separately. The study of mercury in the marine environment is of a relatively recent origin and in the Indian Ocean region data on this metal are very sparse.

In water

Mercury concentrations in dissolved form are normally found at nanogram levels. Their sources are mostly industrial effluents, but some contribution can also be expected from weathering, leaching and atmospheric flux from deposits of mercury in the crustal rocks of the hinterland. High concentrations of mercury in the nearshore waters of the SW coast of India are probably due to deposits of mercury in the adjoining land. In the absence of any industrial source, such high concentrations ranging from 204 to 407 ng/l in the surface waters of this area cannot be due to any other reason.

Ranges of all the observed values are presented in table 2. Without taking into account the variation with depth, the range is from 0 to 222 ng/l. However, a decrease occurs in the concentration of mercury with depth, as is the case with most of the other metals.

In plankton and fishes

An estimation of the total mercury concentration in plankton and fishes was carried out without fractionating the mercury into methyl and inorganic forms. In organic matter, however, it can be assumed that mercury is present mostly in the methyl form and very little in the inorganic form.

The absence of mercury in zooplankton (table 3) indicates that the metal is assimilated by fishes probably through other pathways of the food chain. Table 3 indicates that the mercury concentrations in the muscles of sharks and skipjack tuna are the highest of all the values. Concentrations of non-essential heavy metals, Hg, Cd and Pb, in different tissues of the fishes from the Northern Indian Ocean (table 4) indicate that their highest occurrence is in the liver and kidney. However, the highest concentrations of mercury, found in muscles, are still much lower than the internationally permissible maximum of 0.5 ppm of mercury for human consumption. Analysis of mercury in the muscles of several commercially important fishes from the inshore regions and from a polluted creek in and around the city of Bombay in 1972 and 1975 gave values ranging from 0.004 - 0.57 ppm on a fresh weight basis. However, the concentration of the same metal, when analysed in 1980, in the water, crab muscles and sediments showed an increase by several fold. These values (table 5) also indicate a decrease in the mercury concentration away from the shore.

Chlorinated hydrocarbons

Only a few analyses of DDT and its metabolites in zooplankton have been carried out so far. In most cases, the values were below the detection limit. There was a direct relationship between DDT concentration and lipid content in the plankton, which indicates that the pathway of chlorinated hydrocarbons to the animal tissues is via the fat. The total DDT concentrations in plankton of the northern part of the west coast of India appear to be somewhat higher (max. 3.21 ppm wet weight).

The values of organochlorine and organophosphorous pesticides in some of the fishes from the Indian Ocean region, particularly the plankton feeders, may be appreciably high because of the wide use of pesticides in agricultural activities in the countries bordering the Indian Ocean.

ECOSYSTEM DISTRIBUTION

There are different economically important major ecosystems in the coastal and offshore regions which are being exploited regularly and face several environmental stresses. These are the coastal ecosystems including mangroves, marine algae and seagrasses, and offshore ecosystems including coral reefs.

Coastal ecosystems

Mangroves

Along the Indian coast mangroves are found along the islands, major deltas, estuaries and backwaters of the east coast of India. They also exist along the oceanic island groups of the Andaman-Nicobar and Lakshadweep atolls. The distribution of mangroves along the Indian coast is presented in table 6 and figure 4. Gangetic Sunderbans (418,888 ha), Andaman-Nicobar Islands (115,000 ha), Krishna, Kaveri and Godavari deltas and Mahanadi delta are some of the best mangrove formations of India. On the other hand, the west coast mangroves are scattered, degraded and comparatively small in area.

There are about 45 mangrove species along the Indian coast. The dominant genera are *Rhizophora*, *Avicennia*, *Bruguiera*, *Sonneratia*, *Canocarpus*, *Heretiera*, *Xylocarpus*, *Ceriops*, and *Exoecaria*.

Mangrove forests mainly function as the most ideal spawning, breeding and nursery grounds for nearshore and estuarine organisms like fishes, crabs, prawns, molluscs etc. Some of the common and economically important species are *Mugil cephalus*, *Hilsa ilisha*, *Lates calcarifer*, *Scylla seratta*, *Meretrix casta*, *Crassostrea grephoides* and *Penaeaus* spp.

Apart from the captive and culture fisheries, mangroves are also important as "Coastal Stabilizers" and "Shelter belt areas". These formations protect the coasts and the landward areas from erosion and cyclonic destructions to some extent. Apart from these the mangrove forests of India have importance from a wildlife, recreation and education point of view. "Project Tiger" of Sunderbans and "Crocodile Sanctuary" in the Mahanadi delta are examples of such activities.

Mangroves in India have suffered from various biotic problems such as reclamation, deforestation and pollution. The abiotic problems like extreme climates resulting in cyclones and floods also pose a danger to mangroves. The Gangetic Sunderbans, Cochin backwaters, Bombay region and Gulf of Kutch are examples of indiscriminate exploitation, reclamation and pollution. Thousands of hectares of dense mangrove forests have been converted into agricultural land, fish farms, residential complexes and industrial units.

The latest danger for mangrove swamps is pollution. The rapid industrial development along the coast has resulted in the release of industrial effluents into the estuaries which finally reach highly productive swamps. These effluents destroy life totally at different trophic levels, viz. primary, secondary and tertiary. The level of pollution in the Mahim Creek (Bombay) mangrove area may present an example of one such a situation (table 7). Studies on the effect of petroleum 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. The effect of insecticides and pesticides like Dimacron, Nuvan and Nuvacron was also found to be harmful to these plants although at a slow rate.

Seasonal variation in the concentration of some heavy metals in the mangrove foliage indicated maximum concentrations of Fe and Mn, without any harmful effect. The presence of radioactive elements like uranium were also recorded; these, too, had no immediate effect on mangroves.

Apart from toxic industrial effluents, discharges from thermal power plants have also been reported to be harmful to the general productivity. Similarly, sewage discharge from the coastal townships finds its way finally into the estuaries and the adjoining mangrove swamps. Harmful bacteria and viruses may enter the human system through seafood, cultured and collected from such regions.

Increase in water turbidity as a result of mining and dredging operations, navigation, etc., may also disturb the productivity levels of mangrove waters ultimately affecting the fishery potential.

Marine algae

Marine algae, particularly macrophytes, also form one of the economically important living resources. This resource is being exploited in several countries for the purpose of food, feed, fertilizers, drugs and pharmaceuticals. However, in India, its use is so far limited to agar, alginate and manure.

It has been estimated that about 100,000 tonnes of marine algae (dry wt) can be harvested every year from the intertidal and subtidal waters of the Indian coast. There are about 625 marine algal species reported so far in Indian waters.

Marine algae grows in the euphotic zone on rocky or coralline substratum. Since these plants do not have a root, stem, leaf, etc., the entire body - thallus - absorbs the nutrients from the surrounding waters for its survival. Therefore, toxic or nontoxic pollutants or other chemical compounds, present in the water column, will be absorbed and accumulated in the body. It has been shown that certain species of Ulva, Enteromorpha, Gracilaria verucosa, Chaetomorpha, etc. can tolerate a high level of pollution and hence can be used as "Indicator species" for certain pollutants.

Marine algae have been used as fertilizer since time immemorial. Many developed countries have commercialized algal fertilizer. Recently, in India, attempts have been made to utilize algae as a liquid fertilizer for higher plants. Some of the brown algal species like Stoechospermum marginatum and Dictyota dichotoma showed encouraging results. On the basis of these findings attempts are being made to use non-conventional algal species for fertilizer and to popularize seaweed liquid fertilizer on a commercial scale.

The increasing demand for algal raw material could be met only by undertaking cultivation in the coastal areas. Along the west coast of India, there are areas like Baga, Cabo-de-Rama (Goa), Malvan and Ratnagiri (Maharashtra), Okha (Gujarat) and along the east coast Mandapam (Tamil Nadu), where cultivation of seaweeds is being undertaken on a large scale. Some economically important algal species such as Gracilaria, Hypnea, Gelidiella, Sargassum and Turbinaria are being used for rope cultivation. It has been observed that at some of the localities, algal cultivation is not successful because of siltation and efforts are being made to minimize this effect by selecting economically important algal species that can tolerate siltation.

The coastal ecosystem is a very complex one and is always under stress because of industrial and domestic pollution. Along the Maharashtra coast luxuriant growth of seaweed was observed in Verdant areas, whereas species diversity diminished considerably in areas affected by pollution. Unless measures to minimize the pollution along the coastal area are adopted some of the unique algal flora of the Indian coastline may be lost for ever.

Another aspect that requires attention is siltation caused by mining and dredging. Many areas along the Indian coastline are found to have a high siltation rate. In some areas of high mining activities depletion in the algal crop has been recorded. Another reason for reduction in some of the marine algal species in some areas along the Indian coast is unsystematic harvesting for industrial purposes.

Coral reefs

Around India, coral reef formations are found in the Palk Bay, Gulf of Mannar, Gulf of Kutch, Central West coast of India, Lakshadweep atolls, and Andaman-Nicobar Islands. Both the coral atoll and the fringing coral reefs are of utmost significance in Indian waters. A few species of corals have recently been reported from the Malvan (Maharashtra) coast. 32 genera from Minicoy Islands, 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 also been reported. 342 species belonging to 76 genera from the seas around India have been described.

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

It has been observed that dead as well as live coral beds are exploited for the carbide industry and for white cement. Large scale exploitation of corals in the Gulf of Kutch, has been checked to a great extent due to timely warning. A survey of the coral reefs in the Gulf of Mannar emphasized the need for conservation. Development of Tuticorin harbour and associated industrial activities as well as oil pollution, has resulted in large scale destruction of coral reefs around the islands of Tuticorin.

Andaman-Nicobar fringing reefs and Lakshadweep coral atolls are comparatively free from such problems. However, the recent data of Minicoy and Kavaratti atolls and Great Nicobar Island indicate that there is a definite effect of oil pollution on corals of these areas.

Acanthester plancii, a reef dwelling echinoderm, which feeds extensively on corals, is also responsible for destroying the corals in these two major groups of islands.

Apart from this, use of corals for ornamental and decorative purpose is yet another serious threat to this sensitive ecosystem. Local people of Lakshadweep also use corals for construction and white washing of houses and as mortar. Corals and mangroves occur together at some places in the Gulf and Andaman-Nicobar Islands. Of course mangroves grow mostly in the intertidal region while corals are found in somewhat deeper waters. However, extensive deforestation of mangroves in the Gulf of Kutch resulted in siltation on the coral reefs, which ultimately killed them.

This shows the interrelations between these two different ecosystems.

INPUT STUDIES

Data on the input of different cations and anions to the Indian Ocean are very scanty. Background data on sources of input, e.g., river runoff, load of silt, volume of domestic sewage and industrial effluents, rainfall, and aerosol are not available from all parts of the region. However, some data are available from India (table 8). A rough approximation for all the countries can, perhaps, be obtained by extrapolating the data given in table 8, in relation to population density.

Most of the cations and anions added to the oceans are absorbed on the silt particles. Considering the enormous amount of silt added annually to the Indian Ocean, i.e. 34×10^8 tonnes, siltation may be assumed as one of the principal sources of input.

The mean concentrations of some elements in the rain water from the coastal region of India were (values given in mg/l): Na 4.6, Cl 6.8, Ca 1.34, Mg 0.51 and K 1.02; (values given in µg/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, and Pb 21.5. Aerosol contents over the Indian Ocean vary from 1.4 to 68 $\mu g/m^3$ air. It decreases southwards with the latitude and becomes zero close to Antartica. From these values it can be inferred that the atmospheric flux of the elements is not very significant and the major transport route of pollutants to the Indian Ocean is through the riverine source.

Another important source of input is from the mining activities. Rejects and tailings from the mining operations carried out in coastal and nearshore regions add substantial quantities of heavy metals to the coastal environment.

ASSESSMENT OF POSSIBLE IMPACTS OF POLLUTANTS ON THE MARINE ENVIRONMENT

From the information summarized above it is clear that the data collected so far are quite fragmentary defying a clear understanding of the total pollution load in the Indian Ocean. However, the information also indicates that this region is not yet seriously affected by pollution. Localized problems, both short-term and long-term, do appear from time to time and their overall importance would vary from country to country.

However, the problem which is common to almost all the countries is oil pollution. Because of the transportation of a large volume of oil through the Indian Ocean, many areas are getting damaged. The worst affected ecosystems are the coral reefs and sandy beaches. Significant damage has already been noted on some of the atolls of Laccadives and coral reefs of the Andaman and Nicobar groups of islands.

Other possible impacts can be expected to come from the disposal of untreated or little treated domestic sewage and industrial effluents. Continued washing out of fertilizers, pesticides, herbicides and insecticides due to widespread use in agricultural practices in all the Indian Ocean countries can also pose significant problems.

But in the tropical and equatorial regions of the Indian Ocean, the tides are mostly of the semi-diurnal type with ranges varying from less than 1m to more than 8m. Tidal flushings twice a day, associated with a biannual reversal of the direction of monsoon winds and the surface currents associated with smooth bottom topography help in dispersing and diluting the pollutants and reducing the magnitude of their impact on the marine environment considerably.

Analysis of glacier samples from the Himalayas and ice lake water samples from Antarctica (table 9) have helped to establish background values for heavy metals in the northern and southern ends of the Indian Ocean. Utilizing these, it will be possible to maintain a watch on the health of the Indian Ocean.

ACTIONS IN PROGRESS IN INDIA

The following measures are under progress in India for education, research and development and adopting of measures to abate marine pollution:

Education

In India academic studies in environmental sciences and technology are of rather recent origin. There are a few universities and Institutes of technology which impart academic degrees in different fields of environmental sciences. These degrees are mostly confined to the postgraduate level.

However, because of the growing awareness of the need to protect the environment, there is a general system of extension work among common people. Students at school and college levels are also given a basic understanding of the value of protecting the environment.

Research and development

A substantial amount of research in marine pollution is in progress in India with a humble beginning in 1970. Due to the importance given to the protection of the environment by the Government of India, many contributions have already been made to this field. As regards marine pollution studies, India today has perhaps attained a significant status in the Indian Ocean region.

Prevention and combating of oil pollution

The Northern Indian Ocean (Arabian Sea and Bay of Bengal) are the areas of major transport of petroleum. In 1983, 513 million tonnes (MT) of oil and its products were transported from the Middle East countries across the Arabian Sea. Of this, 291 MT were transported to the western hemisphere and 222 MT along the exclusive economic zone (EEZ) of the Indian West Coast, the southern Bay of Bengal through the Malacca Strait to the Far East and Japan. Of late, there has been a gradual reduction in the volume of transport. Despite this the amount of oil on the sea in Indian waters has not decreased. A statistical calculation indicates that the Northern Indian Ocean is a place of oil slicks and about 4800 MT of floating tar balls with a "residence time" of about 30-60 days occur every year.

Research and development studies in the field of marine pollution have been in progress in India for a long time. A substantial amount of data have been collected on toxicity of chemical dispersants to different marine organisms, microbial decomposition of oil and diffusion and dispersion of spilled oil on the sea. By virtue of all this, India has attained a good deal of capability and know-how in the field of monitoring oil pollution.

The Coast Guard Organisation of India, established in 1978, has been engaged in the field of actual combating of oil spills in the sea. Training of personnel and acquiring of gear for this purpose have been taken up in an arid way. Legislation has been enacted and different means of combating oil spills in different areas have been or are in the process of being studied. A few ships especially equipped for oil pollution control are being indigenously built for the Coast Guard Organisation. This equipment includes skimmers, booms, oil-water separators, spraying-arms and chemical dispersants.

Other pollutants

Considerable studies are in progress on the effect of other pollutants for e.g. toxic and nontoxic heavy metals and metalloids, chlorinated hydrocarbons (pesticides), agricultural wastes and thermal and radioactive pollution. Data have been and are being collected on the effects of all this on the marine life along the Indian EEZ. The data on toxic metals, particularly mercury in the fishes from the Indian Ocean indicate that the concentration at present is about 0.2 ppm wet weight which is well below the maximum adopted by many industrialized countries.

Whatever data on all these pollutants have been collected from the Indian waters, though mainly indicating the effects from the Indian sub-continent, can also be applied to the coastal areas of other countries in this region.

There is a need to collect more data, particularly on pesticides, from the marine environment of India and to identify the studies on toxic effects of many chemicals especially polynuclear aromatic hydrocarbons (PAHs).

It has been observed at different international meetings on environmental pollution that there is a big gap in information on the data on addition to the sea from land of different pollutants. In India, some computations have been made based on scientific data which are appended in table 8. These studies are to be intensified as this will give a clear picture of the area in which efforts need to be intensified.

LEGISLATIVE MEASURES

The legislation which is in force as of now are the following:

- The Water (Prevention and Control of Pollution) Act, 1974
- The Air (Prevention and Control of Pollution) Act, 1981
- The Insecticides Act
- The Industries Development and Regulation Act
- Indian Ports Act
- Merchant Shipping Act

Permissible limits for the discharge and release of pollutants to air, water and soil, have been laid down and are being periodically modified and updated by

Indian Standards Institution.

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

- Regulations for the disposal of radioactive wastes, safe transport for radioactive materials, etc., of the International Atomic Energy Agency.
- International Convention for the prevention of pollution of the sea by oil, 1954 as amended upto 1969.
- The ratification of the International convention for the prevention of pollution from ships, 1973 and protocol 1978 is under active consideration by the Government of India.

ACTIONS NEEDED REGIONALLY

Physical studies

Probably the most important aspect of any marine pollution study is to examine the physical processes occurring in the recipient water body. Outfalls from large cities or industrial belts and from free trade zones in the form of industrial waste and domestic sewage opening into coastal and nearshore waters need to be examined. Dispersion, mixing, residence time and the eventual transport of these pollutants away from their point of discharge depend on the dynamics of any coastal water body. Thus, pollutants released by one country can have their ultimate effect on the coastline of another.

To predict the ultimate fate of any pollutant in coastal waters and estuaries, the factors which determine the dynamics of the recipient water and its neighbourhood must be known spatially and temporarily over a certain period. This is required for the Indian Ocean region particularly as it is influenced by both SW and NE monsoons and has large tidal variations.

For the discharge of wastes into the sea, the factors required to be known are circulation pattern, advection, turbulent mixing, tides, wave action, eddy and other diffusion processes, silting and sedimentation.

If these factors are observed over a certain period of time and maps are prepared, it will help immensely towards predicting the ultimate fate of any pollutant. This requires regional cooperative effort.

Detailed information on the quantity of pollutants which have entered, are entering and likely to enter the sea in the future, need to be prepared. An example is given in table 8. This is essential for the assessment of the present situation which will certainly help in identifying priority problems.

Mass balance of different sensitive and toxic pollutants have to be worked out from systematic analyses of these from their sources and relating to their total dispersion. Simultaneously, the balance of dissolved oxygen in the coastal area also has to be calculated. This will give an idea of how much more pollutant can be absorbed by the area concerned without causing disturbance to the balance in the coastal zone.

There is an inadequate understanding of the country's marine ecosystem and a lack of protective measures. This has led to and is leading to and destruction of coral reefs, mangroves, etc. It is, therefore, essential that preservation of the marine biological diversity is maintained by conducting periodic surveys of the ecosystems to ensure their conservation.

Baseline data of many dangerous pollutants particularly pesticides, herbicides and insecticides in the coastal marine environment of this region is lacking. Efforts should be made to collect maximum possible data, from the sources and sinks on as many pollutants as possible.

The draft agreement concerning cooperation in combating marine pollution by oil and other harmful substances in cases of emergency in South Asia was agreed upon at a meeting of experts at Colombo, 11 - 14 January, 1982. This agreement is under circulation among the countries of the region. It is important that efforts are made to ensure these are approved and signed as soon as possible.

A "Mussel-watch" type of programme is essential for monitoring several dangerous pollutants. Some efforts are in progress in some countries of this region. These efforts should be coordinated and intensified to result ultimately in an internationally cooperative research programme.

Perhaps the most important aspect of all this is training of man-power. For this, regional training courses, organized and coordinated by the countries should be held periodically in different fields.

After completing the official formalities for a cooperative research effort and before its inception, it is essential to organize intercalibration exercises. These will help to evaluate the present state of knowledge and qualified man-power to undertake such studies and improve upon it wherever necessary. Preparations are underway in India to organize such an intercalibration course at the national level.

While preparing the regional contingency plan the role the participating countries would play in effectively cleaning up those stretches of marine area that are polluted, should be clearly defined.

Oil spill contingency plans, if available, should be elaborated in the overall contingency plan.

While formulating plans for the control of pollution in mangroves due cognizance should be taken of UNESCO's ongoing regional programme on mangroves.

All the countries of the region should have comprehensive legislation regarding marine pollution. An agency should be identified in each country to enforce the above legislation.

Table 1: Dissolved/Dispersed hydrocarbons and particulate petroleum residues (tar balls) in the Arabian Sea and Bay of Bengal

Dissolved/Dispersed hydrocarbons (µg/kg)

	Arabian Sea				*Bay of Bengal*		
Coastal Area	Surface:	8.6	–	31.0 (March 1978)	Surface:	0 - 2.3	(June 1978)
	"	10.6	–	17.7 (Oct. 1983)	"	0 - 4.5	(Aug. 1981)
						0 - 2.8	(June 1982)
						0 - 3.4	(Jan. 1984)
Tanker route	Surface:	17.1	+	4.1 (March 1978)	Surface:	21.7 + 1.0	(June 1978)
	"	21.5	–	42.8 (Dec. 1978)	"	75.2 + 10.0	(Feb. 1979)
	"	18.6	–	41.6 (Dec. 1979)	"	5.3 - 27.4	(Jan. 1980)
	"	6.4	–	9.0 (Feb. 1980)	"	6.4 - 11.2	(Feb. 1980)
	"	47	–	230 (Oct. 1980)	10 m	23.2 - 26.9	(June 1978)
	"	200	–	305 (March 1981)	"	22 - 94	(Feb. 1979)
	"	3.0	–	8.9 (July 1983)	"	2.2 - 20.0	(Jan. 1980)
	"	7.4	–	16.2 (sept. 1983)	"	3.1 13.6	(Feb. 1980)
	"	5.7	–	10.6 (Oct. 1983)	20 m	13.1 - 28.2	(June 1978)
	"	5.1	–	12.4 (Nov. 1983)	"	24 - 73	(Feb. 1979)
	10 m	0.9	–	22.9 (March 1978)	"	1.6 - 27.1	(Jan. 1980)
	"	16.8	–	42.5 (Dec. 1978)	"	1.2 - 9.0	(Feb. 1980)
	"	16.9	–	34.5 (Dec. 1979)			
	"	3.1	–	6.3 (Feb. 1980)	RANGE		
	"	77	–	210 (Oct. 1980)			
	"	130	–	267 (March 1981)	Arabian Sea		Bay of Bengal
	"	0	–	1.2 (July 1983)	0 - 42.8		0 - 28.2
	"	3.4	–	8.5 (Sept. 1983)			
	"	2.1	–	5.4 (Oct. 1983)			
	"	1.4	–	6.1 (Nov. 1983)	Average Value		
	20 m	25	–	28 (June 1978)			
	"	28.6	–	37.5 (Dec. 1978)	15.8		4.6
	"	10.4	–	24.9 (Dec. 1979)			
	"	2.4	–	4.5 (Feb. 1980)			
	"	0	–	1.0 (July 1983)			
	"	0	–	1.2 (Sept. 1983)			
	"	0	–	1.1 (Oct. 1983)			
	"	0	–	1.6 (Nov. 1983)			

Particulate Petroleum Residues (Tar Balls) (mg/m²)

	ARABIAN SEA		*BAY OF BENGAL*	
Tanker route	0.02 - 0.32	(March 1978)	0.42 - 3.45	(June 1978)
	1.26 - 3.46	(June 1978)	0 - 1.6	(Jan 1980)
	0 - 0.54	(Dec. 1978)	0 - 69.8	(Feb. 1980)
	0.09 - 6.0	(May 1979)	0 - PI	(Jan. 1984)
	0 - 0.53	(Feb. 1980)		
	0.30 - 112.2	(March 1981)		
	0 - 0.06	(Feb. 1982)		
	0 - PI	(June 1983)		
	0 - –	(July 1983)		
	0 - PI	(Sept. 1983)		
	0 - –	(Jan. 1984)		
	0.06	(May 1984)		

Table 2: Ranges of dissolved heavy metal concentration (μg/l) in the Indian Ocean

Source	Cu	Cd	Fe	Mn	Zn	Pb	Ni	Co	Hg (ng/l)
Topping (1969) (Northern Indian Ocean)	0.5 - 49.1		0.1 - 61.8	0.1 - 4.6	3.9 - 19.5	–	–	–	–
Chester & Stoner (1974) (Central Indian Ocean - Surface only)	0.2 - 1.2	0.02 - 0.14	0.5 - 3.1	0.07 - 0.37	0.3 - 3.0	–	0.3 - 2.6	–	–
Sen Gupta et al (1978 b) (Coastal Arabian Sea)	1.7 - 7.9	–	7.2 - 66.9	–	0.5 - 42.4	–	0 - 11.5	0 - 6.6	–
Singbal et al (1978) (Coastal Arabian Sea)	–	–	–	–	–	–	–	–	13 - 187
Sanzgiri & Moraes (1979) (Laccadive Sea)	1.9 - 19.9	–	8.5-96	1.8 - 80	1.2 - 29.7	–	0 - 16.3	0 - 6.7	–
Danielsson (1980) (Indian Ocean)	0.08 - 0.48	0.01 - 0.16	0.15 - 10	–	0.6 - 13.8	0.02 - 0.18	0.18 - 0.95	0 - 0.02	–
Sanzgiri et al (1979) (Laccadive Sea)	–	–	–	–	–	–	–	–	0 - 204
Braganca & Sanzgiri (1980) (Bay of Bengal)	22 - 37.2	–	6.2 - 131.5	1.8 - 40.8	2.4 - 20	–	0 - 12.1	0 - 7.9	–
Sanzgiri & Braganca (1981) Andaman Sea	1 - 5	0.15 - 1.9	2 - 21.7	1.5 - 24.7	1.2- 12.8	<1-7.5	0 - 1	0 - 1	–
Sanzgiry et al (1983) (Southern Ocean)	<1 - 5.5	0.1 - 1.5	2 - 11.8	<1 - 4.1	8.9 - 46.8	<1 - 4.9	<1 - 6.6	<1 - 1.9	–
Sanzgiry et al (1984) (unpublished) (Arabian Sea)	<1 - 3.8	<0.1 - 1.5	<1 - 37.5	<1 - 33.8	1.5 - 30	<1 - 3.8	<1 - 20	<1 - 3	–

Table 3: Concentration of heavy metals (ppm wet weight) in zooplankton & muscles of certain fishes from the northern Indian Ocean

Fish	Cd	Cu	Mn	Zn	Fe	Pb	Ni	Co	Hg
Zooplankton	0.7 - 6	2 - 5	3 - 7	8 - 31	35 - 94	4 - 7	0.2 - 3	0 - 4	0
Perch	0 - 0.1	0.2 - 0.3	0 - 0.1	3.4 - 6.1	6 - 29	0.8 - 1.0	0.3 - 0.5	0	0.03 - 0.10
<u>Pelutes quadrilineatus</u>									
Jewfish	0.2 - 0.4	0 - 0.8	0.3 - 10	4 - 4.8	6 - 8	0.2 - 1.1	0	0.7 - 1.1	0.01
<u>Johnius osseus</u>									
Mackerel	0.2	1.0	0.01	6	12	0	0	1.8	0.01
<u>Pastrelliger Kandaurta</u>									
Sardine	0 - 0.2	0 - 0.3	0.2	4.5 - 6.3	8 - 10	0	0	0.7 - 1.1	0 - 0.1
Dolphin fish	0 - 0.9	0.2 - 1.7	0 - 3.1	5 - 9	13 - 39	0 - 3.4	0.1 - 1.2	0 - 1.9	0.01 - 0.14
Barracuda	0 - 0.3	0.1 - 0.5	0.2 - 3.1	3.3 - 5.8	4 - 17	0 - 0.3	0.1 - 0.3	0.6 - 1.9	0.07 - 0.2
<u>Sphyraena picuda</u>									
Sharks	0 - 0.8	0.2 - 1.1	0 - 2	4.5 - 12	10 - 57	0.9 - 6.0	0 - 0.3	0 - 3.8	0.08 - 0.19
<u>Eulamia ellioti</u>									
Flying fish	0 - 0.1	0.1 - 0.7	0 - 3.7	4 - 21	4 - 62	1.1 - 3.8	0 - 0.9	0.2 - 1.3	0.01 - 0.07
<u>Cypselurus comatus</u>									
Skipjack Tuna	0 - 0.4	0.3 - 1.3	0.1 - 7.5	4 - 8	7 - 164	0 - 1.4	0 - 1.0	0 - 3.2	0.03 - 0.22
<u>Katsuwonus pelamis</u>									
Malabar Trevally	0 - 0.6	0 - 0.7	0.1 - 9	2 - 5	5 - 11	0 - 0.03	0 - 0.6	0 - 1.2	0.02 - 0.08
<u>Carangoides mariabaricus</u>									
Yellowfin Tuna	0.1 - 0.3	0.6 - 3.0	0.5 - 0.8	4 - 12	11 - 25	0 - 3.0	0.4 - 4.0	0.7 - 1.5	0.02 - 0.23
<u>Neothunnus mocropterus</u>									

Sources KUREISHY et al, (1979, 1981)

Table 4: Range and average concentrations of a few non-essential heavy metals (ppm wet weight) in different parts of fishes from the northern Indian Ocean

BODY PARTS	MERCURY		CADMIUM		LEAD	
	Range	Average	Range	Average	Range	Average
MUSCLE	N.D. - 0.36	0.07	N.D. - 3.24	0.59	<1 - 3.43	1.11
LIVER	N.D. - 0.04	0.01	1.2 - 87.3	20.18	<1 - 17.62	3.8
GILL	N.D. - 0.03	0.016	N.D. - 0.76	0.42	<1 - 7.0	3.14
HEART	N.D. - 0.08	0.026	N.D. - 1.91	0.54	<1 - 3.4	1.36
KIDNEY	N.D. - 0.04	0.015	0.38 - 36.69	9.02	<1 - 69.46	8.61
GONADS	N.D. - 0.03	0.015	N.D. - 8.06	1.25	<1 - 4.76	1.36

Sources: KUREISHY et al, 1979, 1981, 1983 (unpublished).

Table 5: Mercury pollution in and around Bombay city

Components	*Distance from shore*				*Thana Creek*	
	Coast	*1 km*	*1.5 km*	*2 km*		*3 km*
Water (µg/1)	1.4 - 23.0	12 - 29	10 - 35	9 - 30	14	42
Crab muscles (ppm wet weight)	0.2 - 4.1	0.1 - 1.5	0.2 - 1.0	0.3 - 1.3	1.8	7.3
Sediment (ppm dry weight)	0.1 - 27.0	–	–	–	–	38

Source: GANESAN et al (1980)

Table 6: Distribution of mangroves along the Indian coast

West Coast		*(Area in hectares)*
1.	Gujarat	52,616
2.	Maharashtra	62,208
3.	Goa	2,000
4.	Karnataka	–
5.	Kerala	–
6.	Lakshadweep Islands	–
East Coast		
7.	Tamil Nadu	2,640
8.	Andhra Pradesh	18,424
9.	Orissa	12,000
10.	West Bengal	418,888
11.	Andaman-Nicobar Inlands	115,200
Total		681,976

Table 7: Pollution levels in Mahim Creek, Bombay

	Item	Description	Remarks
1.	Water quality	Extremely turbid, black colour, oil present,	Unsuitable for aquatic life, Hazardous to living systems, water treatment poses problem.
2.	Dissolved oxygen concentration	0 to 3 mg/ litre	Extremely low, unsuitable for aquatic organisms, odoriferous due to anaerobic decomposition.
3.	Biochemical Oxygen Demand (BOD)	100 mgs/litre	Considerably high, high organic lcad present causes sceptic conditions.
4.	Potassium content	More than 400 mgs/ litre	Very high, injurious for physiological nutrition.
5.	Magnesium content	1000 mgs/ litre	Above the recommended limits for industrial use.
6.	Chloride content	4000 mgs/ litre	Very high loading to accelerate rate of corrosion.
7.	Sulphate content	2000 mgs/ litre	Very high, capable of attacking concrete structures.

Table 8: Population and related data and some estimates of pollutants entering the sea around India (as of 1984)

Population	720 million
Coastal population (25% of total)	180 million
Area of the Country	$3.276 \times 10^6 km^2$
Agricultural area	$1.65 \times 10^6 km^2$
Exclusive economic zone	$2.015 \times 10^6 km^2$
River runoff (annual mean)	$1645 km^3$
Rainfall per year (on land)	$3.5 \times 10^{12} m^3$
Rainfall per year (on Bay of Bengal)	$6.5 \times 10^{12} m^3$
Rainfall per year (on Arabian Sea)	$6.1 \times 10^{12} m^3$
Domestic sewage added to the sea by coastal population per year (@ 60 l per head/day)	$3.9 \times 10^9 m^3$
Industrial effluents added to the sea by coastal industries per year	$0.39 \times 10^9 m^3$
Sewage and effluents added by the rivers to the sea per year	$50 \times 10^6 m^3$
Solid waste and garbage generated by coastal population per year (@ 0.8 kg per head/day)	53×10^6 tonnes
Fertiliser used per year (@ 30.5 kg/ha yr^{-1})	5×10^6 tonnes
Pesticides used per year (@ 336 g/ha. yr^{-1})	55000 tonnes
Synthetic detergents used per year	125000 tonnes
Oil transported across the Arabian sea in 1983	513×10^6 tonnes
Oil transported to Western Hemisphere in 1983	291×10^6 tonnes
Oil transported to Far East and Japan in 1983	222×10^6 tonnes
Tar deposition on beaches along the West Coast of India per year	750 - 1000 tonnes

Table 9: Concentrations of a few heavy metals (in µg/l) in ice and water, Princess Astrid Coast' Antarctica and in a glacier in the Kashmir Himalayas

Station	*Fe*	*Zn*	*Cu*	*Mn*	*Ni*	*Co*	*Pb*	*Cd*
Antarctic Ice	1.4	14.4	3.0	6.8	2.0	0	0	0
Antarctic Lake	50.5	13.6	3.4	5.6	3.2	0	0	0
Himalayan Glacier (mean)	82.5	4.5	4.1	17.0	1.8	1.1	3.1	0

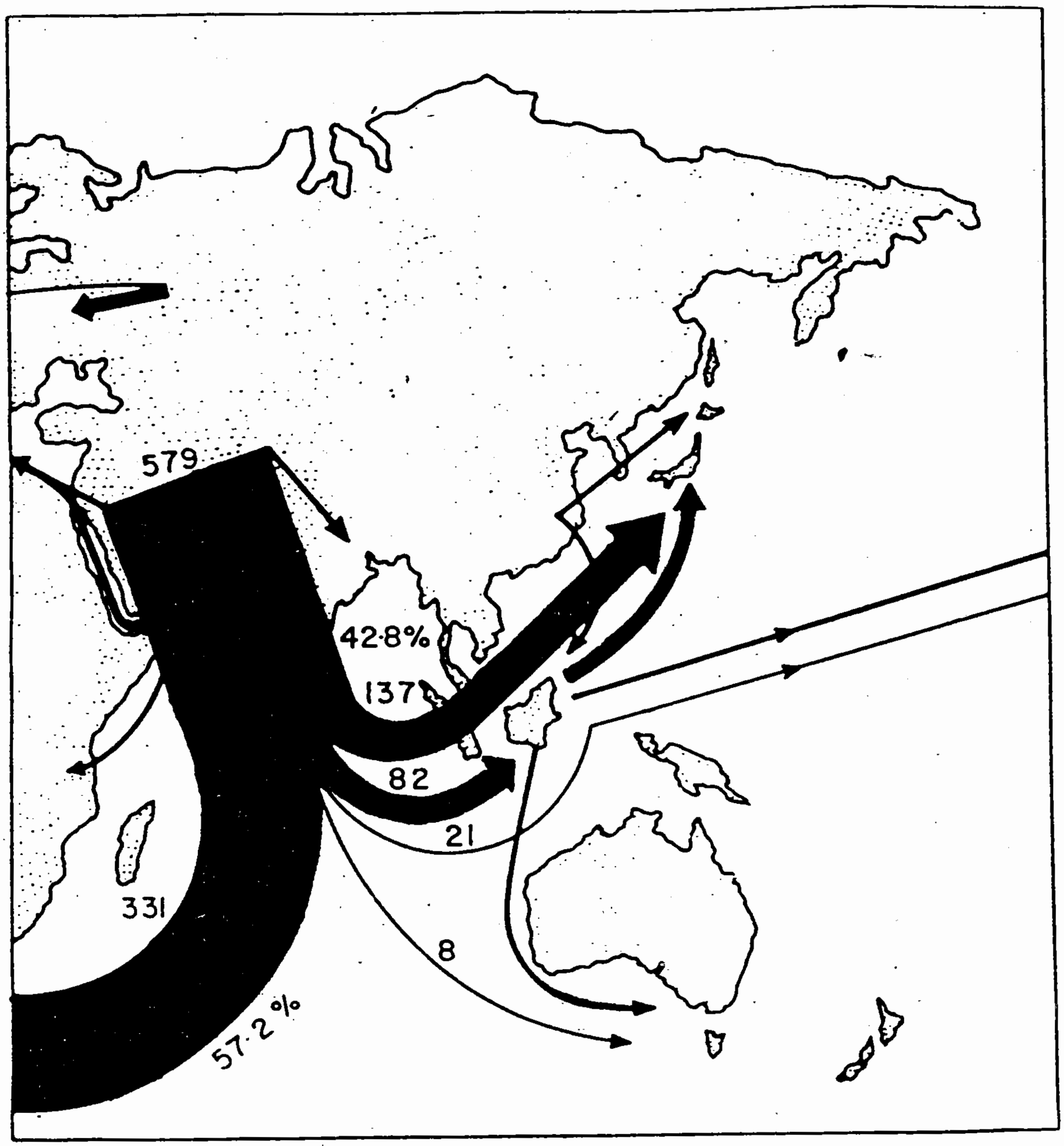

Figure 1: Movement of oil from Middle East countries by sea 1982 (million tonnes)

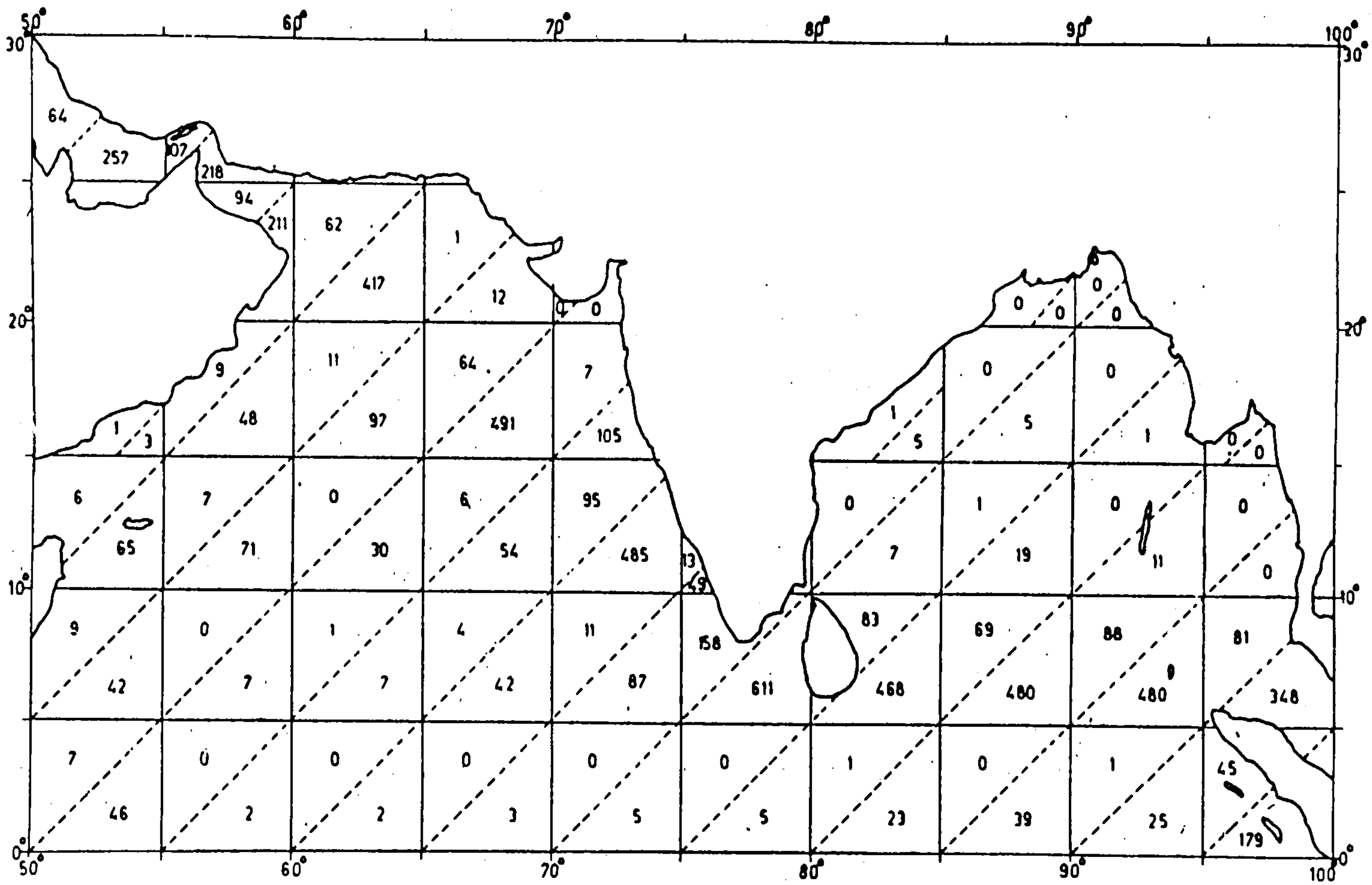

Figure 2: Points of observation of oil slicks &
other floating pollutants on the northern Indian Ocean
(Courtesy: Japan Oceanographic data Centre)

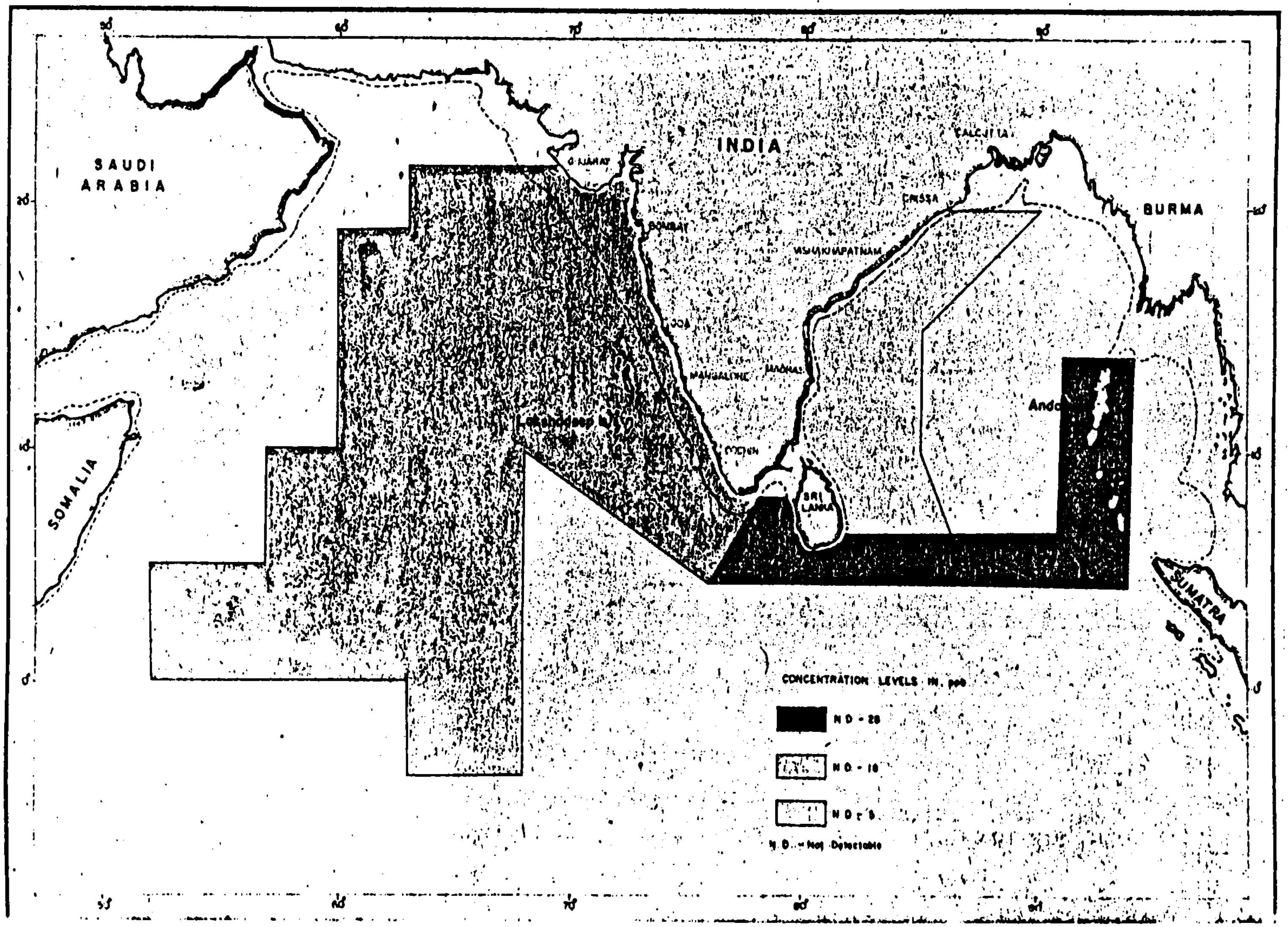

Figure 3: Dissolved petroleum residues in Indian Ocean

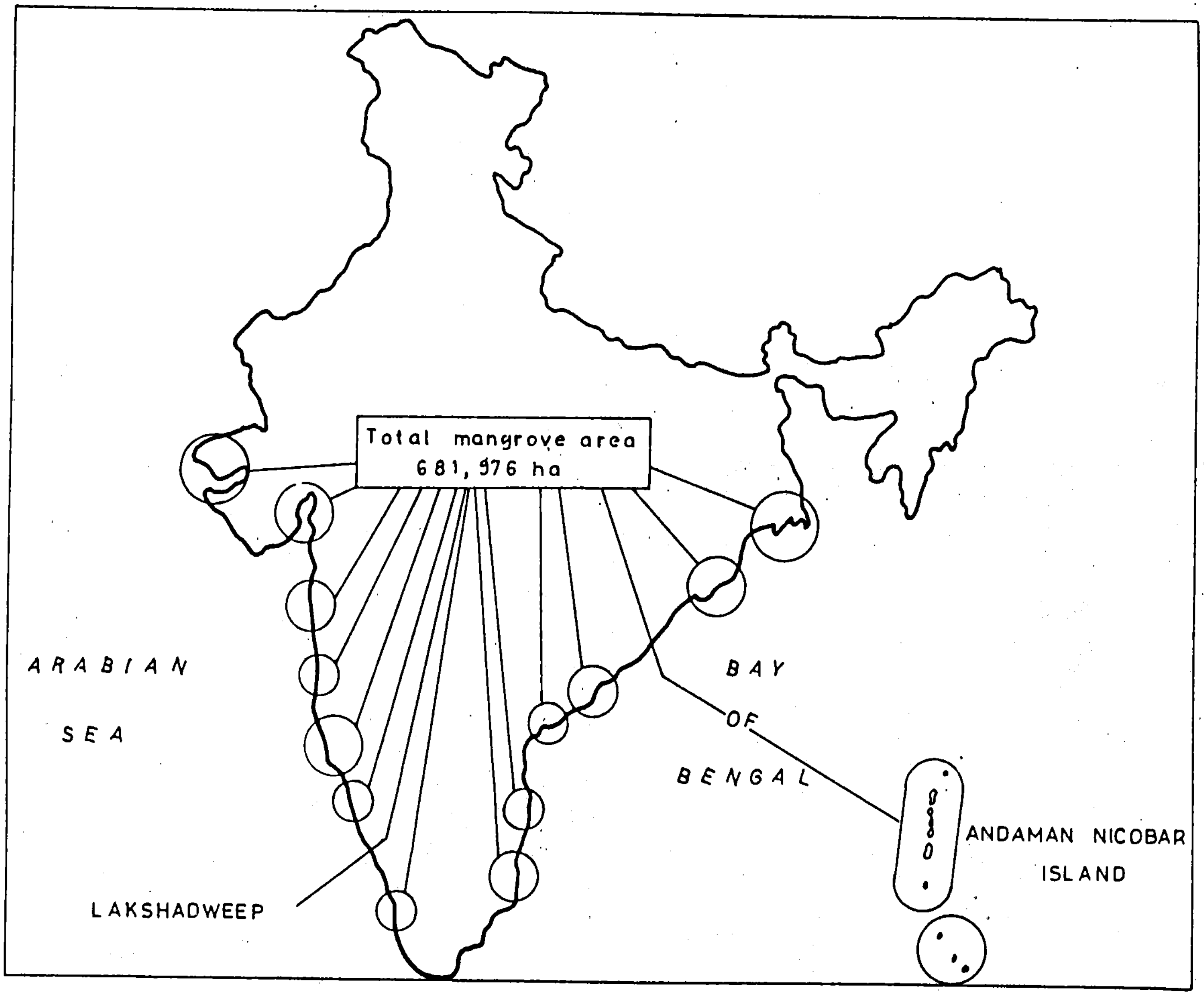

Figure 4: Distribution of mangroves along the Indian coast

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