

MARINE POLLUTION IN THE INDIAN OCEAN - PROBLEMS, PROSPECTS AND PERSPECTIVES

R. SEN GUPTA AND S.Y.S. SINGBAL

National Institute of Oceanography, Dona Paula, Goa 403 004.

INDIAN OCEAN - DEFINITION & PHYSIOGRAPHY

In relation to the equator, the Indian Ocean has an asymmetric shape largely due to the presence of the Asian continent. This results in this ocean being 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 occupies an area of $74.92 \times 10^6 \text{ km}^2$ including the marginal seas (Dietrich 1963). Its average depth is 3873 m. It is a huge sea area ranging from Eastern Africa to Western Australia and bordered on the North by the Asian subcontinent. The area between 25° N and 30° S latitude and between 40° E and 98° E longitude has been considered for this review (Fig.1). This consideration has been done on the basis of data availability. Geographically it is the area from 30° S latitude to the Gulf of Oman and the head of the Bay of Bengal on the north, from the East African coast on the west to the coastlines of Burma, Thailand and Malaysia (excluding the Strait of Malacca) on the east. In this region of the Indian Ocean there are altogether 19 countries. The total area of these countries is about $9.6 \times 10^6 \text{ km}^2$ and they are inhabited by about 1221 million people as on 1982. The average population density is 127 km^{-2} . Thus on an average 22.5% of the world population lives in 18.6% of the total land area.

According to Budyko (1972), the Indian Ocean is an area of negative water balance. Annually it receives 6000 km^3 of river runoff and 88000 km^3 of precipitation while its evaporation is 103000 km^3 . Though the Indian Ocean as a whole is an area

of negative water balance, the Bay of Bengal (North eastern part of the Indian Ocean) is an area of positive water balance. The Bay occupies an area of $4.087 \times 10^6 \text{ km}^2$ between latitudes 0° and 22°N and longitudes 80° and 100° E . It receives annually a precipitation of 11000 km^3 and a runoff of about 2000 km^3 (Qasim & Sen Gupta, 1988). This gives an annual dilution of about 5% for the upper 25 metres which can be assumed as the maximum depth of riverine influence in the Bay of Bengal (Sen Gupta *et al*; 1978).

The Arabian Sea forming the north-western part of the Indian Ocean occupies an area of $6.255 \times 10^6 \text{ km}^2$ between latitudes 0° and 25°N and longitude 50° and 80° E and it is an area of negative water balance, where annual excess of evaporation over precipitation and runoff varies between 7 and 10 km^3 (Venkateshwaran, 1956). The Bay of Bengal and the Arabian Sea together occupy only 3% of the world oceanic area but receive 9% of the global river runoff. This means that this region receives three times more river runoff per unit area as compared to the rest of the world.

One of the interesting features of the Indian Ocean is that in its northern region the surface circulation reverses every half year from northeast during the winter monsoon to southwest during the summer monsoon. This phenomenon makes the Indian ocean a very suitable area to study the ocean-atmosphere interaction. There are three distinct large scale circulation systems in the Indian Ocean (Wyrtki, 1973) namely, (i) the seasonally changing monsoon gyre north of 10°S , (ii) the southern hemispheric subtropical anticyclonic gyre, and (iii) the Antarctic waters with the circumpolar current. The northeast monsoon is quite strong in the Bay of Bengal. Induced by favourable currents and winds, moderate upwelling occurs along the coast of India, during the southwest monsoon, even though the runoff from the rivers may partially compensate for the offshore movement of surface water. During the southwest monsoon the south equatorial current and the Somali current form a strong wind driven gyre in the equatorial Indian Ocean (Wyrtki, 1973).

Dissolved oxygen concentration in the watermass between 100 and 1200 metres in the Northern Indian Ocean is very low. As a result nitrate-nitrogen gets reduced due to denitrification. Combination of accurately measured values of these with the accepted values of diffusion and advection constants gave a turn-over time of the oxygen-poor layer as 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 or atmospheric carbon dioxide concentration may render the layer completely anoxic (Naqvi, 1987).

Almost all the countries bordering the Indian ocean are developing countries. Their major sources of revenue is agriculture, industry, and in some countries also mining. The effects of pollution in the marine environment began to be felt very recently, although these activities are continuing for a long time.

The pollution problems are felt largely near the coastal waters mainly because of the circulation of waters, nature of the botom topography and constant release of domestic and industrial discharges resulting from the increasing urbanization and industrialization throughout the region. Many rivers flowing through the landmass receive the domestic and industrial discharges and contribute substantially to the degradation of the adjoining seas.

NATURE OF ENVIRONMENTAL PROBLEMS

Marine pollution, as defined by GESAMP (Group of Experts on the Scientific Aspects of Marine Pollution of UN), is "Introduction by man directly or indirectly of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities". Strictly speaking the term pollution would mean any departute from purity. When the word pure is used in the context of water pollution it should mean water in its pristine state fit for human use. Any substance that makes the water unfit for human use must be considered a pollutant.

Environmental contamination is not an amoral phenomenon; rather it is the inevitable consequence of the process of development. Pollutants can be native or natural which are not caused by man, generated by man but not created by him, and synthetic pollutants wholly created by man (Johnston, 1976). One can broadly put hydrocarbons, soluble inorganic and organic substances in the first category, redistribution and exploitation by man

of these hydrocarbons etc., in the second, and plastics, radio-nuclides and pesticides in the third.

The oceans are not free from pollution nor are they insensitive to the effect of pollutants. As long as we use the sea as a universal sink, the pollution upto a certain extent is very difficult to avoid. The prominent marine pollutants and the consequences of their marine disposal are detailed in the following paragraphs.

1. *Oil Pollution :*

In an environmental context the term "Oil Pollution" represents pollution by crude petroleum or refined petroleum products. Oil pollution is an inevitable consequence of the dependence of a rapidly growing population on oil based technology. Fortunately, the total record of accidental oil spills in the Indian Ocean (north of the equator) is 15 tanker disasters and 3 blow outs from 1970-1982 (Couper 1983). Consequently, oil originating from ballast, bilge and cooling water of the tankers are the main sources of oil contamination in the Indian Ocean. Other sources such as industrial and domestic discharges, however, cannot be ignored.

(a) *Sources of Oil Pollution :*

A great deal of attention has been attracted by oil pollution of the oceans resulting from tanker disasters, operational or accidental and intentional releases and offshore oil exploration and exploitation. The first tanker disaster took place in 1967 when the *Torrey Canyon* ran aground off Cornwall, England. This event attracted worldwide attention and pointed the risk of oil transport in very large crude carriers. A widely publicized offshore oil blow out took place in 1969 in the Santa Barbara Channel, U.S.A. Two tanker routes from the Middle East countries cross the Arabian Sea. One of them is to the Western hemisphere through the Mozambique channel and the other is to the Far East and Japan across the Southern Bay of Bengal. Because of these tanker routes oil pollution is a chronic problem in the Northern Indian Ocean.

(b) *Effects of Oil Pollution :*

Oil is the only visible pollutant on the sea. The effects of its pollution can be considered as both short term

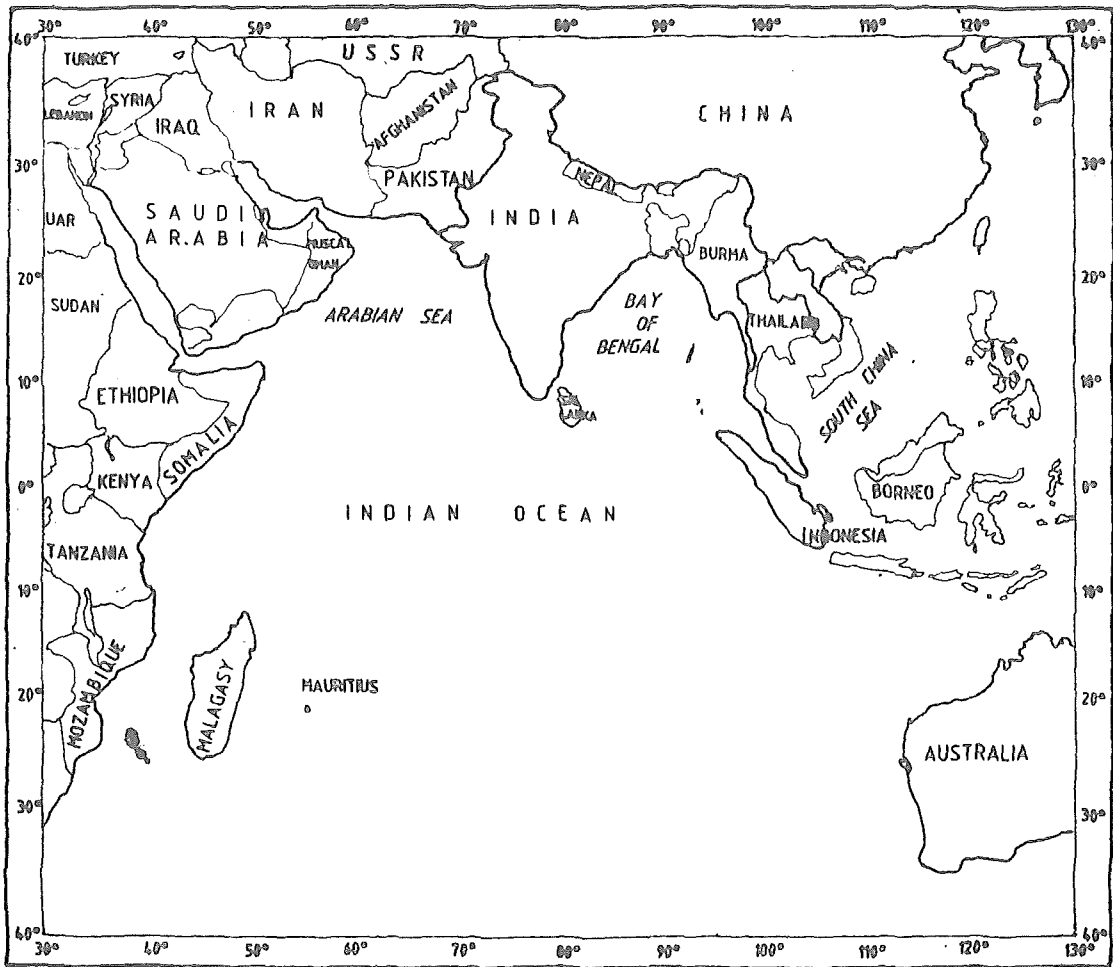


Fig. 1 Geographic layout of the Indian Ocean

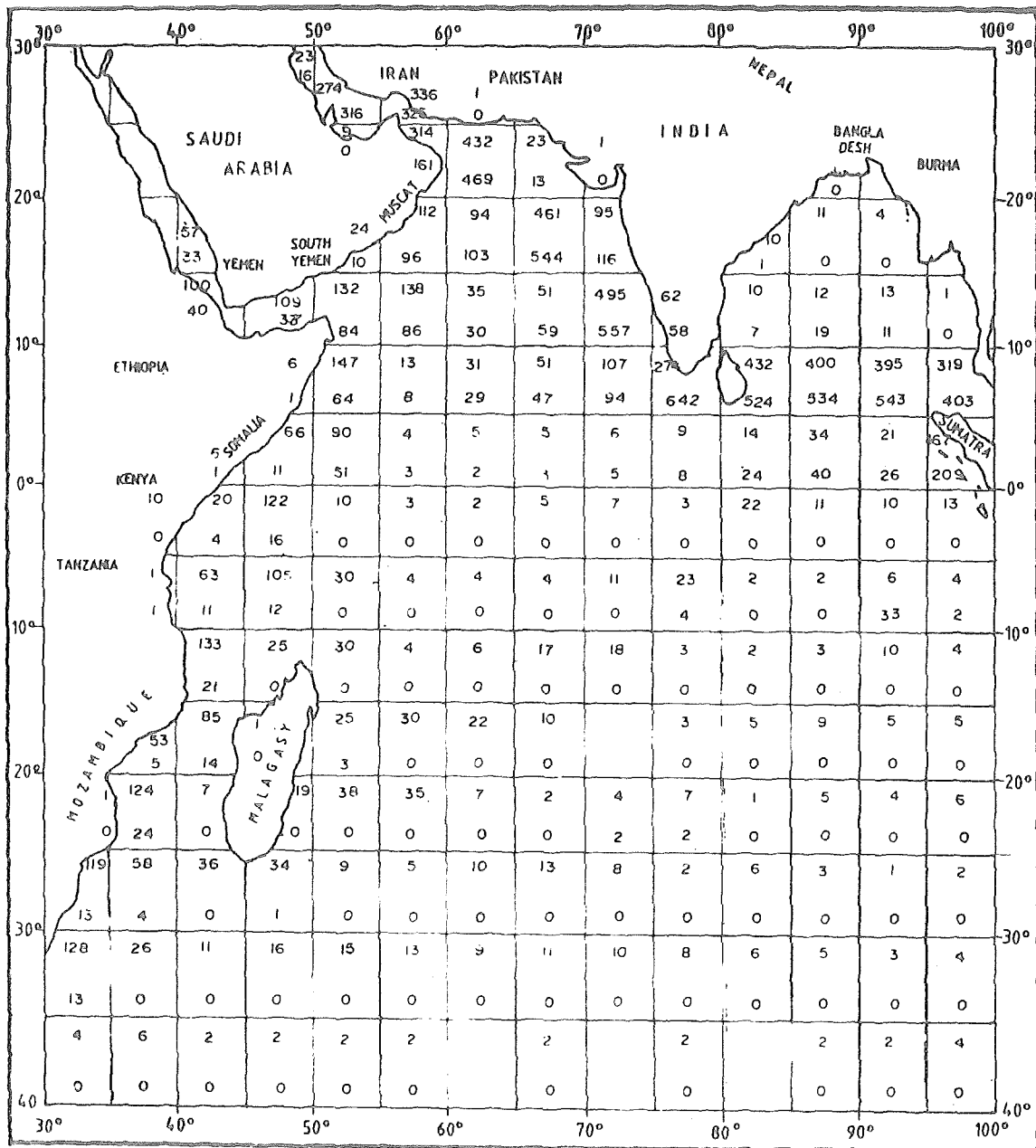


Figure 2. OBSERVATIONS ON OIL SLICKS AND OTHER FLOATING POLLUTANTS EVERY 5° SQUARE IN THE INDIAN OCEAN. THE UPPER VALUES INDICATE THE OCCASIONS OF THE ABSENCE OF OIL SLICKS WHILE LOWER VALUES INDICATE THE OCCASIONS WHEN OIL SLICKS WERE SIGHTED (Courtesy : Japan Oceanographic Data Centre)

and long term. Short term effects are acute toxicity, coating and asphyxiation of avifauna and benthic fauna, reduction of light transmission in the sea, dissolved oxygen reduction etc. The long term effects are not as apparent as the short term ones but disruption of many biological processes occur by some toxic and carcinogenic compounds of oil. One of the most obvious effects of oil pollution, from the aesthetic point of view, is the presence and deposition of tarry lumps (the end-product of oil reaching the marine environment) on the beaches.

(c) *Fate of Spilled Oil :*

There are several processes such as evaporation, dissolution, spreading on surface, emulsification, photo-oxidation, uptake by organisms and adsorption onto particulates sinking to the bottom which controls the fate of oil entering the marine environment.

Spilled oil spreads quickly on the sea surface with an average thickness of 100 mm and depending on wave action a viscous water-in-oil emulsion results. Soon after its discharge the oil loses the lighter fractions by evaporation resulting in increased viscosity and density. A small amount of oil may be dissolved in water and be lost. Processes of photo-oxidation and biodegradation form various types of products including polymerised compounds, making it more viscous and denser finally, to sink as fine particles. Sometimes the water-in-oil emulsion forms a gel-like substance called the "chocolate mousse" and the subsequent chemical and biological reactions are slow because of the small surface area. On reaching the shoreline this chocolate mousse picks up sand and debris and the water evaporates leaving deposits of compact tarry lumps and further degradation is a very slow process.

2. *Heavy Metal Pollution :*

Pollution of the sea by oil is visible and hence attracts immediate attention. But most of the other types of pollutants are not visible and can be understood only by their damaging effects. One of the most significant of these sources are the toxic heavy metals. Heavy metal pollution generally can occur both naturally and through human activities. Natural processes of submarine volcanic activity, weathering etc. may add a considerable amount of metals to the marine environment. Being the most useful material known, ores of some of the metals from under-sea deposits are removed,

smelted and refined, for use in industries. Each of the above mentioned processes release considerable amounts of metals to the marine environment as tailings or rejects where their prolonged stability makes them bio-available for a very long time. Their sources of entry can also be atmospheric transport, river runoff and domestic and industrial discharges. These metals can be classified as essential and non-essential elements for biological processes. While most of the metals come under the essential category, some of them, notably mercury (Hg), cadmium (Cd) and lead (Pb), are among the non-essential ones each having a catastrophic event attached to it e.g. Minamata and Itai-Itai diseases caused by the consumption of fish contaminated by Hg and Cd respectively in Japan.

(a) *Effects of Heavy Metal Pollution :*

Metals are insidious and persistent pollutants and unlike most of the organic pollutants metals cannot be degraded biologically or chemically in nature. They can be altered but the undesirable metals can still be present and in some cases these alterations, like elemental tin and mercury to organic Sn and Hg, assumes greater toxicity. Apart from being outright toxic they also disrupt some enzyme-related biological function of the body. One of the most serious threat of metal pollution however, remains the biological magnification in the food chain resulting in some plants and animals becoming health hazard when used as food.

3. *Agricultural Wastes :*

For human survival, it is necessary to wage a battle against natural pests like insects, weeds and molds. Tonnes of fertilizers and pesticides are therefore used every year, in agriculture pest control and disease - vector control. Pesticides are frequently classified according to their target or their chemical composition and structure. Out of the quantity of pesticides used nearly 25% can be expected to reach the marine environment through atmosphere, river runoff and direct discharges. Some of these pesticides are persistent with 'half-life' of nearly a decade and they are distributed through various segments of the marine environment.

(a) *Effect of Agricultural Wastes :*

Apart from outright toxicity these compounds induce behavioural changes leading to reproduction problems

in marine animals, affect the mortality rate of the young, accumulate in body tissues to the extent that these animals are rendered unfit for human consumption and even affect some lower animals. The ideal example of food chain magnification is DDT which caused widespread egg shell thinning in some marine birds feeding on fishes contaminated with DDT and its isomers. Another effect of agricultural wastes discharge can be eutrophication of the recipient waterbody a phenomenon dealt in some detail in the next section.

4. *Domestic wastes :*

Domestic wastes and sewage generally contain a high load of organic matter including N and P which, though can enrich the coastal environment in small quantities, often create imbalances in large amounts. They also help in multiplication of undesirable species of organisms specially pathogenic bacteria.

Domestic wastes, apart from all of the above categories of pollutants, include several other inorganic constituents which, though are essential for animal growth and fertility of the sea in smaller amounts, cause great damage to the environment when added uncontrolled.

(a) *Effects of Domestic wastes :*

The result of addition of excess N and P to the marine environment is eutrophication - a phenomenon caused by over-fertilization. Dense algal blooms occur and this end up in depletion of dissolved oxygen and the consequent production of toxic hydrogen sulphide. Eutrophication may result in prolific growth of algae of a resistant type limiting the species diversity, which disrupts the ecological balance tremendously. It also aids and abets in the multiplication of undesired species of organisms specially the pathogenic bacteria. Changes in environmental conditions, caused by eutrophication, often release many metals in their toxic forms from non-toxic compounds.

In almost all of the countries tourism is promoted quite aggressively to earn valued foreign exchange which is badly needed for development. The result is that too many large and luxury hotels are being constructed along the seaface. Wastes from these hotels very often pose serious problems in the adjacent marine areas.

Garbage and other solid wastes spoil the aesthetics of the beaches sometimes leading to H_2S formation in nearby waters. But, many a seaside hotel would keep the nearby beach clean, also, for its clientele.

5. *Sensitive/Fragile Environments :*

Some sensitive and fragile environments, such as coral reefs; mangroves and seagrass beds, deserve special mention as they form spawning grounds and nurseries for a number of commercially important fishes, gastropods and crustaceans. They harbour a wide variety of flora and fauna. They can be sources of new drugs and raw material for domestic and industrial uses. Being closer to human habitation, they are facing a great deal of pressure resulting in considerable environmental stress.

(a) *Coral Reefs :*

Coral reefs of the tropical Indian Ocean include fringing and barrier reefs; sea-level atoll; and elevated sea reefs. The areas of occurrences are : NW and SE coasts of India, Lakshadweep islands, Andaman and Nicobar islands, Maldivé islands, Chagos Archipelago, Mauritius, Seychelles, Aldabra and Comores islands, coasts of Kenya, Tanzania and West Malagasy.

Most of these coral reefs have been declared as endangered ecosystems. Several reefs have almost disappeared because of the withdrawal of coral debris and live corals as a raw material for cement industry, while others have become dead due to their constant exposure to pollutants, particularly oil.

(b) *Mangroves :*

Mangrove forests and swamps exist in almost all the countries of the Indian Ocean region in varying extent. The Sundarbans mangroves in India and Bangladesh is one of the largest such area in the world.

Mangroves constitute an important resource and form spawning grounds, nurseries and feeding grounds for economically important fishes and crustaceans. They act as a buffer zone and offer protection to valuable communities like the coral reefs. They also stabilise the sediments, control the local mean water level and the direction of flow. Mangroves constitute a significant

portion of the coastal wetland and provide means of livelihood to many people in many countries.

Due to ever increasing demand for land and fuel many mangroove areas of the Indian Ocean region have been denuded. This has led to heavy siltation in the nearshore regions. With no protective cover of mangroves, the devastation of men and material during the cyclones and coastal areas is immense.

MARINE POLLUTION STUDIES

The overall levels of marine pollution in the Indian Ocean region may not be significant. Coastal population is relatively low and industrial activities are yet to take off at a fast pace. However, in the vicinity of urban and industrial conglomerates along the coast acute problems of pollution have been observed causing damage to the environment and constituting dangers to public health. Pollution control measures in most of the countries are either inadequate or absent.

Monitoring and research activities on marine pollution are either at the embryonic or at developing stages. It has, however, been stated that "research in marine pollution has attained significant status in India, and a substantial amount of data has been collected in different fields" (UNEP 1986). This report will, therefore, be built around mainly the available reports from India. (Qasim *et al*, 1988; Qasim and Sen Gupta, 1980; 1983a & b, 1988; Sen Gupta and Qasim, 1985) substantiated and supported by data from other countries wherever available.

India has a coastline of about 7500 km, including its oceanic islands and an exclusive economic zone (EEZ) of $2.015 \times 10^6 \text{ km}^2$ which is about 61.5% of the total land area of the country of $3.276 \times 10^6 \text{ km}^2$. It is generally the EEZ that is endangered by human activities. About 25% of the Indian population of 750 million live on the coastline and are dependent, directly or indirectly, on the sea for their livelihood. In turn they also put stress on this very environment by releasing their wastes. Added to this the wide variety of wastes brought in by the various riverine systems of the country and the vulnerability of our marine environment due to oil transport, one will get a picture of the state of the marine pollution in India.

We made an attempt to compute the strength of the popula-

TABLE 1 : DISSOLVED/DISPERSED PETROLEUM HYDROCARBONS IN THE UPPER 20M OF THE ARABIAN SEA AND THE BAY OF BENGAL

Year	ARABIAN SEA			BAY OF BENGAL			
	Transport (Million tonnes)	Concentrations (ug/kg) Range	Mean	Transport (Million tonnes)	BB/As %	Concentrations (ug/kg) Range	Mean
1978	975	0.09-42.5	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	25.28	308	35	1.2-27.4	12.47
1981	725	-	-	270	37	0-4.5	2.25
1982	579	-	-	247	43	0-2.8	1.40
1983	513	0-17.7	5.02	222	43	-	-
1984	489	-	-	252	51	0-3.4	1.70
1985	447	0.65-31.0	7.64	232	52	-	-
1986	-	1.0-23.5	7.50	-	-	-	-
Net decrease % 54				28			

tion, who can be dependent on the sea for their living, based on the assumption applied for India. In 1982 the population of all the countries was 1221 million. The average growth rate of population can be assumed as 2% per annum, at least at a first approximation. The population as on 1988, would come to around 1378 million. If 25% of these are dependent on the sea for their living, directly or indirectly, then around 34 million people have their daily bread at the mercy of the bounty of the Indian Ocean.

1. Oil Pollution :

The prospects of the possible existence of oil in the EEZ have spurred many of these countries to start offshore exploration. Some have succeeded while others are still on the look out. India is one of the successful countries. Underwater blow out and accidental seepages during exploration will cause oil pollution of the adjoining sea. However, the main source of oil pollution is the tanker traffic across the two oil tanker routes, originating in the Middle East and passing along the Arabian Sea, the Southern Bay of Bengal and the Southwestern Indian Ocean accounting for nearly two-thirds of the global marine transport of oil. Approximately 447 million tonnes of oil was transported across these tanker routes in 1985 (BP 1986). Because of the relative calm sea, near-absence of surveillance and proximity to the loading ports of the Middle East tankers routinely discharge oily ballast and flush-out their bilge tanks in the region.

Monitoring of oil pollution of the seas is a regular programme in India. Available data have been summed up (Sen Gupta and Kureishy, 1981) and are being periodically updated (Qasim and Sen Gupta 1983a, 1988; Sen Gupta and Qasim, 1985; Qasim *et al* 1987). Oil discharged into the sea appears as oil slicks, dissolved/dispersed petroleum hydrocarbons, floating petroleum residues (tar balls) and tar on beaches.

Figure 2 shows a record of all the available observations on oil slicks over the entire Indian Ocean upto 40°S latitude. The data have been divided into 5° -squares. The numbers at the bottom indicate the occasions when oil slicks were present while those at the top are for occasions when oil slicks were absent. A close look at the number will indicate that oil slicks occur very frequently along the tanker routes while south of the equator there is hardly any trace of oil pollution in the open areas of the Indian Ocean.

Floating tar observations revealed a range of 0 to 6.0 mg/m² with a mean of 0.59 mg/m² in the Arabian Sea. Similar range along the tanker route in the Southern Bay of Bengal was 0 to 69.7 mg/m² with a mean of 1.52 mg/m². The occurrence of the floating tar largely depends on the prevailing current patterns. These tar particles have a residence time of 30-45 days before they start sinking towards the bottom.

The concentrations of dissolved and dispersed petroleum hydrocarbons in the upper 20 m seem to be uniformly distributed except on a few occasions when these were exceptionally high. Seasonal variations were due to the varying intensities of tanker traffic and the prevailing environmental conditions. There was a reduction in the values from 1978 to 1985 because of a decrease in the volume of oil transported (Table 1). The reduction in traffic was sharp from 1979 to 1980 in the Arabian Sea and from 1980 to 1981 in the Bay of Bengal. Thereafter the conditions appear to have stabilised in both the regions and indicate a relative decrease.

Deposition of tar-like residues on the beaches is a chronic problem along the west coast of India. However, this is a seasonal feature and depends 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/m². The computed total deposit on the beaches along the west coast of India is approximately 750-1000 tonnes per year (Dhargalkar *et al.*; 1977). However, from 1977 to 1986, there has been a progressive decline in the occurrence of tar on the beaches. In 1985 and 1986 their appearance during the monsoon months has been sporadic and not very significant.

Almost all the countries in the Indian Ocean region are signatories to the 1973 MARPOL convention and the 1978 protocol. These have resulted in the establishment of reception facilities for oily bilges, ballasts and sludges at almost all the major ports. With more and more such facilities becoming available in ports, the oil pollution in the Northern Indian Ocean can be expected to reduce further. Recent trends indicate increasing concern in the perception of risks than in the risks themselves. There is, thus a decreased concern about oil pollution throughout.

2. *Heavy Metal Pollution :*

Metal pollution generally remains unnoticed until catastrophic events like the 'Minamata' or the 'Itai-Itai' disease (both in Japan) occur. These were caused by mercury and cadmium poisoning respectively. In aquatic environments metals have been termed as 'Conservative pollutants' because once added to the environment, they remain there for ever and cannot be broken down to harmless substances by bacterial action as many organic pollutants undergo. Most of them are, however, natural substances occurring in sea water in extremely low concentrations. They are leached or introduced into the aquatic systems as a result of weathering of soils and rocks, from underwater volcanic activities, or from a variety of man made sources. These processes and activities change the natural concentrations of metals in the sea water resulting in ten or even a hundred-fold increase near the source of an effluent discharge. Although many metals are toxic at a very low concentration they are often vital as trace elements. Thus, while manganese, copper, iron, zinc etc. are considered essential micronutrients, mercury, cadmium and lead are not required for any important biological function by organisms and are termed as non-essential elements.

In general, metal pollution in the Indian Ocean has not yet reached dangerous levels. But the potential threat it offers is sufficient to merit a careful watch, in terms of monitoring programmes. Metals, once introduced in the sea water, as contaminants undergo various alterations. Apart from dilution and dispersion, there are biogeochemical processes which remove metals from the sea water, or in other words, reduce the concentrations of the added metal in the sea water. These are, precipitation, adsorption onto suspended matter and adsorption by the organisms. It is the last process which is of prime concern to man. This has led to much interest in determining the levels of heavy metals in a wide variety of commercially important marine fishes. Fewer studies deal with the levels of heavy metals in other economically unsuitable species to determine and understand the high levels of metals reported in some species which are due to the generally increased levels of the particular metal in the marine ecosystems or are a physiological peculiarity of that particular species. It is generally believed that for every metal in the sea there is one or more organisms which can bio-accumulate it.

Heavy metals monitoring activities present an interesting picture in the Indian Ocean region. Such activities in the island countries of the Western Indian Ocean including the east African countries are either at a very elementary stage or are non-existent. Though the need for monitoring has been repeatedly emphasised, yet nothing tangible could be done due, mainly, to lack of resources both human and material. These activities, are however, quite seriously pursued in countries of the eastern and northern Indian Ocean. Standards and quality of work in some of these countries can be favourably compared to those of the developed countries. Paucity of adequate resources restrict such activities to vulnerable coastal areas or 'hot spots' in most of these countries. The results have indicated that areas off urban and industrial zones are badly polluted rendering some of the fish, crustaceans and gastropods unfit for human consumption.

The picture in the open ocean, however, differs from that in the coastal areas. The concentration of metals in the water show a wide range of variation from area to area and sometimes among the analysts working in the same area. The differences are largely due to errors in sampling, analytical methods and human bias. However, continuous improvements in sampling and standardisation of the analytical instruments have reduced the margins of error considerably. Similar high values have been noted also for metal concentrations in particulate matter, which is caused largely by the addition of 34×10^8 tonnes of sediments through river runoff to the Indian Ocean every year (Holeman, 1968). A major part of the added material settles at the confluences of the river with the sea. This has been demonstrated from studies in the estuarine region of the river Ganga, the largest river to meet the Indian Ocean (NIO, 1986). Estimates indicate that 5-9% of the suspended and particulate metals get precipitated within the riverine and estuarine parts where semi-diurnal tidal incursions occur, 45-50% at the confluence of the river and the sea and 40% finally flows out to the open parts of the Bay of Bengal. Similar observations on the dissolved metals showed that about 85% settle within the estuarine region and at the confluence leaving only 15% to flow out into the Bay of Bengal. Some of these metals are biologically active and their effects on the environment can empirically be demonstrated from analysis of the living organisms.

A good data base is available to draw a scenario of the metal contamination of the fauna of the Indian Ocean. Instead of going into details we have attempted to sum up all the data available on the toxic non-essential heavy metals, Pb, Cd and Hg in the muscles (edible part) of the skipjack tuna (*Katsuwonus pelamis L.*) from the investigations carried out between 1978 and 1982 (Table 2). This migratory fish is a very common food fish of the region and were caught at different open areas of the northern Indian Ocean. The ranges in values in Table include concentrations in fishes of varying length, sex and stages of maturity. Higher concentrations were generally observed in large fishes. From the point of view of food hygiene, the concentrations are below the maximum permissible limits prescribed by the World Health Organisation (WHO) for the metals of fish and fishery products to be used for human consumption. The few isolated cases of high values could, perhaps, be due to physiological peculiarities of the fish itself or as a result of 'errors' in measurements.

TABLE 2 : CONCENTRATIONS OF MERCURY, CADMIUM AND LEAD (IN PPM WET WEIGHT) IN THE MUSCLES OF SKIPJACK TUNE (KATSUWONUS PELAMIS L.) FROM 1978-1982 CAUGHT FROM THE COASTAL REGION OF INDIA

Metals	1978	1979	1980	1981	1982
Mercury	0.16	0.03 - 0.22	0.04	0.03	0.01
Cadmium		ND - 0.34	2.0	ND-0.93	0.90
Lead		1 - 1.19	ND	ND-2.63	0.62

3. Pesticides pollution :

Studies on the pesticide residues in the environment assumes significant importance because of the dependence of all the countries in the Indian Ocean region on agriculture and on the control of any vector - borne diseases. It is because of the control of disease vectors that the role of one of the most persistent and widely used pesticide, DDT, cannot be ignored. DDT, since its introduction and use during the second world war, has been applied extensively throughout the world. According to one report of W.H.O. DDT has been responsible for the spectacular increase in agriculture as well as eradication of several vector-borne diseases. Because of its acute toxicity to all living being the use of DDT has been banned in developed countries.

But its production, instead of a decrease, is indicating a relative increase. An hypothesis of a 'southward tilt' of DDT has been suggested meaning thereby its unabated and increasing use in the developing countries.

Although numerous types of pesticides, herbicides, insecticides, fungicides etc. are commonly used, these can broadly be classified into three categories, namely, organochlorine, Organophosphates and Carbamates. Of these, the organochlorine pesticides like DDT, BHC, Aldrine, Dieldrin, Endrin, Toxaphene etc. are called persistent chemicals with long half lives. The other two groups of pesticides (Organophosphates and Carbamates), on the other hand, have relatively short half lives as they are easily biodegraded to harmless substances. Hence they do not pose any serious environmental problems.

The oceans have always been the ultimate sink for all these chemicals used on land. It is estimated that about 25% of the DDT compounds, produced to date, might have been transferred to the sea. It has also been estimated that

DDT compounds in the marine biota amounts to about 0.1% of its total use. Even such small amounts have produced a significant impact. Effects, such as reproductive failures of seabirds and fish, inhibition of photosynthetic productivity of algae are a few examples apart from its transfer into the marine food chain.

Data on the total consumption of pesticides in Indian Ocean countries are almost non-existent. However, extrapolating the ratio of 2:1 between total landmass and agricultural area and the pesticides annual consumption rate of 336 g/ha in India to the total land area of all the countries the figure for yearly pesticides consumption works out to about 160 000 tonnes. We believe this figure may be accepted as a first approximation.

Monitoring of organochlorines, particularly in water, is extremely susceptible to contamination and hence such values are almost non-existent. Concentrations in biota and plankton are available from India, Thailand, Malaysia and Philippines. All the values in general, barring exceptions on rare occasions, are fairly low.

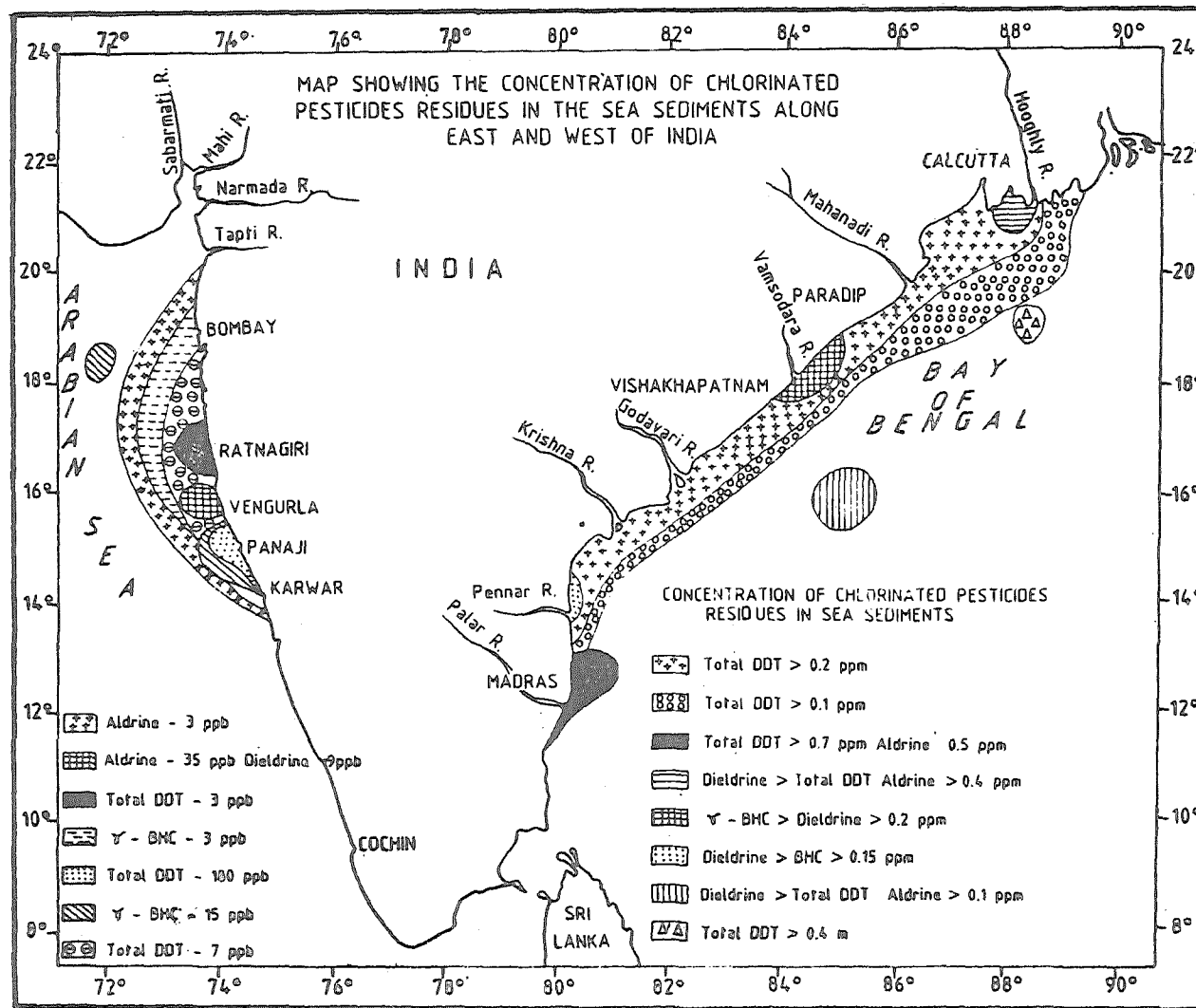


Figure 3 : (Modified from : Qasim & Sen Gupta 1988, Sarkar & Sen Gupta 1987)

Recent studies in India (Sarkar and Sen Gupta - 1987, 1988) on pesticide residues in the sediments indicated that apart from DDT and its isomers, residues of Gamma - BHC, Aldrine and Dieldrine could be recorded from a number of places. Their individual concentrations were, in some areas, higher than total DDT. Fig. 3 indicates a quantitative difference in concentrations between east and west coasts of India. Concentrations along the east coast are in ppm while those along the west coast are in ppb. The east coast receives the major volume of river runoff from India and high concentrations are noted at river mouths mainly. This leads us to believe in the riverine transport of pesticide residues.

PROSPECTS

Having outlined the problems of marine pollution in the Indian Ocean countries let us now try to work out what the future could hold for them in the aspect.

We mentioned initially that the average rate of growth of population in these developing countries is about 2%. This would mean that marine contaminants should also grow at the same rate. But this is not always true, as, with simultaneous or faster growth in industrialization and mechanization marine contaminants are bound to grow exponentially and not linearly.

Marine environment is playing a crucial role in the economy and lifestyle of the countries of the region. The environment is already under stress in many countries and will have to bear the major brunt of the effect of development.

But man is becoming more and more aware of the value of his environment and significance of its preservation. Baseline research and survey to collect data to filling up the existing gaps are already either at the planning or at the implementation stage. Adequate measures are being taken sometimes by the country alone and sometimes in collaboration with neighbouring countries and often with funding and expertise of international organisations. Available environmental pollution control legislations are strictly implemented more and more.

The nature and geographical configuration of the Indian Ocean provide a healthy influence on the well being of this region. This Ocean is subjected, almost throughout, to the impact of semi-diurnal tide of large amplitude and its northern part is influenced by the bi-annual reversal of monsoon winds and the resulting seacurrents. These features give this area enough flushing twice every day and water exchange to dilute and disperse the incoming pollution load.

Thus with increasing public awareness, state legislations and regional cooperation aided by nature the prospects do not seem to be dark. But these steps are absolutely needed and should

be implemented with devotion and dedication or else anything can happen anywhere.

PERSPECTIVES

Problems of pollution of the sea and the necessity for its preservation were first visualized during the UN conference on Human Environment in 1972 leading to the establishment of the United Nations Environment Programme (UNEP). Since then, considerable progress has been made in this direction culminating in the formulation and acceptance of several international conventions and protocols regarding various pollutants and their control.

The programme worked out by UNEP were primarily based on regional cooperation. Instead of taking the oceans as a whole, the entire coastal marine area of the world has been divided into several zones. At the moment, 11 regional seas programmes have been finalized and are in operation under the aegis of UNEP. These programmes are based on the following stages :

- (i) Assessment of sources of pollution and their effects.
- (ii) Management of natural resources on a suitable basis and according to environmentally sound principles.
- (iii) Formulation and adoption of legal component in the form of regional conventions and protocols.
- (iv) Institutional and financial management to implement the programme.

UNEP took the initiative with Governments of different countries, brought them to the discussion table and worked out an unanimously acceptable programme of activities.

The most important recent development is the Third United Nations Conference on the Law of the Sea (UNCLOS-III). According to this, certain areas were identified eg. navigation, fisheries, sea-bed resources, protection of the marine environment, marine scientific research and transfer of technology; which will be supervised by international organisations concerned with the oceans. UNCLOS-III declared that the marine area from the shores of a country to a distance of 200 nautical miles is its exclusive economic zone (EEZ). The country has the sovereign right for exploration and exploitation of all the marine living

and non-living resources in its EEZ. As a result of this, vast areas of the oceans which were once available for research to all, are now almost a closed boundary. For example, there is hardly any international water in the South China Sea, only a small stretch in the central region of the Bay of Bengal and no international water at all in the southwestern Indian Ocean, because of the innumerable islands and island countries.

Boundaries of EEZ are still not clearly demarcated between many countries; but marine pollution knows no frontiers. Conflicts about the right of exploitation of resources and responsibilities of controlling pollution have started arising. There are many countries which do not have the capabilities to survey their EEZ and maintain a surveillance. These countries often charter ships from the developed countries to do the job for them. This is certainly going to create problems in the future.

The World knows that the first international conflict about marine living resources took place way back in the late sixties between Great Britain and Iceland over fishing rights and was known as the 'Cod War'. Who has forgotten the slogan raised by the Icelanders against the British, "God save the God"? International programmes should keep these important aspects in mind because it is only such programmes which can solve such disputes.

REFERENCES

- British Petroleum 1985 *Statistical review of world energy* (British Petroleum London) 32pp.
- Budyko, M.I. 1972 The water balance of the oceans. In: *The World Water Balance. Proc. of the Reading Symposium 1970.* IASH-UNESCO-WMO- Studies and Reports in hydrology, II 1:24-33.
- Couper, A. (ed.) 1983 *The Times Atlas of the Oceans*, Times Books Ltd., London.
- Dhargalkar, V.K., T.W. Kureishy and M.V. Bhandare 1977 Deposition of tar balls (oil residues) on beaches along the west coast of India. *Mahasagar, Bulletin of the National Institute of Oceanography*, 10: 103-108.
- Dietrich, G. 1963 *General Oceanography*, Interscience, New York, 588 pp.

- Dietrich, G. 1973 The unique situation in the environment of the Indian Ocean, In: *The Biology of the Indian Ocean*, editor B. Zeitzchel, Springer, Verlag, Berlin 1-6.
- Holeman, J.N. 1968 The sediment yield of major rivers of the world, *Water Resources Research* 4: 787-797.
- Johnston, R. (1976) *Marine Pollution*, Academic Press, London, 729 pp.
- Naqvi, S.W.A. 1987 Some aspects of the oxygen-deficient conditions and denitrification in the Arabian Sea. *Journal of Marine Research*, 45, 1049-1072.
- National Institute of Oceanography 1986 *A study of Estuarine Environments of Major Indian Rivers -Ganga and Mahanadi Estuaries*, Technical Report NIO/TR/4/86.
- Qasim, S.Z. and R. Sen Gupta 1980 Present status of marine pollution studies in India In: *Management of Environment*, editor B. Patel, Willey Eastern, New Delhi, 310-329.
- Qasim, S.Z. and R. Sen Gupta 1983 a , *Marine Pollution Studies in India*, In: *Water Pollution and Management Reviews*, editor, C.K. Varshney, South Asian Publishers, New Delhi, 139-159.
- Qasim, S.Z. and R. Sen Gupta 1983 b Environmental Characteristics of the Ocean, In: *Environmental Sciences and Engineering*, editors J.R. Pfafflin and E.N. Ziegler, Gordon and Breach Science publishers, New York 294-309.
- Qasim S.Z., R. Sen Gupta and T.W. Kureishy 1988 Pollution of the seas around India. *Proceedings of Indian Academy of Sciences, Animal Science*, 97, 117-131.
- Qasim, S.Z. and R. Sen Gupta 1988 Some problems of coastal Pollution in India, *Marine Pollution Bulletin*, 19, 100-106.
- Sen Gupta, R., S. Naik and S.Y.S. Singbal 1978 A study of fluoride, calcium and magnesium in the Northern Indian Ocean. *Marine Chemistry* 6:125-141.
- Sen Gupta R and T.W. Kureishy 1981 Present State of Oil Pollution in the Northern Indian Ocean. *Marine Pollution Bulletin*, 12, 295-301.

- Sen Gupta R. and S.Z. Qasim 1985 The Indian Ocean - An environmental overview, In: *The Ocean: realities and prospects* editor R.C. Sharma, Rajesh Publications New Delhi 7-40.
- Sarkar, A. and R. Sen Gupta 1987 Chlorinated pesticide residues in marine sediments from the Arabian Sea along the Central West Coast of India. *Bulletin of Environmental Contamination and Toxicology*, 39 1049-1054.
- Sarkar, A. and R. Sen Gupta 1988 Chlorinated pesticide residues in sediments, *Marine Pollution Bulletin*, 19, 35-37.
- United Nations Environmental Programme (UNEP) 1986 *Draft overview of the Coastal environmental problems of the South Asian Seas Region*. UNEP/WG. 153/3.
- Venkateswaran, S.V. 1956 On evaporation from the Indian Ocean, *Indian Journal of Meteorology and Geophysics*, 7, 265-284.
- Wyrtki, K. 1973 Physical Oceanography of the Indian Ocean In: *The Biology of the Indian Ocean*, editor B. Zeitzschel, Springer Verlag Berlin 18-36.