

# Oil Pollution Studies In Northern Indian Ocean

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## INTRODUCTION

Studies on oil pollution in the Indian Ocean region is a comparatively recent field of investigation having been initiated in 1975 with the commencement of the Marine Pollution (petroleum) Monitoring Pilot Project (MAPMOPP) of Integrated Global Ocean Station System (IGOSS). The project was terminated in 1980. The information, pre-

sented in this report, is from the data collected by India and by some of the countries in the Indian Ocean region, mainly during the operation of this project. Data analysed are for oil slicks, floating petroleum residues, dissolved/dispersed hydrocarbons and beach tar.

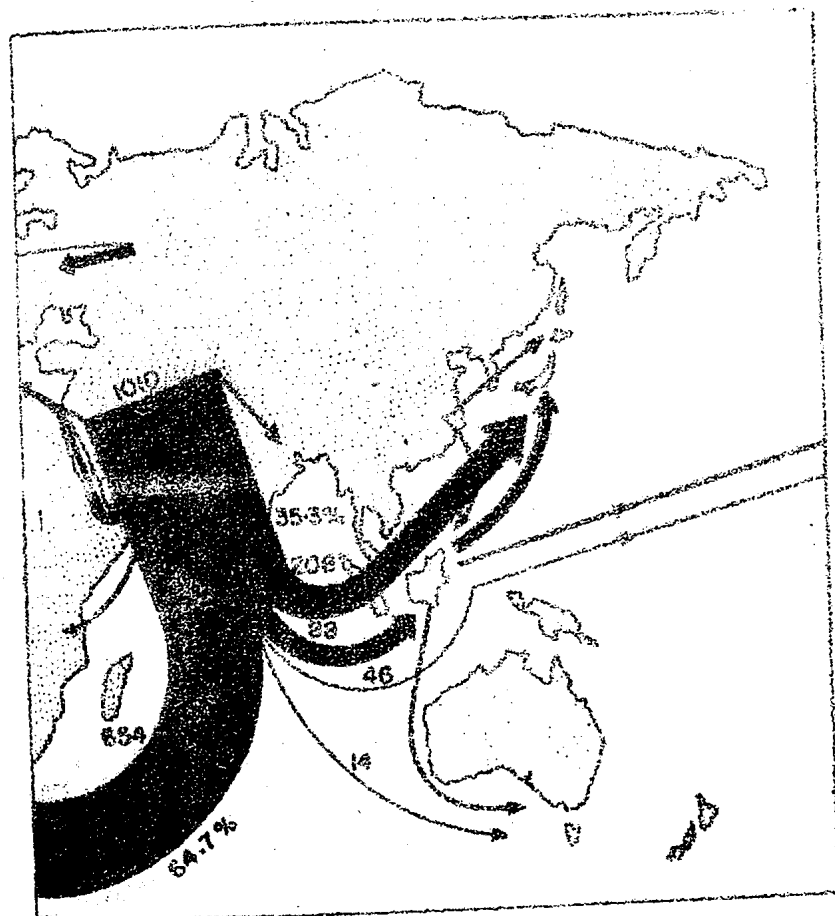
Two of the world's largest oil tanker routes originate in the Gulf countries, whose share in the total

production of oil ranges from 28-38% of the global total but accounts for 49-61% of the marine transport. In fact, 10-95% of total production of oil in the Gulf countries are transported mainly along these two sea routes. Figure 1 presents the two tanker routes originating in the Gulf countries. One of them goes via Mozambique Channel, round South Africa to the Western Hemisphere. The other one is along the exclusive economic zone (EEZ) of India, round Sri Lanka, across the southern Bay of Bengal to Far East and Japan. In 1979 668 million tonnes (MT) or 61.7% of the total transport of 1098 MT from the Gulf countries were transported along the former while the rest was carried along the latter tanker route. With the on-going widening and deepening of the Suez Canal, the transport along the first tanker route may be expected to be reduced. This, in turn, will reduce the risk of oil pollution along the coast of the East African countries but will considerably enhance the same risk in the land-locked Mediterranean Sea.

## OIL SLICKS

Figure 2 presents a total of 6682 observations on oil slicks and other floating pollutants. The two tanker routes and other shipping lanes can be clearly identified in the figure. Intensities on the routes represent the frequency of the number of observations and not the volume of traffic. An analysis of the data indicated that oil was sighted on 5382 occasions or 81.5% of the total observations. It can be seen that the intensities of oil sightings are the highest along the two tanker routes. The percentage frequencies of oil sightings increase away from the source of origin of the oil. It ranges from 73.46% along the west-going route and 74.87% along the route to the East. This would indicate that percentage wise frequency is the same along both the routes.

These observations indicate that



**MOVEMENT OF OIL FROM MIDDLE EAST COUNTRIES BY SEA 1979 (MILLION TONNES)**

Fig. 1. Movement of oil from Middle East countries in 1979. Numbers are in million tonnes. (Modified from B. P. Statistical Review of World Oil Industry, 1979).

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fig. 2. Points of observation on oil slicks and other floating pollutants in the Northern Indian Ocean (Courtesy: Japan Oceanographic Data Centre)

northern Indian Ocean, particularly the Arabian Sea is a place for intense occurrences of oil slicks. It also leads to suggest that the source of these oil slicks is the bilge washings of the ships on their way to the Gulf ports which is reflected in higher percentage frequency in oil sightings; as, so far, tanker disasters have been rare in this region.

Movements of oil slicks and oil spills are regulated by movements of water at the surface of the sea. If the speed and direction of surface currents over a long period of time at any place is known, a meaningful forecast of such movements can be made. Utilizing historical data on current and wind speeds, the movements of a hypothetical oil spill at Bombay High were studied. From May-September, the West Coast of India remains vulnerably exposed to oil spills and oil slicks. During the remaining months of the year, the oil will move away from the Indian coast.

#### FLOATING PETROLEUM RESIDUES/TAR BALLS

After an oil spill, lighter fractions evaporate out. Part of the oil can be degraded microbiologically or by photo-oxidation. Heavier fractions remain floating and most

often form lumps with a particle of sand as nucleus. These floating petroleum residues or tar balls are driven on the surface of the sea by winds and currents. Some of them sink to the bottom and others get washed and deposited on beaches.

In areas of heavy tanker traffic, as the Arabian Sea and the southern Bay of Bengal, one may expect high concentrations of these floating tar balls.

Examining the data collected from 1978 to 1980 for the Arabian Sea, a range of 0 to 6.0 mg/m<sup>2</sup> with a mean of 0.59 mg/m<sup>2</sup> was observed. Applying this to the area of the Arabian Sea, from 0° to 25°N and from 50° to 80°E, of 6.225 × 10<sup>6</sup> km<sup>2</sup> one obtains a figure of 3700 tonnes of floating tar balls at any time on the surface.

A recent observation during March 1981 along the oil tanker route off the West Coast of India, between 12° and 19°N and 70° and 74° 30'E, indicated a range of 0.3 to 112.2 mg/m<sup>2</sup> with an average of 12.7 mg/m<sup>2</sup> for the floating tar balls. This may, perhaps indicate that oil pollution in the Arabian Sea is on the increase.

For the oil tanker route across the southern Bay of Bengal, between 5° and 7°N and 80° to 95°E,

the range of concentration of floating tar balls is 0 to 69.75 mg/m<sup>2</sup> with an average of 1.52 mg/m<sup>2</sup>. The total area enclosed by these coordinates is 0.73 × 10<sup>6</sup> km<sup>2</sup>. Combining the area with the concentration, we arrive at a figure of 1100 tonnes for the total quantity of floating tar balls which can be expected to be present at any time along this tanker route. North of 7°N there is little or no accumulation of floating tar particles in the Bay of Bengal.

Accumulation of floating tar is entirely dependent on the surface currents. In areas of strong surface currents, e.g. Gulf stream in the North Atlantic and Kuroshio in the Northwestern Pacific, heavy accumulations of tar particles have been observed. In the Arabian Sea, off the West Coast of India, the half-yearly changes in direction of the surface flow regulates the accumulation of the tar particles.

The observed concentration in the North Atlantic ranged from 0.12-2.64 mg/m<sup>2</sup> with a maximum of 91.8 mg/m<sup>2</sup>. Similar accumulation in the Northwestern Pacific ranged from 0.02-13.3 mg/m<sup>2</sup>. Thus the oil tanker routes in the Northern Indian Ocean are as much polluted as those in the other oceans.

Assuming that the abundance of oil entering any marine area is proportional to the volume transported, an attempt has been made to compute the entry of tar into the Arabian Sea and the Bay of Bengal. Since the best estimate of the total input of oil from all sources to the world oceans in 1973 was considered to be 6.11 MT, it follows that on a world-wide basis the average input was 0.36% of the total flow. If it is assumed that this percentage did not change from 1973-1979, the amount entering the Arabian Sea and the Bay of Bengal each year is readily calculated. The volume transported across the southern Bay of Bengal has been assumed as 15% of the total transport across the Arabian Sea. The results obtained are presented in Table I.

TABLE I

Year	Flow in 10 <sup>6</sup> tonnes over		Total world flow (10 <sup>6</sup> tonnes)	Entry of (a) oil in 10 <sup>6</sup> tonnes to		Entry (b) of tar in tonnes to	
	Arabian Sea	Bay of Bengal		Arabian Sea	Bay of Bengal	Arabian Sea	Bay of Bengal
1973	990	346	1694	3.6	1.2	36000	12000
1974	992	347	1656	3.6	1.2	36000	12000
1975	918	321	1508	3.3	1.2	33000	12000
1976	1033	361	1706	3.7	1.3	37000	13000
1977	1024	358	1724	3.7	1.3	37000	13000
1978	975	341	1691	3.5	1.2	35000	12000
1979	1009	353	1732	3.6	1.3	36000	13000

(a) Based on  $(6.11/1694) \times 100 = 0.36\%$  rate of loss for 1973.

(b) Based on 1% converted to tar

Arabian Sea	Average entry	= 35700
	Tar present	= 3700
	Residence Time	= $3700/35700 = 0.10$ year or 36 days
Bay of Bengal	Average entry	= 12400
	Tar present	= 1100
	Residence Time	= $1100/12400 = 0.09$ year or 33 days.

Although the fraction of the original input of oil that persists long enough to become transformed into tar differs for oils of different origins, as a first approximation it can be postulated that about 1% of total input will ultimately end up as tar. This seems to be fairly well applicable for the Arabian Sea, as the entire volume transported across it has the same source of origin, i.e. countries in the Middle East. This leads to the range of input of tar to the Arabian Sea from 33000-37000 tonnes between 1973 and 1979. Similar range for the southern Bay of Bengal is from 12000/13000 tonnes for the same period of time. However resistant it may be, tar itself is not immune to weathering and has a limited lifetime on the surface of the ocean. The amount of tar present at any time on the surface of the Arabian Sea has been calculated as 3700 tonnes. On the basis of the average annual entry over the period 1973-1979, the "residence time" of tar in the Arabian Sea would be about 0.1 year or about 36 days. Calculating the same way the "residence time" of tar in the Bay of Bengal comes to about 0.09 year or about 33 days. The similarity between the two periods is remarkable or it may be fortuitous.

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.

From the above, it can be concluded that tar on the sea remains unchanged for 33-60 days.

**DISSOLVED/DISPERSED HYDROCARBONS**

It has been suggested that it is preferable to use the term petroleum residues for the methods being used for analysis is not specific for oil or petroleum or petroleum hydrocarbons. A detailed study by Gas Chromatography-Mass Spectrometry did indicate the presence of alkylated aromatics as well as the

homologous series of normal paraffins in the sea water extracts. This indicates a "boundaries" of local fuels. The data on dissolved/dispersed hydrocarbons in sea water should therefore be interpreted with this in mind.

Observations were confined to the upper 20 m of the sample, mainly on practical difficulties in sampling. Defining the area west and east of the 80°E meridian as being the Arabian Sea and the Bay of Bengal respectively, an attempt has been made to study the spatial variations, if any, of the dissolved/dispersed petroleum residues. Mean values, depthwise, along with the number of observations and range are presented in Table II.

TABLE II

Depthwise mean concentrations (ug/kg) of petroleum residues in the Arabian Sea and the Bay of Bengal

Depth	Arabian Sea			Bay of Bengal			
	n	Mean	Range	n	Mean	Range	
0 m	39	35.5	0-395	6 m	29.1	4-239	
10 m	34	30.6	3-217	10 m	25.1	2-147	
20 m	15	29.4	2-112	20 m	17.6	1-75	
Mean of all values :			32.5	Mean of all values :			24.1

Table II indicates that there is a difference between the mean values and the ranges in both the areas. The ranges indicate the seasonal variations and the intensity of the tanker traffic at the time of the observations. It has, however, been assumed that the mean values will present the average conditions, at least at a first approximation.

Mean values indicate that depthwise the difference in concentrations in the upper 20 m of the Arabian Sea is not very significant, indicating a near homogeneity in the water column. However, in the Bay of Bengal, there is almost a sharp change in both the mean and the range from 10 to 20 m. These concentrations are the petroleum residues present in water which may have been derived from oil spills, from bilge washings of ships, atmospheric fall-out and end-products of photo-oxidation and microbial activities. The difference in values, depthwise and areawise, in Table II may be the result of single or cumulative effect of all these factors.

Calculations based on the area of the Arabian Sea, as mentioned earlier, give a volume of  $0.125 \times 10^6 \text{ km}^3$  for the upper 20 m. Applying this volume and the mean of all values in Table II would indicate that a total of  $4 \times 10^5$  tonnes of petroleum residues should be present in the upper 20 m of the Arabian Sea. This is about 0.4% of the total volume transported and agrees very well with the computed figures for entry of oil, presented in Table I. Of course, all these calculations are based on the assumption that oil spilled in any marine area is directly proportional to the volume transported across it and the oil spills have remained steady since the NAS calculations of the same for 1973. These data should, therefore, be interpreted with these limitations. Similar calculations for the area of the Bay of Bengal would give a figure of  $0.4 \times 10^5$  tonnes for the petroleum residues. Applying the proportionality relation as mentioned above, the amount of dissolved/dispersed petroleum residues in the water of the Bay of Bengal should have been 35% of similar figures for the Arabian Sea. That this is not the case would

indicate that the tankers discharge their ballasts and bilge washings in the Arabian Sea on their way to the Gulf ports for loading of crude oil and its products.

### BEACH TAR

Particulate petroleum residues (tar balls) are end-products of oil spills in the sea. Driven by currents and winds they gradually grow in size and are ultimately deposited on the beaches. Their deposition in large quantities spoil the aesthetics of the beaches and often seriously affect the profitable tourist trade of the surrounding countries.

Arabian Sea is the area of the largest volume of tanker traffic. It is also very much influenced by the monsoon winds. When the long-shore current develops a shoreward component, heavy deposits of tar balls occur on the beaches.

Observations on the beaches along the west coast of India indicated that the tar balls are deposited only between April and October, when the shoreward component of the coastal currents develops. This is also the period of the South west monsoon. During the rest of the year, there is practically no deposition anywhere. Two years of observation on all the beaches on the West Coast of India gave ranges of 0-1336 g/m<sup>2</sup> for 1975 and 0-759 g/m<sup>2</sup> in 1976. The averages worked out as 28 g/m<sup>2</sup> for 1975 and 20 g/m<sup>2</sup> for 1976. The total deposition on all the beaches were about 1900 tonnes for 1975 and about 750 tonnes for 1976.

Similar phenomena were also observed along the beaches of Tanzania and Kenya. There the depositions were highest during April-October which was the season of the southerly monsoon. The depositions ranged from about 20-2400 g/100 m<sup>2</sup>. Tar lumps as heavy as 16 kg have sometimes been observed.

In other words, deposition of tar balls is purely a seasonal phenomenon. But, whenever it occurs, it does so very heavily.

### CONCLUSIONS

From the above descriptions, the following conclusions can be drawn

(i) The Arabian Sea is the world's only area with the heaviest tanker traffic over it. About two-thirds of the world's marine transport of oil and its products are transported along the two tanker routes across the Arabian Sea.

(ii) Large volume of oil is discharged mainly by bilge washings from tankers proceeding to the Gulf ports for loading. This makes the Arabian Sea a place for frequent sightings of oil slicks.

(iii) The oil discharged by the ships results in accumulation of floating tar-like particles, sometimes in high intensities. Annually, about 3700 tonnes of this material is generated in the Arabian Sea. Similar generation along the oil tanker route across the southern Bay of Bengal is of the order of 1100 tonnes per year. "Residence time" of these tar-like residues on the sea has been estimated as 27 to 40 days in these two areas. The observations at Mumbai, India, indicated that the accumulation of these floating tar particles depends on the increase in the monsoon.

(iv) The upper 20 m of the Arabian Sea would contain a total of  $4 \times 10^5$  tonnes of petroleum residues dispersed throughout. This is about 0.4% of the total volume transported over the sea and the which is in good agreement with the global rate of 0.2% between oil added and oil transported over the seas. The number of tonnes of oil in the Bay of Bengal appears to be proportionately less, oil discharged

(v) Deposition of tar balls on the shores of the beaches around the Arabian Sea is a seasonal phenomenon, not being regulated by winds and surface currents. But during periods of deposition heavy amounts of these have been observed at several places.

(vi) The frequency of tanker disasters and blow outs are few and far between in the Arabian Sea. These lead to the obvious conclusion that oil pollution is caused mainly by the tankers cruising along either on ballast or on full load. Perhaps, it is about time for the littoral countries to reconsider the allowing of "innocent passage" on their territorial waters by oil tankers in order to safeguard their living and non-living marine resources.