

Kingdom will have limited success because it can only apply to 10–15% of coastal traffic around the British Isles.

In the absence of any effective marine litter controls at the present time and probably during much of the next decade, litter abatement agencies and environmental pressure groups are initiating campaigns to try and correct the situation. In the United Kingdom the Keep Britain Tidy

Group is promoting voluntary codes of practice, which apply to all seacraft, which seek to eliminate the disposal of litter at sea. More research will be undertaken to assess the environmental impacts of marine litter and establish a quantitative basis for a comprehensive surveillance system.

The pollutants change with progress but the proximate cause is unaltered.

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Present State of Oil Pollution in the Northern Indian Ocean

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A consolidated picture of oil pollution for the northern Indian Ocean is presented. Oil slicks were sighted on 5582 observations, about 83.5% of the total observations of 6689. The range of concentrations, of the floating tar balls, is 0–6.0 mg/m² in the Arabian Sea. Similarly, the oil tanker route in the Bay of Bengal has the range of 0–69.75 mg/m². North of this route, the Bay of Bengal is comparatively free from this floating tar. Mean concentrations of dissolved and dispersed hydrocarbons for 0–20 m are 32.5 and 24.1 µg kg⁻¹, respectively, in the Arabian Sea and the Bay of Bengal.

Since the initiation of Marine Pollution (Petroleum) Monitoring Pilot Project (MAPMOPP) of the Integrated Global Ocean Station System (IGOSS), several reports on the progress of the project and the state of oil pollution in different ocean areas of the world have been published (Sleeter *et al.*, 1974, 1976; Levy & Walton, 1976; Wong *et al.*, 1976; Levy, 1979, 1980; Suzuoki & Shirakawa, 1979; Sano *et al.*, 1979; Shigehara *et al.*, 1979; Gerard, 1979; Kohnke, 1980; Sobchenko *et al.*, 1980; Oostdam, 1980). Most of these reports analysed the data collected from specific areas. Only two reports (Kohnke, 1980; Levy, 1980) cover all the oceanic areas and include the data collected by all the participating countries on the three MAPMOPP parameters, i.e. visual observations of oil slicks and other floating pollutants, particulate petroleum residues (tar balls), and dissolved and dispersed hydrocarbons. Data from a few series of observations from the Arabian Sea and the Bay of Bengal, mainly from the two oil tanker routes across them, have been published recently (Sen Gupta *et al.*, 1978, 1980; Qasim & Sen Gupta, 1980; Fondekar *et al.*, 1980). These reports have mainly dealt with the dissolved

and dispersed hydrocarbons and no attempt has been made so far to present a consolidated picture of oil pollution, covering all the MAPMOPP parameters, in the Indian Ocean incorporating the data collected by all the participating countries in the region.

This report is an attempt to present an analysis of the data collected from the Indian Ocean during MAPMOPP. Since the data available with the Japan Oceanographic Data Centre, which was nominated as Responsible National Oceanographic Data Centre (RNODC) for the Indian Ocean region by IGOSS, covered only the area north of the equator (Fig. 1), this report is entitled 'Present State of Oil Pollution in the northern Indian Ocean'. Data on all the three MAPMOPP parameters, collected from this area up to June 1980, are analysed in detail in this report. The areas covered are 0°–30° N and 50°–100° E for oil slicks and 5°–20° N and 69°–99° E for floating tar and dissolved/dispersed hydrocarbons. The fourth MAPMOPP parameter, beach tar, is not included in this report since these results have been published earlier (Dhargalkar *et al.*, 1977).

India, Thailand and Malaysia are the three countries most actively participating in this project in the Indian Ocean region. While India has submitted to Japan RNODC data on all the three parameters from 1977 onwards, Thailand has submitted data on dissolved and dispersed hydrocarbons from 1978 and Malaysia data on oil slicks and other floating pollutants from 1979. However, the number of participating countries from the region is gradually increasing.

A total of 6689 observations of oil slicks and other floating pollutants, collected by ships from the participating countries in the region and by many other merchant ships participating in the 'Ships of Opportunity' programme of

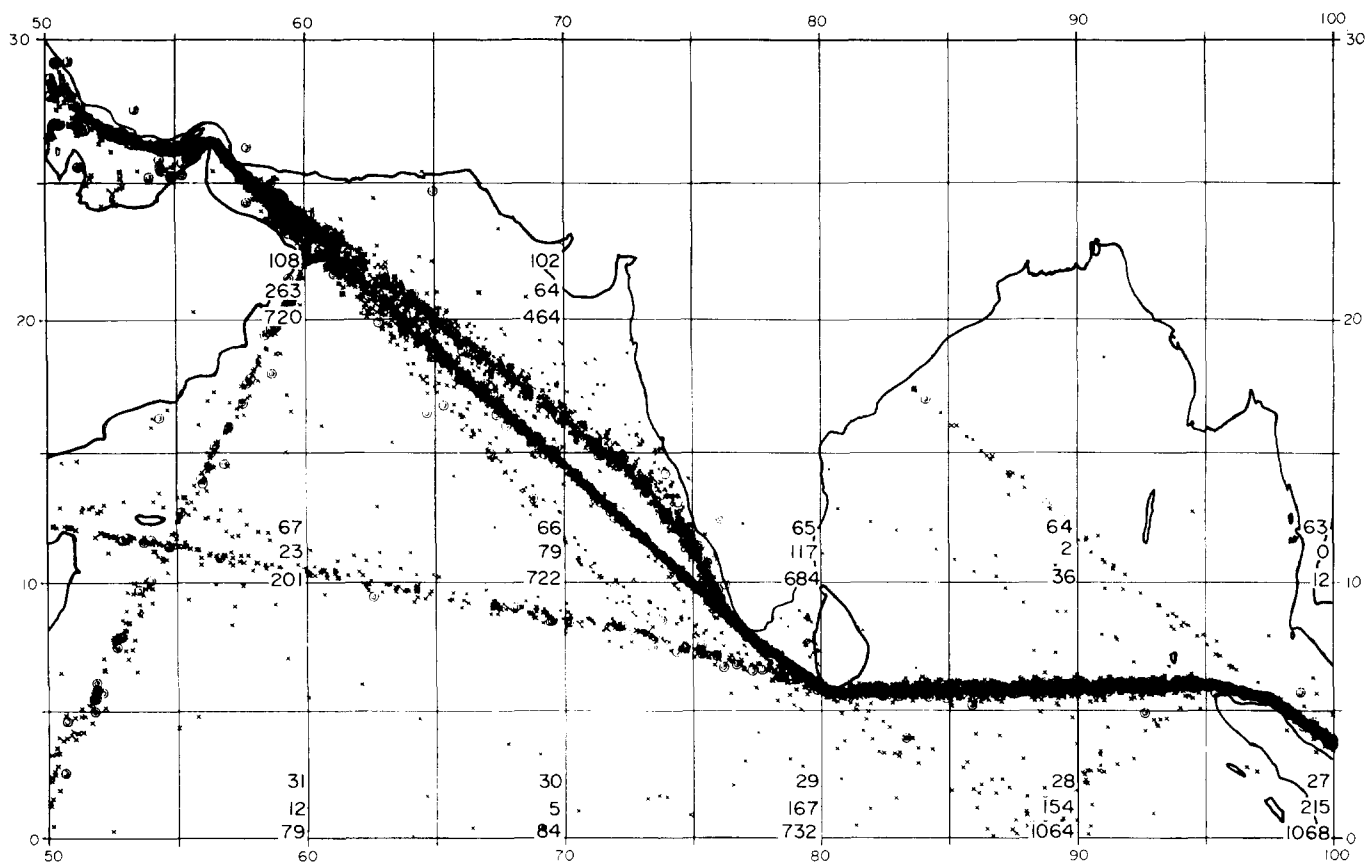


Fig. 1 Points of observation on oil slicks and other floating pollutants in the Indian Ocean (courtesy : Japan Oceanographic Data Centre).

WMO and sailing along the trade and tanker routes in the Indian Ocean, are analysed in this report. However, as with the information received from the Japan RNODC, data on tar balls and dissolved/dispersed hydrocarbons in this region are being collected only by R.V. *Gaveshani* of the National Institute of Oceanography.

A total of 121 observations on floating tar balls and 257 observations on dissolved/dispersed hydrocarbons have been examined in detail in this report.

Methodology

Methods for observations were more or less similar to those outlined in the Manual and Guides, No. 7 (UNESCO, 1976). For visual observations of oil slicks and other floating pollutants, no instruments were used. Some ships might have used polarizing glasses over the binoculars during the observations. It can be expected that a rough approximation of the area covered by the pollutants was also included in the log sheets. A neuston net (1 m × 0.5 m, 300 μm mesh size), having a stainless steel frame, was towed at the surface for 15 min. while the ship was steaming dead slow ahead on one engine. The samples thus collected were frozen on board. In the laboratory they were thawed and after drying in air were divided into several equal aliquots. These were examined under a microscope and the tar balls were separated, pooled and weighed. The concentrations in mg m⁻² were computed using the ship's speed and the mouth area of the net. Dissolved and dispersed petroleum

hydrocarbons were analysed by the method detailed by Sen Gupta *et al.* (1980).

Results

Oil slicks

Data for oil slicks and other floating pollutants were sorted out for every 5° square because of the large number of observations available. Within each square, they were further sorted out into positive, where oil slicks were sighted, and negative, where no oil slick was sighted, observations. These are presented in Fig. 2. Comparing Fig. 1 with Fig. 2, it can be seen that the maximum number of data are from the oil tanker route which goes to the Far East and Japan. Data from the other oil tanker route, which goes to the western hemisphere, are comparatively less. Comparing Fig. 1 with the corresponding figure given by Kohnke (1980) it could be seen that many observations were taken along the oil tanker route to the western hemisphere. Probably these data were submitted only to US RNODC and were not available with Japan RNODC.

Positive observations or number of oil sightings in all the 5° squares ranged from 51% to 96%. The frequency along the trade route from the Eastern to the Western Hemisphere through the Red Sea was also of the same order. The number of oil sightings increases as one goes away from the source of oil, i.e. the gulf region. Tanker disasters along these routes have not been very significant so far. Therefore, it could be concluded that oil is released in this region mainly from the

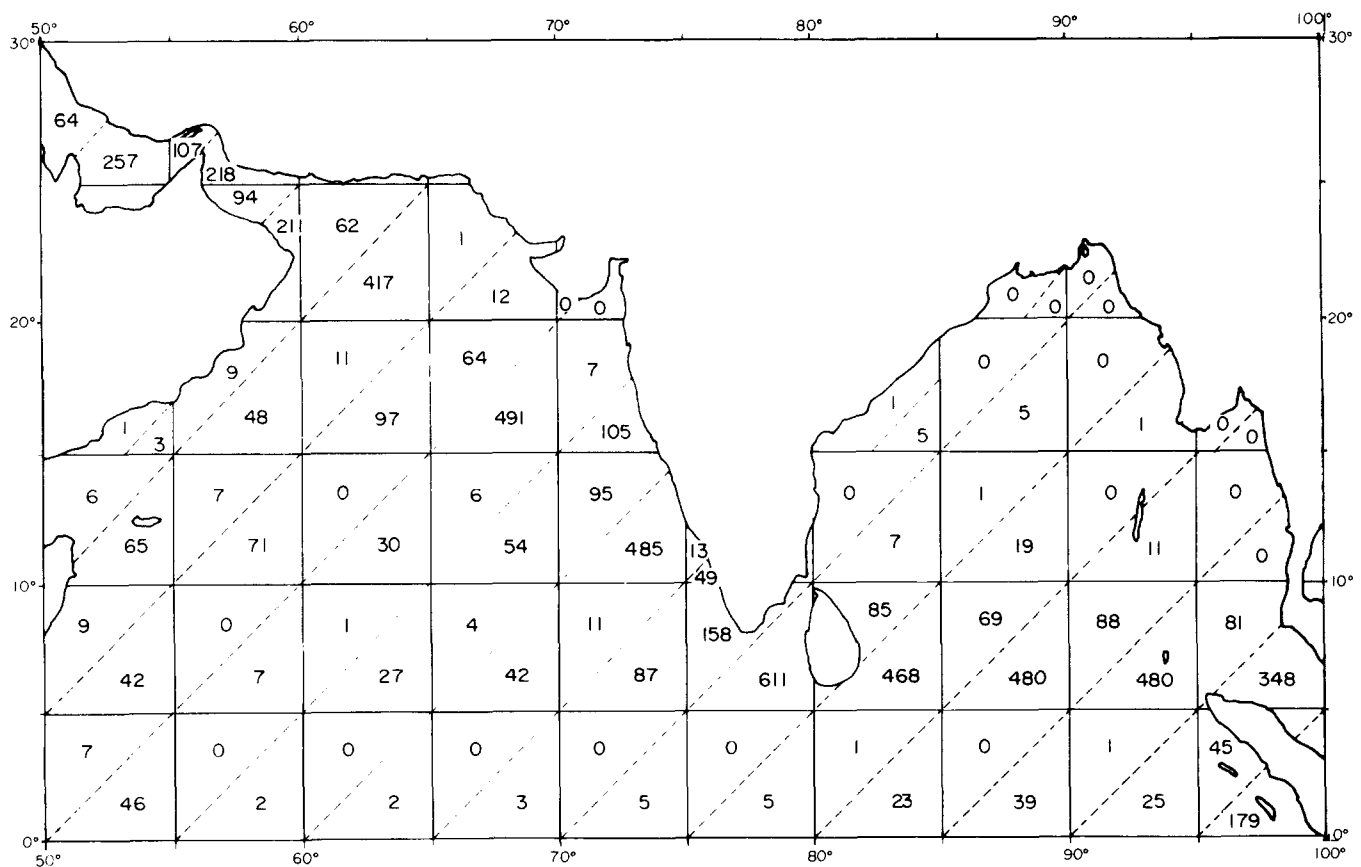


Fig. 2 Observations on oil slicks and other floating pollutants every 5°-square in the Indian Ocean. Numbers at the lower right hand corners of the squares indicate the total occasions when oil slicks were sighted. Numbers at the top left hand corners indicate the occasions of the absence of oil slicks.

ballast and tank washings from the ships proceeding to load oil. This can also be seen from observations away from the tanker routes where, although there are fewer observations, the positive frequency is of the same order. This would indicate that these oil slicks, sighted mostly by research ships, are the result of drift from the tanker and trade routes. Taking all the values together it has been calculated that oil was sighted on 5582 occasions, which is 83.5% of the total observations of 6689. This would indicate that the northern Indian Ocean appears to be a place of oil slicks. One may point out the possibility of the same oil slick being reported several times by different ships on the same route. It is, however, assumed that most oil slicks represent separate events since the repetition in reporting is counter-balanced by the events which have not been reported (Oostdam, 1980).

Combining these observations with those analysed by Kohnke (1980) it can be concluded that the areas of the United Arab Emirates, off the western and southern coasts of India, off the eastern and western coasts of Sri Lanka, the Malacca Strait, Gulf of Thailand and South China Sea, are places where the number of oil sightings was very high. Oostdam (1980) reported the increase in number and percentage of oil slicks towards the Strait of Hormuz. South of the equator, these frequencies are also very high along the East African Coast, the Mozambique Channel, off the east coast of South Africa and south-east coast of Australia.

Tar balls

Since there were fewer observations of this parameter, the data have been divided into 1° squares of their occurrences and are presented in Fig. 3. Calculations of mean values included zero values also. Wherever no zero value was present, a standard deviation has also been calculated.

To study the occurrences of tar balls in the Arabian Sea and the Bay of Bengal separately, the area has been divided as west and east of the 80° E meridian to indicate the two areas.

In the Arabian Sea coastal currents change in direction and intensity with the monsoons. Off the west coast of India, longshore current develops a strong shoreward component during the south-west monsoon (May–October) while during the rest of the year the surface current flows away from the shore. There might also be oceanic fronts, which are areas of convergence where large quantities of floating material may accumulate at the surface. This could be evident from the concentrations of floating tar balls, which were very high during the SW monsoon while during the rest of the year they were either very low or absent. The current pattern is almost similar off the coast of East Africa, where the retreating monsoons (northeast monsoon – November–March) are stronger than the summer monsoon, except the Somali current area, which becomes very similar to western boundary currents during the southwest monsoon. The shoreward component of the longshore current

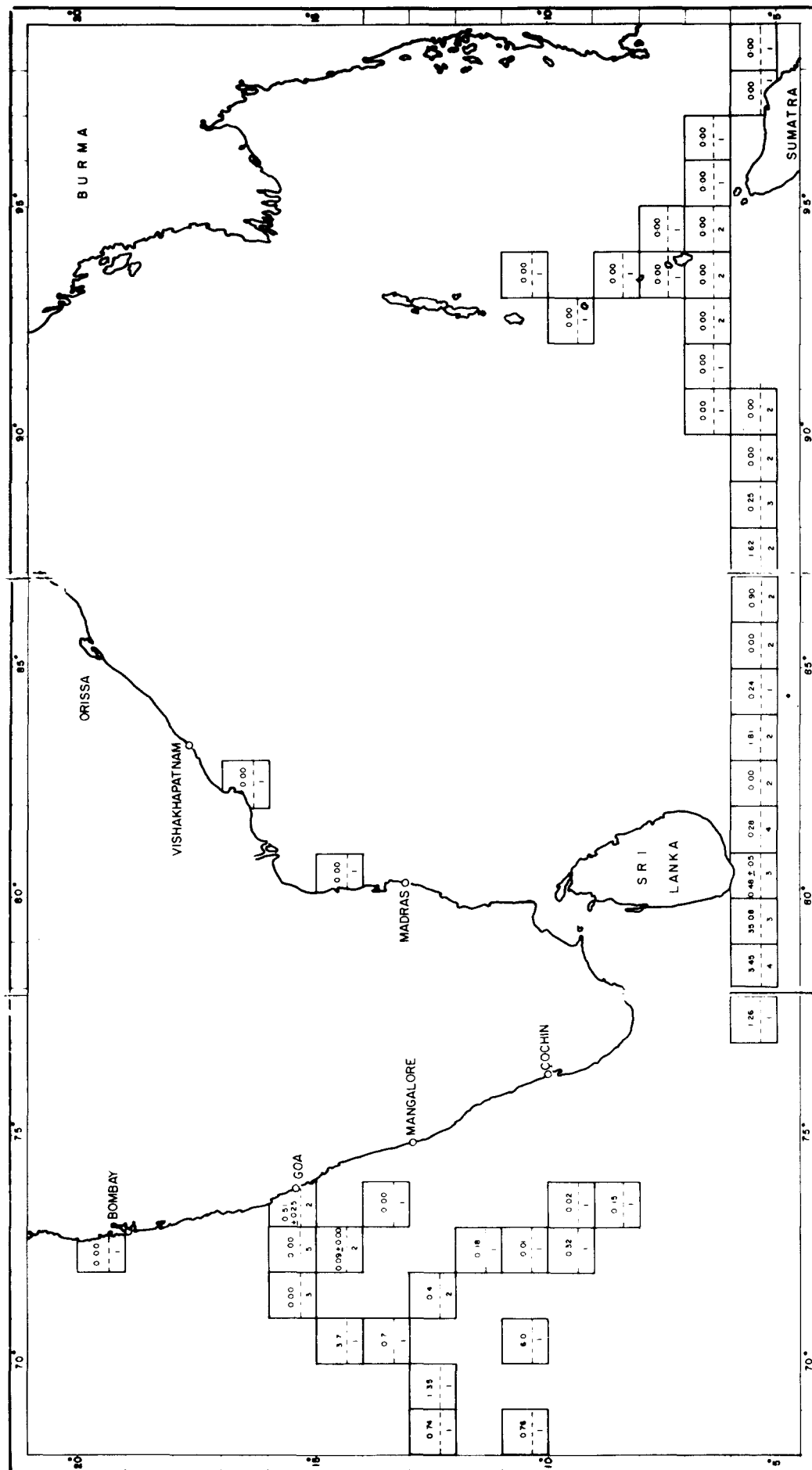


Fig. 3 Observations on particulate petroleum residues (tar balls) every 1°-square in the Indian Ocean. Numbers at the top half of the squares are the mean values in mg m^{-2} while those at the bottom half are the total number of observations.

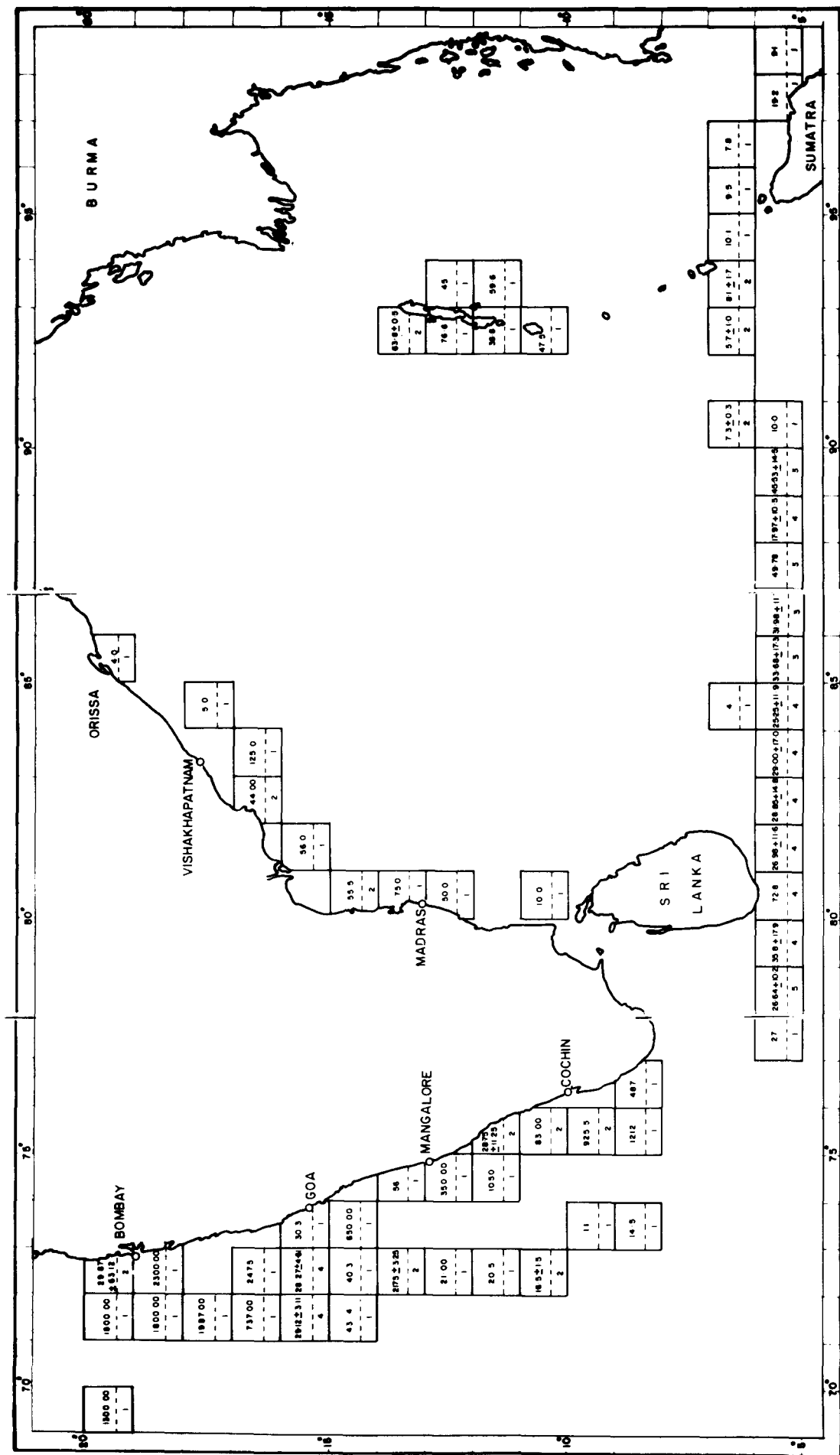


Fig. 4 Observations on dissolved/dispersed petroleum residues every 1°-square in the Indian Ocean. Numbers at the top half of the squares indicate the mean values in µg/kg with standard deviations while those at the bottom half are the total number of observations.

can be expected to be the reverse of what it is along the Indian Coast, as the net transport off East Africa during the southwest monsoon is away from the coast. This may mean that the pattern of variation of floating tar balls, as has been observed up to 69° E, would be similar on the western Arabian Sea but with a reverse trend of their occurrence.

With these assumptions, we have made an attempt to compute the amount of floating tar which may be present in the surface of the Arabian Sea at any given time. As the observations were carried out during different seasons, but during several years, their mean value would indicate the yearly mean, at least at a first approximation. The concentrations ranged from 0 to 6.0 mg m⁻² with a mean of 0.59 mg m⁻². The area of the Arabian Sea, from 0° to 25° N and from 50° to 80° E, is 6.225 × 10⁶ km² (Qasim, 1977). Based on this area and the mean concentration, the total amount of floating tar balls on the surface of the Arabian Sea at any given time is about 3700 tonnes.

For the Bay of Bengal we have computed only for the area bound by 5°–7° N and 80°–95° E. Since there were not many observations outside this area and whenever observations were taken the values were always zero, it can be assumed that north of the oil tanker route, the Bay of Bengal is relatively free of floating tar balls.

With the same assumptions as applied for the Arabian Sea, we have made an attempt to compute the amount of floating tar that can be expected to be present along the oil tanker route at any given time. The area enclosed by the coordinates mentioned above is 0.73 × 10⁶ km². The concentrations ranged from 0 to 69.75 mg m⁻² with a mean of 1.52 mg m⁻². Combining the area with the concentration, we arrive at a figure of 1100 tonnes for the total quantity of floating tar balls.

Thus, it is apparent that the Arabian Sea surface would have more floating tar balls at any given time as compared to the area of the Bay of Bengal. This roughly agrees with the difference in the intensities of tanker traffic and the volumes of transport of oil and its products between the two areas.

Dissolved and dispersed hydrocarbons

It has been suggested (Levy, 1980) that it is preferable to use the term petroleum residues for the material being measured by the analytical procedure, as the method is not specific for oil or petroleum or petroleum hydrocarbons. A detailed study by gas chromatography – mass spectrometry indicated the presence of alkylated aromatics as well as the homologous series of normal paraffins in the sea water extract, which indicates a contribution by fossil fuels (Ehrhardt & Bouchertall, 1980). We shall interpret our data with the above restrictions.

A statistical analysis of 45 surface values from these observations, which was available at the US NODC up to May 1979, indicated a mean of 60.10 µg kg⁻¹ with a standard deviation of 92.66 (Levy, 1980). This was because of the inclusion of the data even from the east coast of India. For a meaningful evaluation of the state of oil pollution in the Indian Ocean, these values have to be left out as there is hardly any transport of oil in the Bay of Bengal north of 7° N and the concentrations may be considered as more or less natural background level.

Data for dissolved and dispersed hydrocarbons for the surface are also presented in 1° squares (Fig. 4). Wherever there was more than one value, the arithmetic mean and

the standard deviation are shown. During one cruise, abnormally high values were recorded and these have been left out of detailed analysis. Observations were carried out by sampling up to 20 m and on a few occasions even up to 30 m.

To study the spatial variations, the area has been divided into two zones, east and west of 80° E meridian, as being the Bay of Bengal and the Arabian Sea, respectively. Mean values along with number of observations and range, to a depth of 20 m, are presented in Table 1.

TABLE 1

Mean concentrations (µg kg⁻¹) of petroleum residues at various depths in the Arabian Sea and the Bay of Bengal.

Depth (m)	Arabian Sea			Bay of Bengal			
	N	Mean	Range	Depth (m)	N	Mean	Range
0	39	35.5	0–395	0	46	29.1	4–229
10	34	30.6	3–217	10	43	25.1	2–147
20	15	29.4	2–112	20	43	17.6	1–75
Mean of all values: 32.5				Mean of all values: 24.1			

The table indicates that there is a difference between the mean values and the ranges in both the areas. The difference in concentrations in the upper 20 m in the Arabian Sea is not very significant. 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 be derived from oil spills, atmospheric fallout and end products of photo-oxidation and bio-degradation. The difference in values in Table 1 may be the result of single or cumulative effect of all these factors.

We then attempted to compute the amount of petroleum residues that could be present in these two areas based on the mean of all values.

Calculations based on the area of the Arabian Sea, as mentioned above, gives a volume of 0.125 × 10⁶ km³ for the upper 20 m. This gives the total volume of petroleum residues as about 4 × 10⁶ tonnes. Similar calculations for the area of the Bay of Bengal gave a figure of 0.4 × 10⁶ tonnes for the petroleum residues.

As was the case with the floating tar balls, these data also indicate that the trade and tanker routes across the Arabian Sea are more contaminated as compared to similar routes over the southern Bay of Bengal. Perhaps this is because of the varying amount in the transport of oil between the two areas.

We wish to thank Dr S. Z. Qasim, Director, National Institute of Oceanography, for his keen interest in this study, Mr Aravind Ghosh for computer analysis and Mr C. V. G. Reddy for all his help. We are greatly indebted to Japan RNOCD for the data on oil slicks.

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The *Antonio Gramsci* oil spill

Impact on the littoral and benthic ecosystems

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On 27 February 1979 the tanker *Antonio Gramsci* grounded off Ventspils (USSR) in the Baltic Sea. Some 5000–6000 t of crude oil were spilled, and drifted towards the archipelago of Stockholm (Sweden) and Åland (Finland). About 500 t oil was mechanically recovered in the Åland area. The effects of the oil on the littoral communities were studied for two months after the spill, and for the benthic community the long-term changes were recorded for three years. The immediate effects were small in the uppermost littoral (the *Cladophora* belt), but in the lower littoral (the *Fucus* belt) severe effects were recorded. Meiofaunal densities decreased in crustacean and mollusc species, but remained stable for the total community. Macrofaunal long-term changes could not be linked to the oil spill. Thus the effects of the oil were rather small, although a large area was contaminated.

On 27 February 1979 the tanker *Antonio Gramsci* grounded off Ventspils (Latvia, USSR), and resulted in the largest oil spill so far in the Baltic Sea (Pfister, 1980). About 5000–6000 t of crude oil were spilled, and drifted northwards. The oil was first observed south of Finland in late March, whereafter it was taken by the winds towards the archipelago of

Stockholm (Sweden). In early May the oil reached the Åland islands (SW Finland) when the breeding season for the seabirds had just started (Fig. 1). Here some 500 t of crude oil were mechanically recovered from an area covering 1300 km². No dispersants were used, and the work was disturbed by rough weather and new oil slicks drifting ashore several times.

The biological effects of the spill were followed by intensive fieldwork in several areas starting in early May 1979. The main sampling programme for studying the effects on the littoral and benthic subsystems lasted until the end of June 1979. Sampling of benthic macrofauna was continued until August 1980. The fieldwork was administered from Husö Biological Station (Fig. 1), situated in the vicinity of both the contaminated and the reference area.

Previously the effects of the groundings of the tankers *Palva* (1969) and *Tsesis* (1977) have been studied in the northern Baltic Sea (Johansson *et al.*, 1980; Leppäkoski, 1973; Lindén *et al.*, 1979). Notini (1978) studied the effects of oil in the *Fucus* belt, and Leppäkoski & Lindström (1978) studied the long-term effects of chronic oil induction on soft bottom macrofauna.