

Probable Movement of a Hypothetical Oil Patch from the Bombay High Region

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Potential drift trajectories of accidental oil spills from the Bombay High region have been shown. Both theoretical and empirical results have been applied to mean wind and current data to produce a chart of probable oil patch movement in the sea. The chart shows that the threat to the coastline is mainly from May to September, when the oil patches are expected to reach the coast in about 15 days after their release. The chances of accidental oil spills are greater during this period. From October to March, the oil patches will drift offshore. In April, the oil will very slowly approach the coast far south of Bombay.

THE fate of the oil spilled over the sea surface, either by accident or due to negligence, is a complicated multiprocess phenomenon called 'weathering'. Weathering consists of spreading, evaporation, dispersion, emulsification, autooxidation and microbial degradation. While these processes are occurring, there will be a movement of the oil patch under the influence of wind and ocean currents. The complex nature of the oil and its interaction with water during its movement make it difficult to have a comprehensive study of the problem. As a result, scattered studies have been made of the various aspects and, in particular, those aspects that appear dominant under certain conditions¹. Besides a number of studies have been carried out after the actual oil spills such as in the 'Torrey Canyon' and 'Santa Barbara' disasters^{2,3}. Simulation studies by Teesun *et al.*⁴ show a good agreement with theoretical and empirical results.

Like any other place in the world where offshore oil is being exploited, in the Bombay High region also there are chances of oil spills due to the presence of tankers, drilling rigs, production platforms and submarine pipelines. Any major oil spill in the Bombay High region can affect the Indian shoreline and inshore water. Attempts to prevent this requires a forecast of the movement of accidental spills from the region. This paper presents the slick movement predictions for a hypothetical spill from the Bombay High, where offshore petroleum production has already started.

Materials and Methods

It is generally agreed^{2,4-8} that regardless of the physical properties of oil and water, the size of the oil spill and its spreading tendency, the movement of an oil spill on the sea surface is given by

$$\bar{V} = (0.035 U_w) \bar{k}_w + (0.56 U_c) \bar{k}_c \quad \dots(1)$$

where \bar{V} = oil spill drift velocity, U_w = wind speed

at 10 m above the sea surface, U_c = current speed near the surface, \bar{k}_w = unit vector in the direction of wind drift (inclined at an angle α to the wind direction due to the earth's rotation), and \bar{k}_c = unit vector in the direction of the current.

Although there is no general agreement on the direction of the oil drift induced by the wind, a good working value for α is $\alpha = 25^\circ$ to the right of the wind direction in the northern hemisphere^{4,7,9-13}.

Thus to predict the course of movement of an oil patch, knowledge of the following parameters is necessary: (i) time of occurrence, (ii) place of occurrence, (iii) predicted winds and (iv) currents.

The region where an oil spill is likely to occur has been taken as a circular patch of 5 nautical miles radius with its centre at $19^\circ 30'N$, $71^\circ 30'E$. The area bounded by lat. $14^\circ-22^\circ N$ and long. $68^\circ-76^\circ E$ has been divided into 2° grids. Wind and current data were collected from the K. Ned. Met. Inst. Pub. No. 135¹⁴ for various months of the year and for each 2° grid.

The oil drift vector, for each 2° grid, was computed monthwise using the eq. 1 and plotted in Fig. 1. Assuming that oil spills occur at the beginning of a month, the track of the oil patch movement for 30 days has been determined using the oil drift vectors for the month. The subsequent movement was obtained with the oil drift vectors for the next month. The process was continued till the trajectory crosses long. $68^\circ E$, lat. $14^\circ N$, or meets the coastline. These trajectories have been plotted in Fig. 2. The positions of the centre of the oil patches are marked on each track at intervals of 5 days.

Results and Discussion

The drift trajectories show the movement of the oil from the spills occurring in the Bombay High region at the beginning of each month. It can be seen from Fig. 2 that the tracks for the spills occurring later in any month lie between the tracks plotted for that month and the next.

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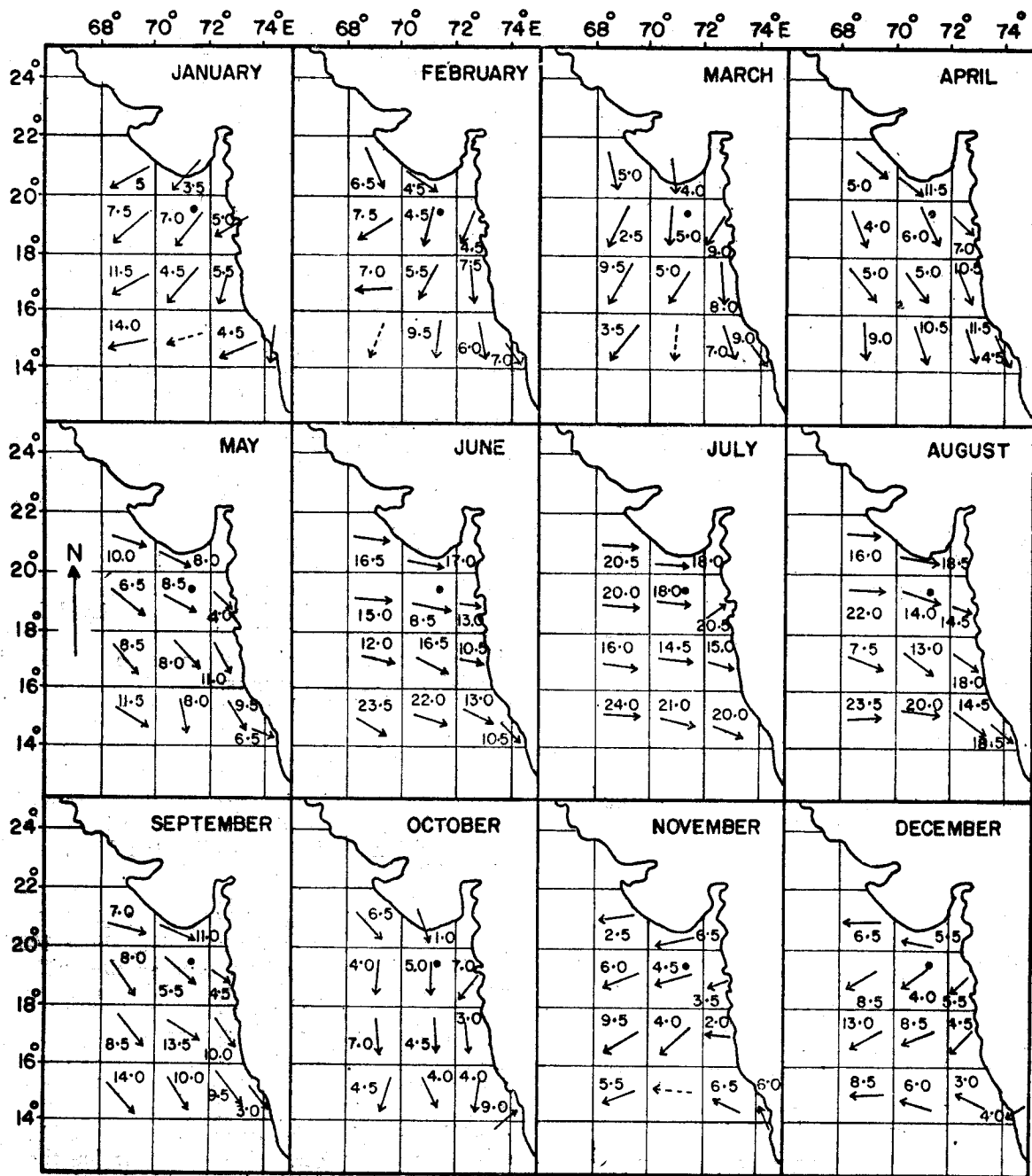


Fig. 1 — Slick drift directions during January-December [Speeds of slick drift in nautical miles/day are indicated along the arrows. Interpolated directions are shown by broken arrows]

October-January — Any spill occurring in these months will pose no threat to the Indian coastline, as the oil movement will be directly away from the coast except in October when the movement would initially be parallel to the coast before turning to the west.

February-March — Movement of the oil from the spill in these months would initially be SSW, but after about 50 days, movement will be parallel to the coast at distances ranging from 250 to 100 nautical miles from the coast. These slicks will be much weathered before they are, if at all, washed ashore on the beaches far south.

April-September — From mid-March to early July, the threat to the coastline from the oil spill moves northwards and simultaneously the time interval between the spill and the oil being washed ashore decreases. The reverse trend is seen from mid-July to early September. Spills occurring in late September drift out to the sea after initially moving parallel to the coast. The coastline threatened from April to September and the time interval between the spill and the oil being washed ashore are given in Table 1.

Tar ball deposits on the west coast of India confirm that from May to September the coastline

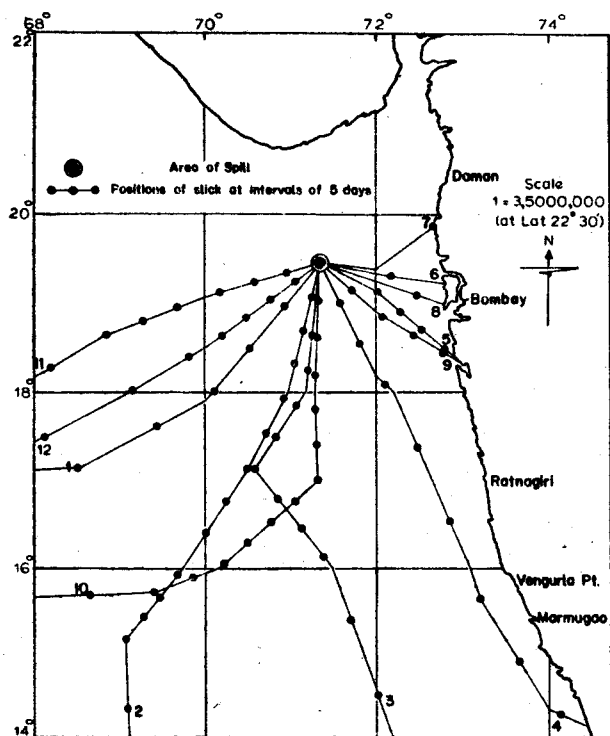


Fig. 2 — Trajectories of oil spills occurring in different months of the year [1-12 represent the calendar months, January to December]

TABLE 1 — TIME INTERVAL FOR THE SPILLED OIL TO REACH AND AFFECT THE COASTLINE

Time of spill	Coastline threatened as a result of spill	Time interval between spill and oil reaching shore (in days)
Early March	No threat	—
Mid March	Far south of Bombay	105
Early April	Around Karwar	45
Mid April	Around Ratnagiri	35
Early May	70-80 km south of Bombay	22
Early June	Around Bombay	10
Early July	70-80 km north of Bombay	4½
Early Aug.	Around Bombay	7
Early Sept.	70-90 km south of Bombay	22
Mid Sept.	No threat	—

would be seriously affected by the spills off the coast¹⁵. Due to high wave activity and sea turbulence during the period, a sizeable volume of spilled oil is likely to be dispersed into the sea¹⁶. Any evaporation loss (20-25% of the initial volume) that is likely to take place will occur in the first 7 hr after the spill¹⁷. In the dispersed state, the oil is more subjected to bacterial degradation and is also available in larger quantities to marine organisms^{18,19}. Hence its toxic effects are likely to be greatly enhanced²⁰. The process of degradation is slow compared to the time interval of 15 days or so^{18,21} required for the oil to reach the coast. Hence the oil reaching the coast after evaporation and dispersive losses will undergo very little degradation and will form a tarry residue on the rocks, settling birds and

beaches. The resultant ecological damage in this case would be quite severe.

In predicting the movement of the oil patches, statistical fluctuations in the wind and current speeds and directions have not been taken into account. An assumption is, therefore, made that the slick remains in a grid long enough to feel the resultant wind and current conditions for the month. Currents move the surface water and so any oil on the sea surface will also be moved. In the case of tidal currents, movements are cyclic with only a small residual movement in any one direction. The residual movement is assumed to be small in the region of the study and hence only the general surface currents have been taken into account. A part of the mass transport effected by the waves is accounted for in the value $0.035 U_w$ given in the eq. 1 (ref. 1).

An accurate prediction of the movement of spilled oil is not very easy to make. While the tidal currents are given on Admiralty Charts, the residual currents are not usually available. Also the wind velocities are measured only at few places, which may be miles away from the oil slick. Local wind conditions may differ from the measured ones and also from those which have been predicted for the next forecast period. The data on currents do not give a true average picture because of the paucity of observations on currents.

Although winds have random characteristics, their effect on the movement of the spilled oil has been treated here on a predetermined basis. It is hoped that we shall be able to improve on the predictions by taking into account the random winds, random shift of the winds at random intervals and the transitional drift of the oil patch due to sudden wind shifts.

Any large oil spill in the period May to September can probably cause significant biological and mechanical damage to the coastline, about 100 km on either side of Bombay, because the spilled oil would hit the coast in less than 15 days much before the process of weathering has rendered it harmless. Moreover, during the period May to September, the harsh oceanographical and meteorological conditions in the Bombay High region will increase the chances of accidental oil spills.

While planning the programmes to combat oil spills, care should be taken to determine the best possible methods. Physical methods of containment are satisfactory for small oil spills. Chemical dispersants can remove oil from the surface by dispersing it in the water. However, indiscriminate use of the chemical dispersants can cause more harm than the oil itself, as many of the dispersants are found to be toxic^{2,20}. Even when non-toxic dispersants are used, the dispersed oil becomes available to marine organisms in larger quantities and hence the inherent toxicity of the spilled oil is greatly enhanced. Burning large quantities of oil at the surface in nearshore areas can be hazardous and may also produce air pollution locally.

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