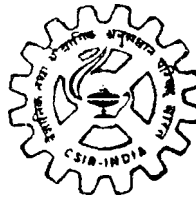


NATIONAL INSTITUTE OF OCEANOGRAPHY

(Council of Scientific and Industrial Research)

DONA PAULA, GOA-403 004, INDIA



BOMBAY HIGH OIL SPILL AND ITS ENVIRONMENTAL IMPACT

21 MAY—23 MAY, 1993

O. R. V. SAGAR KANYA

DIRECTOR : Dr. B. N, DESAI
PROJECT CO-ORDINATOR : Dr. L. U. JOSHI
PROJECT LEADER : Dr. S. P. FONDEKAR

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PARTICIPANTS

Dr. S.P. Fondekar - Chief Scientist

Dr. X.N. Verlencar

Dr. S.G.P. Matondkar

Dr. P.V. Shirodkar

Technical Assistance

Dr. K. Sawkar

Mr. N. Mahamal

Secretarial Assistance

Mr. Rajaram Patil

Mr. Fotu Gauns

EXECUTIVE SUMMARY

- a) On 17 May 1993, a major oil-slick about 10 miles long and 2 miles wide, was formed about 165 km north off Bombay after the Bombay-High-Uran pipeline ruptured and estimated 3000-6000 tonnes of oil was spilled into the sea. Steps were immediately taken to contain the oil slick with the help of rubberised booms as well as treating it with chemical dispersants.
- b) Alerted by the news, Joint Secretary, Department of Ocean Development (DOD), requested the Director, National Institute of Oceanography (NIO) to send a team of scientists to the area of the oil spill (Bombay High region) to estimate the magnitude of the oil spill as well as assess the environmental impact in the spill area.
- c) Director, NIO, advised *ORV Sagar Kanya*, the research vessel, to take onboard 4 scientists and proceed immediately to the spill area. The ship sailed from Bombay on 20 May evening and reached the site on 21 May morning.
- d) After reaching the spill area, contact was established with the Coast Guard vessel *Vajra* to get the latest

position of the oil slick. Three transects, parallel to one another and 12 stations, 4 on each transect were worked out. The total area surveyed was 1564 square nautical miles.

- e) Observations were made on oil slicks, floating tar balls, dissolved/dispersed petroleum hydrocarbons (DPH), chlorophyll, zooplankton and bacteria. Water sampling was restricted to a depth of 25m.

- f) Observations in the spill area showed that the oil-slick had broken into small patches by winds, currents and waves and because of the treatment of chemical dispersants, a chocolate - mousse like appeared floating on the sea. The probable direction of the drifting of oil slick was south-easterly towards south of Bombay coast. Aerial survey observations showed some signs of oil patches drifting towards the coastal areas of Murud Zanzira, south of Bombay. Concentrations on tar balls ($0-95.82 \text{ mg/m}^2$) and DPH ($0.19 - 3.65 \text{ mg/l}$) were found quite on the higher side as compared to normal values.

- g) The floating oil patches will ultimately end up as floating tar particles which, finally will either sink to the bottom or be washed ashore on beaches.

1. BACKGROUND

On 17 May, 1993, a major oil slick about 10 miles long and 2 miles wide was formed about 165 km north off Bombay (latitude 19°32'N and Longitude 71°18'E) after the Bombay - High-Uran pipeline ruptured. The accident occurred around 0800 hr, thus spilling roughly 3000-6000 tonnes of oil into the sea. Oil continued to leak out of the pipeline at the rate of around three barrels per minute. Steps were immediately taken to depressurise the line by closing all the wells and stopping operation of the pipeline.

The Coast Guard was alerted about the oil spill at, about 0930 hr on the same day and by 1350 hr, it had commenced spraying of chemical dispersants on the slick. The spread of oil was limited with the help of the rubberised booms and the oil was being recovered with the help of the skimmers in operation. Coast Guard vessels *Vajra*, *Vijay*, *Vivek* and *Ahilyabai* were involved in the containment operation along with two ONGC vessels *Samudra Surakaha* and *Nand Shamik*.

Under the action of the chemical dispersants sprayed on the oil-slick, the slick had been broken up into seven or eight patches scattered along the periphery of the 20 square nautical miles. The largest of these, was a patch of around 400 meters long and 100 meters wide and was located 75 nautical miles away from the coast on 18 May, 1993.

On 18 May, the Joint Secretary, Department of Ocean Development (DOD) telephonically contacted the Director, National Institute of Oceanography (NIO) requesting him to send out a team of scientists on board *ORV Sagar Kanya*, one of their research vessel, at the earliest. The main aim was to proceed to the area of the oil spill (Bombay High region), estimate the magnitude of the oil spill and assess the environmental impact in the Bombay High region. Four scientists from Goa were nominated to the task who proceeded to Bombay and boarded *ORV Sagar Kanya*. The ship sailed out on its mission on 20th evening. After completing the survey in Bombay High region and covering about 350 line nautical miles, the ship came back to Bombay on 23 May.

2. OIL ON THE SEA

Weathering Process:

Immediately after a spill, the lighter fractions of oil evaporate. In the warm waters of the equatorial and tropical oceans, it has been observed that this evaporation will remove as much as 40% of the spill during the first 24 hours. Oil will also be oxidised by dissolved oxygen at the rate of 1 mg of oil per 3 mg of oxygen consumption. Microbial degradation will account for 2g of oil per square meter per day. Around 1% of the spilled oil will be dissolved or

dispersed in water. In addition, photo-oxidation by solar radiation will also degrade a part of the oil. Thus, it can be expected that around 45-50% of any oil spill will be removed during the first 24 hours in the warm zone of the ocean. The heavier fractions of the spill will form drifting patches being split up by the prevailing winds and currents. These patches will ultimately end up as floating tar particles which finally, will either sink to the bottom or be washed ashore on beaches.

Chemical Dispersion:

clearly oil does not remain permanently on the sea surface. It may disperse into the water column either completely or partially under the action of natural forces and/or it may come shore. Dispersants are simply a means of increasing the natural dispersion rate so that sufficient dispersion will have occurred to remove the oil from the sea surface before it reaches the shore.

Dispersants are mixtures which include surface active agents to reduce the interfacial tension between oil and sea water. This makes it possible for an oil-slick to break into very fine droplets (less than 100 microns in diameter) which are rapidly distributed throughout the water volume because of the natural water movement. With normal mixing energies, the oil concentration in the water column rapidly decreases

to background levels. The droplets may rise slowly to the surface water but special components in the dispersants (stabilizer) inhibit reagglomeration or coalescence. The dispersion action is enhanced by mixing energy derived from wave action, propeller wash, etc.

All dispersants are likely to be toxic to marine life and as such direct application of the dispersants may prove fatal to most marine organisms. Hence, the dispersants to be used, must be carefully chosen with particular reference to their toxicity and applied with caution.

3. SLICK MOVEMENT PREDICTIONS FOR A HYPOTHETICAL SPILL IN BOMBAY HIGH REGION

Movements of oil slicks and oil spills are regulated by movements of water at the surface. If the speed and direction of surface currents over a long period of time at any place is known, then a meaningful forecast of such movements can be made. Using this concept, National Institute of Oceanography, Goa, carried out the studies for a hypothetical oil spill movement from the Bombay High region.

Fig. 1 shows the trajectories of oil spills occurring in different months of the year whereas the interval for the spilled oil to reach and affect the coastline is given in Table 1. The drift trajectories show the movement of the oil

from the spills occurring in Bombay High region at the beginning of each month. It can also be seen from Fig.1 that the tracks for the spills occurring later in any month lie between the tracks plotted for that month and the next.

In general, the findings conclude that from May to September i.e. the period of south-west monsoon, the west coast of India remains vulnerably exposed to oil slicks and oil spills whereas during the remaining part of the year, the spilled oil moves away from the coast.

4. WORK PLAN

Three transects, parallel to one another and 12 stations, 4 on each transect were worked out (Fig. 2). The distances between the transects and the stations were put roughly as 15 nautical miles (NM). Transect I was along the directions of the drifting of oil-slick whereas transects II and TIT were on the either side and parallel to transect I. The total survey area covered was around 1563 NM².

The northern and southern limits were at 19°38' and 18°49'N latitudes and the eastern and western limits were at 72°16' and 71°19'E longitudes. The station 8 (19°24'N - 71°32'E) was about 16 NM from the spill area (19°32'N - 71°18'E) whereas the nearest station 12 (19°10'N 72° 16'E) from the Bombay coast was around 32 NM) .

5. METHODOLOGY

At every station, two Neuston nets (300 M) having a mouth area of 30 x 15 cm each rigged in a catamaran arrangement, were towed at the surface, for 15 minutes with the ship steaming at 2 knots. The strata sampled were 0 - 15 cm and 20 - 30 cm. This would collect floating tar balls and other debris.

Water samples were collected to a maximum depth of 25m for DPH using Niskin water samplers at 0, 10 and 25m depth. All the water samples were analysed for their dissolved/dispersed petrol sum hydrocarbon (DPH) contents, by spectrofluorometry after hexane extraction. Samples were also analysed for chlorophyll, phaeophytin and primary productivity upto a depth of 40m.

Plankton samples, freed from tar and other floating matter, were examined for their biomass and preserved for detailed examination.

6. OBSERVATIONS (21-23 May : 4-6 days after the spill)

Oil sightings:

Observations on oil sightings, showed no signs of oil patches either treated or untreated in the spill area at

latitude 19°32'N and longitude 71°18'E: where the incident occurred. Since this incident occurred in the month of May which is the period of south-west monsoon, the spill might have already drifted as a whole or in patches in south-easterly direction towards the Bombay coast as predicted in our earlier findings. Several small isolated patches of treated oil (oil + dispersant) were sighted in the south easterly direction along the track I and between the stations 1 and 3. The size of the treated oil patches varied roughly between 1 x 0.5 m to 10 x 2 m. Only one patch of untreated oil (about 100 x 2 m) was observed at station 3 along the name track. No oil patches either treated or untreated were sighted at other stations along the transects II and III throughout the survey. Aerial observations carried out later on 25 May showed some signs of oil patches drifting towards the coastal areas of Murud Zanzira, south of Bombay.

Tar balls:

Tar could be collected at 7 of the 12 stations. In general, tar concentrations ranged between 0 - 95.82 mg/m², with a mean value of 8.52 mg/m² (Table 2). Maximum concentrations of tar were observed along the transect I at stations 1,2 and 8 (1.38 - 95.82 mg/m²). This was the transect, where maximum oil patches were also observed drifting in south-easterly direction. The observed concentrations were quite on the higher side as compared to

those in the Arabian Sea (0-6 mg/m²).

After the first 24 hours, owing to sea state and high temperature, water-in-oil mousse may be formed due to the prevailing wind which will adsorb on to the surface of any suspended particle to form tar balls. These tar balls either sink to the seabed or get suspended by the buoyancy of its size in an intermediate water mass and flow out. The remaining tar balls will, ultimately, be washed ashore on the nearby beaches. Since this is a period (May - September) of SW monsoon when the alongshore surface current develops an easterly shoreward component, there is every possibility that these tar balls will be deposited on the beaches along the west coast of India between Bombay and Goa.

Dissolved/dispered petroleum hydrocarbons (DPH):

DPH concentrations ranged between 0.19 and 3.65 mg/l, with a mean value of 0.89 mg/l (Table 2). The highest concentration (3.65 mg/l) was obtained at the surface (#1) whereas the lowest concentration (0.19 mg/l) was at 25m depth (# 12). The maximum concentrations were obtained at the stations along the track I (0.53 - 3.65 mg/l) as compared to those obtained along the tracks II (0.37 - 3.23 mg/l) and III (0.19 - 0.70 mg/l). The higher concentrations along the track I showed the similarity with that of oil patches and tar balls which were also maximum along the same track. In general, the DPH concentration showed a gradient with depth.

The observed DPH concentrations between 0.19 and 3.65 mg/l (ppm) were higher by 3 orders of magnitude or around 1000 times as compared to those background levels in Bombay High region (1 - 30.8 ppb) and in the Arabian Sea (3 - 22 ppb) as shown in Table III.

*Chlorophyll a (Chl a) Phaeophytin (Phaeo)
and Primary productivity (PP) :*

Table 4 shows that in the region of oil patch, the mean value of extinction coefficient (i.e. a light penetrating index) was 0.14. Chlorophyll a (chl a) and phaeophytin (phaeo) values in surface waters ranged from 0.24 to 1.78 mg m⁻³ and from 1.37 to 8.32 mg m⁻³, respectively. The mean primary productivity (pp) in the surface waters was 9.3 mgC m⁻³ day⁻¹. In the vertical water column, mean values of chl a, phaeo and pp were 14.2 mg m⁻², 77.9 mg m⁻² and 0.19 gC m⁻² day⁻¹, respectively. Mean zooplankton biomass was 49.3 ml/100 m³. As seen from table 5, the total zooplankton counts ranged from 2438 to 8038 nos/100m³.

In the oil free region, the mean extinction coefficient value was 0.36. This high value was due to water turbidity as a result of agitated bottom sediments. Chl a, phaeo and pp in surface waters ranged from 0.27 to 3.18 mg m⁻³, 1.39 to 12.4 mg m⁻³ and 0.74 to 4.36 mg C m⁻³ day⁻¹, respectively. In the water column, the mean values of chl a, phaeo and pp

were 30.9 mg m^{-2} , 15.26 mg m^{-2} and $0.25 \text{ g C m}^{-2} \text{ day}^{-1}$. The mean zooplankton biomass was $23.2 \text{ ml}/100 \text{ m}^3$. The total zooplankton counts as shown in Table 5 ranged from 1123 to 20000 nos/100 m^3 . Visual observations showed that some portion of oil slick. was associated with Trichodesmium bloom. Organisms such as medusae, were found floating and entangled in the oil slick and small crabs crawled on the oil mass.

As compared to chlorophyll, the concentrations of phaeophytin were high in the area surveyed. Also the rate of photosynthetic production showed low values of $7.7 \text{ mg C}(\text{mg Chl a})^{-1} \text{ day}^{-1}$ along the oil patch region as compared to that of $54.1 \text{ mg C}(\text{mg chl a})^{-1} \text{ day}^{-1}$ in the region free of oil patch. This indicated adverse effects of oil on basic photosynthetic processes. Copepods which generally dominate the zooplankton organisms showed very low counts (at # 4 and #5) of less than 32% and 18% respectively (Table 5). Also hydromadusae group dominated at # 5. These results indicate poor quality of water and consequent adverse effects on the basic . biological processes and life in the area affected by oil spill.

7. CONCLUSIONS

- i) The estimated volume of spilled oil is about 3000 - 6000 tonnes, around 40% of which should have been evaporated

within first 24 hours. This could mean that the remnants should be of the order of 1800 - 3600 tonnes of continuously decaying oil in the Bombay High region.

ii) The volume of the oil was further reduced by treating with chemical dispersants, as a result of which, the oil is partially dispersed into the water column.

iii) The winds, currents and swells broke the remaining part of the spill into several patches. Since, this is a period of SW monsoon, these patches were drifted in south-easterly direction towards the south of Bombay coast. These patches will ultimately end up as floating tar balls which finally, either sink to the bottom or be washed ashore on the beaches.

TABLE - I : 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	30
Early July	70-80 km north of Bombay	4.5
Early August	Around Bombay	7
Early Sept	70-90 km south of Bombay	22
Mid Sept	No threat	

TABLE II: Data on oil-sightings, tar balls and DPH in oil-spill area

Station Nos.	Date	Lat °N	Long °E	Oil sightings	Tar balls DPH mg/l (ppm)			
					mg/m ²	0m	10m	25m
1	21.05.93	19°16.3'	71°47.9'	Treated oil patch	95.82	3.65	2.86	0.74
2	-do-	19°06.4'	71°55.2'	-do-	4.36	1.35	1.07	0.81
3	-do-	19°01.3'	72°09.5'	untreated oil patch	A	1.62	0.91	0.82
4	-do-	18°49.4'	72°01.1'	A	0.21	3.23	0.61	0.58
5	22.05.93	18°57.3'	71°46.0'	A	A	0.56	0.44	0.37
6	-do-	19°04.9'	71°34.3'	A	A	0.63	0.63	0.64
7	-do-	19°13.4'	71°19.6'	A	A	0.50	0.60	0.52
8	-do-	19°24.5'	71°32.2'	A	1.38	3.03	0.61	0.53
9	-do-	19°38.3'	71°45.3'	A	A	0.49	0.52	0.34
10	-do-	19°27.4'	71°56.9'	A	0.48	0.38	0.43	0.39
11	23.05.93	19°17.8'	72°09.1'	A	0.05	0.54	0.37	0.22
12	-do-	19°10.3'	72°16.8'	A	PT	0.70	0.51	0.19

DPH - Dissolved/dispersed petroleum hydrocarbons

A - Absence

PT - Presence indicated.

TABLE III - Comparison of the data on floating tar balls and DPH concentrations.

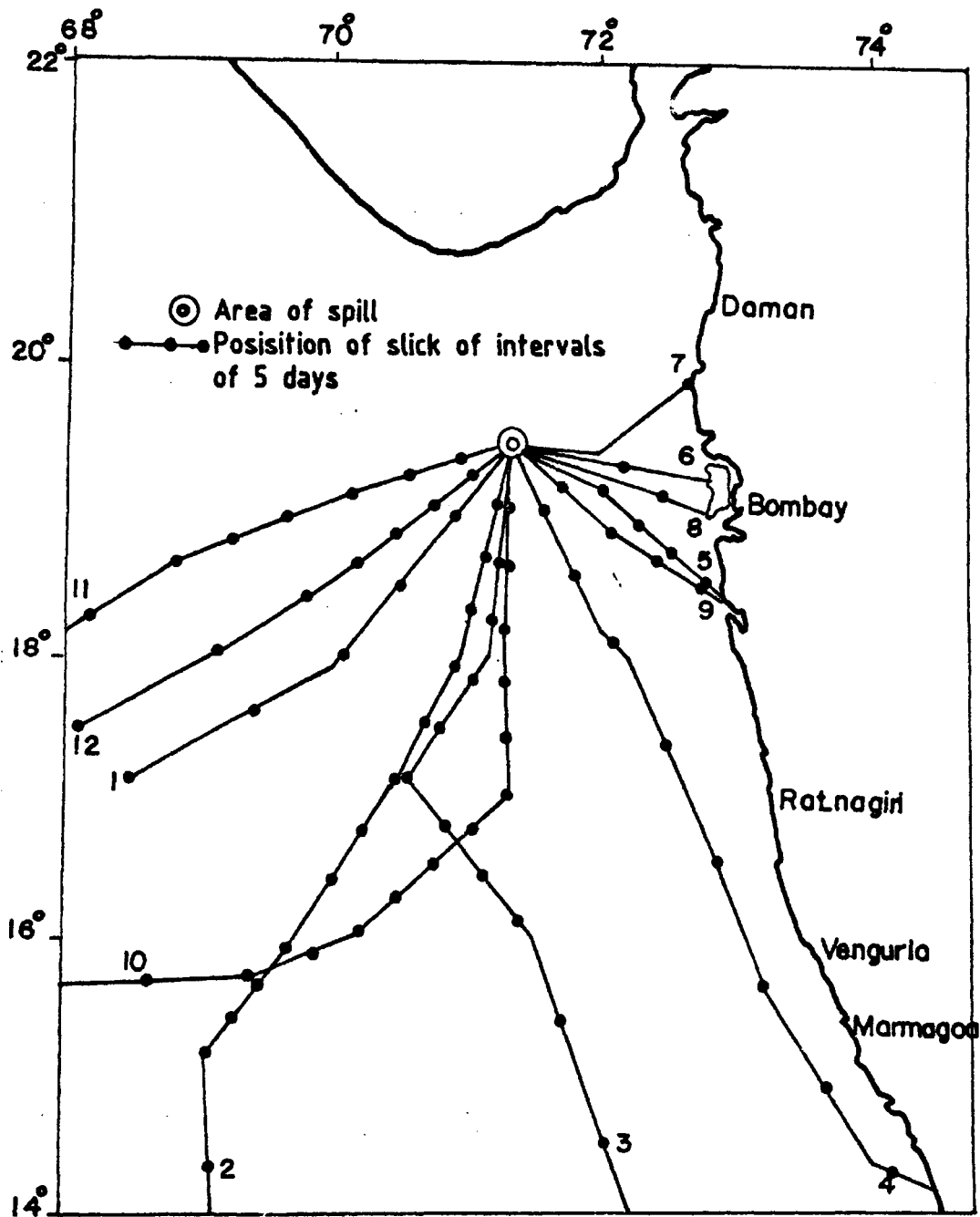
Variables	Spill area	Normal values		Remarks
	Bombay High region	Bombay High region	Arabian Sea	
Floating tar balls	0 - 95.82 mg/m ²		0 - 6 mg/m ²	Increase
DPH (0 - 25 m)	0.19 - 3.65 mg/l (ppm)	1 - 30.8 Mg/l (ppb)	3 - 22 Mg/l (ppb)	Increase

TABLE IV: Data on chlorophyll a, phaeophytin and primary productivity in the oil spill area.

Variables	Oil patch region				Oil free region			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Extinction coeff.	0.12	0.15	0.14	0.01	0.09	0.85	0.36	0.33
<u>Surface waters</u>								
Chlorophyll a								
mg m ⁻³	0.24	1.78	0.64	0.07	0.27	3.18	1.21	1.10
Phaeophytin								
mg m ⁻³	1.37	8.32	3.2	3	1.39	12.4	5.44	4.20
Primary productivity								
mg Cm ⁻³ day ⁻¹)			9.3		0.79	4.36	2.58	
Zooplankton biomass								
ml/100 m ³	13.1	100	49.4	32	4.8	65.5	23.2	20.4
<u>Vertical water column</u>								
Chlorophyll a								
mg m ⁻²	3.9	37.4	14.2	13.6	10.4	85.0	30.9	24
Phaeophytin								
mgm ²	2.1	190	77.9	66	53.7	407	152.6	112
Primary productivity								
gC m ⁻² day ⁻¹			0.19		0.2	0.29	0.25	

TABLE V - Zooplankton taxa in the spill area

Groups <Nos/100m3)	S t a t i o n s											
	1	2	3	4	5	6	7	8	9	10	11	12
HYDROKEDUSAE	38.0	100.0	46.4	38.0	8609.5		57	38	38	1276	57	
SIPHOSOPHORA	152.2	416.6	61.9	704.7	419.0	266.6	57	1809	57	666	95	19
SALPS AND DOLIOLIDS	323.8	232.1	66.6	95.2		38.0						
CLADOCERA		23.8										76
LDCIFEP SP.			94.0	228.5								
OSTRACODS		19.0		914.2								
AMPHIPODA		60.7		1180.9	38.0					95		
COPEPODA	1333.3	4095.2	2563.0	2571.4	2095.2	2000.0	800.0	6095	12190	34666	18666	13142
ISOPODA		23.8										
DECAPODA		83.3	28.5	1752.3	114.2	57.1	133	38	38	1923	57	38
CHAETOGNATHA	95.2	65.4	39.2	419.0	38.0	38.0		19	95	3428	895	114
APPENDICULARIA	152.3	11.9				76.1		57	57			
PTEROPODA					38.0		38	57				
GASTROPODA		15.4	53.5		38.0	95.2					190	
LAMELLEBRANCH LARVA				76.1	57.1							
ECHINODERM LARVA					228.5	114.2						
FISH EGGS	304.7	32.1	178.5		57.1	266.6		95				
FISH LARVA		9.5	8.3	57.1	19.0	57.1					38	19
OTHERS	38.0	13.0	23.8			19.0	38	38				19
TOTAL	2438.0	5202.3	3164.2	8038.0	11752.3	3028	1123	8247	12476	42059	20000	13428



TRAJECTORIES OF OIL SPILLS OCCURRING IN DIFFERENT MONTHS OF THE YEAR (1-12 REPRESENT THE CALENDER MONTHS, JANUARY TO DECEMBER)

FIG. 1

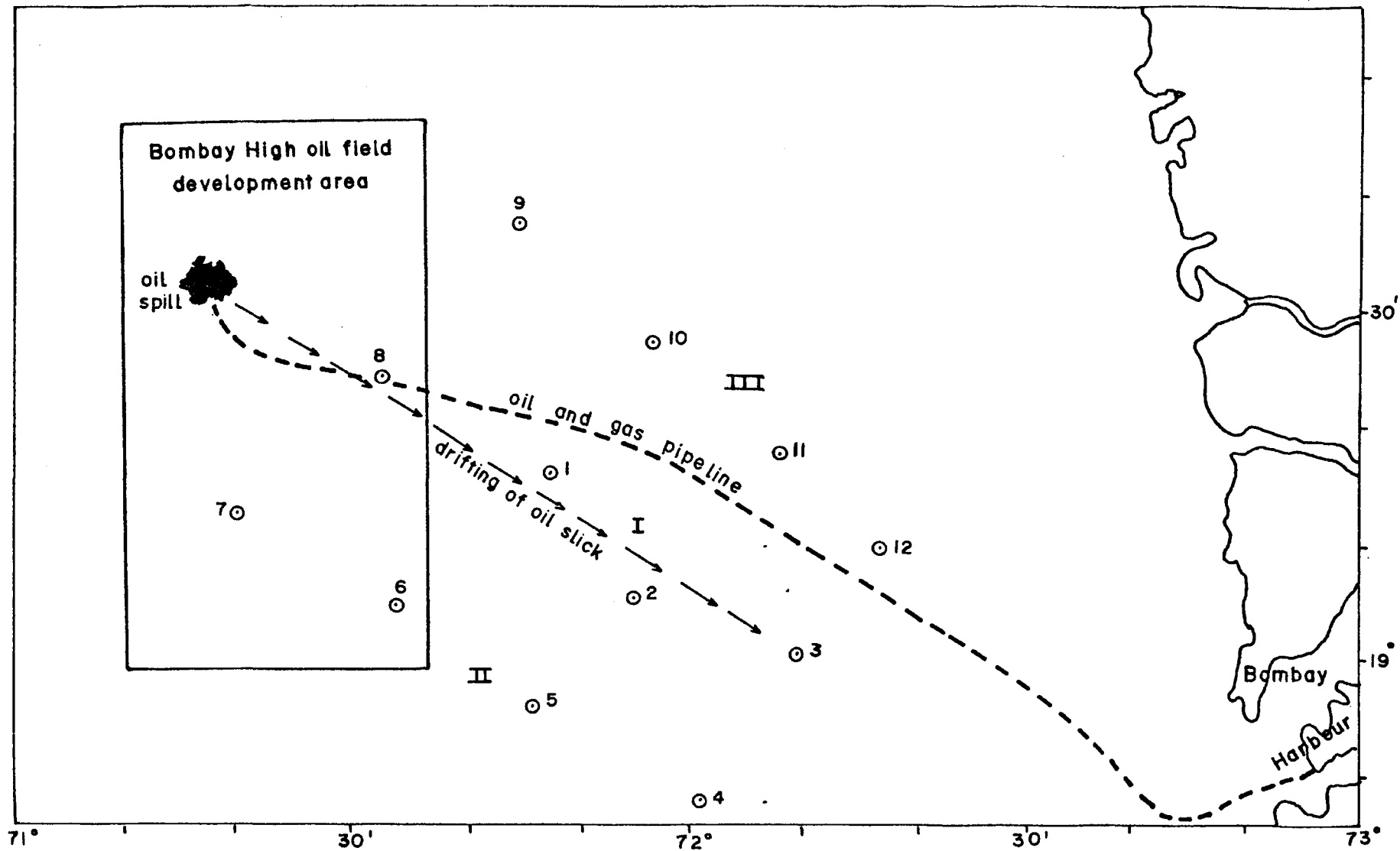


Fig. 2 CRUISE TRACK IN OIL SPILL AREA IN BOMBAY HIGH REGION