

Oil Spill in Bombay High Marine Impacts

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July 1993

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EXECUTIVE SUMMARY

- a) Rupture of feeder pipeline in Bombay High on 17th May, 1993 resulted in spillage of crude oil variably estimated between 3000 and 6000 tonnes into the sea. The Contingency plan for combatting oil pollution was pressed into action and the vessels belonging to TCG and ONGC fought the spill by skimming as well by spraying chemical dispersants.

- b) As a follow-up of the decisions taken at various Governmental levels, ORV Sagar Kanya, with an expert group of scientists on board cruised the spill area between 21st and 23rd May 1993. Another expert scientific group monitored the coastal zone of Murud between 27th May and 1st June, 1993 where the weathered spilled oil was expected to be drifting under the prevailing premonsoon environmental conditions.

- c) The oil slick had broken into several patches of varying sizes and many of them were already in the "chocolate-mousse" state when ORV Sagar Kanya arrived on the scene. These oil patches were scattered over a large area and the general trend of drift was in the south easterly direction as predicted on the basis of movement of a hypothetical spill in Bombay High. It was expected that more toxic volatile components of spilled crude would

have evaporated and total mass lost through evaporation along was estimated at 1500-3000 tonnes.

- d) The observed concentrations of floating and dissolved-diepersed petroleum residues in certain regions in Bombay High far exceeded the expected background exposing the water column flora and fauna to much higher environmental stress. Accidently, these regions revealed localised impacts on biota in terms of decrease in the rate of primary productivity and changes in the composition of zooplankton.
- e) The patches of weathered crude reached the coastal waters of Murud on 28th May depriving recreation to the holidaying tourists. Considerable deterioration in water quality was evident when compared with the base-line established on the basis of COMAPS programme of the DOD.
- f) Localised impacts on plankton with mortalities in several instances were also observed. Microscopic examinations revealed phytoplankton cells coated with tarry material and some zooplankton clearly showed the presence of tar in the gut. These effects however were restricted to areas of floating oil and were expected to be only transient. Fairly quick recovery of the aquatic ecosystem was considered likely on the basis of

experiences elsewhere. The fish catch however was unaffected as expected.

- g) The scenic Murud beach and the rocky shores around were heavily oiled due to the deposition of tarry lumps on the shore on the 29th May 1993. The beach alone was estimated to have an overburden of over 1000 tonnes of tar with a deposition density of 25 kg/m². The deposits melted under the summer heat and percolated into the sand atleast upto 5 cm depth. Such heavy deposits were expected to seriously damage the intertidal biota.
- h) The oyster beds and the mangroves of the estuarine regions were also affected.
- i) Suitable recommendations are made to evolve reliable data base for water quality, sediment quality and biological characteristic and also recovery of biota for use in future assessments.

INTRODUCTION

A rupture in a feeder 'riser' pipeline from Bombay High-North Platform (BHN) resulted in spilling of large quantities of crude oil into the sea on 17th May 1993 about 80 NM from the shoreline north of Bombay. Although exact quantity of crude spilled into the sea was not known, it is variously estimated between 3000 to 6000 tonnes. Several vessels belonging to the Indian Coast Guard (ICG) and the Oil & Natural Gas Commission (ONGC) were pressed into service for clean-up operations by skimming as well as by spraying dispersants. Under the prevailing environmental conditions and with the use of dispersants, the spill was reported to have broken down into several patches of varying sizes scattered in the region.

At this juncture, it was necessary to establish the extent of contamination and to assess in gross terms, the probable damage to the marine ecology due to oil pollution. As a follow-up of the decision of the Government, research vessel Sagar Kanya with a team of scientists proceeded to the spill area on 20th May 1993.

Subsequently a joint aerial survey by a team drawn from NIO and ONGC was conducted on 23rd May 1993. The team observed large number of brownish patches of degraded crude scattered throughout the Bombay High region. In addition a

large patch, dark gray in colour, was sighted drifting in the southerly direction at 135°, The size of the patch was roughly estimated at 20 x 1 km. Although it was late May, premonsoon conditions of strong winds and rough sea had not developed. At the mean wind speed of 20 km/h then prevailing, it was considered that the floating oil would reach the Konkan coast within, 3 to 5 days with the shore of Murud as the most likely landfall area.

During joint discussion among Director, NIO; Chairman, Central Pollution Control Board; Member Secretary, Maharashtra Pollution Control Board (MPCB); Dy. G.M. ONGC and other officials on 25th May 1993 prior to the visit of the Minister of state, Department of Environment and Forests and Wild Life (DOEn) it was considered prudent to send a team of scientists drawn from NIO and MPCB to Murud immediately. The team was to camp at Murud for 2 to 3 days to assess the marine environmental quality in view of the probable contamination of the coastal zone by oil. Accordingly a team consisting of scientific personnel (five from NIO and two from MPCB) visited Murud and sampled the nearshore and intertidal coastal zone between 27th May and 30th May 1993.

This report which includes findings of the aftermath of oil spill is divided into two parts. Part I, includes the findings of the team on ORV Sagar Kanya and Part II deals with the survey results of the team stationed at Murud.

P A R T - I

1. BACKGROUND

On 17 May, 1993, a major oil slick about 10 miles long and 2 miles wide was formed about 80 nautical miles (NM) north off Bombay (latitude 19°32'N and Longitude 71°18'E) after the Bombay High-Uran pipeline ruptured. The accident occurred around 0800 hrs, 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 to some extent with the help of the rubberised booms and the oil was partly recovered with the help of the skimmers. Coast Guard vessels *Vajra*, *Vijay*, *Vivek* and *Ahilyabai* were involved in the containment operation along with two ONGC vessels *Samudra Suraksha* and *Nand Shamik*.

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

ORV Sagar Kanya with four scientists on board proceeded to Bombay High on 20 May 1993 with the task to estimate the magnitude of the oil spill and to assess the marine environmental impact particularly to the living resources. After successful completion of the survey and covering about 350 line NM, the ship returned 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 hr. 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 hr 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.

Several dispersants are likely to be toxic to marine life and thus direct application may prove harmful to many

marine organisms. Hence, the dispersants to be used, must be carefully chosen with particular reference to their toxicity and should be applied with caution.

3. PREDICTIONS OF MOVEMENT OF A HYPOTHETICAL SPILL IN THE BOMBAY HIGH

Movements of oil slicks and 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 a given place are known, a meaningful forecast of such movements can be made. Using this concept, National Institute of Oceanography, Goa, carried out the studies for the prediction of movement of a hypothetical oil spill in Bombay High region.

Fig. 1 shows the trajectories of oil spills expected in different months whereas the time required for the spilled oil to reach the coastline is given in Table 1. The drift trajectories in Fig.1 are constructed for environmental conditions expected at the beginning of each month. It can be seen from Fig.1 that the tracks for the spills occurring later in the month lie between the tracks for consecutive months. In general, it is evident that from May to September i.e. during south-west monsoon, the central west coast of India remains vulnerably exposed to oil spills in Bombay High

whereas during the remaining part of the year, the spilled oil is expected to move away from the coast.

4. WORK PLAN

On reaching the designated spill area, the contact was established with the vessel Vajra of ICG. Three parallel transects, with 4 stations on each were planned (Fig. 2). The distances between the transects and the stations were roughly put as 15 NM. Transect I was along the direction of the drifting oil-slick whereas transects II and III were on the either side and parallel to the 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 having a mouth area of 450 cm² each rigged in a catamaran arrangement, were towed at the surface for 15 min with the ship steaming at 2 knots. The near surface strata at levels 0 - 15 cm and 20 - 30 cm

were sampled to collect floating tar balls and other debris.

Water samples were collected at depths of 0,10, and 25 m for dissolved-dispersed petroleum hydrocarbon residues (DPH) using Niskin water samplers. All the water samples were analysed for their DPH by spectrofluorometry after preconcentration by hexane extraction. Samples obtained upto a depth of 40 m were also analysed for chlorophyll, phaeophytin and primary productivity.

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

6. RESULTS

The results discussed below pertain to the period 21-23 May 1993 and the first observation was after 4 days of the spill.

Oil sightings:

Observations for oil sightings were negative with no signs of oil patches-either treated or untreated, in the reported spill location at latitude 19°32'N and longitude 71°18'E (where the incident occurred). As the spillage took place in the month of May- the beginning of the south-west monsoon, the spill could have already drifted as a whole or

in patches in south-easterly direction towards the Bombay coast as predicted on the basis of hypothetical spill movement discussed under section 3. Several small isolated patches of treated oil (oil + dispersant) were sighted drifting in the south easterly direction between stations 1 and 3 along the track I. The sizes of oil patches were estimated to vary between 1 x 0.5 m to 10 x 2m. Only one patch of untreated oil (about 100 x 2 m) was observed at station 3. No oil patches either treated or untreated, were observed along the transects II and III throughout the survey. Aerial survey carried out on 25 May however showed several oil patches of varying sizes drifting towards the coast 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 the south-easterly direction. The observed concentrations were markedly on the higher side of the range (0-6 mg/m²) observed for the Arabian Sea (Table 3). With the then prevailing sea state, high temperature and wind speed, it was expected that the water-in-oil mousse would

have formed after environmental exposure of oil for more than 24 hr. Such emulsions would soon be adsorbed on to the surfaces of suspended particles eventually to form tar balls. Such tar balls either sink to the seabed or get suspended due to the buoyancy of its size in an intermediate water mass and drift along the current directions. Depending on the coastal circulation these tar balls would ultimately, be washed ashore on the nearby coast. The spill occurred in a period (May - September) of south-west monsoon when the alongshore surface currents would develop a strong easterly shoreward component, there was every possibility that these tar balls would be deposited on the shores of the central west coast of India between Bombay and Goa.

Dissolved-dispersed 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 (station 1) whereas the lowest concentration of 0.19 mg/l was noted 25m depth (station 12). The high concentrations were obtained at the stations along track I (0.53 - 3.65 mg/l) as compared to those obtained along 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 decreasing

gradient with depth. The observed levels which varied between 0.19 and 3.65 mg/l were higher by about 3 orders of magnitude or around 1000 times, as compared to the background levels in Bombay High region (1 - 30.8 Mg/l) and in the Arabian Sea (3 - 22 Mg/l) as compiled in Table 3.

Chlorophyll a, Phaeophytin and Primary productivity :

Table 4 shows that in the region of oil patch, the mean value of extinction coefficient (i.e. light penetration index) was 0.14. Chlorophyll a (Chl a) and phaeophytin (phaeo) values in the surface waters ranged from 0.24 to 1.78 mg/m³ and from 1.37 to 8.32 mg/m³, respectively. The mean primary productivity (pp) in the surface waters was 9.3 mgC/m³/day. In the vertical, mean values of chl a, phaeo and pp were 14.2 mg/m², 77.9 mg/m² and 0.19 gC/m² / day, 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/100 m³.

The high mean extinction coefficient of 0.36 was perhaps due to the 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/m³, 1.39 to 12.4 mg/m³ and 0.74 to 4.36 mgC/m³ /day, respectively in this region. In the water column, the mean values of chl a, phaeo and pp were 30.9 mg/m², 15.26 mg/m² and 0.25 gC/m² /day. The mean

zooplankton biomass was 23.2 ml/100 m³. The total zooplankton counts as shown in Table 5 ranged from 1123 to 2000 nos/100 m³. Visual observations indicated 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 chl a the concentration of phaeo were high in the area surveyed. Also the rate of photosynthetic production was low in the oil patch region as compared to the region free of oil patches. This indicated an adverse effect of oil on basic photosynthetic processes. Copepods which generally dominate the zooplankton organisms, showed very low counts (stations 4 and 5) of less than 32% and 18% respectively (Table 5). Also hydromadusae group dominated at station 5. These results indicate poor quality of water perhaps due to the adverse effects of environmental contamination on the basic biological processes and life in the area affected by oil spill.

TABLE - 1 : TIME INTERVAL FOR THE SPILLED OIL TO BEACH 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	4 1/2
Early August	Around Bombay	7
Early Sept	70-90 km south of Bombay	22
Mid Sept	No threat	

TABLE 2 : 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/1			
					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	PI	0.70	0.51	0.19

DPH - Dissolved-dispersed petroleum hydrocarbons
A - Absence
PI - Presence indicated.

TABLE 3 - Comparison of the data on floating tar balls and DPH concentrations.

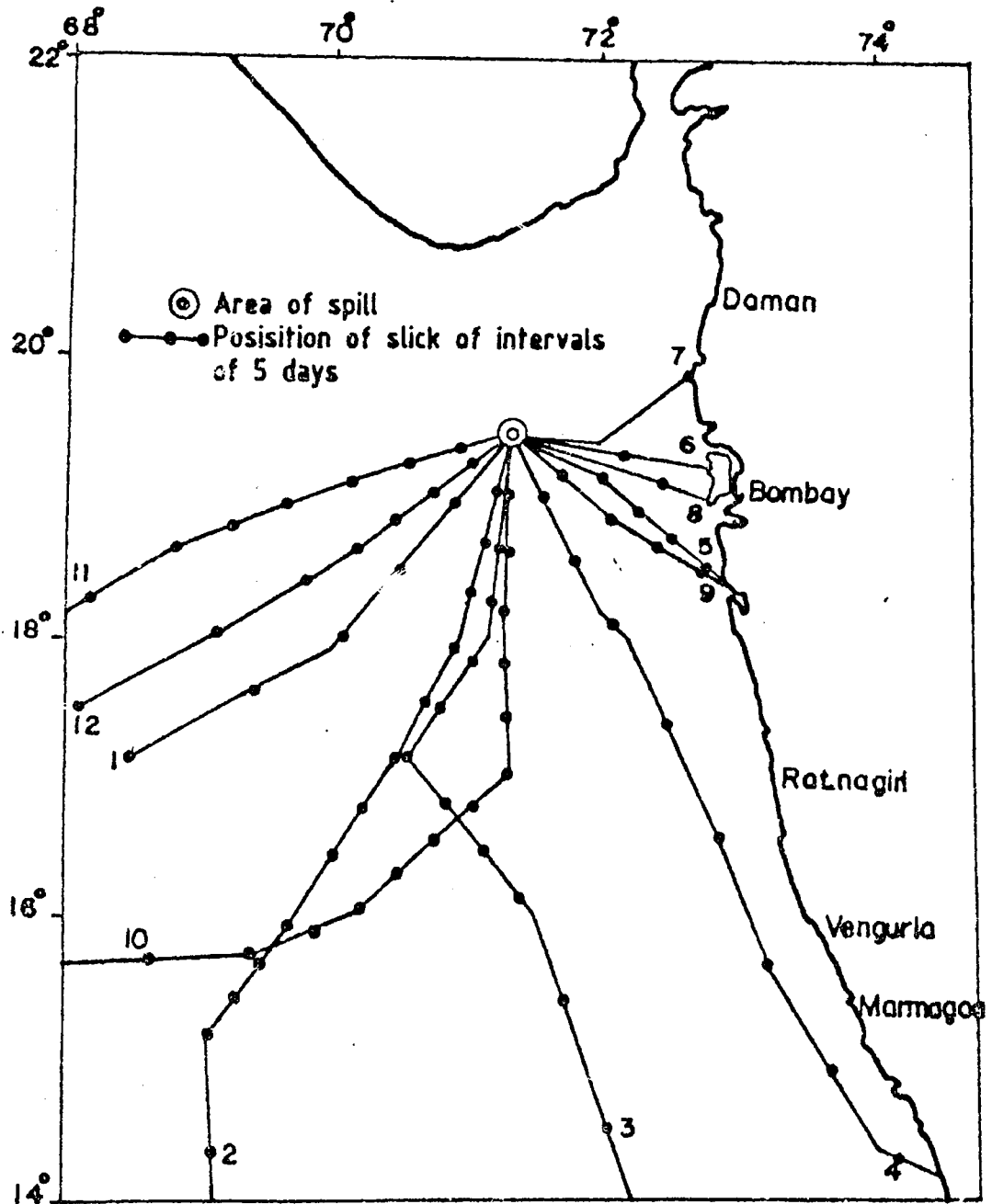
Variables	Spill area		Normal values		Remarks
	Bombay High region	Bombay High region	Bombay High region	Arabian Sea	
Floating tar balls	0 - 95.82 mg/m ²			0 - 6 mg/m ²	Increase
DPH (0 - 25m)	0.19 - 3.65 mg/l		1 - 30.8 Mg/l	3 - 22 Mg/l	Increase

TABLE 4: 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	0.95	0.36	0.33
<u>Surface waters</u>								
Chlorophyll <u>a</u> , 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 C/m ³ /day	-	-	9.3	-	0.79	4.36	2.58	
Zooplankton biomass ml/100 m	13.1	100	19.4	32	4.8	65.5	23.2	20.4
<u>Vertical water column</u>								
Chlorophyll <u>a</u> mg/m ²	3.9	37.4	14.2	13.6	10.4	85.0	30.9	24
Phaeophytin mg/m ²	2.1	190	77.9	66	53.7	407	152.6	112
Primary productivity gC/m ² /day	-	-	0.19	-	0.2	0.29	0.25	

TABLE 5 - Zooplankton taxa in the spill area

Groups (Nos/100m ³)	S t a t i o n s											
	1	2	3	4	5	6	7	8	9	10	11	12
HYDROMEDOSAE	26.0	100.0	46.4	38.0	8609.5	-	57	38	38	1276	57	
SIPHONOPHORA	152.1	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
LUCCIFER S.P.	-	-	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	-	9	95	3428	395	114
APPENDICULARTA	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

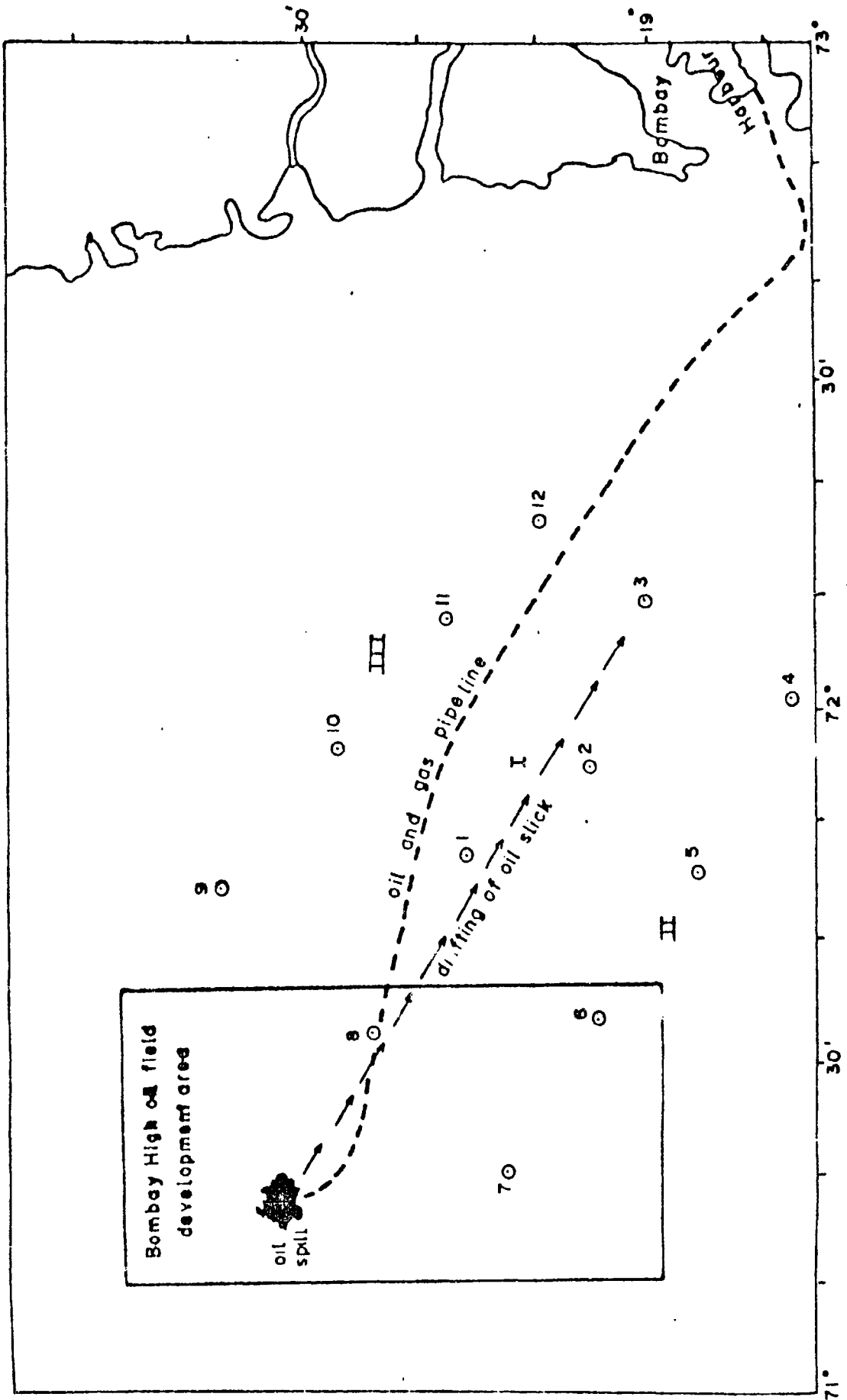


FIG. 2 CRUISE TRACK IN OIL SPILL AREA IN BOMBAY HIGH REGION

PART II

BACKGROUND

A joint serial survey by a team drawn from NIO and ONGC was conducted on 23rd May 1993. The team observed large number of brownish patches of degraded crude scattered throughout the Bombay High region. In addition, a large patch, dark gray in colour was sighted drifting in the southerly direction at 135°, The size of the patch was roughly estimated at 20 x 1 km. Although it was late May, premonsoon conditions of strong winds and rough sea had not developed, At the moon wind speed of 20 km/h then prevailing, it was considered that the floating oil would reach the Konkan coast within 3 to 5 days with the shores of Murud as the most likely landfall area.

The findings of NIO team are discussed in this report along with the relevant literature information on the behaviour of crude oil in the marine environment and its ecological significance

2 OBJECTIVES

To identify immediate changes if any in marine environmental quality of Murud in the event of pollution by petroleum hydrocarbon residues (PHC),

3 STUDIES UNDERTAKEN,

3.1 Approach strategy

An objective marine environmental impact assessment following pollutant contamination requires reliable baseline against which the measured environmental quality can be compared. Fortunately, the coastal waters of Murud are being periodically monitored under the Coastal Ocean Monitoring and Prediction System (COMAPS) programme of the Department of Ocean Development (DOD) since 1989, Under COMAPS, the nearshore area upto a distance of 25 km from the shoreline is monitored for water quality, sediment quality and biological characteristics at four stations at distances of 0, 3 to 5, 10 to 15 and 20 to 25 km from the shoreline. The adjacent Rajapuri creek is also monitored over a tidal cycle to evaluate tide induced changes. Hence, a fairly good baseline is available for the region for April-May as given in Tables 3.1 to 3.5. This baseline is used for comparisons in the present report. Unfortunately, as beach characteristics, beach quality and intertidal biota are not studied under COMAPS, the baseline for the intertidal region is not available.

The field party reached Murud on 27th May 1993 and undertook sampling from 27th to 30th May 1993. The water and sediment

environment was monitored at more or less same locations operated under COMAPS, However, due to prevailing rough weather conditions, extensive sampling was not possible. The locations of campling are given in Figure 3.1.

The Murud beach was also sampled particularly for PHC. The procedure recommended by United Nations Environment Programme (UNEP) was modified to suit local requirements.

3.2 Sampling and methods of analyses

Sampling procedure

All-plastic Niskin sampler with a closing mechanism at a desired depth was used for collecting sub-surface water samples. Sampling at the surface was done using a clean polyethylene bucket.

Oblique hauls for zooplankton were made using a Heron Tranter Net (Mesh sizes 0.33 mm, mouth area 0.25 m²) with an attached calibrated TSK flow meter. All collections were of 6 min. duration. Samples were preserved in formalin.

Sediment samples were collected using a Van-Veen grab of 0.04 m² area.

Representative beach areas (1 x 1 m) around the high water mark were compled for PHC by hand picking. The PHC collected was transferred to alluminium foil for further investigations in the laboratory at Bombay.

The water camples wore analysed in the shore laboratory temporarily established at Murud, Colorimetric measurements were made on a Spectronic (Bausch and Lomb) spectrophotometer.

Methods of analysis

(a) Salinity and chloride content

A suitable volume of the sample was titrated against silver nitrate (20 g/) with potassium chromate as an indicater. The salinity was calculated using Standard Tables.

(b) Suspended solids

Known quantity of water was filtered through a preweighed 0.45 Ou Millipore membrane filter paper, dried and weighed again.

(c) pH

pH was measured on a ECIL pH meter. The instrument was calibrated with standard buffers just before use.

(d) DO and BOD

DO was determined by Winklor method. For the determination of BOD, direct unseeded method was employed. The sample was filled in to BOD bottle in the field and was incubated in the laboratory for 5 days after which DO was again determined.

(e) Nitrite

Nitrite in the sample was allowed to react with sulphanilamide in acid solution. The resulting diazo compound was reacted with N-(1-Naphthyl)-ethylenodiamino-dihydrochloride to form a highly coloured ozo-dye. The light absorption was measured at 543 nm.

(f) Nitrate

Nitrate was determined as nitrite as above after its reduction by passing the sample through a column packed with amalgamated cadmium.

(g) Ammonium

Ammonium compounds (NH_3^+ , NH_4^+) in water give a blue colour of indophenol when reacted with phenol in presence of hypochlorite. The absorbance was measured at 630 nm.

(h) Phosphate

Acidified molybdate to reagent was added to the sample to yield a phosphomolybdate complex which was then reduced with ascorbic acid to a highly coloured blue compound which was measured at 882 nm.

(i) PHC

Water sample (2.5 l) was extracted with hexone and the organic layer was separated, dried over anhydrous sodium sulphate and reduced to 10 ml at 30° C under low pressure. The fluorescence of the extract was measured at 360 nm (excitation at 310 nm) with crude oil residue as a standard.

(j) Phytoplankton pigments

A Known volume of water was filtered through 0.45 µm Sartorius membrane filter paper and the pigments retained on the paper were extracted in 90% acetone, The extinction of the acetone extract was measured at 665 and 750 nm before and after treatment with dilute acid for the estimation of chlorophyll a and phaeophytin.

(k) Zooplankton

Volume (biomass) was obtained by displacement method, A portion of the sample (25-50%) was analysed under a microscope for faunal composition and population count.

(l) Benthos

The sediment was sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered formalin. Total population was estimated as number of animals in 1 m² area and biomass on wet weight basis.

(m) Fishery

The boat used for sampling did not have adequate facilities for trawling. Hence, trawl data was obtained from other local fishing vessels operating in the region during the period of survey.

(n) Sediment grain size

The sample was split into sand and silt-clay fractions on a 62 µ sieve. The silt and clay content in silt-clay fraction was estimated by standard procedure of pipette analysis.

(o) Sediment organic matter

The percentage of organic carbon in sediment was determined by oxidising the organic matter in the sample by the chromic acid and estimating the excess chromic acid by titration against ferrous ammonium sulphate. Per cent organic carbon was multiplied by 1.73 to obtain per cent organic matter.

(p) PHC in sediments

The sediments after refluxing with KOH-methanol mixture was extracted with hexane. After removal of excess hexane, the residue was subjected to clean-up procedure by silica gel column chromatography. The hydrocarbon content was then estimated by measuring the fluorescence as describe under (i).

(q) Trace metals in sediments

The sediment was brought into solution by treatment with concentrated HF-HClO₄ -HNO₃ and the metals were estimated by flame AAS on a Spectra 30A (Varian) atomic absorption spectrophotometer.

(r) PHC on Murud beach

The hand picked material was carefully separated from sand and other debris and the PHC estimated gravimetrically.

4 FATE OF PETROLEUM CRUDE IN MARINE ENVIRONMENT

The major spills of crude oil and its products in the sea occur during their transport by oil tankers, loading and unloading operations, blowouts, etc. When introduced in the marine environment the oil goes through a variety of transformation involving physical, chemical and biological processes. Physical and chemical processes begin to operate soon after petroleum is spilled on the sea. These include evaporation, spreading, emulsification, dissolution, sea-air exchange and sedimentation. Chemical oxidation of some of the components of petroleum is also induced in the presence of sunlight. The degraded products of these processes include floating tar lumps, dissolved and particulate hydrocarbon materials in the water column and materials deposited on the bed.

Biological processes though slow also act simultaneously with physical and chemical processes. The important biological processes include degradation by microorganisms to carbon dioxide or organic material in intermediate oxidation stages, uptake by large organisms and subsequent metabolism, storage and discharge.

Crude oil and its products are highly complex mixtures. Since the fate of petroleum in the marine environment depends on the composition, a preliminary knowledge of major components and types is necessary for understanding the fate of petroleum when spilled on water.

Crude oils of different geologic and geographic sources vary widely in composition. Thousands of individual compounds, mostly hydrocarbons in varying proportion, are present in crude oil which determine the physical as well as chemical properties of petroleum. The approximate composition of an average crude oil is considered as :

Normal Type

Gasoline ($C_5 - C_{10}$) 30%; kerosene ($C_{10} - C_{12}$), 10%; light distillate oil ($C_{12} - C_{20}$), 15%; heavy distillate oil ($C_{20} - C_{40}$), 25% residuum oil ($>C_{40}$), 20%,

By molecular type

Paraffins (alkanes), 30%; naphthenes (cycloalkanes), 50% aromatics, 15% nitrogen, sulphur and oxygen containing compounds (NSO) 5%.

4.1 Spreading

Spreading of crude oil on water is probably the most important process following a spill. Apart from chemical nature of oil, the extent of spreading is affected by wind, waves and currents. Under the influence of hydrostatic and surface forces, the oil spreads quickly attaining average thickness of less than 0.03 mm within 24 h. Once a spill has thinned to the point that surface forces begin to play an important role, the oil layer is no longer continuous and uniform but becomes fragmented by wind and waves into islands and windrows where thicker layers of oil are in equilibrium with thinner films rich in surface active compounds.

In addition, surface currents driven by wind, waves and convectional cells determine the shape and direction of movement of the spill; the wind being the most influential external factor.

The occurrence of NSO compounds in petroleum crude play an important role in the fate of oil released in the marine environment. The high surface activity of many of these compounds facilitates spreading and emulsifiability of petroleum.

4.2 Evaporation

Evaporation and dissolution are the major processes degrading petroleum crude when spilled on water. The composition of oil, its surface area and physical properties, wind velocity, air and sea temperatures, turbulence and intensity of solar radiation, all affect evaporation rates of hydrocarbons. Hydrocarbons containing less than about C₁₅ (boiling point < 250 C) are volatilized from the ocean's surface within 10 days. It is those components that represent the most toxic constituents of the oil. Hydrocarbons in the C₁₅ -C₂₅ range (boiling point 230 - 400 C) show limited volatility and will be retained for the most part of the life of the oil slick, Above C₂₅ (boiling point > 400 C) there is very little loss. Thus evaporation alone will remove about 50% of hydrocarbons in an "average" crude oil on the ocean's surface.

Loss of volatile hydrocarbons increases the density and the kinematic viscosity of oil. As more volatile hydrocarbons are lost, the viscosity of the resulting oil increases and this results in breakup of slick into smaller patches. Agitation of these patches enhances incorporation of water due to increased surface area.

4.3 Photooxidation

The natural sunlight in the presence of oxygen can transform several petroleum hydrocarbons into hydroxy compounds such as aldehydes and ketones and ultimately to low molecular weight carboxylic acids, As the products are hydrophilic, they change the solubility behaviour of the spill, Photooxidation which is inversely proportional to the film thickness, is a slow process and may take days to weeks to obtain significant results. Such reactions preferentially occur in branched alkanes and aromatics,

4.5 Dispersion

Dispersion is oil-in-water emulsion resulting from the incorporation of small globules of oil into water column. Oil begins dispersing immediately on contact with water and is most significant during the first ten hours or so. Although, such oil in water emulsions are not stable in the natural aquatic environment, they are considerably stabilised by suspended particles, natural or added emulsifiers or dispersants.

Unstabilized oil particles tend to resurface and again, form into a slick. The turbulence generally plays a major role in controlling the dispersion of particle formation and suspension. Water-in-oil emulsions formed particularly from heavy asphaltic crudes or residual oils tend to be more coherent semisolid lumps referred to as "Chocolate Mousse". Experimental and limited field studies have shown that these persistent emulsions contain approximately 50 percent water and that bacteria, or solid particulate matter do not seem to be required for their formation.

The fate of oil-in-water emulsions appear to be dissolution in the water column or association with solid particulate matter or detritus and eventual biodegradation as incorporation in bottom sediments.

4.6 Dissolution

Dissolution is another physical process in which the low molecular weight hydrocarbons as well as polar nonhydrocarbon compounds are partially lost from the oil to the water column. Rates of dissolution for the various constituents of oil depend on several factors such as the properties of oil (molecular structure of compounds and their relative abundances) and the physico-chemical

characteristics of the environment (salinity, temperature, turbulence). The water solubility of hydrocarbons drop drastically as one goes to higher carbon numbers. For example, of the normal paraffins, n-C₅ has distilled water solubility of about 40 ppm; n-C₆ about 10 ppm; n-C₇ about 3 ppm; n-C₈ about 1 ppm. For aromatic hydrocarbons, C₆ (benzene) has a distilled water solubility of about 1780 ppm; C₇ toluene about 515 ppm; C₈ (xylenes) about 175 ppm; C₉ (alkylbenzenes) about 50 ppm; C₁₄ (anthracene) about 0.075 ppm and C₁₈ (chrysene) about 0.002 ppm. Hydrocarbon solubility is probably 12-30% less in seawater as compared to distilled water.

Branched alkanes demonstrate greater solubilities for a given carbon number than their straight chain counterparts. Ring formation also enhances solubility for a given carbon number or molar volume. The degree of saturation is inversely proportional to solubility for both chain and ring structures. The addition of a second or third double bond increases solubility proportionately and the presence of a triple bond. increases solubility to a greater proportion than presence of two double bonds. Therefore, the most water soluble hydrocarbons will be those with the lowest molar volume and greatest aromatic/arofinic of character. Dissolved

organic matter present in natural waters also enhances solubility due to its surface active nature,

4.7 Degradation

Biodegradative processes influencing fate of petroleum in aquatic environment include microbial degradation, ingestion by zooplankton, uptake by aquatic invertebrates and vertebrates as well as bioturbation.

Microorganisms capable of oxidising petroleum hydrocarbons and related compounds are widespread in nature. The rate of microbial degradation vary with the chemical complexity of the crude, the microbial populations and many of the environmental conditions. Because of the complexity, it is impossible to predict the rate of microbial oil removal. Environmental stress such as temperature and salinity changes, turbulence and sunlight not only directly affect the growth and metabolism of the microorganisms but also alter the physical and chemical states of the hydrocarbons. The degradation by naturally occurring bacteria in the aquatic environment is generally slow and their impact on the oil spill may be noticeable after some duration.

5 EFFECTS OF PETROLEUM CRUDE ON MARINE BIOTA

The biological effects of oil include the possibility of

- (a) hazards to man through eating contaminated seafoods
- (b) decrease of fisheries resources or damage to wild life such as sea birds and marine mammals,
- (c) decrease of aesthetic values due to unsightly slicks or oiled beaches,
- (d) modification of marine ecosystems by elimination of species with an initial decrease in diversity and productivity and
- (e) modification of habitats, delaying or preventing recolonization.

When an oil spill occurs, many factors determine whether the spill will cause heavy, long lasting biological damage, comparatively little or no damage or some intermediate degree of damage. Thus for instance, if a spill occurs in a small confined area so that the oil is unable to escape, damage will be greater for a given volume and type of oil spilled than if the same volume was released in a relatively open area.

In the open sea the possible impact on biota can be on phytoplankton, zooplankton, benthos, fishery, birds, mammals, etc. whereas in coastal waters the impacts will also be on intertidal fauna, aquaculture, seaweeds and mangroves as listed Tables (4.1 and 4.2).

5.1 Phytoplankton

Biological effects from oil spills vary so widely that it is difficult to generalize on any specific topic such as phytoplankton. The sensitivity varies among major groups and sometimes within species, Green algae are more sensitive to hydrocarbons than diatoms, blue green algae and flagellates. Hence bloom of flagellates may appear as a result of relaxed grazing pressure and slow sinking of diatoms allowing them to dominate. Phytoplankton appear to absorb hydrocarbons but there is no transfer inside the cell.

5.2 Zooplankton

Zooplankton and especially the neuston (fish eggs, fish larvae, Lucifer sp) in the surface layer of the sea can be at risk because of exposure to higher concentrations of water soluble constituents leaching from floating oil. In general, the eggs and planktonic larval stages of pelagic as well as benthic organisms are sensitive to low oil

concentrations (10-100 Mg/l). However, significant detrimental impact on plankton has never been demonstrated in the open sea. It is suggested that the dose and duration of oil exposure during spills will never reach the threshold in the open sea. Oil spill in enclosed or semienclosed areas can however lead to decrease in plankton populations but overall effects are expected to be minor. Moreover, these organisms can reproduce rapidly and any population reductions can be soon restored. Larval forms of fish, crustaceans and molluscs may be on the contrary, severely affected and recovery may be delayed for long periods.

Zooplankton can accumulate oil and can concentrate both aliphatic and aromatic hydrocarbons which may subsequently be depurated to a large extent. But the metabolites are highly resistant to depuration. Their retention may pose long term consequences by their transfer through food chain.

The sublethal effects of petroleum encountered in zooplankton vary widely and include alterations in feeding, growth, reproduction and fecundity, reduction in larval life span, reduction in mean brood size and number of young ones produced, inhibition of molting in larval crustaceans, inhibition of yolk utilization, the occurrence of abnormal

intermediate larval stages, morphogenic abnormalities and alterations in swimming activity and food perception.

5.3 Benthos

The most severe impact of oil spills in shallow waters is seen on benthos as part of the oil sinks to the bottom and since many benthic animals are essentially immobile or slow moving cannot get away from pollution. Although the water column gets relatively free of oil shortly after oil spill freeing pelagic organisms from contamination, the benthos has to often face an oily environment for years. Oil in solution or as dispersed droplets can damage benthos with effects ranging from detrimental behaviour to mortality. Oil carried to the sea bed can affect the eggs of the bottom-spawning fish. Temporary tainting of several benthic organisms like shellfish can also result. Massive destruction of benthic populations have been reported due to accidental oil spill and recovery was not complete even after a decade.

The meiofauna is considered to be more sensitive to oil pollution than macrofauna. Significant reduction in the populations of certain meiofaunal groups like harpacticoid copepods, turbellarians, and ostracods is observed when

exposed to oil. In heavily contaminated areas meiifauna may be totally absent while nematodes may dominate in moderately polluted regions. Oil concentration of 110 Mg/1 (dry sediment) even for longer time (5 months) however may not affect species diversity of macrobenthos but may result in decrease in faunal density. Macrofaunal polychaetes are relatively less sensitive than amphipods, to oil pollution. Sediment containing 5000-7000 ppm oil do not inhibit recruitment of selective bivalves and polychaetes.

Various sublethal effects of oil on benthos such as changes in population structure, alterations in physiological, cellular and biochemical responses, changes in reproductive cycles and changes in respiratory activity and behavioural responses can occur at an oil concentration in water between 50 to 1000 Mg/1.

Benthic animals like polychaetes, sipunculids, crustaceans including crabs, shrimps and lobsters and molluscs such as gastropods, mussels, cockles and oysters rapidly accumulate petroleum hydrocarbons from contaminated sediment, water and food. The selected compounds are however rapidly depurated.

5.4 Fish

Fish often shows avoidance reaction even at low concentration of oil in water. Moreover, the fish possesses an enzyme system which can deal with petroleum hydrocarbons in its tissues. Hence, fish kills due to oil pollution are rare and when occur, the numbers involved are not usually significant. No conspicuous decline in the fisheries of accidental oil spill areas are observed though some changes in the composition of catch and often fish populations, are reported. Large spills in enclosed areas can make the habitat unsuitable for fishing and render the fish commercially unacceptable because of taint which occurs when certain components of oil are present in the flesh even at low concentrations. The levels as low as 1 mg/l of dissolved petroleum can result in tainting. But the contamination is temporary and the levels reduce considerably when the ambient hydrocarbon concentrations return to normal. Although the body burden of petroleum hydrocarbons is considerably reduced through metabolism and excretion, the metabolites such as polyaromatic carcinogenic and mutagenic compounds may be retained for longer period which may be of concern to human health.

The greatest threats of oil pollution are to benthic fish, spawning and breeding grounds of fish, their eggs and larvae and shellfish grounds. The larval stages of finfish and shellfish are much more sensitive to oil pollution. Concentrations of 1 mg/l of petroleum in water can cause lethal effects on fish eggs and larvae. Such concentrations are unlikely to occur or persist in the marine environment except immediately after the spill.

Sublethal exposure of oil to fish can result in structural changes from gross anomalies to subtle subcellular defects which are of considerable importance concerning population and community stability. The sublethal effects which can widely vary are, biochemical alterations, cellular and subcellular changes, morphological alterations in eye, skin and kidney, physiological alterations, developmental abnormalities of eggs and early life history stages and behavioural alterations.

5.5 Birds

Aquatic birds are particularly vulnerable to oil spills because the oil soaks their plumage and destroys its water-proofing, buoyancy and insulating properties, so that the birds are chilled and may die of exposure or by sinking or

drowning. Often they attempt to clean themselves of oil, thereby ingesting it, causing internal damage. Large spills usually cause bird mortalities but the extent depends on the location of the spill, the season of the year and the species involved. Since, birds are relatively long living and have low reproductive rates, losses are not easily recouped and the recovery is a slow process. It is generally believed that often the oil spill causes more damage to sea birds populations than to any other form of marine life (Table 4.2).

Indirect effects of oil pollution on reproduction appear to be much less important than the direct mortality of adult birds.

5.6 Intertidal habitats

Intertidal organisms are much hardier than the subtidal forms living in a more constant environment.

Oil trapped in tide pools on falling tides can saturate small volumes of water with dissolved organics for periods ranging to several hours. Oil deposits on the attached epifauna and flora may cause damage when the stranded oil contacts tissues directly.

Oil stranded on beaches on falling tides tends to percolate into the sediments, which provides an opportunity for intimate contact with the fauna. Sedimentary transport processes can move the oily particles away from the region of initial contact, then extending them along the shore as well as to sutatidal waters. Stranded oil is not readily removed from low-energy sedimentary beaches, and if still liquid, drains down into substratum. Oil can be transported into estuaries and inlets where it becomes incorporated in sediments. In addition to the immediate damage to the fauna, the persistence of toxicity prevents the start of recovery processes.

Salt marshes and mangroves swamps are like intertidal mud banks, low energy areas, trapping oil. The plants which form the basis for these ecosystems suffer accordingly. The effect of oil pollution on plants living in a salt marsh depends on the season. If the plants are in bud stage, flowering is inhibited, if the flowers are oiled they rarely produce seeds, if the seeds are oiled, germination is impaired. Experience of isolated oil spills suggests that oil pollution of this kind is less damaging to salt marshes than efforts to clean up the oil.

Mangroves present a rather different problem. They live in anoxic muds and have extensive air spaces carrying oxygen to the submerged part of the tree. Lenticles, by which the air is taken up, occur on the aerial roots of *Avicennia* or propoots of *Rhizophora* and if the lenticles are clogged with the oil, the oxygen level in the root air spaces fall. Although, mangroves have certainly suffered damage by oil spills, there are a number of cases where heavy oilings have not killed the plants.

5.7 Hunan health

The major concerns of oil pollution for man are the degradation of aesthetic quality mainly caused by tar residues on beaches and shorelines and the probable health hazard through consumption of contaminated seafood.

The bioacummulation and retention of carcinogenic compounds like benzopyrene is of serious concern to human health. However, on the global scale, oil is an insignificant source of such carcinogens as compared to other sources.

6 MARINE ENVIRONMENTAL QUALITY AT MURUD

The coastal area of Murud consisting of broad and gently sloping 3 km long beach bordered on the north by a rocky

cliff and Rajapuri creek to the south with an imposing historical fort in the forefront is a famed scenic spot and attraction for many tourists who flock the area during April-May. The Rajapuri creek forms the entrance to the important fishing port of Agadanda and harbours mangroves in the interior marsh.

The baseline marine environmental quality parameters evolved on the basis of COMAPS programme are given in Table 3.1 to 3.5. These data collected over 1989-93 represent premonsoon conditions and each value is a mean of several individual determinations. The coastal waters including the creeks and bays around Murud are under negligible environmental stress in the absence of industrialisation and urbanisation and the variabilities evident in Tables 3.1 to 3.5 on natural occurrence inherent to any nearshore water body. Hence, assessment of environment quality should be made

keeping these variations in view.

6.1 Water quality

During the field survey and sample collections on 27th May 1993, the seawater as well as the beach was relatively clean and there was no evidence of high concentration of PHC in the water column (Table 6.1). Several patches of floating

PHC were however noticed on the sea surface upto 15 km from the shoreline on 28th May. The whole area was also strewn with tarry lumps of varying sizes. Evidently the PHC in the water column varied widely and levels upto 3348 Mg/l were observed. It must be noted that sampling for PHC in the water column was undertaken at 1 m depth from surface as per standard practice and the observed concentrations could be considered as abnormally high. The advantage of sampling below the water surface is that the results are not adversely biased due to patchiness of water insoluble PHC floating on the surface. The decrease in DO to 1.5 ml/l at some locations and its high variability was associated with the enhanced BOD of the PHC in the water column, The water quality however improved on the following day (29th May) and the levels of PHC decreased considerably in the offshore as the patches moved to nearshore areas. One such patch floating off Murud is shown in Plate 1(b).

Although due to operational reasons and hostile sea conditions the area of surveillance was restricted to region around Murud, floating patches of PHC were reported by the local fishermen at least upto Shrivardhan 25 km south of Murud. Deposition of PHC on the shore several km south of Murud was reported during Helicopter surveillance by the

joint team on 30th May 1993. On 29th and 30th May 1993, the nearshore water particularly in the vicinity of the beach was severely contaminated with PHC keeping the holidaying tourists away from swimming.

The oil patches entered Rajapuri creek on 29th May 1993 and oscillated within the creek under the tidal influence and eventually oiled the shores and some mangroves.

6.2 Shore quality

The beach was relatively clean and unaffected on 27th May except for a few tar balls scattered around the high water mark. On 28th May several tarballs mixed with sand were observed around the high water mark, density of which varied between 50 to 200 g/m². This type of tarball deposition is often observed along the beaches of the central west coast of India and has been attributed to tanker traffic and offshore oil exploitation activities.

The rocky shore north of the beach, at the mouth of Rajapuri creek and around the fort also did not give any indication of major PHC contamination on 27th-28th May 1993.

The high tide of 28th night dramatically changed the scenario. Large quantities of tarry material were brought to the shore by the rising tide and with the ebb, the whole

beach which was relatively clean (Plate 1(a)) was covered under a mat of offensive tarry material (Plate 2(b)). The beach sampling undertaken on 29th and 30th May 1993 (Plate 3(a)) indicated deposition density varying between (5 to 35 kg/m₂) in a width of 15-20 m on the beach. Considering average deposit of 25 kg/m₂, the beach was estimated to have 1000 tonnes of overburden of PHC, By afternoon, under the blazing summer heat, the PHC deposited on the beach melted (Plate 3(b)) and trickled into the nearshore water. Part of the liquid also penetrated the sand upto a depth of about 3 to 5 cm.

The rocky shores were also covered with PHC and pools of water formed in between the rocks during low tide trapped the thick oily mass (Plates 4 and 5), The fish landing jetty and open spaces around often used for sorting of fish etc., were covered with PHC.

Although the PHC had entered the creek (Plate 2(a)), the mangrove swamps were not seriously affected though the oyster bods at the entrance of Rajapuri creek were coated with PHC in patches.

6.3 Impacts on biota

Whenever we consider assessment of oil pollution implications, we must be aware of the fact that, despite many changes it may cause in the physico-chemical properties of seawater and the sea bottom, the ultimate consequences are inevitably of a biological nature. Therefore, the biological investigations of ecosystems and particularly, of their communities constitute an important part of impact assessment study.

Biological production potential and impact of oil on biota was evaluated on the basis of the following ;

- (i) Phytoplankton pigments, cell counts and composition as a measure of primary productivity,
- (ii) Zooplankton biomass and population to estimate secondary productivity,
- (iii) Biomass and population of macrobenthos to Quantify benthic productivity.
- (iv) Fish catch as a measure of fishery potential,
- (v) Intertidal fauna and mangroves.

(a) Phytoplankton

The level of chlorophyll a. varied in 0.5 - 5.3 mg/l range during 27th-30th May (Table 6.2) which fell within the range set for the baseline (Table 3.2). Incidentally highest and lowest values of chlorophyll a were observed on 29th May (Day of high contamination by PHC). Such significantly large random variations are often normal occurrences in the coastal waters and are perhaps due to the patchiness and uneven distribution of phytoplankton.

Phaeophytin also varied widely and was unevenly distributed. The concentration frequently exceeded those chlorophyll a indicating environmental stress perhaps due to PHC contamination. The water supported fairly high chlorophyll and cell count of phytoplankton,

Large number of species of phytoplankton (67 No.) belonging to 6 different classes were identified in the collections, In the order of dominance, Bacillariophyceae was followed by Cyanophyceae, Desmophyceae, Dinophyceae, Chlorophyceae and Eugleanophyceae. The cell count which varied widely between 7.7×10 and 280×10 counts/l was generally high in the surface water. Highest cell count (280×10 counts/l) was recorded at station 3 on 29 May where the diatom *Ditylum*

brightwelli and Asterionella japonica were predominant. Diatoms were the dominant forms and were represented mainly by Nitzschia. sp, N.pungus, Navicula sp and Rhizosolgnia sp, Phytoplankton species diversity was generally higher at stations 2 and 3 as compared to station 1.

Microscopic examination of cells indicated that a few specimen particularly of Nitzchia were damaged with a coatings of black layer presumably of PHC, around the cell. Some species of Ditylum brightwelli, Trichodesmium sp, Rhizosolenia sp, Saurirolla sp, Chaetoceros sp, Nitzschia cloestarium and Biddulphia sinensis from collections at station 3 were also damaged. The maximum damage to phytoplankton cells were noticed, at station 2 and 3, Rest of the species ware healthy and their distrilution was normal.

From the extensive literature reports some of which are discussed under section 5, it is unlikely that weathered oil residue from a small spill like the one under discussion, in the open ocean would cause any measurable and long term damage to phytoplankton, It is expected that whatever marginal damage caused by the impact, will be quickly recovered.

(b) Zooplankton

The zooplankton biomass, total population, total groups and faunal consumption are given in Table 6.3 which agreed well with the baseline (Table 3.3). The highest biomass recorded at station I was due to the predominance of Lucifer sp (27.2%), mysids (8.6%) and ctenophores (3.4%). The average zooplankton biomass decreased in the order - station 1 (38.2 ml/100 m³) > station 2 (8.4 ml/100 m³) > station 3 (5.6 ml/100 m³) > station 4 (4.7 ml/100 m³). The total population at station 1 which was maximum among all the stations was represented by eleven groups. The most dominant group was copepods (41.9%). The minimum population which was observed at station 2 also consisted of eleven groups with the dominance of copepods (46.7%). Lucifer sp (21.9%), gastropods (14.6%) and decapods (9.7%). Thus, copepods were the most dominant group contributing over 70% of the total population, Copepods were followed by Lucifer sp (8.2%), decapods (5.9%), ctenophores (2.6%) and chaetognaths (1.5%). The other groups in the collection were siphonophores, medusae, fish eggs, lamellibranchiata, mysids, gastropods, polychaetes, isopods, Acetes sp, appendicularians, stomatopod larvae and cephalopods.

The faunal diversity varied between 9 to 16 with the highest diversity of 16 at station 2 on 27th May before the oil spill reached Murud. The zooplankton sampled after 28 May showed considerable variations in biomass, population. Faunal composition and decrease in faunal diversity (Table 6.3). A number of damaged and dead species of chaetognaths copepods, *Lucifer* sp, *Acetes* sp and fish larvae were noticed in collections made between 28th and 30th May at stations 2, 3 and 4.

Microscopic examination of animals revealed black residue presumably of PHC in the body of some species of chaetognaths and copepods.

Copepods were mostly dominated by *Acartia spinicauda*, *Acartia* sp, *Acrocalanus gracilus*, *Acrocalanus* sp, *L. pectinata*, *Tortanus* sp and *Centrophages* sp. However, PHC was noticed only in few species of *Labidocera pectinata*, *Canthocalanus pauper* and *Acartia* sp.

The impact of PHC on zooplankton of coastal waters of Murud was only marginal and damages were noticed generally in samples collected from areas having floating oil patches. The sea areas free from floating PHC did not reveal any visual damage. As noticed in crude oil spills, such damages

are only transient and normal populations are restored quickly as plankton in general have high replacement capacity.

(c) Benthos

Subtidal macrofaunal standing stock in terms of biomass (0.1-52.9 g/m³ wet wt) and population (713-11500/m³) varied widely in the area. The earlier studies (Table 3.4) indicated average macrofaunal biomass and population at stations 1, 2, 3 and 4 as 26.4, 1.3, 1.7 and 9.5 g/m³ and 2810, 776, 2820 and 3330/m respectively. The faunal group diversity was the highest (av 8) at station 4 whereas it was least (av 3) at station 3. Thus, the earlier studies accounted for a better biomass and population density at stations 1 and 4, respectively. During the present investigation it was observed that faunal group diversity and composition were comparable to the baseline (Table 3.4) within the general variability inherent to the benthos. The higher benthic productivity of (3 to 7 times more) numerical abundance and biomass (2 to 15 times more) observed during the present study could probably be due to seasonal variability in the fauna abundance.

These studies did not reveal any gross adverse impact on benthic organism. This was expected since the collections were made during the period when FHC was floating/dispersed in the water column and had not deposited on the sediment.

(d) Intertidal fauna

The field team had no opportunity to study the intertidal fauna as the shores were heavily contaminated by PHC on 28th May. Moreover baseline for intertidal fauna is not available for comparison. Under the heavy deposition of PHC on the shores and subsequent relocation in the sediment it is expected that the intertidal fauna will be severely affected. Literature reports indicate that intertidal fauna of heavily oiled shores is severely damaged and recovery is often slow. It is necessary that long term studies of recovery of intertidal fauna of sandy beaches and rocky shores should be undertaken forthwith. In this respect the study of commercially important oyster populations at the mouth of Rajapuri creek will prove useful for future reference.

A large number of dead organisms belonging to *Porfita* sp, were washed ashore and strewn on the beach. It is therefore necessary to investigate the post spill biological effects

on some selected marine communities to ascertain their recovery.

(e) Mangroves

The inner intertidal regions of Rajapuri creek have dense

mangroves spread over large areas which have been declared as environmentally sensitive zone by DOEn. Such areas are known to be spawning and nursing zones for a variety of commercially important fish and shell-fish. Although till 31st May PHC deposition in those areas was not serious, but tarry oil had already entered the creek.

Subsequent local inquiries indicate that some of the mangrove areas are affected. Further detailed study is therefore necessary to delineate the impacts on the mangrove ecology and in the trends their recovery.

(f) Fishery

The trawl catch of commercially operating fishing trawler was examined on 28th May. There was neither any evidence of damage to the fish caught nor there were tar lumps, in the catch. The haul examined was dominated by eleven species of fishes and 4 species of prawns (Table 6.5). The catch composition was comparable to the baseline (Table 3.5).

Table 3.1 : Baseline water quality at Murud (1990-1992)

Parameters	Year	Station 1	Station 2	Station 3	Station 4	Station 5
Temp (⁰C)	90	25.2	25.0	25.7	25.3	25.4
	91	30.2	30.0	29.8	29.1	25.8
	92	28.1	28.0	27.4		
	Mean	26.2	27.7	27.6	27.2	27.1
Salinity x 10⁻³	90	36.2	36.1	35.2	35.1	35.1
	91	36.1	35.6	35.2	35.1	35.1
	92	36.8	36.1	36.2		
	Mean	36.4	35.9	35.5	35.1	35.1
pH	90	8.1	8.1	8.2	8.3	6.4
	91	7.6	7.9	7.9	7.9	7.9
	92	7.8	7.8	7.9	-	-
	Mean	7.8	7.9	8.0	8.1	8.2
Suspended solids (mg/l)	90	193	112	69	18	14
	91	76	36	1	19	15
	92	137	84	73		
	Mean	135	77	53	19	15

Dissolved oxygen (mg/l)	90	4.5	4.6	4.4	4.6
	91	4.2	4.0	4.1	3.8
	92	4.4	3.5	4.1	
	Mean	4.4	4.0	4.2	4.2
BOD (mg/l)	90	1.0	2.2	1.4	1.0
	91	3.0	0.9	1.0	1.2
	92	1.3	0.5	2.0	
	Mean	1.8	1.2	1.5	1.1
NO₃-N (µg/l)	90	23.5	192	280	91
	91	67	59	35	17
	92	238	328	123	
	Mean	180	193	146	54
NO₂ -N (µg/l)	90	17	10	15	13
	91	17	13		1
	92	7	6	2	
	Mean	14	10	6	7.0

NH₄⁺-N (µg/D)	90	7	10	13	3
	91	17	6	2	1
	92	15	36	4	
	Mean	13	17	6	2
PO₄⁻³-P (µg/l)	90	72	82	64	12
	91	66	43	11	8
	92	45	42	5	
	Mean	61	46	45	10
PHC (µg/l)	90	0.9	0.7	0.6	0.3
	91	3.9	0.8	2.0	ND
	92	3.4	0.4	1.6	
	Mean	2.7	0.6	1.4	0.2

Table 3.2 : Baseline biological characteristics (Phytoplankton) at Murud

Years	Chlorophyll <i>a</i> ($\mu\text{g}/\text{m}^3$)		Phaeophytin ($\mu\text{g}/\text{m}^3$)		Phytoplankton (no. $\times 10^3/\text{l}$)				Major species	
	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot
Station 1										
1990	2.1-3.9 (3.2)	0.9-2.8 (2.1)	1.6-8.1 (3.4)	2.1-8.0 (4.1)	-	-	-	-	-	-
1991	6.4-13.4 (8.4)	5.9-11.8 (8.5)	1.4-1.5 (1.4)	2.8-3.3 (3.1)	-	-	-	-	-	-
1992	2.7-4.8 (4.0)	7.0-4.8 (4.0)	0.8-4.7 (1.9)	0.7-1-4 (0.8)	-	-	-	-	-	-
Station 2										
1989	1.1-3.7 (2.0)	1.1-2.1 (1.5)	0.4-2.7 (1.6)	1.2-3.1 (1.9)	16.0-20.8 (18.3)	6.1-17.6 (12.4)	12-14 (13)	6-9 (8)	Pyxidicula sp. Peridinium sp.	Peridinium sp. Coscinodiscus sp.
1990	1.7-2.1 (1.8)	0.9-2.7 (1.6)	0.5-2.1 (1.3)	0.9-2.1 (1.3)	-	-	-	-	-	-
1991	2.1-11.2 (6.4)	3.2-5.3 (4.4)	0.1-0.1 (0.1)	0.2-0.2 (0.2)	-	-	-	-	-	-
1992	1.6-4.3 (3.0)	1.6-2.1 (1.4)	1.4-1.8 (0.7)	0.7-1.4 (0.8)	-	-	-	-	-	-
Station 3										
1989	1.6-2.1 (1.9)	1.6-2.1 (1.9)	0.1-1.0 (0.6)	0.9-1.0 (0.9)	12.5 (12.5)	8.2-18.2 (13.2)	8(8)	5-12	Peridinium sp. Coscinodiscus sp.	Skeletonema sp. Peridinium sp.
1990	0.5-0.5 (0.5)	0.5-0.8 (0.7)	0.2-2.1 (1.1)	1.0-1.6 (1.2)	-	-	-	-	-	-
1991	3.2-3.7 (3.7)	1.6-3.2 (2.4)	-	0.3 (0.3)	-	-	-	-	-	-
1992	2.1-2.1 (2.1)	1.1-1.6 (1.3)	-	-	-	-	-	-	-	-
Station 4										
1989	1.6-2.1 (1.9)	0.5-1.1 (0.8)	0.1-0.6 (0.4)	0.8-1.0 (1.0)	28.3 (28.3)	17.6 (17.6)	11-15 (13)	11	Skeletonema sp. Gyrodinium sp.	Chaetoceros Rhizosolenia sp.
1990	1.5-2.1 (1.8)	1.1-1.1 (1.1)	0.6-1.7 (1.2)	0.4-1.0 (0.7)	-	-	-	-	-	-
1991	1.6-1.6 (1.6)	1.6-2.1 (1.9)	1.0 (1.0)	0.6 (0.6)	-	-	-	-	-	-

Table 33: Baseline biological characteristics (zooplankton) at Murud

Year	Biomass ml/100	m ³	Population density no,10 ³ /100 m ³	Total groups	Major groups	
1990	2.1-26.1	(12.1)	19.0-150.7	(66.5)	14-17(16)	Copepods, chaetognaths, decapods, <i>Acetes</i> , mysids, <i>Lucifer</i> sp.
1991	1.4-30.7	(11.0)	1.6-4.8	(3.5)	12-14(13)	Copepods, decapods, <i>Lucifer</i> , sp, medusae.
1992	4.2-8.3	(5.7)	5.4-13.9	(11.2)	9-14 (11)	Decapods, mysids, copepods, chaetognaths, <i>Lucifer</i> SP.
1993	1.7-10.1	(6.9)	4.3-19.0	(12.3)	13-15(15)	Copepods, decapods, amphipods, chaetognaths, <i>Lucifer</i> sp.
<u>Station 2</u>						
1989	10.8-49.7	(24.9)	15.9-21.5	(18.1)	11-12(11)	Copepods, decapods, <i>Lucifer</i> sp., chaetognaths, ctenophores.
1990	1.9-5.3	(3.3)	6.3-25.1	(14.6)	16-17(17)	Copepods, decapods, chaetognaths, <i>Acetes</i> , medusae, <i>Lucifer</i> sp.
1991	3.7-35.7	(17.5)	2.3-5.8	(3.5)	9-11 (10)	<i>Lucifer</i> sp., copepods, decapods, fish eggs.
1992	1.5-3.2	(2.6)	3.2-17.1	(8.7)	10-13(11)	Copepods, decapods, chaetognaths, fish larvae, mysids.
1993	3.9-10.4	(6.1)	6.2- 12.3	(7.0)	11-11(11)	Copepods, decapods, amphipods, chaetognaths, <i>Lucifer</i> SP. stomatopods.
<u>Station 3</u>						
1989	43.4-63.9	(53.7)	1.2-59.0	(55.1)	15-16(16)	Copepods, chaetognaths, decapods, <i>Lucifer</i> sp., gastropods.
1990	8.1-25.5	(16.8)	16.2-19.8	(18.0)	14-15(15)	Copepods, decapods, chaetognaths, medusae, <i>Lucifer</i> sp.
1991	7.6-9.4	(8.6)	96.2-102.2	(99.2)	18-20(19)	Copepods, decapods, chaetognaths.
1992	0.5-1.0	(0.8)	3.4-3.4	(3.4)	11-12(12)	Copepods, decapods, chaetognaths, medusae, fish larvae.
1993	4.2	(4.2?)	8.8	(8.8)	12(12)	Decapods, copepods, acphipods, gastropods, chaetognaths.
<u>Station 4</u>						
1989	120.3	(120.3)	31.9	(31.9)	18(16)	Copepods, chaetognaths, ctenophores, siphonophores.
1990	8.0-30.5	(19.3)	38.7-55.3	(47.0)	16-18(17)	Copepods, chaetognathe, amphipods, medusae, decapods.
1991	3.5-4.4	(4.4)	4.0-13.8	(8.9)	18-20(19)	Copepods, fish eggs, siphonophores.

Table 4: Baseline biological characteristics (Macrobenthos) at Murud

Year	Biomass wet	Population .wt.g/m ²	Total groups No/m ² (No.)	Major groups
<u>Station 1</u>				
1989	-	-	-	-
1990	15.6	1715	7	Polychaetes, molluscs, crabs, amphipods.
1991	52.9	4252	4	Polychaetes, copepods, crabs.
1992	9.3	2475	7	Polychaetes, decapods, molluscs, mysids.
<u>Station 2</u>				
1939	0.1	275	1	Polychaetes
1990	3.1	713	6	Polychaetes, molluscs, amphipods.
1991	0.9	1113	2	Polychaetes.
1992	0.9	1002	4	Polychaetes, molluscs, amphipods.
<u>Station 3</u>				
1989	0.3	1177	4	Foraminiferans, polychaetes.
1990	0.5	1714	3	Foraminiferans, polychaetes.
1991	1.6	1526	4	Polychaetes, copepods.
1992	4.2	6076	6	Foraminiferans, polychaetes, molluscs.
<u>Station 4</u>				
1989	1.1	1790	8	Polychaetes, Foraminiferans, Copepods.
1990	3.0	3383	6	Foraminiferans, polychaetes, molluscs.
1991	24.4	4829	9	Polychaetes, molluscs, amphipods.
1992	-	-	-	-

Table 5: Baseline biological characteristics (Fishery) at Murud

Year	Sts	Catch (kg/hr)	Total species	Major species
1989	2	27.1	28	<u>Coilia dussumieri</u> , <u>Johnius dussumieri</u> , <u>Scolidon laticaudata</u> , <u>Harpodon nehereus</u> , <u>Pampus argenteus</u>
	3	29.0	20	<u>C. dussumieri</u> , <u>Squilla</u> sp., <u>J.dussumieri</u> , <u>S.laticaudata</u> , <u>Trichiurus savala</u>
1090	2	29.6	29	<u>Squilla</u> sp, <u>J.dussumieri</u> , <u>S. laticaudata</u> , <u>Exhippolysmata ensirostris</u> , <u>Parapenaeopsis</u> sp, <u>Panulirus polyphagus</u> , <u>Acetes</u> sp.
	3	16.7	13	<u>Squilla</u> sp, <u>S. laticaudatus</u> , <u>Neptuneus sanguinolentus</u> , <u>Johnius</u> sp, <u>C.dussumieri</u> , <u>Trichiurus haumela</u> , <u>P. argenteus</u> , <u>P. cinensis</u>
	4	14.7	22	<u>Squilla</u> sp, <u>S. laticaudatus</u> , <u>Charybdis annulata</u> , <u>N.sanguinolentus</u> , <u>T.savala</u> , <u>C. dussumieri</u> , <u>Exhippolysmata ensirostris</u> , <u>Parapenaeopsis</u> , <u>stylitera</u>
1991	2	22.9	26	<u>C.dussumieri</u> , <u>P.cninensis</u> , <u>P. argenteus</u> , <u>H.nehereus</u> , <u>J. glaucus</u> , <u>S. laticaudatus</u>
	3	33.7	25	<u>C. dussumieri</u> , <u>Solenocera</u> sp, <u>P. argenteus</u> , <u>P. chinensis</u> , <u>Squilla</u> sp, <u>Metapenaeus affinis</u>
	4	37.5	21	<u>C. dussumieri</u> , <u>H. nehereus</u> , <u>J. glaucus</u> & <u>Exhippolysmata ensirostris</u>

Table 6: Effects of oil in some major ecosystems

Ecosystems	Expected initial impact	Expected recovery
Open ocean	<p>Light: Impact on pelagic plankton dependent on chance event of contacting floating slick. Many organisms may avoid spill, surface dwellers may be affected. Not likely that oil would accumulate in open-ocean sediments to lethal or sublethal levels.</p>	<p>Fast: Rapid dispersion and degradation of oil. Effective reproduction and dispersal mechanisms for most pelagic organisms.</p>
Outer continental shelf	<p>Light to moderate: Impact on plankton populations light. Impact on spawning populations of fish larvae severe. Moderate impact on benthic systems if oil reaches bottom.</p>	<p>Fast to moderate: Fast recovery for plankton because of rapid regeneration times. Moderate recovery of benthic systems if oil reaches bottom.</p>
Open estuarine areas, bays, channels and harbours	<p>Moderate to heavy: Chronic oil may depress populations of fish and some benthos, or induce changes in species abundance and distributions. Spilled oil affects dependent on time of year (spawning, migration, etc) and oil's persistence.</p>	<p>Fast to slow: Dependent on flushing characteristics, route to benthos, shoreline characteristics and community stability. Individual year, classes of larval fauna may be severely affected.</p>
Wetlands, marshes and mangroves	<p>Heavy: Potential serious threat as result of vulnerability to spills and significance of estuarine functions (nursery and breeding grounds; high productivity). Faunal mortalities leading to decrease in population density, changes in species abundance and distribution. Damage to marsh grasses after repeated exposure and decrease in productivity. Damage to mangroves and neighbouring grasses</p>	<p>Moderate to slow: Persistence of oil in sediments prolongs toxicity. Once oil is removed, biological succession may be moderate in some areas, since organisms generally reproduce and disperse fairly rapidly. Mangrove swamps particularly complex and may take long to recover. Marsh areas may be affected for many years.</p>

continued...2

Ecosystem	Expected initial impact	Expected recovery
Coral reefs	Unknown: Some reports of lethal and sublethal damage.	Unknown: Recover could be slow because of structural complexity of coral communities
Polar ecosystems	Unknown: Some reports of effects of arctic lakes and on individual organisms	Unknown: Recovery could be slow since spilled oil may persist longer at colder temperatures and since polar organisms have slower growth rates. Extended life cycles, longer reproductive periodicity and narrower-ranging dispersal stages. However, recovery may be more rapid because organisms have already adapted to harsh conditions.

Table 4.2: Effects of oil on marine populations and communities.

Community or population type	Expected degree of initial impact	Expected recovery rate
Plankton	Light to Moderate	Fast to Moderate
Benthic communities		
Rocky intertidal	Light	Fast
Sandy or muddy intertidal	Moderate	Moderate
subtidal, offshore	Heavy	Slow
Fish	Light to Moderate	Fast to Moderate
Birds	Heavy	Slow
Marine mammals	Light	Slow, If population, seriously affected.

Table 6.1 : Water quality of Murud during May 1993

Date	Station	Time	Depth (m)	Sample level*	AT (°C)	WT (°C)	pH	DO (ml/l)	BOD (ml/l)	S x10 ⁻³	PO ₄ ³⁻ -P (ug/l)	NO ₂ ⁻ -N (ug/l)	NO ₃ ⁻ -N (ug/l)	NH ₄ ⁺ -N (ug/l)	PHC (g/l)
27.5.93	1	1900	6	S	33.1	32.5	8.1	4.8		35.7	7A	4	60	5	0.5
	2	1730	10	S	32.8	32.2	8.0	4.9		35.C	27	5	46		0.6
28.5.93	2	1630	12	S	32.5	33.0	8.4	1.8	0.3	35.9	18	2	42	1	6.4
				B		33.0	8.3	1.4	1.4	35.9	52	10	86	4	
	3	1315	14	S	32.0	31.2	8.4	4.7	5.2	36.4	7	1	7	3	14.0
				S		31.5	8.5	4.6	3.4	35.0	19	2	14	2	
	4	1430	16	S	34.0	32.5	8.3	2.3	0.8	36.2'	15	3	20	1	10.5
				B		32.5	8.3	2.2	0.1	36.0	16	6	53	ND	
29.5.93	1	1445	6	S	32.5	33.1	8.1	3.9		35.7	35	14	50	2	197
				B		33.3	8.2	3.9		35.5	34	13	37	7	
	2	1400	10	S	32.6	33.0	8.0	4.3	4.2	35.7	17	3	50	3	64.2
				B		33.0	7.9	4.6	6.0	35.7	42	11	76	5	
	3	1300	12	S		39.0	8.4	4.S	4.9	35.7	42	3	44	5	334S
				B	32.5	33.2	8.3	4.3		35.7	41	6	61		
2													4	224	
30.5.93	1	1000	6	S		32.0	8.1	3.9		35.7	3	S	59		84.2
				B	32	32.1	8.1	4.5		35.7	37	13	47		

S - surface; B - bottom; AT - air temperature; Wt - water temperature; DO - dissolved oxygen; S - salinity; PHC - petroleum hydrocarbon residue

•Sample for PHC collected at 1mbelow the sea surface.

Table 6.2 : Distribution of phytoplankton pigments and population at Murud

Stn	Date (Time)	Tide	Sampling (Depth)	Chl. a (mg/m ³)	Phaeo- phytin, (mg/m ³)	Phyto- plankton cell counts,	Total species	Major species	Remarks
2	27.5.93	Eb	Surface	0.5	2.1	190	23	<u>Nitzschia</u> sp. <u>Navicula</u> sp. <u>Nitzschia pungens</u> , <u>Rhizosolema</u> sp. <u>Thallossirea dicipiens</u>	Normal
2	28.5.93 (1600)	Fl	Surface	2.7	1.1 <u>Chaetoceros</u>	196	22	<u>Nitzschia</u> sp. <u>N.pungens</u> , <u>Navicula</u> sp. sp.	Normal
2	28.5.93 (1600)	Fl	Bot	2.14	2.3				
2	29.5.93 (1400)	Fl	Surface	1.1	N.D.	152	25	<u>Nitzschia</u> sp, <u>N.pungens</u> , <u>R.stolterfothi</u> , <u>Rhizosolenia</u> sp. <u>R.setigera</u> , <u>Coscinodis</u> us sp. <u>Chaetoceros</u> sp.	2S*
2	29.5.93 (1400)	Fl	Bot	0.5	2.1	65	22	<u>Nitzschia</u> sp, <u>N.pungens</u> , <u>Thallossionema</u> <u>nitzshoids</u> , <u>Coscinodiscs</u> sp and <u>Navicula</u> sp.2B*	
2	30.5.93	Fl	Surface	2.7	6.3	-			
2	30.5.93	Fl	Bot	1.1	4	-			
2S*	Few species of Nitzschia were noticed as damaged and coated by their black layer.								
2B*	Few species of Nitzschia were noticed as damaged.								
3	28.5.93 (1300)	Fl	Surface	1.0 <u>Ditylum</u> ,	1.2	14	22	<u>Nitzschia</u> sp. <u>Trichodesmiur</u> sp. <u>Brightwellii</u> , <u>Rhizosolenia</u> sp.	3AS*
3	28.5.93 (1300)	Fl	Bot	1.1	0.8	15.2	15	<u>Nitzschia</u> sp. <u>Rhizosolenia</u> sp. <u>Thallossionema nitzschoides</u> , <u>Chaetoceros</u> sp.	3AB*

Table 1 (contd)

3	29.5.93 (1300)	F1	Surface	5.3	ND	280	42	<u>Ditylum brightwelli</u> <u>Asterionella japonica</u> , <u>Nitzschia bungens</u> , <u>Nitzschia sp.</u> , <u>Chaetoceros sp.</u>	3S*
3	29.5.93 (1300)	F1	Bottom			40	16	<u>Nitzschia sp.</u> , <u>Rhizosolenia sp.</u> , <u>R. setigera</u> , <u>Ditylum brightwelli</u>	Normal
4	28.5.93 (1430)	F1	Surface	3.74		6.40	21	<u>Nitzschia pungens</u> , <u>Nitzschia sp.</u> , <u>Trichodesmium sp.</u> , <u>Synedra sp.</u> , <u>Coscinodiscus sp.</u>	Normal

3AS* Few species of Ditylum brightwellii, Trichodesmium sp, Rhizosolenia sp, Surirella sp, Chaetoceros, Nitzschia clostrium were noticed as damaged and coated with black residue.

3AB* Few species of Ditylum brightwellii and Chaetoceros were noticed as damaged.

3S* Chaetoceros sp., Biddulphia sinensis were noticed as damaged and coated with this black layer.

Table 1 (contd)

1	27.5.93	Eb	Surface	3.7	1.5	68	6	<u>Nitzschia</u> sp, <u>Rhizosolenia</u> sp, <u>Coscinodiscus</u> sp, <u>Pleurosigma</u> sp.	Normal
1	29.5.93 (1445)	Fl	Surface	3.2	N.D	80	18	<u>Nitzschia</u> sp, <u>N.cloesterium</u> , <u>N.pleupens</u> , <u>Skeletonema costatum</u> , <u>Rhizosolenia</u> sp.	1B*
1	29.5.93 (1445)	Fl	Bot	2.7	5.6 <u>Coscinodiscus</u>	8.0	9	<u>Nitzschia</u> sp, <u>Pleurosigma</u> sp, sp, <u>Thalassiosira</u> sp.	Normal
1	30.5.93	Fl	Surface	2.1	0.1	17	15	<u>Nitzschia</u> sp, <u>N.pungens</u> , <u>Rhizosolenia</u> sp, <u>Pleurosigma</u> sp, <u>Oscillatoria</u> sp.	1S*

1B* Few species of Nitzschia, Cloestarium and Pleurosigm, v.tre noticed as damaged.

1S* Few species of Nitzschia, Rhizosolenia & Ditylum brigwelli were noticed as damaged.

Table 6.3: Distribution of zooplankton at Murud

S t n	Date & Time	Tide	Biomass ml/100m ³	Population Density no. x10 ³ /100 m ³	Tot al gro ups	Faunal composition %	Remark
2	27.5.93	F	6.9	31.5	16	Copepods (79.61), decapod larvae (5.1), chaetognaths (4.76), fish eggs (1.7), lamellibranchiates (1.7), <u>Acetes</u> sp. (1.36), medusae (1.02), <u>Lucifer</u> sp. (1.02), gastropods (1.02), fish larvae (0.68), appendicularians (0.68), siphonophores (0.34), stomatopod larvae (0.34), cephalopods (0.01)	Normal distribution
2	28.5.93 (1600)	F1	3.4	19.7	11	Copepods (75.21), appendicularians (9.72), decapod larvae (5.71), fish eggs (4.67), medusae (1.56), chaetognaths (1.56), <u>Lucifer</u> sp. (1.04), lamellibranchiates (0.52), ctenophores (0.01), polychaetes (0.01), amphipods (0.01)	Chaetognaths species with black residue in gut
2	29.5.93 (1130)	F1	11.2	46.1	10	Copepods (75.63), medusae (14.57), decapod larvae (4.20), ctenophores (1.68), <u>Lucifer</u> sp. (1.12), fish eggs (1.12), chaetognaths (0.84), appendicularians (0.56), gastropods (0.26), polychaetes (0.01)	Few decapod and chaetognaths and <u>Lucifer</u> sp., copepods are with black residue in body
2	29.5.93 (1400)	F1	17.5	46.7	10	Copepods (69.95), medusae (16.46), ctenophores (5.14), decapod larvae (4.11), <u>Lucifer</u> sp. (2.06), chaetognaths (1.44), fish eggs (0.62), gastropods (0.21), amphipods (0.01), fish larvae (0.01)2

S t n	Date & Time	Tide	Biomass ml/100m ³	Population Density no.x10 ³ /100 m ³	Tot al gro ups	Faunal composition %	Remark
2	30.5.93 (1530)	F1	2.9	7.3	11	Copepods (48.7), <u>Lucifer</u> sp. (21.92), gastropods (14.61), decapod larvae (9.74), lamellibranchiates (1.94), medusae (0.97), chaetognaths (0.97), mysids (0.97), fish larvae (0.07), polychaetes (0.05), isopods (0.04)	Damaged & dead <u>Lucifer</u> sp.
3	28.5.93 (1300)	F1	6.9	38.4	10	Copepods (95.88), decapod larvae (1.57), siphonophores (0.63), <u>Lucifer</u> sp. (0.63), chaetognaths (0.32), amphipods (0.32), lamellibranchiates (0.32), appendicularians (0.32), fish eggs (0.02), polychaetes (0.01)	Damaged & dead chaetognaths (40-50%), Damaged & dead <u>Lucifer</u> sp. (40-50%), Damaged & dead decapod larvae (5-10%), <u>Acetes</u> sp. (80-90%)
3	29.5.93 (1300)	F1	4.2	33.1	9	Copepods (86.19), fish eggs (7.43), appendicularians (2.92), decapod larvae (2.65), medusae (0.27), <u>Lucifer</u> sp. (0.27), fish larvae (0.27), cladocera (0.01), stomatopod larvae (0.01)	Few damaged & dead chaetognaths & <u>Lucifer</u> sp.
4	29.5.93 (1445)	F1	4.7	48.1	9	Copepods (95.8), decapod larvae (2.38), chaetognaths (0.72), appendicularians (0.72), medusae (0.48), siphonophores (0.24), gastropods (0.24), fish eggs (0.02), polychaetes (0.01)	Damaged & dead chaetognaths, <u>Lucifer</u> sp., <u>Acetes</u> sp., Fish larvae, Few copepods with oil residue

S t n	Date & Time	Tide	Biomass ml/100m ³	Population Density no.x10 ³ /100 m ³	Tot al gro ups	Faunal composition %	Remark
1	27.5.93	Eb	52.9	41.7	11	Copepods (76.61), Acetes sp. (8.06), decapod larvae (5.38), <u>Lucifer</u> sp. (3.5), chaetognaths (3.2), mysids (0.81), fish larvae (0.81), medusae (0.54), gastropods (0.54), fish eggs (0.54), isopods (0.01)	Normal with big fish larvae
1	29.5.93 (1445)	F1	21.4	22.9	12	Copepods (53.9), ctenophores (17.65), medusae (8.49), decapod larvae (6.54), gastropods (4.9), <u>Lucifer</u> sp. (3.27), chaetognaths (1.96), mysids (1.31), lamellibranchiates (0.98), polychaetes (0.33), fish eggs (0.33), fish larvae (0.33)	Swarming of ctenophores
1	30.5.93 (0955)	Eb	74.4	52.9	11	Copepods (41.94), <u>Lucifer</u> sp. (27.21), decapod larvae (15.19), mysids (8.61), ctenophores (3.4), gastropods (2.27), medusae (0.68), lamellibranchiates (0.45), chaetognaths (0.23), fish eggs (0.01), fish larvae (0.01)	
1	30.5.93 (1700)	F1	4.2	14.2	10	Copepods (52.07), <u>Lucifer</u> sp. (13.02), mysids (10.42), decapod larvae (7.81), gastropods (7.81), lamellibranchiates (3.64), medusae (2.60), chaetognaths (2.08), ctenophores (0.52), fish larvae (0.02).	

Table 6.4: Macrofauna] polulation (no/m²)
and biomass (g/m²).

Groups	Station 2	Station 3	Station 4
Polychaetes	5350	1175	1600
Foraminiferans		9250	9500
Amphipoda	50	75	100
Copepoda	100	50	100
Tanaidacea	100		
Mysids		25	
Crustacean larvae		25	
Seapen			25
Molluscs			125
Miscellaneous			25
Total Population	5600	10600	11475
Biomass	(19.23)	(3.74)	(11.29)

Table 6.5 : Trawl catch of fishes at Murud

Stn. Date/Time	Total catch Kg/h	No. of species	Species
2 to 3 (1430) P - 4	28.5.93	65	F-11
	O-1		
			<u>Johnius glaucus</u> , <u>Coilia dussumjeri</u> <u>Scoliodon laticaudus</u> , <u>Thryssa mystax</u> , <u>Harpodon nehereus</u> , <u>Osteogenejosus</u> <u>militaris</u> , <u>Otolithoides biauritus</u> , <u>Trichiurus haumela</u> , <u>Lepturacanthus</u> <u>savala</u> , <u>Congresox talabonoides</u> , Scomberoidae sp., Acetes, Prawns: <u>Parapenaepsis styliferus</u> , <u>Metapenaeus affinis</u> , <u>Exhippolysmata</u> <u>ensirostris</u> , <u>Solenocera</u> sp., Juveniles of metapenaeus and parapenaepsis.

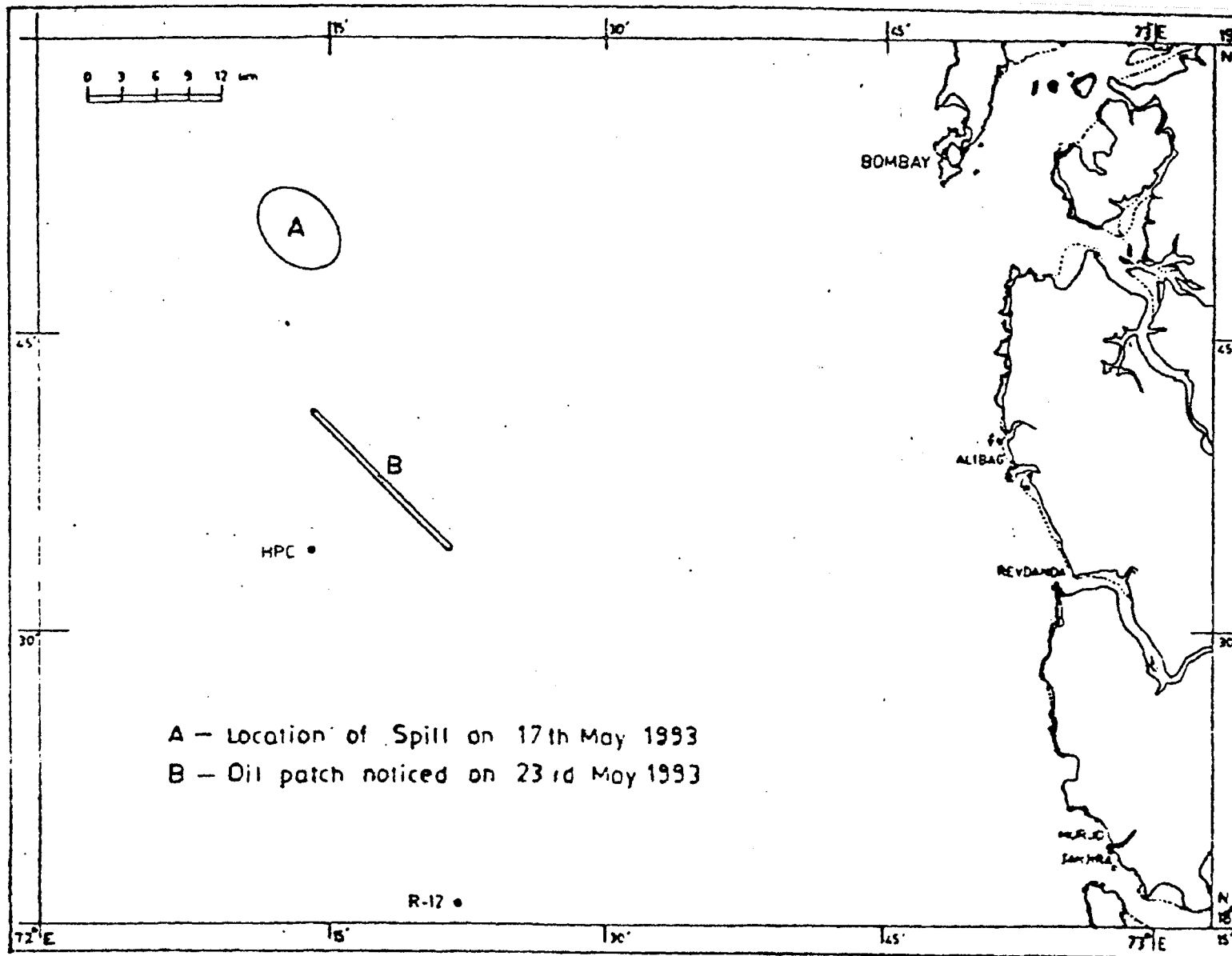


Fig 1.1 Position of oil Spill in Bombay High

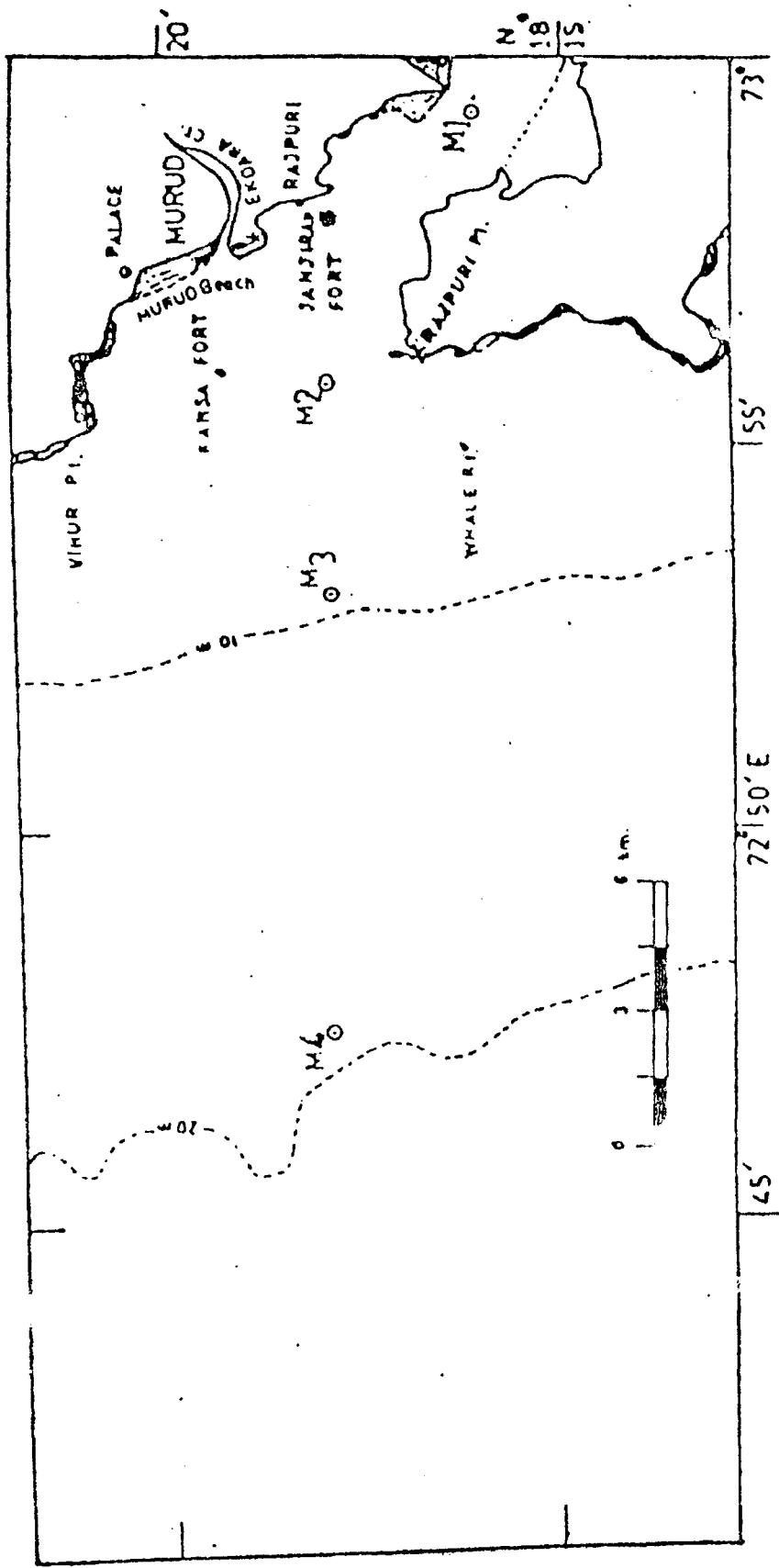


Fig.3-1 Location of stations off Murud

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The conclusions given below are based on the basis of short term limited studies undertaken in Bombay High and coastal marine environment of Murud. Hence the conclusions are primarily suggestive of their prevailing conditions and indicate only immediate observed impacts. To enable reliable longterm predictions and assessments of environmental degradation and damages to biota and their recovery detailed planned investigations are required to be undertaken.

- a) The accidental spillage of crude oil spilled in Bombay High on 17th May 1993 was estimated between 3000 - 6000 tonnes. Under the prevailing environmental conditions it was considered that around 40% of the spill (1500 - 3600 tonnes) would have evaporated within a couple of days. The remaining viscous mass would undergo further weathering and degradation with the passage of time. As the high toxicity of crude oil is largely associated with the volatile aromatic fractions, the residual tarry material is not likely to cause large scale long terms environmental damage in the open sea, though nearshore benthic organisms and intertidal may be at risk.

- b) The observed concentrations of floating and dissolved / dispersed petroleum residues in certain areas of Bombay

High far exceeded the expected background.

- c) Localized impacts in terms of decrease in its rate of primary productivity and changes in the composition of zooplankton were evident.
- d) The predicted oil spill movement indicated probable vulnerability of coastal region between Bombay and Goa during May - September with high probability of contamination of Murud-Janjira coastal belt during May.
- e) Weathered crude contaminated the nearshore waters of Murud on 28th May in the form of a large number of oily patches of varying sizes severely affecting the seasonal tourist industry. The Murud beach and adjacent rocky shores were heavily oiled on the 29th May (morning) with deposits as high as 35 kg/cm^2 on the beach. The beach alone was estimated to have an overburden of over 1000 tonnes of the tarry residue. The oil which entered the adjacent creeks, oscillated up and down the creeks with tidal movement and was ultimately trapped in the interior tidal marshes some of which harboured extensive mangroves. The oyster beds around the rocky shores were also affected.
- g) The beach tar melted under the summer heat and

percolated into the sand spreading the contamination at least upto 5 cm below surface.

- h) Although only Murud coast was monitored, the beaches upto at least 30 km south also had heavy tarry deposits.
- i) The approaching tarry patches caused considerable deterioration in water quality and localised damages to plankton. The fishery however did not seem to have affected.

RECOMMENDATIONS

- a) Non-availability of reliable baseline during different seasons for Bombay High as well as for the vulnerable coastal regions was glaringly evident during the present study. A long-term study to evolve the baseline with respect to water quality sediment quality and biological characteristics should be initiated forthwith. Such a study should take into account seasonal changes as well as natural vulnerability in Bombay High coastal waters and intertidal flora and fauna.
- b) It was evident that local damage was observed in the areas of investigation. It is therefore essential that studies of recovering of damaged flora and fauna including vital intertidal and sub-tidal areas are

undertaken. This will evolve understanding of the impacts and recoveries of tropical ecosystems due to oil spills which is largely lacking and will serve as an important source of information in future.

- a) Impact of Bombay High crude and its weathered products on detected biota at different trophic levels should be studied through laboratory simulation experiments.

- d) Chemical dispersants and formulations frequently used in the combating operations are sometimes known to cause more harm to ecology than crude oil itself. Hence, all dispersants should be strictly tested for its toxicity to tropical marine organisms prior to bulk procurement. Test samples from the bulk stored, should also be occasionally tested for toxicity to ascertain that the stock supplied is similar to the sample tested.

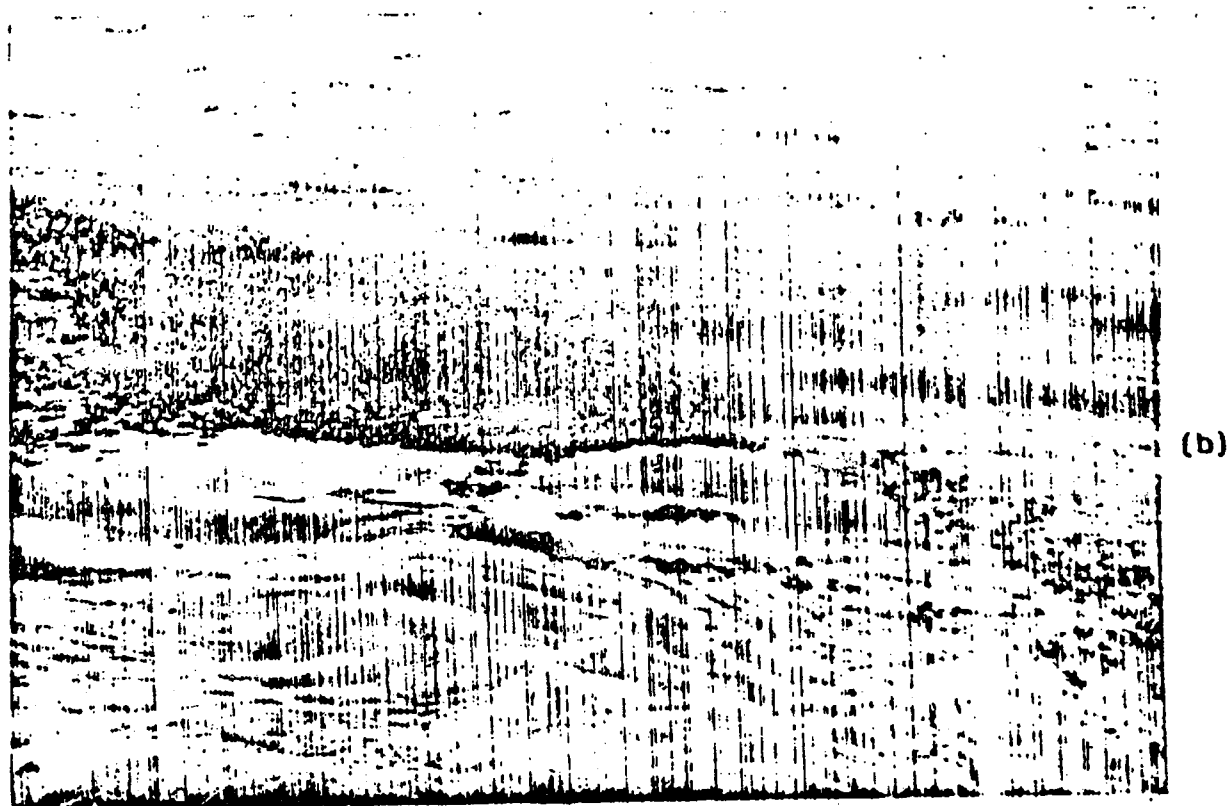
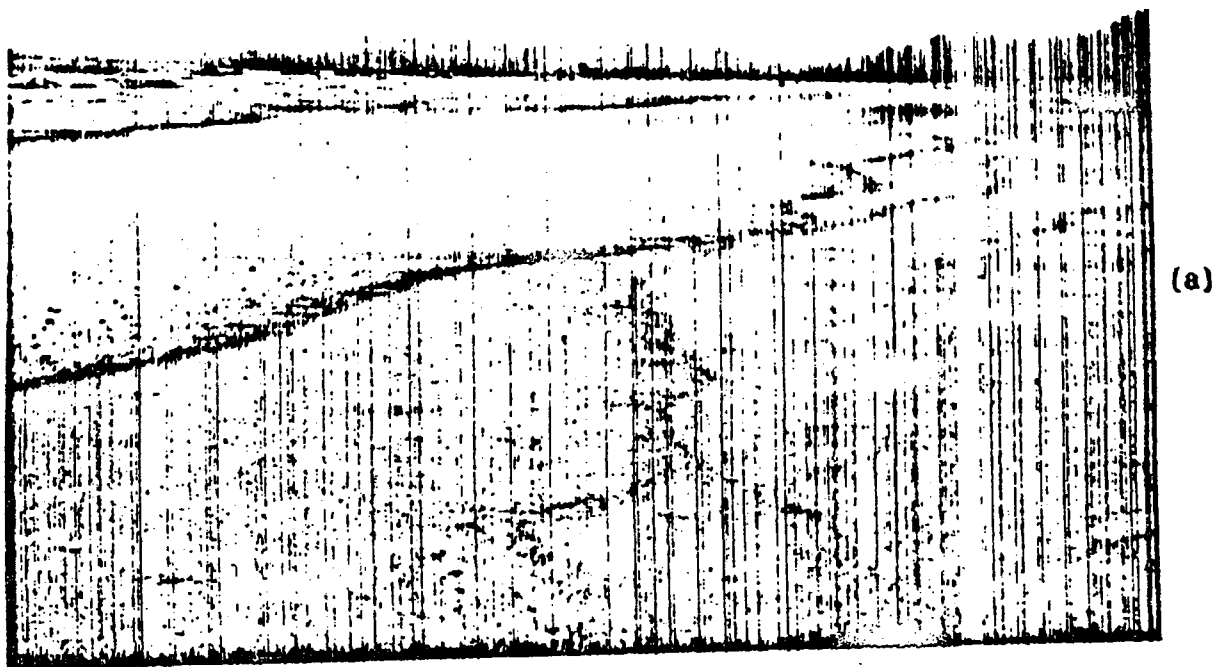


Plate 1 : (a) Beginning of PHC deposition on Murud beach on 23.5.93

(b) Emulsified floating PHC about 2 km off Murud beach on 29.5.93

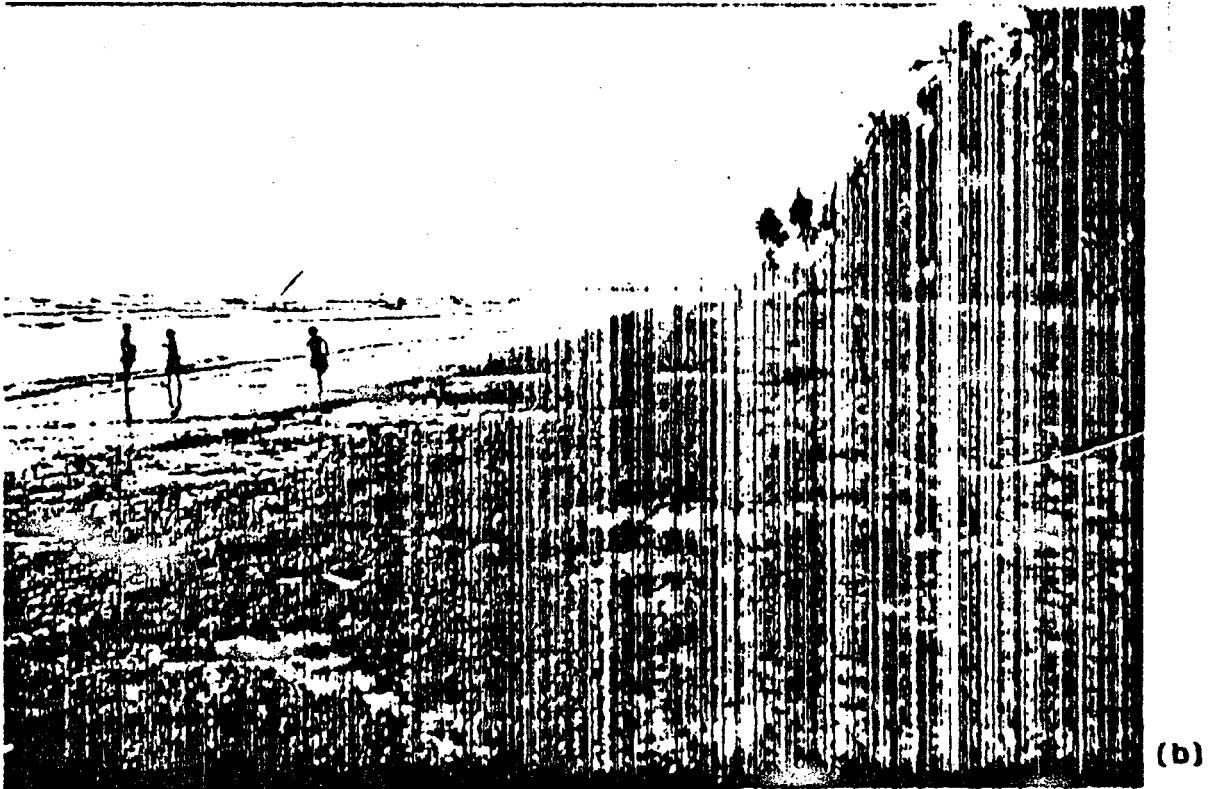
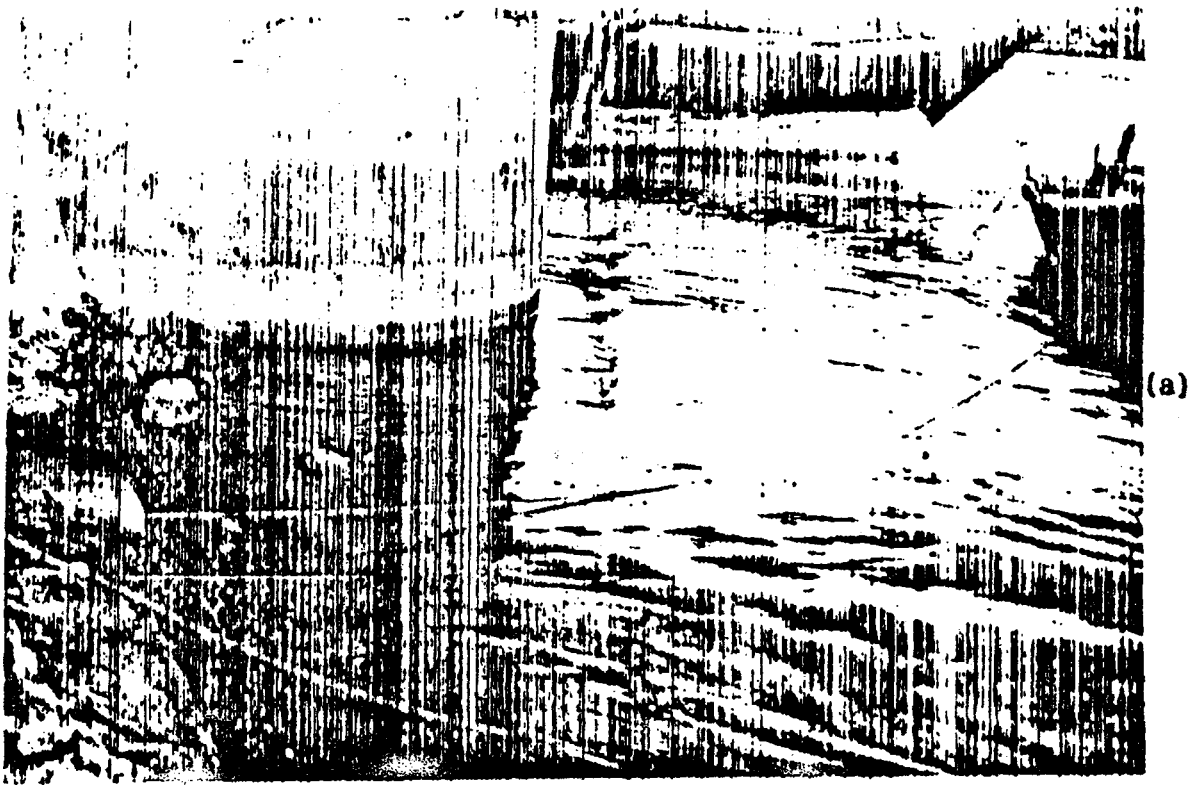


Plate 2 : (a) PHC entering Ekdara creek during high tide on 29.5.93
(b) Heavy PHC deposits on Murud beach on 29.5.93

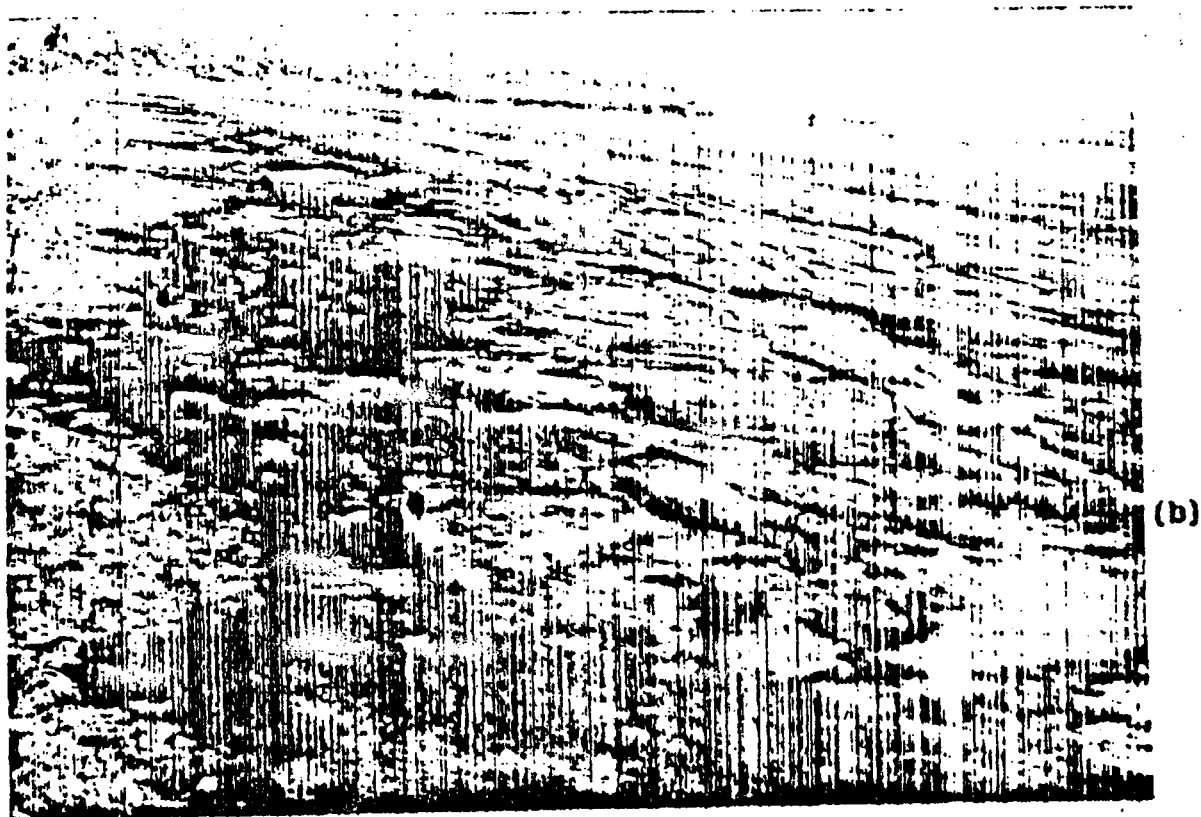


Plate 3 (a) PHC on Murud beach being sampled for further analysis.
(b) Under blazing sun the PHC melted was partly soaked into sand and partly washed to sea during low tide on 30.5.93.

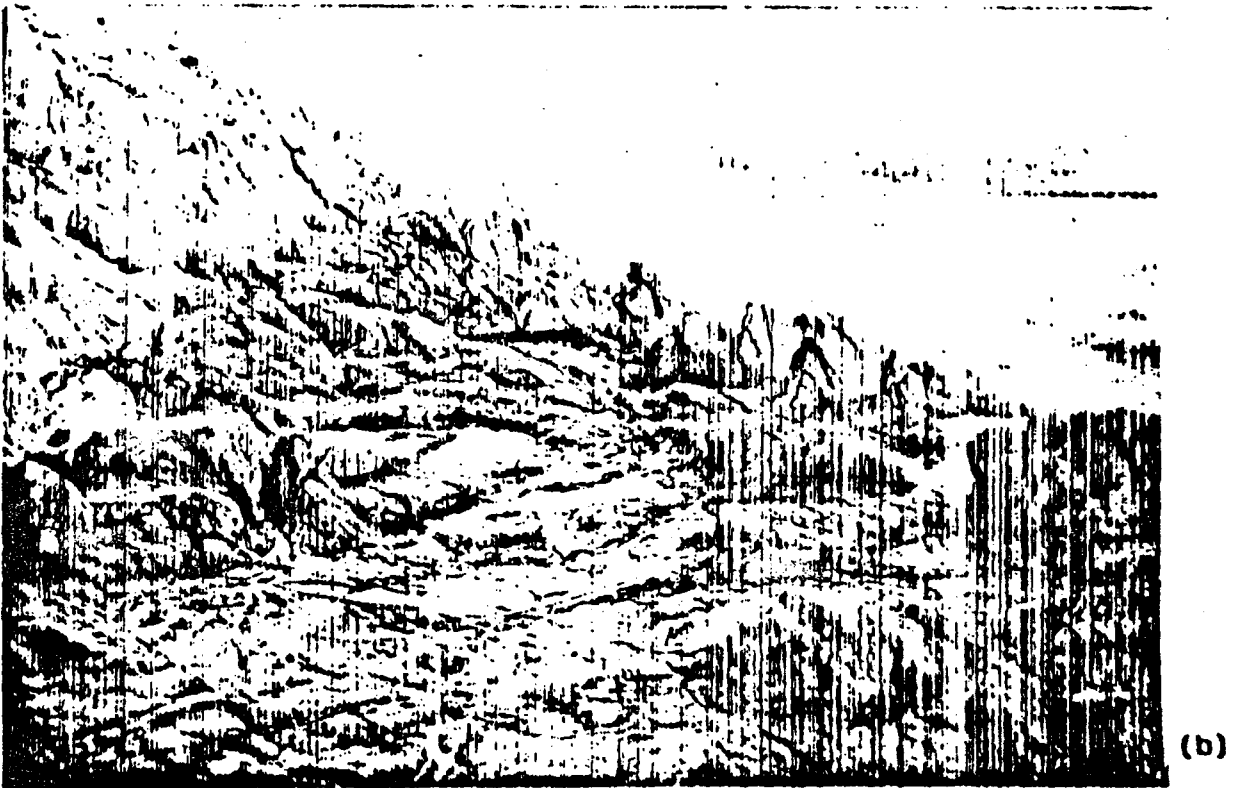
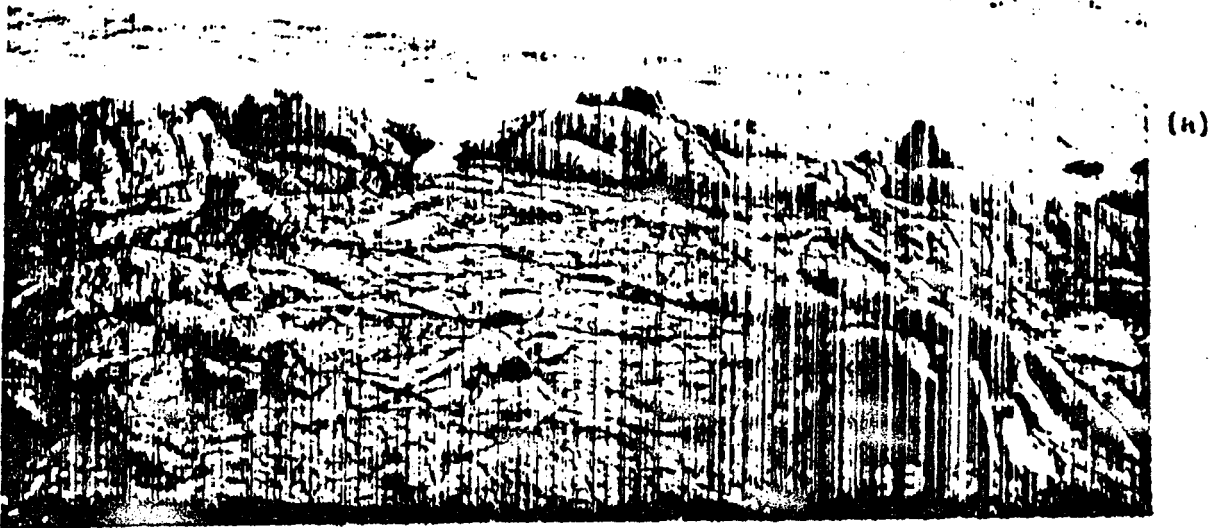
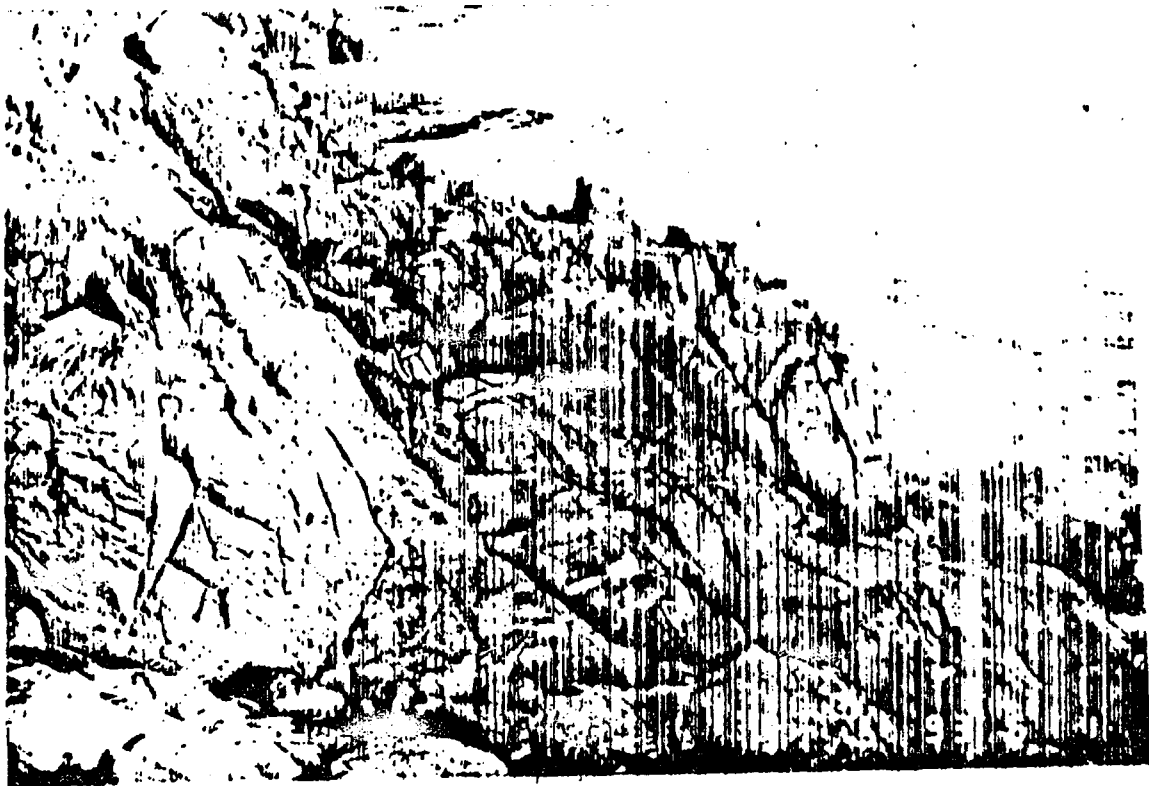


Plate 4 : (a) & (b) PHC got trapped in rocky pools on 1.6.93



(a)



(b)

Plate 5 : (a) & (b) Intertidal rocks fully covered with PHC on 1-6-93