Six Monthly Compliance report

DAHEJ HARBOUR AND INFRASTRUCTURE LIMITED

For

April 2026 to September 2026

DAHEJ HARBOUR AND INFRASTRUCTURE LIMITED
PO: Dahej, DAHEJ
DIST: BHARUCH - 392 130
GUJARAT, INDIA

DAHEJ HARBOUR AND INFRASTRUCTURE LIMITED

Letter Ref: DHIL/BC/ENV/I/15040/2026-27/080

Date: 16th November 2026
PCB ID: 15040

The Regional Office,
Ministry of Environment Forests & Climate Change (MoEF & CC)
"KARMAYOGI BHAWAN" Block no -3, F-2 Wing Fifth Floor
Near CH-3 circle, Sector-10A, Gandhi Nagar-382010

Sub: Half-Yearly EC Compliance report for the period from April 26 to September 26

Ref.: 1. Environmental Clearance for Copper smelter and jetty facilities Dahej vide letter No.11011/7/94-IA II dated 14-03-1995.
2. Environment clearance for approval of construction of approach bund for Copper Smelter project at Dahej vide letter no. J-17011/18/93-IA.III dated 12-01-1996 letter No. J-11011/ 7/94-IAII(I) dated 03-01-2000.

Respected Sir,

With reference to the above subject, we are submitting herewith the Half Yearly EC Compliance Report of **M/s Dahej Harbor and Infrastructure Limited** P.O. Dahej, Lakhigam, Dist. Bharuch, Gujarat, for the period from April 26 to September 26 for your kind perusal please.

The receipt of the report may kindly be acknowledged.

Yours faithfully,
For Dahej Harbour and Infrastructure Ltd.

Krishnaraju Kumaravel
(President & Unit Head)

Encl: as above
CC:

1. Member Secretary, Gujarat Pollution Control Board, Paryavaran Bhavan, Sector -10 A, Gandhinagar - 382 010
2. Regional Officer, Gujarat Pollution Control Board, Bharuch 392001
3. Member Secretary, CPCB Parivesh Bhawan, East Arjun Nagar Delhi - 110032
4. Regional Director CPCB, Zonal office, Parivesh Bhawan, Atmajyoti Ashram Road, Opp. VMC office ward no.10 Subhanpura Vadodara-Gujarat-390023
5. The Director (Monitoring Cell), Ministry of Environment, Forest & Climate Change, IPB, Aliganj, Jorbagh Road, New Delhi – 110003

Registered Office : P.O. Dahej, Lakhigam, Dist. Bharuch, Gujarat – 392 130, INDIA Tel: 91-02641–256004-6 Fax : 91–02641–251012,251024,251002,251003
Corporate Office : Aditya Birla Centre, 3rd Floor, B Wing, S.K.Ahire Marg, Worli, Mumbai, 400 025, INDIA. Tel: 91–022–56525800, 56525000 Fax: 91–022–56525801, 24995801-2

Dahej Harbour and Infrastructure Ltd
P. O. Dahej, DAHEJ

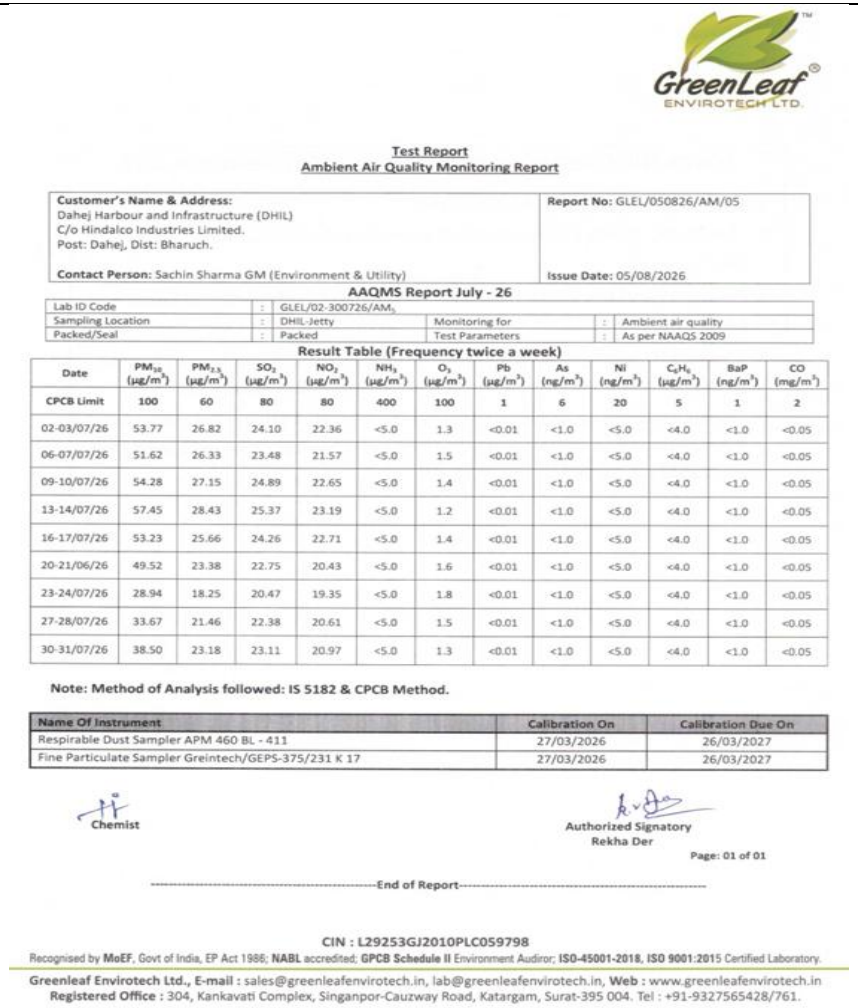
Compliance to conditions of Environmental Clearance for Copper smelter and Jetty facilities Dahej

vide letter no.11011/7/94-IA II dated 14-03-1995.

(Half Yearly compliance report from April 26 to September 26)

Sr. No	Details of condition	Compliance status
i	The project authority must strictly adhere to the stipulations laid down by the State Pollution Control Board and the State Govt.	**Complied.** The unit has already obtained a valid Consent to Establish & Operate (CC&A) from the Gujarat Pollution Control Board vide Consent Order No. AWH-149225 dated 04.10.2025, which is valid up to 19.08.2031. A copy of the latest CC&A is enclosed as **Annexure-1.** The unit complies with all specific and general conditions stipulated under the CC&A, including provisions related to air pollution control, water pollution control, and hazardous waste management. Compliance is maintained through adherence to the requirements of GPCB, the State Government, and other statutory authorities, ensuring effective environmental management and regulatory compliance
ii	Any expansion of the plant either with the existing product mix or new products can be taken up only with the prior approval of this Ministry.	**Complied** The condition is noted and shall be strictly complied with. Any expansion of the plant, whether involving the existing product mix or introduction of new products, will be undertaken only after obtaining prior approval from the Ministry and other concerned statutory authorities, as applicable.
iii	Comprehensive EIA report for the proposed copper smelter and captive jetty facilities should be submitted within 15 months.	**Complied.**

		The company had submitted a comprehensive Environmental Impact Assessment (EIA) Report for the Copper Smelter and Captive Jetty facilities on 25.08.1996. The stipulated condition has been complied with.
iv	The gaseous emissions from various process units should confirm to the standards prescribed by the concerned authorities from time to time. At no time the emission level should go beyond the stipulated standards. In the event of failure of any pollution control system adopted by the units, the respective unit should be put off operation immediately and should not be restarted until the control measures are rectified to achieve the desired efficiency.	**Complied.** There are no process units at the Captive Jetty that generate gaseous emissions; therefore, compliance with gaseous emission standards is not applicable to jetty operations. The compliance requirements related to gaseous emissions are being addressed under the Environmental Clearance (EC) conditions applicable to **Hindalco Industries Limited (Birla Copper Unit)** and its associated process facilities, where the relevant emission control and monitoring systems are in place.
v	Adequate number of ambient air quality monitoring station should be set up in the down wind direction as well as where maximum ground level concentration is anticipated, especially covering the human settlements for the estimation of particulates, fluoride dust SO2, etc. in consultation with the SPCB. Monitoring network should be designed taking into consideration the existing land-use pattern, location of stacks, meteorological condition and topographic features including existing ambient air quality data.	**Complied.** The Environmental Clearance covers both the Copper Smelter Complex and Captive Jetty operations. Ambient Air Quality Monitoring (AAQM) is being carried out as part of the EC compliance of Hindalco Industries Limited (Birla Copper Unit). In addition, one Ambient Air Quality Monitoring Station has been installed at the Jetty approach road for monitoring ambient air quality in the jetty area. The monitored data is regularly submitted to MoEF&CC, CPCB, and GPCB as part of the statutory compliance requirements. Further, monthly ambient air quality monitoring is also conducted through a NABL-accredited and MoEF&CC/GPCB-approved laboratory. A sample copy of the Ambient Air Quality Monitoring Report for the Jetty area for the month of July 2026 is enclosed below for reference.



Test Report
Ambient Air Quality Monitoring Report

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post: Dahej, Dist: Bharuch. **Contact Person:** Sachin Sharma GM (Environment & Utility)	**Report No:** GLEL/050826/AM/05 **Issue Date:** 05/08/2026

AAQMS Report July - 26

Lab ID Code	:	GLEL/02-300726/AM$_5$			
Sampling Location	:	DHIL-Jetty	Monitoring for	:	Ambient air quality
Packed/Seal	:	Packed	Test Parameters	:	As per NAAQS 2009

Result Table (Frequency twice a week)

Date	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (µg/m^3)	NO_2 (µg/m^3)	NH_3 (µg/m^3)	O_3 (µg/m^3)	Pb (µg/m^3)	As (ng/m^3)	Ni (ng/m^3)	C_6H_6 (µg/m^3)	BaP (ng/m^3)	CO (mg/m^3)
CPCB Limit	100	60	80	80	400	100	1	6	20	5	1	2
02-03/07/26	53.77	26.82	24.10	22.36	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
06-07/07/26	51.62	26.33	23.48	21.57	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
09-10/07/26	54.28	27.15	24.89	22.65	<5.0	1.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
13-14/07/26	57.45	28.43	25.37	23.19	<5.0	1.2	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
16-17/07/26	53.23	25.66	24.26	22.71	<5.0	1.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
20-21/06/26	49.52	23.38	22.75	20.43	<5.0	1.6	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
23-24/07/26	28.94	18.25	20.47	19.35	<5.0	1.8	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
27-28/07/26	33.67	21.46	22.38	20.61	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
30-31/07/26	38.50	23.18	23.11	20.97	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05

Note: Method of Analysis followed: IS 5182 & CPCB Method.

Name Of Instrument	Calibration On	Calibration Due On
Respirable Dust Sampler APM 460 BL - 411	27/03/2026	26/03/2027
Fine Particulate Sampler Greintech/GEPS-375/231 K 17	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

Page: 01 of 01

----------End of Report----------

CIN : L29253GJ2010PLC059798
Recognised by **MoEF**, Govt of India, EP Act 1986; **NABL** accredited; **GPCB Schedule II** Environment Auditor; **ISO-45001-2018, ISO 9001:2015** Certified Laboratory.
Greenleaf Envirotech Ltd., E-mail : sales@greenleafenvirotech.in, lab@greenleafenvirotech.in, **Web :** www.greenleafenvirotech.in
Registered Office : 304, Kankavati Complex, Singanpor-Cauzway Road, Katargam, Surat-395 004. Tel : +91-9327565428/761.

Reports are being periodically furnished to GPCB, CPCB & MoEF & CC. Copy of AAQ Monitoring Report from the April 26 to September 26 is enclosed as Annexure –2

The monthly minimum, maximum, average ambient air quality data for Jetty from by NABL accredited third party for the compliance period from April 26 to September 26

DAHEJ HARBOUR INFRASTRUCTURE LIMITED (DHIL)												
AMBIENT AIR ANALYSIS REPORT (April 26 to September 26)												
Parameters	**PM10**			**PM2.5**			**SO2**			**NOx**		
Permissible Limit (µg/m3)	**100**			**60**			**80**			**80**		
Month	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
April 26 to September 26	50.71	54.46	52.89	26.54	27.76	26.54	23.08	25.43	24.37	21.30	23.50	22.37

vi All the stacks of the plant must be provided with on-line stack emission monitoring equipment for the estimation of SO2, fluoride, SPM etc. Stack emission and ambient air quality data must be submitted to the State Pollution Control Board once in 3 months and once in 6 months to the Ministry of Environment and Forests along with statistical analysis and interpretation.

Complied.

There is no SO2 and fluoride emission at jetty. There is no process stack. However, a small bag filter is attached at transfer point in jetty on belt conveyor to control the fugitive emission. Monitoring results of Jetty conveyer bag filter stack and ambient air quality at jetty is given below: -

DAHEJ HARBOUR AND INFRASTRUCTURE Stack & AAQM analysis report						
Sr No.	**Month**	**April 26 to September 26**				
		Jetty Conveyer Bag Filter Stack	**Ambient Air Monitoring at Dahej Harbor Infrastructure Limited**			
		Particulate matter	**PM10**	**PM 2.5**	**SO2**	**NOX**
GPCB Norms		**150 mg/Nm3**	**100 µg/m3**	**60 µg/m3**	**80 µg/m3**	**80 µg/m3**
1	Apr-26	41.76	50.71	26.86	25.10	22.23
2	May-26	42.98	54.29	27.76	25.43	22.23
3	Jun-26	38.27	52.09	26.03	24.47	22.24
4	Jul-26	43.22	53.23	25.66	24.26	22.71
5	Aug-26	41.55	52.58	26.58	23.86	21.30
6	Sep-26	40.29	54.46	26.34	23.08	23.50

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<tr><td>Average</td><td>41.35</td><td>52.89</td><td>26.54</td><td>24.37</td><td>22.37</td></tr>
<tr><td>Maximum</td><td>43.22</td><td>54.46</td><td>27.76</td><td>25.43</td><td>23.50</td></tr>
<tr><td>Minimum</td><td>38.27</td><td>50.71</td><td>25.66</td><td>23.08</td><td>21.30</td></tr>
</table>
Environmental monitoring of stack emissions is carried out regularly through a GPCB, MoEFCC, CPCB approved, NABL-accredited laboratory, M/s Green Leaf Envirotech Ltd. Reports are being periodically furnished to GPCB, CPCB and MoEFCC. Stack monitoring report for the compliance period from April 2026 to September 2026 is attached as Annexure 3
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<td>vii</td>
<td>Fugitive emissions of dust/mist vapors, fumes, SO2 and HC should be controlled, and work environment monitored for prevailing contaminants regularly. Fugitive dust generated during pyrite crushing screening and handling at various transfer points should be reduced to the minimum by installing adequate dust collection and extraction system and regularly monitored.</td>
<td>Complied.

Adequate pollution control measures have been provided at the Captive Jetty to control fugitive emissions. Bag filters are installed at material transfer points to minimize dust generation and ensure a clean working environment.

Mist, vapours, fumes, SO_2, and HC emissions are not generated from Jetty operations; therefore, monitoring of these parameters is not applicable to the Jetty. Further, pyrite crushing, screening, and handling activities are not carried out at the Jetty; hence, fugitive emissions associated with these operations are not applicable.

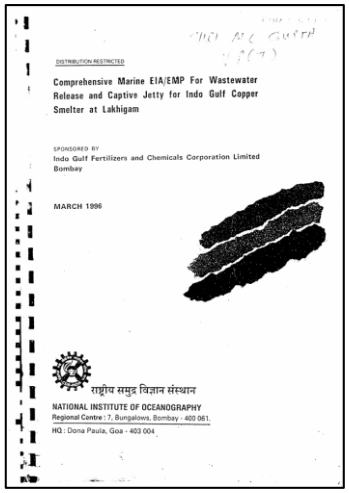
Compliance related to fugitive emissions and work environment monitoring for the Copper Smelter Complex is covered under the Environmental Clearance compliance of Hindalco Industries Limited, Unit – Birla Copper.</td>
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<td>viii</td>
<td>Adequate scrubbing system must be provided to remove silica, fluoride, and rock phosphate dusts from flue gases.</td>
<td>Complied.

No flue gas is generated from Jetty operations. This condition is not applicable.</td>
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<tr>
<td>ix</td>
<td>There should be no change in the stack design without prior approval from the State Pollution Control Board and this Ministry.</td>
<td>Complied.
Noted and shall be complied with.</td>
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x	An adequate number of effluent monitoring station must be set up in consultation with the State Pollution Control Board. If the effluent quality at any time exceeds the standards prescribed, the corresponding unit of the plant which is contributing to the excessive pollution level shall be immediately stopped from operating till the quality of pollutant discharged from the respective units are brought down to the required standards	**Complied.** Cargo hold wash wastewater from cargo is sent to ETP of Hindalco Industries Limited through tankers for treatment The compliance of this condition is covered in Environmental clearance, Hindalco Industries Limited, Unit – Birla Copper.
xi	The treated effluents should conform to the prescribed standards and be discharged into the sea at a point approved by the State Pollution Control Board and NIO, Goa. Efforts should also be made to recycle the treated effluents for green belt development to the maximum possible extent	**Complied.** Please refer S.R. No. "x" of EC compliance conditions.
xii	The industry should provide separate drain for storm water, sanitary wastewater and process effluents and the entire layout plan for the above must have the approval of the State Pollution Control Board.	**Complied.** Jetty is not manufacturing unit therefore storm water and process water drains are not required. Sanitary waste generated from jetty is transported to Sewage treatment plant of Hindalco Industries Limited through tankers for treatment Cargo hold wash wastewater from cargo is sent to ETP of Hindalco Industries Limited through tankers for treatment. The compliance of this condition is covered in Environmental clearance, Hindalco Industries Limited, Unit – Birla Copper.
xiii	A guard pond must be constructed near the terminal end of all the effluents before final disposal of effluents. This pond must have two compartments of which one will be kept empty while the other will be operated as a routing guard pond. When the concentration of effluents is high in the final effluents, corrective measures should be taken at source and the effluent shall be	**Complied.** Cargo hold wash wastewater from cargo is sent to ETP of Hindalco Industries Limited through tankers for treatment and disposal. The compliance of this condition is covered in Environmental clearance, Hindalco Industries Limited, Unit – Birla Copper.

	discharged at a regulated rate after treatment, to conform to the prescribed standards.	
xiv	Disposal site of Phosphogypsum, spent cathodes etc. should be impervious to avoid ground water contamination. These sites should have the approval of State pollution control Board. Adequate monitoring of the impounded sites (soil, surface, and ground water) should be carried out regularly and record maintained.	**Complied.** Phosphogypsum and spent cathodes are not handled at Jetty. Therefore, this condition is not applicable for DHIL.
xv	The radium content in the Jordan rocks proposed to be imported should be intimated to Ministry of Environment & Forests.	**Complied.** Jordan rocks are no longer imported because phosphoric acid plant is not operation since April 2020 and is under dismantling. Therefore, this condition is not applicable.
xvi	Spent Cathode should be enclosed in reinforced cement concrete vaults/ container before disposal. Recovery of carbon and fluoride from the spent cathode lining should be attempted.	**Complied.** Spent cathodes are not handled at Jetty. Therefore, this condition is not applicable for DHIL.
xvii	Fluoride levels in the ground water around the project site should be monitored on a regular basis and report submitted to this Ministry every 6 months.	**Complied.** This condition is not applicable for DHIL.
xviii	Detailed risk analysis should be carried out and inventories located in such a manner so as to contain the impact zone under the worst scenario within the plant boundary. The risk analysis should include Hazard identification using standard methods, fault tree analysis, reliability and failure analysis and worst scenario for MCA such as catastrophic failure of tanks and pipelines. The risk analysis report should be submitted in this Ministry for review within a period of one year.	**Complied.** The Risk and Disaster Management Plan is prepared and submitted to the Ministry's Regional Office, GPCB and CPCB. Latest copy is attached as **Annexure-4**

xix	Efforts should be made to sell sulfuric Acid (H2SO4) to the maximum extent possible. The capacity of the proposed phosphoric acid plant should be reduced to half so that the quantity of Phosphogypsum generated is reduced.	**Complied.** Efforts have been made to maximize the sale and utilization of Sulphuric Acid (H_2SO_4). Further, the Phosphoric Acid Plant has remained non-operational since April 2020 and has been removed from the Consolidated Consent & Authorization (CC&A) vide Consent No. 155156 dated 27.03.2026. The plant is currently under dismantling. As the Phosphoric Acid Plant is no longer in operation, there is no generation of Phosphogypsum. Therefore, the condition regarding reduction of phosphoric acid plant capacity to minimize Phosphogypsum generation is not applicable.
xx	Long term workable plan for utilization and disposal of Phosphogypsum should be worked out and report submitted to this Ministry for review within 10 months.	Complied. The Phosphoric Acid Plant has remained non-operational since April 2020 and is currently under dismantling. Consequently, there is no generation of Phosphogypsum. The legacy Phosphogypsum stored in the yard has been completely evacuated, and the land is being reclaimed under the supervision of NEERI. Accordingly, the requirement for submission of a long-term workable plan for utilization and disposal of Phosphogypsum is no longer applicable, as no Phosphogypsum is being generated or stored at the site.
xxi	A study to assess the impact due to disposal of solid waste/sludge on land should be carried out and report submitted to this Ministry for review within 6 months.	**Complied.** Solid waste/sludge generation does not take place due to Jetty operations. Therefore, this condition is not applicable. The compliance of this condition is covered in Environmental clearance, Hindalco Industries Limited, Unit – Birla Copper, Dahej.
xxii	A study to assess the impact of the proposed pipeline for disposal of treated effluent should be carried out and reports submitted to this Ministry for review within 6 months.	**Complied.** A study to assess the impact of the pipeline for disposal of treated effluent is carried out by National Institute of Oceanography, Goa. The report is already submitted to the Ministry.

		The front page of the study is given below: -  DISTRIBUTION RESTRICTED Comprehensive Marine EIA/EMP For Wastewater Release and Captive Jetty for Indo Gulf Copper Smelter at Lakhigam SPONSORED BY Indo Gulf Fertilizers and Chemicals Corporation Limited Bombay MARCH 1996 राष्ट्रीय समुद्र विज्ञान संस्थान NATIONAL INSTITUTE OF OCEANOGRAPHY Regional Centre : 7, Bungalows, Bombay - 400 061. HQ : Dona Paula, Goa - 403 004. The report is attached as **Annexure-5**
xxiii	A community welfare scheme for improving the socio-economic environment should also be worked out and report submitted to this Ministry for review within 6 months.	**Complied.** Community welfare schemes aimed at improving the socio-economic environment of nearby communities are undertaken by Hindalco Industries Limited. The progress of these initiatives is monitored and reported to the Ministry periodically. Compliance with this condition is covered under the Environmental Clearance compliance reporting of Hindalco Industries Limited.
xxiv	The project authorities must submit on-site/off-site emergency preparedness plan based on detailed risk analysis. Approval from the nodal agency should be obtained for the above plan.	**Complied.** The on-site/off-site emergency preparedness plan based on detailed risk analysis is carried out and obtained approval of required nodal agency. The condition is complied with. Onsite emergency plan is attached as **Annexure-4**

<table>
<tr><td>xxv</td><td>All recommendations made in the EMP based on comprehensive EIA report and detailed risk analysis reports should be implemented.</td><td>Complied.

The recommendations made in the EMP based on comprehensive EIA report by Tata Consultancy services are implemented.</td></tr>
<tr><td>xxvi</td><td>A detailed green belt development plan should be submitted to this Ministry for review within 3 months. The proposed green belt design should have scientific basis and plant species identified should be indigenous and not exotic varieties.</td><td>Complied.

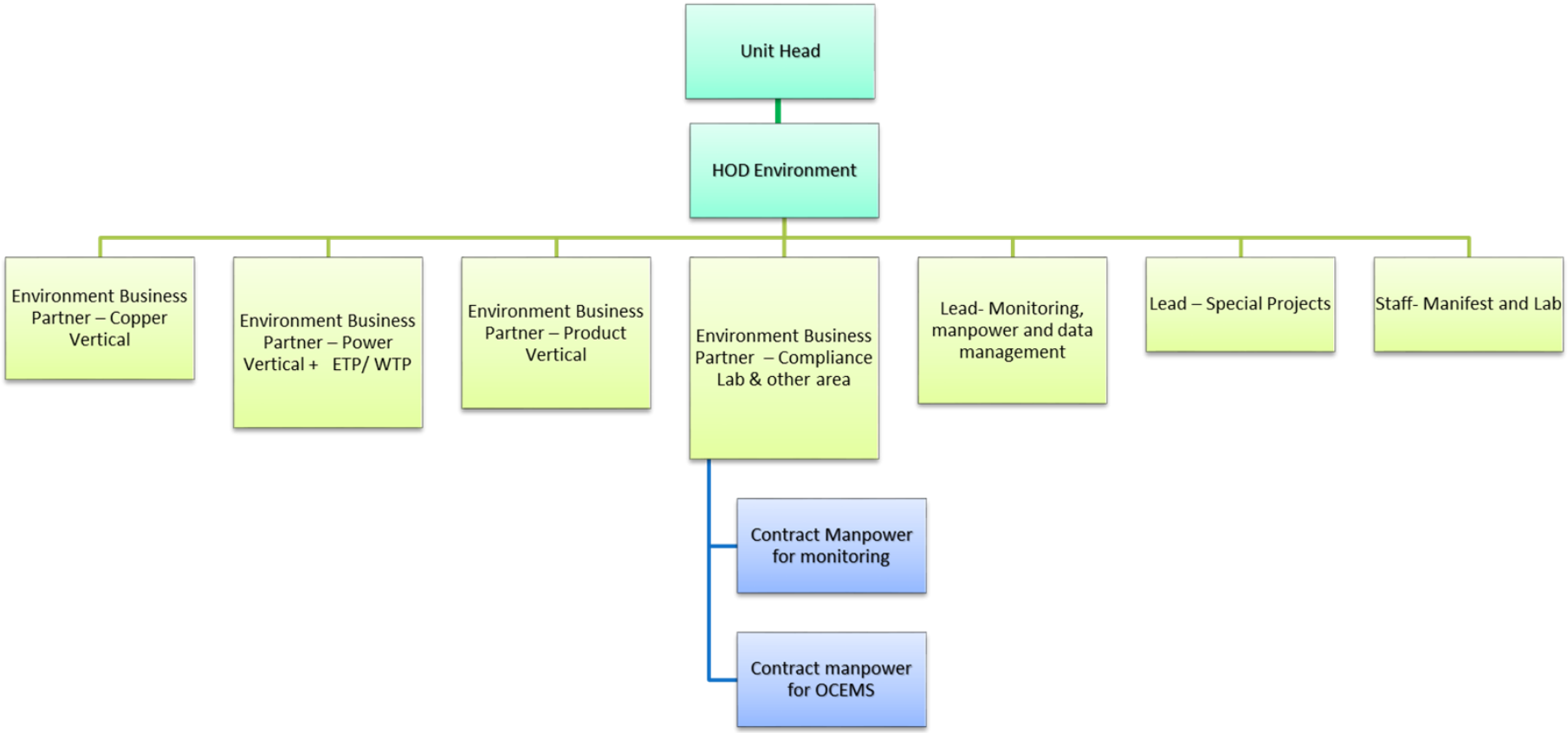
A well-developed greenbelt has been established all along the periphery as well as within the plant premises to enhance the environmental quality and improve the ecological balance of the area. The existing greenbelt covers approximately 123.50 Ha out of the total plant area of 341.65 Ha, comprising about 240055 trees within the plant premises. Additionally, approximately 3,000 trees have been planted outside the plant premises near the Material Gate and adjoining areas. Plant species have been selected in consultation with the District Forest Officer (DFO) and in line with CPCB guidelines, with preference given to native and pollution-tolerant species. Continuous plantation, gap-filling, maintenance, and survival monitoring activities are undertaken to further strengthen the greenbelt.
Compliance with this condition is covered under the Environmental Clearance compliance reporting of Hindalco Industries Limited</td></tr>
<tr><td>xxvii</td><td>The project authorities must set up laboratory facilities for collection and analysis of samples under the supervision of competent technical personnel who will report directly to the Chief Executive.</td><td>Complied.

A full-fledged separate Environmental Laboratory is set up and equipped with all necessary instruments/ equipment’s. The following equipment and consumable are available in the laboratory:

<table>
<tr><th>S.No.</th><th>Environment Monitoring Equipment</th><th>S.No.</th><th>Environment Monitoring Equipment</th></tr>
<tr><td>1</td><td>CAAQMS (04)</td><td>11</td><td>OCEMS (36)</td></tr>
<tr><td>2</td><td>Atomic Absorption Spectrophotometer</td><td>12</td><td>Weather station</td></tr>
<tr><td>3</td><td>PM2.5, PM10 Combo</td><td>13</td><td>Stack Monitoring Kit (2)</td></tr>
<tr><td>4</td><td>Noise Level monitors (02)</td><td>14</td><td>Handheld SO2, NH3, HF analyser</td></tr>
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			5	Multi gas Analyzer (SO2, NOx, CO2, HC, O2, and CO)	15	Ion selected Fluoride analysers	
			6	Spectrophotometer (visible range)	16	BOD incubator	
			7	COD reflux set up	17	Single pan balance	
			8	Relevant chemicals as per IS 5182	18	Hot Air Oven	
			9	Stopwatch	19	Thermometer	
			10	PH Meter	20	Titration set	

ENVIRONMENTAL MANAGEMENT CELL



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<td>xxviii</td>
<td>A separate Environmental Management Cell with suitable qualified people to carry out various functions should be set up under the control of senior executive who will report directly to the Head of the Organization.</td>
<td>Complied.

A separate Environmental Management Cell has been established and is headed by a suitably qualified person who reports directly to the President & Unit Head.

Kindly refer to the compliance status provided against Condition No. XXVII. The stipulated condition has been complied with.</td>
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<td>xxix</td>
<td>The funds earmarked for the environmental protection measures should not be diverted for any other purpose and year wise expenditure should be reported to the Ministry.</td>
<td>Complied.

The requisite funds have been earmarked and utilized towards capital and recurring costs for environmental pollution control measures in accordance with the conditions stipulated by MoEF&CC and the State Government. The implementation of these measures has been successfully carried out, ensuring compliance with regulatory requirements.

The total year wise capital and recurring expenditure incurred on key environmental infrastructure includes:
<table>
<tr><th>Year</th><th>Capital Cost in lacs. (Cumulative)</th><th>Recurring Cost in Lacs.</th></tr>
<tr><td>2017-18</td><td>16357</td><td>7767.45</td></tr>
<tr><td>2018-19</td><td>30137</td><td>9984.0</td></tr>
<tr><td>2019-20</td><td>30137</td><td>9782.39</td></tr>
<tr><td>2020-21</td><td>38806</td><td>8536.75</td></tr>
<tr><td>2021-22</td><td>38806</td><td>13319.39</td></tr>
<tr><td>2022-23</td><td>38806</td><td>13578.52</td></tr>
<tr><td>2023-24</td><td>42357</td><td>14703.71</td></tr>
<tr><td>2024-25</td><td>42357</td><td>11486.88</td></tr>
<tr><td>2025-26</td><td>42357</td><td>14178.67</td></tr>
<tr><td>2026-27</td><td>50607</td><td>14290.22</td></tr>
</table>
The company has incurred capital cost of Rs 506.0715 crore and recurring cost Rs. 142.902 crore (in FY26-27) implement the conditions stipulated by the Ministry of Environment & Forests as well as the State Government.</td>
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</table>

xxx	Proposed Jetty and the related infrastructure should be in conformity with the provisions of the Coastal Regulation Zone.	**Complied.** The Jetty and the related infrastructure are in conformity with the provisions of the Coastal Regulation Zone Notification -2011 and amended thereof. The related permission for Jetty construction is attached as **Annexure-6**
xxxi	Screening of pollutants in the harbor waters should be taken up by the project authorities and periodical monitoring reports on water quality parameters must be forwarded to this Ministry at six monthly intervals.	**Complied.** Monitoring of treated effluent quality is carried out on a monthly basis through NABL-accredited laboratories, and the monitoring reports are regularly submitted to the concerned regulatory authorities. The treated effluent consistently conforms to the prescribed standards. Compliance with this condition is covered under the Environmental Clearance compliance reporting of Hindalco Industries Limited In addition, marine environmental monitoring is carried out through Gujarat Ecological Society (GES), Vadodara, to assess the impact of deep-sea discharge on the marine environment. The study includes monitoring of marine water quality, sediment quality, plankton, benthos, and other ecological parameters. The monitoring results indicate no adverse impact on the marine ecosystem due to the treated effluent discharge. The latest marine monitoring report is enclosed as **Annexure-7**
xxxii	A comprehensive disaster Management Plan considering worst-case disaster scenarios with respect to specific cases like oil/ chemical spills, fire/explosion, terrorist attack, flood, etc. Spelling out definite/adequate measures to be taken to prevent and contain such disasters. A report on this must be forwarded to this Ministry within six months from the date of issue of the environmental clearance.	A comprehensive disaster Management Plan prepared, considering worst case disaster scenarios with respect to specific cases like oil/ chemical spills, fire/explosion, terrorist attack, flood, etc. and adequate measures are taken to prevent and contain such disasters accordingly. The reports prepared and submitted to the Ministry dated August 1997. Please refer to **condition xviii and xxiv**
xxxiii	To prevent discharge of sewage, bilge wastes and other liquid wastes into the marine environment, adequate system for collection, treatment and disposal of liquid wastes including shoreline interceptor for receiving liquid wastes from all shoreline	**Complied** Adequate measures are taken for collection, treatment and disposal of liquid waste including shoreline interceptors to prevent discharge into the marine environment.

	installations and special hose connection for ships to allow for discharge of sewage must be provided.	We have a dedicated sewage treatment plant and provision for sewage collection from ships. The collection and treatment are carried out as and when required, depending on the request received from ships. No such request received during the period from April 26 to September 2026.
xxxiv	Appropriate devices such as oil water separator, oil monitor, oil skimmer etc. must be provided to remove all floatable material including oil spills while re-fueling the vessels, because of operations of cargo handling equipment and allied machinery, cranes, tractors etc. to tackle the oil pollution in the port area and marine environment.	**Complied.** Oil spillage contingency plan has been prepared along with five other nearby jetties in Dahej region and according to the available plan, appropriate devices such as Oil spill dispersant, Oil skimming pads, Portable Oil spill dispersant pumps etc. are provided to remove all floated material. Also dedicated oil spillage kits are available at the jetty platform for emergency oil spillage control.
xxxv	Proper firefighting arrangements must be ensured by providing adequate number of fire hydrants in free prone areas. The entire firefighting line must be maintained under pressure through jockey pumps for appropriate volume of dead storage water must be ensured for this purpose. The employees must be kept alert and trained to combat fire by conducting regular fire drills to keep these facilities in working conditions.	**Complied.** Adequate firefighting arrangement is provided in plant as below: • All plants/ facilities are connected with fire Hydrant system, kept under pressure to control any fire / emergency. • A water sprinkler system is provided in the Fuel storage area. • Three Fire tenders are placed. • Fire extinguishers are installed within the plants. • Fire Alarm system and smoke detection system are installed. • Availability of Safety shower, Breathing Apparatus sets, Air Line Respirator, Life Jackets, Aluminum fire entry suits, Fire Proximity suits, etc. • Personal Protective Equipment's like Helmet, safety shoes, safety goggles, etc., to all employees. • Regular training for safe working and firefighting is provided. • Regular fire drills/mock drills are conducted.
xxxvi	The quality of treated effluents, solid wastes, emissions and noise levels etc. must conform to the standards laid down by the competent authorities including central/state Pollution control	**Complied.**

	board and under the Environment (Protection) Act, 1986, whichever are more stringent.	Regarding the solid waste management-wet waste and dry waste is segregated in plant premises. Wet waste is sent to in house biogas plant for biogas generation and utilization in guest house kitchen and waste slurry generated from biogas plant is collected and used as manure for green belt development. Dry waste such as plastic, e waste and general domestic waste after segregation are sent to authorized vendors. The noise levels are being monitored identified locations and report is being submitted to GPCB on monthly basis. The qualities of treated effluents - kindly refer compliance of condition no.” x”. The emissions conformity - kindly refer compliance of condition no.” iv”. All the above is submitted to GPCB, MOE&CC on six monthly basis.
xxxvii	The project authority should take necessary measures to avoid adverse impact on marine life in consultation with the Zoological Survey of India.	**Complied.** The study is being carried out by a competent expert agency approved by the Government of Gujarat to avoid adverse impact on marine life once in every two years. The latest report is attached as **Annexure-7**. The report clearly indicates that the ecosystem is stable, and no significant change is observed over last decades. It could be concluded from the study that the ecosystem around the coastal waters surrounding the Birla Copper installations and discharge point has maintained a healthy environment without any deviation in the physical and chemical properties of the waters or sediments.

xxxviii	The project authority should take approval of State Pollution Control Board for the proposed dumping site within the plant area and provide proper lining of the area.	**Complied.** No Waste is generated from DHIL (Jetty) hence this Condition is not applicable.
xxxix	With respect to the facilities, if any to be provided within 500 mts. If HTL, the directions issued by the Supreme Court on 12.12.1994 in respect of Writ Petition No.664/93 and 561/94 should be complied with. In view of this no construction work pertaining to jetty etc. within 500 mt of HTL should be undertaken.	**Complied.** The unit is complying with the direction issued dated 12.12.1994 from Hon'ble Supreme court in respect of Writ petition no-664/93 and 561/94.

Dahej Harbour and Infrastructure Ltd

P. O. Dahej, DAHEJ

Compliance to conditions of Environment clearance for approval of construction of approach bund for Copper Smelter project at Dahej vide letter no. J-17011/18/93-IA.III dated 12-01-1996 and letter no. J-11011/7/94- IA II (I) dated 03-01-2000

(Half Yealy compliance report from April 26 to September 26)

Sl No	Condition stipulated	Compliance Status
1.	Conditions stipulated vide Ministry's O.M No.J.11011/7/94-IA-II dated 14th March 1995 should be strictly implemented.	**Complied** The Consolidated consent & authorization obtained for captive jetty facility at Dahej, District Bharuch vide letter no. CCA No. AWH-149225 dated 04-10-2025 for DHIL, which is valid up to 19-08-2031. The stipulation laid down by the State Pollution Control Board is complied with. A copy of CC & A of DHIL is attached as **Annexure 10A**
2.	No quarry activity should be undertaken within 500 M of Coastal Regulation Zone	**Complied** No quarrying activity has been undertaken. The construction of the jetty and its associated facilities is being carried out in compliance with the provisions of the Coastal Regulation Zone (CRZ) Notification, including applicable requirements within the 500 m CRZ area.

3.	Muck generated during construction and various activities should be properly disposed off at designated sites and proper leveling /dressing should be ensured.	**Complied** Muck generated during construction and various activities had been properly disposed of at designated sites and proper leveling /dressing was done. Hence the condition is complied with.
4.	No ground water should be tapped within 500 M of HTL for any construction activity.	**Complied** No ground water is being tapped within 500 M of HTL for any construction activity, conditions are complied with.
5.	The pile approach be so designed as to have minimum interference with the tidal movement in the region.	**Complied** Construction of approach bund is up to 1320 mts. from HTL, piled approach is for 1044 mts. and berthing platform is 210 mts. long for jetty, which is now operational and hence there is minimum interference with the tidal movement in the region.
6.	Ministry reserves the right to add additional conditions required, if any in future on the basis of the results of the monitoring report.	Noted
7.	Full support to be extended to the scientists from this Ministry's Regional office at Bhopal during monitoring stage by furnishing data and reports on the follow up action initiated on various conditions stipulated in our O.M No.J.11011/7/94-IA-II dated 14th March,1995	**Complied** Whenever scientists from the Ministry's Regional Office, Gandhinagar visit the site, Dahej Harbour and Infrastructure Limited will extend full cooperation by providing all requisite data, records, and reports on the actions taken towards compliance with the conditions stipulated in Office Memorandum No. J-11011/7/94-IA-II dated 14 March 1995.
8.	In case of any deviation or alteration in the project proposal from those submitted to this Ministry for clearance, a reference should be made for re-appraisal.	Noted
9.	These stipulations would be enforced among others under the provisions of the water (Prevention and control of Pollution Act, 1974 and Air (Prevention and control of pollution Act 1986 and the public liability(insurance) Act 1991 along with their amendments and rules.	**Complied** All applicable environmental regulations are being complied with in accordance with the provisions of the Water (Prevention and Control of Pollution) Act, 1974, the Air (Prevention and Control of Pollution) Act,

		1981, the Public Liability Insurance Act, 1991, and the rules and amendments made thereafter. DHIL has obtained the Consolidated Consent and Authorization (CC&A) from the Gujarat Pollution Control Board vide Order No. AWH-149225 dated 04.10.2025, which is valid up to 19.08.2031. Accordingly, the stipulated conditions are being complied with.

GPCB

GUJARAT POLLUTION CONTROL BOARD

PARYAVARAN BHAVAN, SECTOR 10-A,
GANDHINAGAR - 382010,
(T) 079-23232152

By R.P.A.D.

CONSOLIDATED CONSENT AND AUTHORIZATION (CC & A)
CCA NO: AWH- 149225

NO: GPCB/BRCH/CCA-747(3)/ID-15040/ 879687 **DT: 04/11/2025**

In exercise of the power conferred under Section-25 of the Water (Prevention and Control of Pollution) Act-1974, under Section-21 of the Air (Prevention and Control of Pollution) Act-1981 and Authorization under rule 6(2) of the Hazardous & Other Wastes (Management and Transboundary Movement) Rules-2016, framed under the E(P)Act-1986.

And whereas Board has received consolidated application dated 20/08/2025 and inward no. **401046** for the consolidated consent and authorization **(CC & A)** of this Board under the provisions / rules of the aforesaid Acts, Consolidated Consent & Authorization is hereby granted as under.

CONSOLIDATED CONSENT AND AUTHORISATION:
(Under the provisions / rules of the aforesaid Environmental Acts)

To,
M/s. Dahej Harbour & Infrastructure Ltd.,
P.O. Dahej,
Tal.: Vagra, Dist.: Bharuch.

1. **Consent Order No. : AWH-149225 date of Issue 04/10/2025.**
2. The consent under Water Act –1974, Air Act – 1981 and Authorization under Environment (Protection) Act, 1986 shall be valid up to **19/08/2031** to operate industrial plant for following activities:

Sr. No.	Products	Quantity (MT/Month)	Remarks
1	Captive jetty (only cargo receipt/discharge from ship, area: 270m x 270m) at a distance of 2 km from shoreline). Name of materials to be handled at jetty shall be as follows: (1) copper concentrate (2) mureate of potash (3) ammonia (4) phosphoric acid (5) copper cathode/anode (6) rock phosphate (7) coal (8) sulphuric acid (9) Anode (10) copper slag(11) gypsum (12) project cargo (machinery & equipments) (13) dap/npk	416666.660	50,00,000 TPA

3. **Specific Condition**

a) Unit shall maintain record of collected hold wash wastewater from cargo and transported to ETP of Hindalco Industries Limited through tankers for treatment & disposal and submit the same on quarterly basis to GPCB.

b) Hold wash wastewater from cargo of maximum 2 ships per month shall be collected and transported to ETP of Hindalco industries Limited through tanker for treatment & disposal.

c) Unit shall have to comply with all the condition of EC issued by MoEF & CC vide letter dated 14/03/1995, 12/01/1996 and 03/01/2000.

d) Unit shall have to comply with all the directives given in CRZ permission.

Outward No: 879687 dt: 11/11/2025

4. CONDITION UNDER THE WATER ACT:

4.1 Unit shall submit statement endorsed by Ship's commander for receipt of mentioned quantity of drinking water.

4.2 The quantity of water consumption for industrial purpose shall not exceed 60 KL/Month and industrial wastewater generation (hold wash wastewater from Cargo) shall not exceed 60 KL/Month.

4.3 Screening of pollutants in the harbor water should be taken up by the project authorities and periodical monitoring reports on water quality parameters be forwarded to MoEF & CC at six monthly intervals.

4.4 To prevent discharge of sewage bilge wastes and other liquid wastes into the marine environment, adequate system for collection, treatment and disposal of liquid wastes including shoreline interceptor for receiving liquid wastes from all shoreline installations and special hose connection ships to allow for discharge of sewage shall be provided.

4.5 The quantity of total water consumption shall not exceed **46.00 KL/Day** as per below:

a) Industrial: 30.00 KL/Day
b) Domestic: 16.00 KL/Day

4.6 The quantity of total waste water generation shall not exceed **33.00 KL/Day** as per below:

a) Industrial: 30.00 KL/Day
b) Domestic: 3.00 KL/Day

4.7 Mode of disposal of wastewater:

a) Mode of disposal of treated industrial effluent: ETP of Hindalco Industries Ltd.
b) Description for treated industrial effluent disposal: The ship cargo hold wash wastewater 30 KLD shall be collected in tanker from ship at jetty and transfer to ETP of Hindalco Industries Ltd.

4.8 Domestic sewage management:

a) Mode of disposal of treated domestic sewage: STP of Hindalco Industries Ltd.
b) Description for treated domestic sewage disposal: Domestic wastewater generated at jetty shall be sent to STP of Hindalco Industries Ltd. through tankers for treatment & disposal and shall have to maintain records and submit the same to GPCB on quarterly basis.

4.9 Unit shall affix of water meters for the purpose of measuring and recording the quantity of water consumed at such places as may be required, within 15 days and it shall be presumed that the quantity indicated by the meter has been consumed by the unit until the contrary is proved.

4.10 The GIDC drainage connection given by the GIDC for discharge of industrial effluent shall be disconnected & the outlet shall be sealed.

4.11 Disposal system for storm water shall be provided separately. In no circumstances storm water shall be mixed with the industrial effluent.

4.12 Leachate from the hazardous solid waste, if any shall also be connected into a collection tank through leachate collection facilities and shall be treated along with industrial effluent.

4.13 Unit shall keep accurate records of quantity of production of each product, quantity of water consumption, quantity of effluent generated and consumption of electricity on

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day to day basis and required to submit the complied record of each month to GPCB on or before fifth day of the succeeding month.

4.14 The Environmental Management Unit/Cell shall be setup to ensure implementation on and monitoring of environment safeguards and other conditions stipulated by statutory authorities. The Environmental Management Cell / Unit shall directly report to the Chief Executive of the organization and shall work as a focal point for internalizing environmental issued. These Cells also coordinate the exercise of environmental audit and preparation of environmental statements.

4.15 The Environmental audit shall be carryout yearly, if applicable. The environmental statements pertaining to the previous year shall be submitting to this State Board latest by 30th September every year.

4.16 The Board reserves the right to review and/or revoke the consent and / or make modifications in the conditions which it seems fit in accordance with provisions of Water Act-1974.

5. CONDITIONS UNDER THE AIR ACT:

5.1 There shall be no use of any fuel anywhere in the manufacturing process and consequently there shall be no flue gas emission from the manufacturing process and any other ancillary industrial operation.

5.2 The applicant shall install and operate comprehensive adequate air pollution in order to achieve prescribed norms control system so as to achieve standards.

5.3 The Process emission through various stacks/ vent of reactors, process, vessel shall conform to the following standards.

Stack No.	Stack attached to	Stack Height	APCM	Parameter	Permissible limit
1.	Jetty Conveyor	20 m	Bag Filter	PM	150 mg/Nm^3

5.4 The concentration of the following parameters in the ambient air within the premises of the unit shall not exceed the limits specified hereunder.

Sr. No.	Parameters	Permissible Limit (microgram /m^3)	
		Annual	24 Hours Average
1.	Particulate Matter (PM_{10})	60	100
2.	Particulate Matter ($PM_{2.5}$)	40	60
3.	Sulphur Dioxide (SO_2)	50	80
4.	Nitrogen Dioxide (NO_2)	40	80

a. **Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice aweek 24 hourly at uniform intervals.**

b. **24 hourly or 08 hourly or 01 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutivedays of monitoring.**

5.5 Unit shall operate industrial plant / air pollution control equipment very efficiently and continuously so that the gaseous emission always conforms to the standards specified as above.

5.6 The consent to operate the industrial plant shall lapse if at any time the parameters of the gaseous emission are not within the tolerance limits specified as above.

5.7 Unit shall provide portholes, ladder, platform etc at chimney(s) for monitoring the air emissions and the same shall be open for inspection to/and for use of Board's staff. The

Outward No: 370687/1/AE/2025

chimney(s) vents attached to various sources of emission shall be designed by numbers such as S-1, S-2, etc. and these shall be painted/ displayed to facilitate identification.

5.8 Unit shall take adequate measures for control of noise levels from its own sources within the premises so as to maintain ambient air quality standards in respect of noise to less than 75 dB(a) during day time and 70 dB (A) during night time. Daytime is reckoned in between 6a.m. and10 p.m. and nighttime is reckoned between 10 p.m. and 6 a.m.

5.9 All efforts shall be made to control VOC emissions and odor problem, if any.

6. AUTHORISATION FOR THE MANAGEMENT & HANDLING OF HAZARDOUS WASTES Form-2 (See rule 6(2)).

6.1 Number of authorization: **AWH-149225 date of Issue 04/10/2025.**

6.2 **M/s. Dahej Harbour & Infrastructure Ltd**. is hereby granted an authorization to operate facility for following hazardous wastes on the premises situated at **P.O. Dahej, Tal.:Vagra,Dist: Bharuch.**

Sr. No.	Name of Hazardous Waste	Category Number	Quantity MT/Year	Facility
1	Used or Spent Oil	5.1-SCH-I	1	Collection, Storage, reuse within premises or Transportation, send to registered re-refiners/Re processors

6.3 The authorization is granted to operate a facility as above.

6.4 The authorization shall be in force for a period up to **19/08/2031.**

6.5 The authorization is subject to the conditions stated below and such other conditions as may be specified in the rules from time to time under the Environment (Protection) Act-1986.

7. TERMS AND CONDITIONS OF AUTHORISATION:

7.1 The authorised person shall comply with the provisions of the Environment (Protection) Act, 1986, and the rules made there under.

7.2 The authorisation or its renewal shall be produced for inspection at the request of an officer authorised by the Gujarat Pollution Control Board.

7.3 The person authorised shall not rent, lend, sell, transfer or otherwise transport the hazardous and other wastes except what is permitted through this authorisation.

7.4 Any unauthorised change in personnel, equipment or working conditions as mentioned in the application by the person authorised shall constitute a breach of his authorisation.

7.5 The person authorised shall implement Emergency Response Procedure (ERP) for which this authorisation is being granted considering all site specific possible scenarios such as spillages, leakages, fire etc. and their possible impacts and also carry out mock drill in this regard at regular interval of time;

7.6 The person authorised shall comply with the provisions outlined in the Central Pollution Control Board guidelines on "Implementing Liabilities for Environmental Damages due to Handling and Disposal of Hazardous Waste and Penalty"

7.7 It is the duty of the authorised person to take prior permission of the Gujarat Pollution Control Board to close down the facility.

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7.8 The imported hazardous and other wastes shall be fully insured for transit as well as for any accidental occurrence and its clean-up operation.

7.9 The record of consumption and fate of the imported hazardous and other wastes shall be maintained.

7.10 The hazardous and other waste which gets generated during recycling or reuse or recovery or pre-processing or utilization of imported hazardous or other wastes shall be treated and disposed of as per specific conditions of authorization.

7.11 The importer or exporter shall bear the cost of import or export and mitigation of damages if, any.

7.12 An application for the renewal of an authorization shall be made as laid down under Hazardous & Other Wastes (Management and Transboundary Movement) Rules-2016.

7.13 Any other conditions for compliance as per the Guidelines issued by the Ministry of Environment, Forest and Climate Change or Central Pollution Control Board from time to time.

7.14 Annual return shall be filed by June 30th for the period ensuring 31st March of the year.

7.15 Unit shall have to display the relevant information with regard to hazardous waste as indicated in the Court's order in W.P. No. 657 of 1995 dated 14th October 2003.

7.16 Unit shall have to display on-line data outside the main factory gate with regard to and nature of hazardous chemicals being handled in the plant, including waste water and air emission and solid hazardous waste generated within the factory premises.

7.17 Unit shall have to manage used or spent oil; empty or discarded barrels / containers / liners contaminated with hazardous chemicals / wastes, process waste as per Hazardous & Other Wastes (Management and Transboundary Movement) Rules-2016, framed under the E(P)Act-1986 and shall apply Authorization for all applicable waste.

FOR AND ON BEHALF OF
GUJARAT POLLUTION CONTROL BOARD

(Dr. S. N. AGRAVAT)
UNIT HEAD- BHARUCH

Outward No:879687, 11/11/2025

Annexure-2

GreenLeaf ENVIROTECH LTD.

Test Report
Ambient Air Quality Monitoring Report

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post: Dahej, Dist: Bharuch. **Contact Person:** Sachin Sharma GM (Environment & Utility)	**Report No:** GLEL/040526/AM/05 **Issue Date:** 04/05/2026

AAQMS Report April - 26

Lab ID Code	:	GLEL/02-300426/AM_5			
Sampling Location	:	DHIL-Jetty	Monitoring for	:	Ambient air quality
Packed/Seal	:	Packed	Test Parameters	:	As per NAAQS 2009

Result Table (Frequency twice a week)

Date	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	NH_3 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	Pb ($\mu g/m^3$)	As (ng/m^3)	Ni (ng/m^3)	C_6H_6 ($\mu g/m^3$)	BaP (ng/m^3)	CO (mg/m^3)
CPCB Limit	**100**	**60**	**80**	**80**	**400**	**100**	**1**	**6**	**20**	**5**	**1**	**2**
02-03/04/26	51.34	25.93	24.31	21.62	<5.0	2.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
06-07/04/26	52.78	26.33	24.97	21.53	<5.0	2.2	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
09-10/04/26	51.67	25.53	24.18	22.04	<5.0	2.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
13-14/04/26	50.71	26.86	25.10	22.23	<5.0	2.0	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
16-17/04/26	52.43	27.15	25.68	23.07	<5.0	2.2	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
20-21/04/26	51.29	26.44	24.57	22.31	<5.0	2.0	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
23-24/04/26	52.64	26.72	25.39	22.53	<5.0	1.8	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
27-28/04/26	54.17	27.03	26.11	23.45	<5.0	1.7	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
30-01/05/26	55.24	27.38	25.76	23.10	<5.0	1.9	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05

Note: Method of Analysis followed: IS 5182 & CPCB Method.

Name Of Instrument	Calibration On	Calibration Due On
Respirable Dust Sampler APM 460 BL - 411	27/03/2026	26/03/2027
Fine Particulate Sampler Greintech/GEPS-375/231 K 17	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------End of Report----------

CIN : L29253GJ2010PLC059798
Recognised by **MoEF**, Govt of India, EP Act 1986; **NABL** accredited; **GPCB Schedule II** Environment Audiror; **ISO-45001-2018, ISO 9001:2015** Certified Laboratory.

Greenleaf Envirotech Ltd., E-mail : sales@greenleafenvirotech.in, lab@greenleafenvirotech.in, **Web :** www.greenleafenvirotech.in
Registered Office : 304, Kankavati Complex, Singanpor-Cauzway Road, Katargam, Surat-395 004. Tel : +91-9327565428/761.

GreenLeaf ENVIROTECH LTD.

Test Report
Ambient Air Quality Monitoring Report

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post: Dahej, Dist: Bharuch. **Contact Person:** Sachin Sharma GM (Environment & Utility)	**Report No:** GLEL/030626/AM/05 **Issue Date:** 03/06/2026

AAQMS Report May - 26

Lab ID Code	:	GLEL/04-280526/AM_5			
Sampling Location	:	DHIL-Jetty	Monitoring for	:	Ambient air quality
Packed/Seal	:	Packed	Test Parameters	:	As per NAAQS 2009

Result Table (Frequency twice a week)

Date	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	NH_3 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	Pb ($\mu g/m^3$)	As (ng/m^3)	Ni (ng/m^3)	C_6H_6 ($\mu g/m^3$)	BaP (ng/m^3)	CO (mg/m^3)
CPCB Limit	**100**	**60**	**80**	**80**	**400**	**100**	**1**	**6**	**20**	**5**	**1**	**2**
04-05/05/26	56.38	28.43	26.87	22.58	<5.0	1.9	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
07-08/05/26	53.17	26.68	25.75	21.47	<5.0	1.7	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
11-12/05/26	55.41	28.53	26.19	22.86	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
14-15/05/26	54.29	27.76	25.43	22.23	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
18-19/05/26	55.62	28.51	26.17	23.07	<5.0	1.1	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
21-22/05/26	56.81	28.73	27.31	24.51	<5.0	1.0	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
25-26/05/26	58.43	28.12	26.78	24.84	<5.0	1.2	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
28-29/05/26	57.24	27.86	25.93	23.35	<5.0	1.1	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05

Note: Method of Analysis followed: IS 5182 & CPCB Method.

Name Of Instrument	Calibration On	Calibration Due On
Respirable Dust Sampler APM 460 BL - 411	27/03/2026	26/03/2027
Fine Particulate Sampler Greintech/GEPS-375/231 K 17	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------**End of Report**----------

CIN : L29253GJ2010PLC059798

Recognised by **MoEF**, Govt of India, EP Act 1986; **NABL** accredited; **GPCB Schedule II** Environment Audiror; **ISO-45001-2018, ISO 9001:2015** Certified Laboratory.

Greenleaf Envirotech Ltd., E-mail : sales@greenleafenvirotech.in, lab@greenleafenvirotech.in, **Web :** www.greenleafenvirotech.in
Registered Office : 304, Kankavati Complex, Singanpor-Cauzway Road, Katargam, Surat-395 004. Tel : +91-9327565428/761.

GreenLeaf ENVIROTECH LTD.

Test Report
Ambient Air Quality Monitoring Report

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post: Dahej, Dist: Bharuch. **Contact Person:** Sachin Sharma GM (Environment & Utility)	**Report No:** GLEL/030726/AM/05 **Issue Date:** 03/07/2026

AAQMS Report June - 26

Lab ID Code	:	GLEL/01-290626/AM_5			
Sampling Location	:	DHIL-Jetty	Monitoring for	:	Ambient air quality
Packed/Seal	:	Packed	Test Parameters	:	As per NAAQS 2009

Result Table (Frequency twice a week)

Date	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	NH_3 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	Pb ($\mu g/m^3$)	As (ng/m^3)	Ni (ng/m^3)	C_6H_6 ($\mu g/m^3$)	BaP (ng/m^3)	CO (mg/m^3)
CPCB Limit	**100**	**60**	**80**	**80**	**400**	**100**	**1**	**6**	**20**	**5**	**1**	**2**
01-02/06/26	51.84	26.41	25.07	22.51	<5.0	1.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
04-05/06/26	50.33	25.81	24.36	22.23	<5.0	1.6	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
08-09/06/26	51.93	25.47	24.51	22.38	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
11-12/06/26	53.71	27.86	25.13	23.19	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
15-16/06/26	52.36	26.12	24.43	22.31	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
18-19/06/26	51.63	25.73	24.30	22.05	<5.0	1.2	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
22-23/06/26	50.92	24.65	24.81	22.37	<5.0	1.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
25-26/06/26	49.78	24.33	25.09	22.46	<5.0	1.6	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
29-30/06/26	49.26	24.28	24.73	22.38	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05

Note: Method of Analysis followed: IS 5182 & CPCB Method.

Name Of Instrument	Calibration On	Calibration Due On
Respirable Dust Sampler APM 460 BL - 411	27/03/2026	26/03/2027
Fine Particulate Sampler Greintech/GEPS-375/231 K 17	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------**End of Report**----------

CIN : L29253GJ2010PLC059798

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Test Report
Ambient Air Quality Monitoring Report

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post: Dahej, Dist: Bharuch. **Contact Person:** Sachin Sharma GM (Environment & Utility)	**Report No:** GLEL/050826/AM/05 **Issue Date:** 05/08/2026

AAQMS Report July - 26

Lab ID Code	:	GLEL/02-300726/AM_5			
Sampling Location	:	DHIL-Jetty	Monitoring for	:	Ambient air quality
Packed/Seal	:	Packed	Test Parameters	:	As per NAAQS 2009

Result Table (Frequency twice a week)

Date	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	NH_3 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	Pb ($\mu g/m^3$)	As (ng/m^3)	Ni (ng/m^3)	C_6H_6 ($\mu g/m^3$)	BaP (ng/m^3)	CO (mg/m^3)
CPCB Limit	**100**	**60**	**80**	**80**	**400**	**100**	**1**	**6**	**20**	**5**	**1**	**2**
02-03/07/26	53.77	26.82	24.10	22.36	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
06-07/07/26	51.62	26.33	23.48	21.57	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
09-10/07/26	54.28	27.15	24.89	22.65	<5.0	1.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
13-14/07/26	57.45	28.43	25.37	23.19	<5.0	1.2	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
16-17/07/26	53.23	25.66	24.26	22.71	<5.0	1.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
20-21/06/26	49.52	23.38	22.75	20.43	<5.0	1.6	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
23-24/07/26	28.94	18.25	20.47	19.35	<5.0	1.8	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
27-28/07/26	33.67	21.46	22.38	20.61	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
30-31/07/26	38.50	23.18	23.11	20.97	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05

Note: Method of Analysis followed: IS 5182 & CPCB Method.

Name Of Instrument	Calibration On	Calibration Due On
Respirable Dust Sampler APM 460 BL - 411	27/03/2026	26/03/2027
Fine Particulate Sampler Greintech/GEPS-375/231 K 17	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------End of Report----------

CIN : L29253GJ2010PLC059798
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Test Report
Ambient Air Quality Monitoring Report

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post: Dahej, Dist: Bharuch. **Contact Person:** Sachin Sharma GM (Environment & Utility)	**Report No:** GLEL/070926/AM/05 **Issue Date:** 07/09/2026

AAQMS Report August - 26

Lab ID Code	:	GLEL/03-310826/AM_5			
Sampling Location	:	DHIL-Jetty	Monitoring for	:	Ambient air quality
Packed/Seal	:	Packed	Test Parameters	:	As per NAAQS 2009

Result Table (Frequency twice a week)

Date	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	NH_3 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	Pb ($\mu g/m^3$)	As (ng/m^3)	Ni (ng/m^3)	C_6H_6 ($\mu g/m^3$)	BaP (ng/m^3)	CO (mg/m^3)
CPCB Limit	**100**	**60**	**80**	**80**	**400**	**100**	**1**	**6**	**20**	**5**	**1**	**2**
03-04/08/26	52.64	25.34	23.51	20.87	<5.0	1.2	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
06-07/08/26	54.38	26.51	23.88	21.91	<5.0	1.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
10-11/08/26	55.83	27.64	24.12	22.71	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
13-14/08/26	50.37	24.81	23.49	20.86	<5.0	1.7	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
17-18/08/26	52.58	26.52	23.86	21.30	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
20-21/08/26	53.41	26.95	23.54	20.78	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
24-25/08/26	55.29	27.34	23.75	21.18	<5.0	1.4	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
27-28/08/26	58.13	27.19	22.94	20.65	<5.0	1.3	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
31-01/09/26	59.25	26.54	23.08	21.13	<5.0	1.2	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05

Note: Method of Analysis followed: IS 5182 & CPCB Method.

Name Of Instrument	Calibration On	Calibration Due On
Respirable Dust Sampler APM 460 BL - 411	27/03/2026	26/03/2027
Fine Particulate Sampler Greintech/GEPS-375/231 K 17	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------End of Report----------

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Test Report
Ambient Air Quality Monitoring Report

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post: Dahej, Dist: Bharuch. **Contact Person:** Sachin Sharma GM (Environment & Utility)	**Report No:** GLEL/051026/AM/05 **Issue Date:** 05/10/2026

AAQMS Report September - 26

Lab ID Code	:	GLEL/01-290926/AM_5			
Sampling Location	:	DHIL-Jetty	Monitoring for	:	Ambient air quality
Packed/Seal	:	Packed	Test Parameters	:	As per NAAQS 2009

Result Table (Frequency twice a week)

Date	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	NH_3 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	Pb ($\mu g/m^3$)	As (ng/m^3)	Ni (ng/m^3)	C_6H_6 ($\mu g/m^3$)	BaP (ng/m^3)	CO (mg/m^3)
CPCB Limit	**100**	**60**	**80**	**80**	**400**	**100**	**1**	**6**	**20**	**5**	**1**	**2**
01-02/09/26	57.30	27.82	25.84	22.99	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
04-05/09/26	59.18	29.08	26.24	24.11	<5.0	1.7	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
08-09/09/26	60.75	30.30	26.50	24.98	<5.0	1.8	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
11-12/09/26	54.85	27.24	25.82	22.98	<5.0	2.0	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
15-16/09/26	57.24	29.09	26.22	23.45	<5.0	1.8	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
18-19/09/26	58.13	29.56	25.87	22.89	<5.0	1.6	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
22-23/09/26	60.16	29.98	26.10	23.32	<5.0	1.7	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
25-26/09/26	63.23	29.82	25.23	22.75	<5.0	1.6	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05
29-30/09/26	64.44	29.11	25.38	23.27	<5.0	1.5	<0.01	<1.0	<5.0	<4.0	<1.0	<0.05

Note: Method of Analysis followed: IS 5182 & CPCB Method.

Name Of Instrument	Calibration On	Calibration Due On
Respirable Dust Sampler APM 460 BL - 411	27/03/2026	26/03/2027
Fine Particulate Sampler Greintech/GEPS-375/231 K 17	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------End of Report----------

CIN : L29253GJ2010PLC059798

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GreenLeaf ENVIROTECH LTD.

TEST REPORT
STACK SAMPLE ANALYSIS REPORT

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post, Dahej, Dist. Bharuch. **Contact Person:** Sachin Sharma HOD (Environment & Utility)	**Report No:** GLEL/140426/01 **Issue Date:** 15/04/2026

Lab ID Code	:	GLEPL/140426/ST_1			
Description of Stack	:	Jetty Conveyor bag filter stack			
Date of Sampling	:	14/04/2026	Stack Dia (cm)	:	0.4
Sample collected by	:	GLEL Team	Stack Height (m)	:	20
Stack Type	:	Flue	Stack Temperature (^{0}C)	:	36

RESULT TABLE

Sr. No.	Test Parameters	Test Method	Unit	Result	GPCB Limit
1.	Particulate Matter	IS:11255 (P-1):1985	mg/Nm^3	41.76	**150**

Name Of Instrument	Calibration On	Calibration Due On
Envirotech Stack Sampler VSS1 Sr. No. 183-DTC-2019	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------**End of Test Report**----------

CIN : U29253GJ2010PLC059798
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GreenLeaf ENVIROTECH LTD.

TEST REPORT
STACK SAMPLE ANALYSIS REPORT

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post, Dahej, Dist. Bharuch. **Contact Person:** Sachin Sharma HOD (Environment & Utility)	**Report No:** GLEL/150526/01 **Issue Date:** 17/05/2026

Lab ID Code	:	GLEPL/150526/ST_1			
Description of Stack	:	Jetty Conveyor bag filter stack			
Date of Sampling	:	15/05/2026	Stack Dia (cm)	:	0.4
Sample collected by	:	GLEL Team	Stack Height (m)	:	20
Stack Type	:	Flue	Stack Temperature (^{0}C)	:	36

RESULT TABLE

Sr. No.	Test Parameters	Test Method	Unit	Result	GPCB Limit
1.	Particulate Matter	IS:11255(P-1):1985	mg/Nm^3	42.98	**150**

Name Of Instrument	Calibration On	Calibration Due On
Envirotech Stack Sampler VSS1 Sr. No. 183-DTC-2019	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------End of Test Report----------

CIN : L29253GJ2010PLC059798
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TEST REPORT
STACK SAMPLE ANALYSIS REPORT

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post, Dahej, Dist. Bharuch. **Contact Person:** Sachin Sharma HOD (Environment & Utility)	**Report No:** GLEL/140626/01 **Issue Date:** 16/06/2026

Lab ID Code	:	GLEPL/140626/ST_1			
Description of Stack	:	Jetty Conveyor bag filter stack			
Date of Sampling	:	14/06/2026	Stack Dia (cm)	:	0.4
Sample collected by	:	GLEL Team	Stack Height (m)	:	20
Stack Type	:	Flue	Stack Temperature (^{0}C)	:	34.5

RESULT TABLE

Sr. No.	Test Parameters	Test Method	Unit	Result	GPCB Limit
1.	Particulate Matter	IS:11255 (P-1):1985	mg/Nm^3	38.27	**150**

Name Of Instrument	Calibration On	Calibration Due On
Envirotech Stack Sampler VSS1 Sr. No. 183-DTC-2019	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------**End of Test Report**----------

CIN : L29253GJ2010PLC059798
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TEST REPORT
STACK SAMPLE ANALYSIS REPORT

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post, Dahej, Dist. Bharuch. **Contact Person:** Sachin Sharma HOD (Environment & Utility)	**Report No:** GLEL/150726/01 **Issue Date:** 16/07/2026

Lab ID Code	:	GLEPL/150726/ST_1			
Description of Stack	:	Jetty Conveyor bag filter stack			
Date of Sampling	:	15/07/2026	Stack Dia (cm)	:	0.4
Sample collected by	:	GLEL Team	Stack Height (m)	:	20
Stack Type	:	Flue	Stack Temperature (^{0}C)	:	32.5

RESULT TABLE

Sr. No.	Test Parameters	Test Method	Unit	Result	GPCB Limit
1.	Particulate Matter	IS:11255 (P-1):1985	mg/Nm^3	43.22	**150**

Name Of Instrument	Calibration On	Calibration Due On
Envirotech Stack Sampler VSS1 Sr. No. 183-DTC-2019	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------End of Test Report----------

CIN : L29253GJ2010PLC059798
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TEST REPORT
STACK SAMPLE ANALYSIS REPORT

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post, Dahej, Dist. Bharuch. **Contact Person:** Sachin Sharma HOD (Environment & Utility)	**Report No:** GLEL/200826/01 **Issue Date:** 21/08/2026

Lab ID Code	:	GLEL/200826/ST_1			
Description of Stack	:	Jetty Conveyor bag filter stack			
Date of Sampling	:	20/08/2026	Stack Dia (cm)	:	0.4
Sample collected by	:	GLEL Team	Stack Height (m)	:	20
Stack Type	:	Flue	Stack Temperature (^{0}C)	:	32.5

RESULT TABLE

Sr. No.	Test Parameters	Test Method	Unit	Result	GPCB Limit
1.	Particulate Matter	IS:11255 (P-1):1985	mg/Nm^3	41.55	**150**

Name Of Instrument	Calibration On	Calibration Due On
Envirotech Stack Sampler VSS1 Sr. No. 183-DTC-2019	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------**End of Test Report**----------

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TEST REPORT
STACK SAMPLE ANALYSIS REPORT

Customer's Name & Address: Dahej Harbour and Infrastructure (DHIL) C/o Hindalco Industries Limited. Post, Dahej, Dist. Bharuch. **Contact Person:** Sachin Sharma HOD (Environment & Utility)	**Report No:** GLEL/180926/01 **Issue Date:** 18/09/2026

Lab ID Code	:	GLEPL/170926/ST_1			
Description of Stack	:	Jetty Conveyor bag filter stack			
Date of Sampling	:	17/09/2026	Stack Dia (cm)	:	0.4
Sample collected by	:	GLEL Team	Stack Height (m)	:	20
Stack Type	:	Flue	Stack Temperature (^{0}C)	:	31.8

RESULT TABLE

Sr. No.	Test Parameters	Test Method	Unit	Result	GPCB Limit
1.	Particulate Matter	IS:11255 (P-1):1985	mg/Nm^3	40.29	**150**

Name Of Instrument	Calibration On	Calibration Due On
Envirotech Stack Sampler VSS1 Sr. No. 183-DTC-2019	27/03/2026	26/03/2027

Chemist

Authorized Signatory
Rekha Der

----------End of Test Report----------

CIN : L29253GJ2010PLC059798

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ON SITE EMERGENCY PLAN

[As per required by Schedule 8-A, Rules 68-J (12)(1) of the GFR 1963]
[The rule 13(1) of MSIHC Rules 1989 (Manufacture, Storage and Import of Hazardous chemicals Rule – 1989)]

M/s HINDALCO INDUSTRIES LTD
(Unit: BIRLA COPPER)

AT & PO DAHEJ, NEAR LAKHIGAM,
GIDC INDUSTRIAL ESTATE , TA: VAGRA - 392130
BHARUCH, GUJARAT, INDIA.

MAY- 2025

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PREFACE

Our First Emergency Plan was prepared and then after it is updated annually based on the learning outcome from various Mock drills or on account of expansion of the facility. Mock drills are to be conducted to test the plan and improve our emergency preparedness. The goals and objectives will be to improve quality of work and working life through dedicated and concentrated efforts consistent with the requirements of safety, health and environment at work place. The results of these exercises, identification and assessments of all credible scenarios, survey of various Rules, Regulations and standards will be taken as basis for modifying the ON-SITE Emergency Plan. Classification of Emergencies as well as keeping in view the requirements of implementation of ISO 14001:2015 and ISO 45001:2018.

As emergencies arise suddenly the necessity to stay alert at all times & ready with supporting facilities to face them is of paramount importance. This document cannot be said to be complete is always under continuous evaluation based on current emergency response. Well planned and well-rehearsed Emergency Plan will help organization to mitigate / control emergency situation in minimum time and also to restart operation with minimum losses.

The Onsite Emergency Plan (OSEP) is prepared and revised after reviewing & refereeing Last few Mock drills was conducted by sites.

All the key personnel are requested to study the document and become familiar with the contents and disseminate information to those working with them.

Mr. K. N. Bhandari

Occupier

Annexure-4

Annexure-5

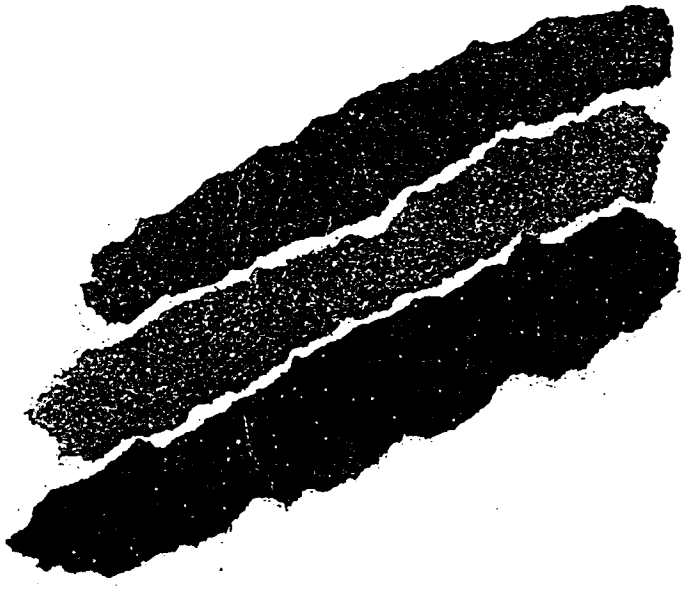
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Comprehensive Marine EIA/EMP For Wastewater Release and Captive Jetty for Indo Gulf Copper Smelter at Lakhigam

SPONSORED BY

Indo Gulf Fertilizers and Chemicals Corporation Limited
Bombay

MARCH 1996



राष्ट्रीय समुद्र विज्ञान संस्थान

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1 INTRODUCTION

1.1 Background

Indo Gulf Fertilizers & Chemicals Corporation Limited (Indo Gulf) has planned to set up a copper smelter at Lakhigam in Bharuch district of Gujarat for the production of 100,000 t y^{-1} of copper cathodes. The sulphuric acid produced as a byproduct will be utilized for the manufacture of phosphoric acid (700,000 t y^{-1}).

The process plants will generate about 5300 m^3 d^{-1} of wastewater which will be treated to the standards prescribed by the Gujarat Pollution Control Board (GPCB). Indo Gulf proposes to release the treated wastewater in the nearshore marine waters off Lakhigam in a manner that the impact on the marine ecosystem is minimised.

Indo Gulf is also proposing to establish a port terminal to berth upto 30,000 DWT bulk carriers primarily to import copper concentrate, rock phosphate, sulphur and coal and to export copper cathodes and phosphoric acid. The total cargo handled at the terminal will be of the order of 1 x 10^6 t y^{-1}.

Indo Gulf had appointed Multi Mantech International Private Limited (Multi Mantech) as their consultants who in turn had contracted the National Institute of Oceanography (NIO) to undertake initial marine environmental impact assessment due to the release of treated process wastewater and establishment of port facility near Lakhigam, on the basis of data available with NIO. The report **"Rapid marine environmental impact assessment due to Indo Gulf Copper Smelter at Lakhigam"** was submitted during November 1994.

While granting clearance to the project, the Ministry of Environment and Forest, Government of India, (MOEF) stipulated several conditions of which the conditions pertaining to marine environment are listed below:

i) Comprehensive EIA report for the proposed copper smelter and captive jetty facilities should be submitted within a period of 15 months.

ii) Treated effluents should conform to the prescribed standards and discharged into the sea at a point approved by the State Pollution Control Board and NIO, Goa. Effort should be made to recycle the treated effluents for green belt development to the maximum possible extent.

iii) A study to assess the impact of the proposed pipeline for disposal of treated effluent should be carried out and reports submitted to the Ministry for review within 6 months.

iv) Proposed jetty and related infrastructure should be in conformity with the provisions of the Coastal Regulation Zone.

v) Screenings of pollutants in the harbour waters should be taken up by the project authorities and periodic monitoring reports on water quality parameters must be forwarded to the ministry at six monthly intervals.

vi) A comprehensive disaster management plan considering worst case disaster scenarios with respect to specific cases like oil/chemical spills, fire/explosion, terrorist attack, flood etc, spelling out definite/adequate measures to be taken to prevent and contain such disasters must be forwarded to the ministry within six months from the date of issue of the environmental clearance.

vii) Appropriate devices such as oil water separator, oil monitor, oil skimmer etc. must be provided to remove all floatable materials including oil spills while refuelling the vessels, because of operations of cargo handling, equipment and allied machinery, cranes, tractors etc. to tackle oil pollution in the port area and marine environment.

In view of above stipulations, Indo Gulf contracted NIO to undertake studies leading to the preparation of a Comprehensive Marine Environment Impact Assessment report.

1.2 Objectives

a) Evolve baseline marine environmental quality of coastal water of Lakhigam.

b) Suggest suitable location for release of treated wastewater off Lakhigam in a manner that the prevailing marine environmental quality is maintained.

c) Assess impacts of proposed activities and development of port terminal on marine ecology and suggest mitigation measures.

d) Examine the proposed shore-based facilities in view of Coastal Regulation Zone (Notification by MOEF dated 19th February, 1991).

1.3 Scope of studies

In view of the high tidal regime of the Gulf of Khambhat and the vicinity of Narmada estuary the following scope of work was designed after discussions with Indo Gulf.

The field observations to be conducted at 6 stations as illustrated in Figure 1.3.1. Out of these, stations 3 and 4 to be operated for time series measurements over a tidal cycle. The parameters to be studied are listed below:

a) Circulation and currents:

Neutrally buoyant drifters to be released at predetermined location and followed over a tidal cycle during average tide conditions to obtain the trajectories of tidal movements representing coastal circulation. The data on currents given in the report **"Report on current and float observations for jetty at Dahej/Lakhigam (Bharuch)"** to be made available by Indo Gulf to be utilised wherever required.

b) Stratification:

Salinity-temperature variations in the water column to be determined over tidal cycles to assess extent of stratification. These measurements to be taken at 3 depths.

c) Water quality:

Time series measurements of water quality parameters to be undertaken at selected locations to understand their tidal variability. The samples to be analysed for temperature, salinity, pH, inorganic phosphate, nitrate, nitrite, ammonia and dissolved oxygen (DO). Samples collected at high tide and low tide to be analysed for BOD, suspended solids, petroleum hydrocarbon residues (PHC) and phenols.

d) Sediment quality:

Sediment from selected locations to be analysed for texture, organic matter, total phosphorus, trace metals and PHC.

e) Biological characteristics:

Biological productivity of the region to be evaluated on the basis of (i) phytoplankton pigments/cell counts as a measure of primary productivity, (ii) zooplankton standing stock in terms of population and biomass, (iii) identification of fish/shellfish eggs and larvae, their seasonal abundance and commercial importance, and (iv) macrofaunal population and biomass to quantify benthic productivity.

1.4 Approach strategy

It is inevitable that release of wastewater into the sea would cause environmental impacts, the intensity of which would vary depending on several factors such as quality and quantity of wastewater, digestive capacity of the receiving seawater and degree of ecological sensitivity of the marine area. As the enhancement of levels of pollutants in the receiving water over the natural background is the prime factor

controlling the extent of influence on ecology, the primary interest of a study aimed at identifying suitable site for release of wastewater to establish the probable dispersion of a pollutant on entering seawater and its sphere of influence, on marine biota. The important physical factors which control dispersion in coastal waters are tides, currents, thickness of water column, circulation and stratification.

The construction of port terminal consisting of a jetty to berth 30,000 DWT bulk carries, piled and rubble bund approach and subsequent operations of unloading and loading of cargo can potentially cause adverse impacts on the marine environment. A reliable assessment requires the knowledge of proposed marine structures; construction methodologies, techniques of cargo handling, nature of cargo and probable spillages, and sewage and other discharges by ships visiting the port terminal

Whether it is release of wastewater or construction of a port terminal, the acquisition of baseline marine environmental data representing different seasons is a prime requisite for assessing the impacts.

A scan of published scientific literature and available technical reports indicated that apart from studies undertaken by NIO during 1979 and 1993-95, the information related to the ecology of the coastal sea off Lakhigam was rather scanty. The field studies during 1993-94 were carried out along two transects parallel to the shore between Dhadhar and Narmada estuaries. Transect 1 was 2.5 km from the

shoreline along which 4 stations were operated while transect 2 with a similar intertidal expance of 2.5 km to the west of transect 1 along which 3 stations were sampled. The area of field observations during 1995 was confined to the mouth of Narmada estuary. Some of these stations were sampled over tidal cycles to evaluate temporal variability of hydrographic parameters, inherent to nearshore waters under high tidal influence.

The information regarding manufacturing processes, wastewater, raw materials, finished products, port terminal etc was provided by Indo Gulf. Four reports namely

(a) Environmental impact assessment and environmental management plan, prepared by Metallurgical & Engineering Consultants (India) Limited, New Delhi,

(b) Feasibility report for proposed marine material handling facility at Dahej/Mangalore, prepared by Howe (India) Private Limited Consulting Engineers, New Delhi,

(c) Current and float observations for jetty area at Dahej/Lakhigam (Bharuch) by Elcome Surveys Private Limited, Bombay,

(d) Berthing facilities near Lakhigam village in the Gulf of Khambhat, India, by Delft Hydraulics, U.K. were made available by Indo Gulf.

1.5 Programme of work

The field studies of the present survey were carefully framed after assessing the available information on the basis of existing bathymetry (chart 2039 and ELCOME report) and proposed marine activities six stations as illustrated in Figure 1.3.1 were selected for environmental data acquisition. These stations were on two north-south transects with transect 1 at 11 m depth contour and transect 2 about 2 km away from transect 1 in the seaward direction. Stations 3 and 4 were operated for time series measurements to augment support base with respect to baseline criteria. In addition, the sediment from 15 locations on 3 transects around the approach road of the proposed port terminal was also collected for evolving benthic productivity.

The coastal waters are subject to profound seasonal variations and ideally, information during premonsoon, monsoon and postmonsoon baseline should be established to enable future assessments if accidental emergencies arise. However, as the region is under monsoonal spell during June-September, studies during this period are not feasible due to the hostile sea conditions under which field surveys by conventional means are not possible. Moreover monsoon studies are not critical since high turbulence generated by monsoonal influence is expected to enhance dispersion of pollutants, reducing the impact on the ecology. High freshwater discharge of Narmada river during monsoon is also expected to arrest the transport of pollutants to the productive estuarine zone.

The present studies were carried out only during postmonsoon and the assessment presented to this report pertains to this season only and need not necessarily be applicable to premonsoon scenarios.

1.5.1 Circulation and stratification

Circulation in the coastal water was estimated by deploying a neutrally buoyant biplane drogue from a predetermined location and tracking it continuously using a boat, during average tide. The position of the drogue was fixed periodically with a GPS (Nav - 5000) and plotted to obtain the trajectory. Drogues with lights were used to facilitate tracking during night.

Due to the high current speeds, insitu measurements using salinity-temperature probes was unsuccessful since the probes when lowered in water were lifted to the surface even when weighed with a sinker. Hence, the salinity-temperature measurements were achieved by collecting water samples at different depths.

1.5.2 Water quality

a) Sampling procedure:

Surface water samples for general analyses were collected using a clean polyethylene bucket while an adequately weighed Niskin sampler with a closing mechanism at a desired depth was used for obtaining subsurface water samples. Sampling at the surface, mid-depth and bottom (1m above the bed) was done when the station depth exceeded 5 m. For shallow regions only surface and bottom samples were collected. Due to strong currents sometimes mid-depth sampling

was not possible. A glass bottle sampler (2.5 l) was used for obtaining samples at 1 m depth, for the estimation of PHC.

b) Methods of analysis:

Majority of water quality parameters were analysed in the field laboratory established at Bharuch. Colorimetric measurements were made on a 1201 UV (Schmadzu) spectrophotometer. LS 3B (Perkin Elmer) fluorescence spectrophotometer was used for estimating PHC. The analytical methods of estimations were as follows:

i) Salinity:

A suitable volume of the sample was titrated against silver nitrate (20 g l^{-1}) with potassium chromate as an indicator. The salinity was calculated using Standard Tables.

ii) Suspended solids:

A known volume of water was filtered through a preweighed 0.45 μ Millipore membrane filter paper, dried and weighed again.

iii) pH:

pH was measured on a Labindia microprocessor controlled pH analyser. The instrument was calibrated with standard buffers just before use.

iv) DO and BOD:

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

v) Nitrite:

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

vi) Nitrate:

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

vii) Ammonia:

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.

viii) Phosphate:

Acidified molybdate 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.

ix) PHC:

Water sample (2.5 l) was extracted with hexane 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 as a standard.

x) Phenols:

Phenols in water (500 ml) was converted to orange coloured antipyrine complex by adding 4-amino antipyrine. The complex was extracted in chloroform (25 ml) and the absorbance was measured at 460 nm using phenol as a standard.

1.5.3 Sediment quality

a) Sampling procedure:

Surficial bed sediment from all locations was obtained by a van Veen grab of 0.04 m^2 area. The sediment after retrieval was transferred to a polythene bag and preserved for further analyses at Bombay.

b) Methods of analyses:

i) Texture:

The sample was split into sand and silt-clay fractions on a 62 μ sieve and the texture was determined.

ii) Organic matter:

The percentage of organic carbon in sediment was determined by oxidising the organic matter in the sample by chromic acid and estimating excess chromic acid by titrating against ferrous ammonium sulphate.

iii) Trace metals:

The sediment was brought into solution by treatment with conc HF-$HC10_4$-HNO_3 acids and the metals were estimated by flame AAS on a Spectra 30A (Varian) atomic absorption spectrophotometer.

iv) Total phosphorus:

The sediment was brought into solutions by treatment with conc HF-$HC10_4$-HNO_3 acids and total phosphorus was estimated as described under water quality.

v) PHC:

The sediment after refluxing with KOH-methanol mixture was extracted with hexane. After removal of excess hexane, the residue was subjected to clean-up procedure on alumina column. The PHC content was then estimated by measuring the fluorescence as described under (i) with Saudi Arabian Crude residue (b.p. > 100°C) as a standard.

1.5.4 Biological characteristics

a) Sampling procedure:

Polyethelene bucket and Niskin sampler respectively, were used for sampling surface and bottom water for the estimation of

phytopigments. Oblique hauls for zooplankton were made using a Heron Tranter net (Mesh size 0.33 mm, mouth area 0.25 m^2) with an attached calibrated TSK flow meter. All collections were of 6 min duration. Samples were preserved in formalin.

Sediment samples for benthos were collected using a van-Veen grab of 0.04 m^2 area. For intertidal sampling three transects off Lakhigam viz I, II and III were selected (Figure 1.3.1). Collections were done at selected locations from the lowest low water (LLW) to the highest high water (HHW).

b) Methods of analyses:

i) Phytoplankton pigments:

A known volume of water was filtered through a 0.45 μ Millipore membrane filter paper and the pigments retained on the filter 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.

ii) 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.

iii) 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 m^2 area and biomass on wet weight basis.

iv) Fish eggs, fish larvae and decapod larvae:

These groups were sorted out from zooplankton samples of 1993-95. The larval stages were identified into species and compared with the adults found in the area.

2 AREA DESCRIPTION

The site (21° 42' N, 72° 33' E; Figure 1.3.1) at Lakhigam is near Dahej village and about 40 km from Bharuch town. Indo Gulf has acquired 250 ha of land for the complex which is about 520 m east from the high tide line along the open coast.

The land terrain of Lakhigam is generally flat and sloping in the direction of the sea towards the west. The Narmada river with extensive intertidal mud flats and inlets runs along the southern boundary while, the Dhadhar river forms the northern limit of the area.

The land is generally barren and covered by silty loam and saline soil having low nutrient content. Small pockets of agricultural areas are cultivated for rainfed crops such as cotton, tuvar, jowar and wheat. General vegetation of the region is primarily dominated by salt tolerant plants such as *Prosopis juliflora, Acacia arabica, A.nitotics,*

A.leucophlora, Capparis zeylanica and *Zyzypus sp.* Alia Bet, an island at the mouth of Narmada which remains largely submerged during high tides, has vast stretches of grasslands that is traditionally utilized for grazing cattle. Extensive low lying coastal areas which get inundated during high tide are mostly barren and composed of either sand or silty clay.

The coastal strip between Dhadhar and Narmada estuaries is expected to undergo considerable transformation once the planned large scale industrial projects are commissioned. Among the industries under commissioning in this area are a petrochemical complex, a phosphoric acid plant and Indo Gulf's Copper Smelter.

Villages within 10 km radius of the plant site have a total population of around 14000 people with a maximum population of 4000 in Dahej village. All these villages have primary schools and basic medical and postal services. They are well connected by road and bus which is the main mode of transport. Dug wells are the primary source of drinking water though tank water is also occasionally used for domestic needs.

The wide and shallow Narmada estuary meets the Gulf of Khambhat (hereafter termed as Gulf) at Luhara. Extensive sand banks, many of which are exposed during low tide and that may shift from season to season, are present in the estuarine zone which make navigation hazardous during low tide. The river also contains many

sand banks with channels between them which are shallow and very intricate.

Bharuch channel is the principal entrance to the estuary. The flood tidal stream entering the estuary extends atleast as far as Zanor, a distance of about 70 km from the mouth during summer when the riverine flow is meagre. Flooding of the river is a recurring feature during July - August and the level often exceeds the danger mark (6.7 m) at Bharuch. When this occurs vast nearshore areas get inundated causing extensive damage to agriculture and property. The coastal terrain around Narmada is flat and the black soil is highly fertile and well cultivated, except along the Arabian Sea coast which is largely barren.

The shallow Dahej creek located along the coast northwards of Luhara with wide and bar-strewn mouth nearly dries-up during low tide. With its tidal port however, it forms an important commercial link across the Gulf. Several salt pans and vast stretches of marshy lands with isolated scrubby mangroves in patches, surround the creek.

The climate of the region in general is hot and humid except during winter between December and February. The mean maximum temperature during summer is about 40°C and mean minimum temperature during winter is around 12°C. The region comes under the monsoonal influence during June-September receiving over 100 cm of rainfall during this period.

3 PROJECT SCHEME

3.1 Site attributes

Since operation of the proposed copper smelter is based on the imported copper concentrate, a coastal area with a potential for establishing berthing facilities for bulk carriers is preferred. The site at Lakhigam was selected as a large plot of land was available in the proximity to the sea not only to establish the complex but also to store waste products such as slag, phosphogypsum and fly ash. Transportation of raw materials to the complex and finished products to the berth was also considered convenient at this location. The region is barren and very thinly populated. Therefore, the socio-economic impact of establishing the complex was expected to be negligible. Additionally, the proximity to the sea was ideal for disposing treated wastewater generated in the process plants. Other environmental conditions also favoured the selection of the site.

Dahej port is 4 km away and also serves as a railway station on narrow gauge. Nearest broad gauge railway passes through Vadodara and Bharuch which are 100 and 40 km away respectively. The site is also well connected to Vadodara and Bharuch by road.

The raw water requirement of 24,750 $m^3 d^{-1}$ of the complex will be met through an intake well to be constructed near Jhanor on Narmada river, about 75 km from the site. The power supply for the complex will be drawn from 220 KV Haldharna substation, 55 km from site. However, a captive power plant of 24.5 MW capacity is also envisaged for emergency supply.

3.2 Brief description of the process

Copper concentrate which is the major raw material in the process contains 30 - 32% copper, 28 - 32% sulphur and 7 - 10% moisture. Five major steps in the extraction of copper are the following.

i) Drying of copper concentrate.

ii) Smelting of concentrate to obtain matte containing 65% copper and slag.

iii) Converting liquid matte to blister copper (98 - 99%).

iv) Refining of blister copper to produce 99.5% pure copper.

v) Electrolytic refining pure copper to produce copper cathodes (99.99% pure).

During extraction, sulphuric acid is recovered from the off-gases. A small quantity of gold and silver is also obtained from anode slime.

3.2.1 Copper smelting and refining

Indo Gulf has selected Outokumpu Process for smelting. In this process, the wet concentrate containing 7 - 10% moisture is dried in a steam dryer to reduce the moisture content to 0.2%. It is then smelted with preheated oxygen enriched air in a flash smelting furnace from where the liquid matte containing about 65% copper is tapped to a cylindrical furnace (converter) to separate blister copper (98.5%) and slag. Copper is purified to 99.5% in anode furnaces and casted on rotating anode casting wheels. The metal is further purified by electrolytic refining using Isa Process. In this process, stainless steel electrodes are used as cathodes and copper (99.5%) obtained from smelting as anodes, to obtain 99.99% pure copper.

3.2.2 Sulphuric acid

Around 2,85,000 t y^{-1} of sulphuric acid will be produced by double conversion-double absorption (DC-DA) process. The sulphurous off-gases from the smelting furnace and converter are mixed, cleaned and scrubbed to remove dust and harmful impurities. The emerging SO_2- rich gases are mixed with air and dried in a drying tower with 96% concentrated sulphuric acid. The dried gases are further converted to SO_3 in heat exchangers at 400 - 500°C in presence of V_2O_5 catalyst. The converted gases are then absorbed in 98% concentrated sulphuric acid to get final product i.e. 98.4% sulphuric acid.

3.2.3 Phosphoric acid

Phosphoric acid (7,00,000 t y^{-1}) will be produced by wet process by treating phosphate rock with sulphuric acid. Calcium sulphate which precipitates as phosphogypsum is separated by filtration to recover phosphoric acid from filtrate. The residue of gypsum cake is further treated with sulphuric acid and the filtrate of the reaction mixture is recycled to the first stage filter. The weak acid is then concentrated to the required strength.

3.2.4 Power plant

A lignite based 24.5 MW power plant is proposed to meet anticipated shortfall in power availability and also provide an opportunity to utilise waste heat of the metallurgical process.

3.3 Characteristics and disposal of wastes

Adequate pollution control facilities are envisaged in the complex to treat the solid, gaseous and liquid wastes.

3.3.1 Solid waste

The smelter is expected to produce 160,000 t y^{-1} furnace slag containing 28% silica, 49% iron, 1% copper, 0.9% sulphur etc. Other solid wastes are phosphogypsum (500,000 t y^{-1}) and fly ash (70,000 t y^{-1}) from power plant. The wet phosphogypsum filter cake containing gypsum, silica and small amount of untreated rock phosphate will be dewatered and desludged in a lagoon. All the solid wastes will be stored in the open area within the complex and no solid waste will be disposed in the sea.

3.3.2 Gaseous emissions

The off-gases from flash furnace and convertors are cooled in waste heat boilers and remaining dust recovered in the hot gas precipitators. The gas are scrubbed and cleaned in electrostatic mist precipitators. The purified gases will be used in sulphuric acid production. The tail gas containing acid mist and SO_2 will be washed in a counter current scrubber before they are discharged into the atmosphere. The fluorine contents in weak phosphoric acid will be removed during acid concentration stage as vapours, which will be scrubbed for recovery of hydrofluorosilicic acid. If such recovery is uneconomical then fluorine will be absorbed in the condenser cooling water and neutralised using a bleed from the cooling water circuit.

3.3.3 Liquid effluent

Although the complex will use around 24,750 m^3 d^{-1} of freshwater, the liquid effluents generated in various processes will be restricted to within 5300 m^3 d^{-1} which will be treated to the standards prescribed by the GPCB (Table 2.3.1) and released to the sea at a location to be identified after detailed studies. The spent cooling effluent and domestic wastewater will be treated and recirculated upto the extent of 95%. The wastewater may be generated from the following sources:

i) Refinery plant may generate a small quantity of acidic effluent which together with spillages etc will be neutralised with lime in an effluent treatment plant and sent for discharge.

ii) Small quantities of acidic effluent will result from sulphuric acid plant which will also be neutralised prior to discharge.

iii) The phosphogypsum filter cake will be collected in a lined pond and after settling of phosphogypsum, clear water will be recirculated in the process. Scrubber bleed containing phosphates, fluorides, hydrofluorosilicic acid, calcium chloride etc along with plant spillages will be adequately treated prior to discharge to the sea.

iv) Domestic wastewater generated from the township having water requirement of 1500 m^3 d^{-1} will be used for green belt development after proper treatment. Hence, release of domestic wastewater to the sea is not envisaged.

3.4 Port terminal

Indo Gulf is considering establishment of a port terminal to berth upto 30,000 DWT bulk carriers primarily to import copper concentrate, rock phosphate, sulphur and coal and to export phosphoric acid. The terminal will consist of a berth (210 x 20 m) suitable for loading and unloading cargo with a 1044 m long piled approach and 1320 m long rubble bund road upto the high tide line (Figure 3.4.1).

The imported cargo will be unloaded using a 800 t h^{-1} capacity grab unloader on the berth structure. The material will be transported by a pipe conveyor system to the copper concentrate storage shed and rock phosphate silos within the boundary of the complex.

A deck plate hinged to the unloader structure will collect any material that may be spilled from the grab and at all transfer points of the pipe conveyer and the unloader. A dust control system with additional water spray system will also be installed to keep dust emissions within permissible limits.

It is envisaged that there will be no spillage of the cargo during unloading operations. Hence, the marine environment will not be adversely affected due to the contamination by cargo during unloading operations.

The liquid handling system to transport phosphoric acid from the plant to the berth for export (or import of ammonia in future) will consist separate pipelines with flexible hose connections at the berth.

The transport will be through fail safe system preventing any leakage during pumping operations.

4 PREVAILING MARINE ENVIRONMENT

4.1 Coastal dynamics

The spreading of a pollutant released to the sea is governed by advection caused by large scale water movements effecting a local change in concentration of a pollutant, and diffusion due to comparatively small-scale random and irregular movements without causing any net transport of water. The important flow properties governing the fate of wastewater in the coastal sea are, the extent of tidal influence, currents, circulation and stratification.

4.1.1 Tides

The tides at Lakhigam closely resemble those at Bhavnagar on the west bank of the Gulf. The tide is of a semidiurnal type with a considerable diurnal inequality and occurring about 30 min ahead of the tide at Bhavnagar. The following tidal parameters (with respect to Chart Datum) are computed for Lakhigam:

Highest high water spring	9.8 m
Mean high water spring	8.3 m
Highest high water neap	6.5 m
Mean high water neap	3.1 m
Lowest low water neap	1.9 m
Lowest low water spring	1.1 m

Predicted high water and low water in the area reveal that the tides of range between 6.2 and 7.7 m occur during 34% of time, tides of range lower than 6.25 m occur about 34% of the time and the tides greater than 7.7 m occur for around 30% of the time.

The high, tidal oscillations prevalent off Lakhigam induce turbulence and shear of the coastal region that could facilitate distribution of an effluent cloud released to the sea, over a large area fairly quickly. Also, because of high tidal range, the dilution attained as the wastewater plume surfaces or sinks through the water column (depending on the specific gravity of wastewater) may vary considerably attaining minimum during spring low tide and maximum during spring high tide.

4.1.2 Currents

The inflow and outflow of large volumes of water across the Gulf associated with high tidal influence, generate strong currents and speeds of 0.8 - 2 m s^{-1} have been recorded in the interior Gulf.

The flood and ebb current speeds attain maximum after about 2 and 1 - 1.5 h respectively from reversal of the tide. The surface, peak neap flood and ebb current speeds were comparable (1.2 - 1.4 m s^{-1}). During flood, the direction of the current varied between 0° and 41° and during ebb between 180° and 236°. The peak current speeds decreased considerably in the vertical and were 0.8 - 0.9 m s^{-1} at the bottom.

Nearshore, the surface currents were weaker and the peak surface speeds were less than 1 m s^{-1} except during spring tide when the peak speed increased to 1.6 m s^{-1}. As expected, the speeds decreased considerably at the bottom and the maximum was 0.8 m s^{-1} during spring. The direction of currents was generally comparable in the vertical.

Thus in general, the currents in the coastal water of Lakhigam are bimodal with prominant north - northeasterly direction during flood and south - southwesterly direction during ebb. The slack period between the change over of tides is very short at the surface and mid-depths although a period of 40 - 45 min is evident at the bottom.

The currents were resolved into offshore-onshore and alongshore components. Analysis of 4 continuous tide cycles recorded during January 94 indicated alongshore component of 0.17 m s^{-1} supporting a net flow in the southerly direction. The past salinity measurements undertaken in the Gulf supported accumulation of freshwater transported through the major rivers such as Narmada, Mahi and Sabarmati. It is possible that the southerly drift is accelerated by the freshwater getting accumulated in the Gulf.

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The net across-the-shore component was positive (0.09 m s^{-1}) indicating a weak dominance of preferential offshore drift. However, due to regional nearshore features such as estuaries, bays and mudflats considerable spatial variations are possible in coastal waters of Lakhigam.

4.1.3 Circulation

Real time circulation pattern off Lakhigam was assessed through drogue trajectories over tidal cycles. The drogue was released from a predetennined station at the start of high or low tide and tracked over a tide cycle. Some representative trajectories of the present and earlier studies are illustrated in Figures 4.1.1 to 4.1.5.

The circulation pattern in the nearshore water of Lakhigam is elliptical with major axis (parallel to the shore) varying in 12 - 35 km range and minor axis (perpendicular to the shore) varying in the range 0.5 - 7 km. The area defined by the drogue during the movement of a tidal cycle vary considerably but typically exceed 25 km^2 and the average speed of the drogue movement are as high as 1 m s^{-1}.

Although general pattern indicates small but definite offshore component of currents governing the circulation, considerable deviation during flood tide with shoreward transport at the mouth and estuarine zones of Narmada and Dhadhar estuaries, is evident.

The nearshore circulation pattern indicates that (i) the wastewater will disperse over a wide area under the influence of tides, attaining high

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... of dilution in the process, (ii) the probability of build-up of ... in the coastal water due to recirculation is remote, (iii) while ... dispersed, the wastewater will be advected preferentially in a ... parallel to the coast and shoreward transport will be weak until ... under the local influences of estuaries and creeks and, (iv) the ... water will be considerably diluted by the time it reaches nearby ... waters such as Narmada and Dhadhar estuaries.

4.1.4 Stratification

When wastewater having specific gravity lower than that of receiving water is released through a subsurface outfall, the available water column above the discharge decides the degree of initial dilution which is crucial when designing an outfall. In many coastal areas sluggish vertical mixing of water masses leads to stratification resulting in distinct layers having different densities. In such instances, mixed wastewater-seawater plume may not rise to the sea surface and may spread at an intermediate level of stratified interface. Hence, the entire water column above the release point is not available for diluting a rising plume thus, restricting initial dilution to the effective water depth i.e. upto the occurrence of stratification. Hence, it is important that the nature and intensity of stratification in a water column, if any, is established.

Salinity/temperature measurements at different stations indicated following average values:

Station		Salinity (ppt)	Temperature (°C)
1	Sur	25.6	31.7
	Mid	25.6	31.7
	Bot	25.5	31.7
2	Sur	25.5	31.9
	Mid	25.4	31.7
	Bot	25.4	31.8
3	Sur	26.3	32.2
	Mid	26.4	31.5
	Bot	26.8	31.8
4	Sur	27.2	31.2
	Mid	27.2	31.1
	Bot	27.3	31.3
5	Sur	27.6	30.1
	Mid	27.8	31.0
	Bot	28.0	31.1
6	Sur	27.3	30.5
	Mid	27.5	30.5
	Bot	27.6	30.8

These values indicate absence of stratification in the coastal water during postmonsoon even in the presence of high riverine discharge of Narmada River which can be due to high turbulence generated by strong tidal currents.

4.2 Water quality

4.2.1 Existing wastewater fluxes

The coastal strip between Dhadhar and Narmada estuaries is underdeveloped with no major industrial or urban settlement around except Bharuch town which is 40 km in the east. Therefore, at present there are no direct wastewater discharges to the coastal sea off

Lakhigam. However, Dhadhar and Narmada rivers in their interior segments receive industrial as well as domestic wastewaters which may potentially transport the pollutants to the coastal sea. Considering the distances over which the pollutants have to travel to reach the sea and their quantities, their impact on marine ecology is expected to be small.

Several large industrial complexes are planned in the region which may change the existing environmental scenario. Some of these complexes are Gandhar Petrochemicals Complex, Gujarat Alkalies and Chemicals Limited and Indo Gulf Copper Smelter. In addition, three port terminals between Ambheta and Dahej are under consideration for the transportation of cargo. It is therefore inevitable that human interference with the coastal environment will increase many folds in near future. Large inputs of wastewaters from a variety of industries are also expected which may adversely influence the baseline environmental quality of the region if not managed properly by selecting suitable sites for release of treated wastewater in the coastal region after detailed oceanographic investigations.

4.2.2 Baseline characteristics

The water quality off Lakhigam was assessed during October 1995 and the values are represented in Tables 4.2.1 to 4.2.6 and Figure 4.2.1. The results of 1993 monitoring are given in Tables 4.2.7 and 4.2.8, and Figures 4.2.2 and 4.2.3 for comparison. The general features are as follows.

a) Temperature

Water temperature varied in line with the air temperature. The water body was generally well mixed with the absence of significant thermal stratification.

d) pH

By virtue of the strong buffering action of $CO_2/HCO_3^-/CO_3^{2-}$ systems prevailing in seawater, the pH varied in a narrow range 7.7 - 8.1.

c) Suspended solids

The coastal water of Lakhigam is muddy and turbid with high and variable suspended matter. Clear gradation of the suspended load with a substantial increase from the surface to bottom indicated that it resulted from the dispersion of fine grained seafloor material in the water column by strong tidal currents sweeping the Gulf.

d) Salinity

The salinity of coastal water was markedly lower than expected for seawater (35 - 37 ppt) under the influence of riverine freshwater flow, particularly through Narmada River. Temporal changes (Figure 4.2.1) indicated a marginal change over a tidal cycle and absence of vertical stratification.

e) DO and BOD

The DO off Lakhigam was generally slightly lower than the saturation level suggesting that the consumption of oxygen was more or less balanced by the replenishment, as expected for a healthy aquatic

environment. The mean DO was fairly high and varied in a narrow range of 4.8 - 7.1 mg l^{-1}. The occurrence of occasional low values-below 2 mg l^{-1}, however warrants caution since increase in organic load through anthropogenic sources may impose additional stress. The occasional low DO however appears to be a chance occurrence. The variation from the surface to the bottom was generally marginal due to the high mixing potential of water. The BOD was low (<0.2 - 1.8 mg l^{-1}) in the absence of any known anthropogenic discharge though occasional higher values were evident.

f) Phosphorus and nitrogen compounds

Phosphorus and nitrogen compounds present in seawater play a major role in the productivity of a water body. Nitrogen is mainly present as nitrate with low concentrations of nitrite and ammonium while, the major inorganic species of phosphorus is phosphate. The concentrations of nutrients are largely influenced by geology of the region and influx of freshwater and anthropogenic discharges.

The mean nitrate and phosphate contents are markedly high (393 - 533 μg l^{-1} and 27 - 147 μg l^{-1} respectively) which is the characteristic of the South Gujarat region. The nutrients are perhaps transported to the Gulf by numerous rivers draining predominantly agricultural areas in the plains. Mean nitrite and ammonium levels on the contrary were low as expected, indicating good oxidizing conditions in the coastal environment. It appears that the high content of nitrate is not consumed due to poor utilization by phytoplankton.

g) Phenols and PHC

Major contaminations by phenols and PHC in seawater generally

originate from anthropogenic sources such as industrial wastes. Obviously, in absence of any such discharges in the coastal water of Lakhigam, the average phenol and PHC levels were low.

h) Trace metals

The concentrations of trace metals in natural surface waters are extremely low though some such as lead, cadmium and mercury even at low concentrations are undesirable as they get bioaccumulated in several commercially important marine organisms, ultimately transferring them to man.

The studies conducted so far indicate that the concentrations of trace metals off Lakhigam are as follows:

Metal	Concentration ($\mu g\ l^{-1}$)
Chromium	ND - 0.5
Manganese	3 - 15
Iron	5 - 15
Cobalt	ND - 0.3
Nickel	ND - 1.0
Copper	2 - 10
Zinc	3 - 15
Cadmium	ND - 1.0
Lead	ND - 4
Mercury	ND - 0.1

ND : Not detectable

POLICY SCHEDULE 531723

Policy Number : 230305/36/10/01/00000417 Dept : Liability Insurance Oriental Insurance Company Limited

Previous Policy Number : 230100340901000000433
Insured's Name: M/S ECO CHEM SALES & SERVICE Issuing Office: Unit 230150
Address : OFFICE FLOOR,ACHOKA PAVILLION A,OPP.KAPADIA HEALTH CLUB,NEW CIVIL ROAD,SURAT Dist. : SURAT, Gujarat 395001
Address : 3RD FLOOR, J.K .CHAMBERS, PANI-NI-GHIT ,BHAGA TALAO,SURAT SURAT SERVICE TAX NO AAA
Telephone No. : 2599297,2594659 Fax: 2595435
Trade : POLLUTION CONTROL CONSULTANTS,CONTRACTORS,AUDITORS
Work Details : EFFLUENT TREATMENT PLANT OPERATION & ENVIORMENT MONITORING AT VARIOUS LOCATIONS AS PER LIST ATTACHED.

Development Officer / Agent : 561 / 58225
Date Of Proposal & Declaration: 24/12/2009
Policy Period : From 28/12/2009 To Mid Night of 27/12/2011 Receipt Date & No. : 24/12/2010 230100/01/10/00000010679
Net Premium : Rs.26,927 RUPEES TWENTY SIX THOUSAND NINE HUNDRED TWENTY SEVEN ONLY
Risk Situation : Pan

Premium details for Employees with wages less than Rs.8000/-

Description of Employees	No. Of Employees	Cash Total Wages (Rs.)	Endorsement No.	Rate (%)	Premium (Rs.)
OPERATORS AND HELPERS	10	5,06,064	38;177	30.82	15,596.39
CLERICAL STAFF	3	2,73,000		1.76	480.48

Premium details for Employees with wages more than Rs.8000/-

Description of Employees	No. Of Employees	Cash Total Wages (Rs.)	Endorsement No.	Rate (%)	Premium (Rs.)
COMMERCIAL TRAVELLERS	2	5,52,000	258	13.14	2,954.88
ENGINEER	1	1,40,000	38;177	30.82	3,043.64

List of Clients

Surat Dist. Co.Op. Milk Producers Union Ltd Sumul Dairy Post Box No. 501, SURAT – 395 008.	Gujarat State Electricity Corporation Ltd , Gas Based Power Station, Utran – 394 105, Dist. Surat.
National Thermal Power Corporation Ltd., Kawas, Hazira, Dist. Surat.	Oil & Natural Gas Corporation Ltd. CPF.Gandhar

HP Series PCL 5e (61.63.351.0); Microsoft Windows XP 5.1.2600.1; Unidrv 0.3.3790.

NX.

$$\frac{0.1 \times BR \times N \times 10,00000}{\text{Volume}} = \text{ppm}$$

2505

35 → 58 → 1.77
35

Sea water

58 — 23

Mol 2.93%
40% 1.16% Na
60% — 1.77% Cl

①	Ca^+	84 ppm	
②	Mg^+	426 ppm	
③	Total Hardness	510 ppm	
④	Cl^-	17750 ppm.	
⑤	pH	7.45	1.77%

B.R
$\frac{25.0 \times 0.1N \times 35.5}{5} = \frac{17.75 gpl}{} \times 1000$
= 17750 ppm

Cl
Na 1.77%
1.16%

28 PPM = 0.0028%
2.80%

10,00,000 = 1PPM

1.

20 PPT

36

3.60% 2.0%

1

20 — 0 — 15 — 1000

4.3 Sediment quality

4.3.1 Texture

The sediment texture of the subtidal as well as upper and lower intertidal regions from Lakhigam to Dahej narrowly varied from sandy to silty sand as follows:

Area	Texture
Station 1	Silty sand
Station 2	Sandy
Station 3	Sandy
Station 4	Sandy
Station 5	Silty sand
Station 6	Sandy
Upper intertidal	Sandy
Lower intertidal	Silty sand

4.3.2 Trace metals

Determination of trace pollutants such as heavy metals and organic compounds in water often reveals fluctuations as the concentrations depend on location and time of the sampling, nature of pollutant and chemical characteristics of water. Moreover, several trace pollutants get rapidly fixed to particulate matter and are thus removed from the water column. It has been observed in several instances that even close to the location of release, the metal content in water often decreases to normal value making the assessment of contamination through analysis of water, a difficult task.

The pollutants absorbed by the particulate matter are ultimately transferred to the bed sediment, on settling. Evidently, concentrations of pollutants in sediment increase over a period of time in regions receiving fluxes of these pollutants. Hence, if the levels of pollutants in sediment are reliably known prior to a development likely to influence these levels, they form a useful baseline for comparison while assessing sediment contamination after a few years of development.

The average concentrations of trace metals off Lakhigam varied as follows:

Metal	Concenration ($\mu g\ g^{-1}$; dry wt)	
	Subtidal	Intertidal
Chromium	37 - 63	72 - 92
Manganese	478 - 1039	754 - 923
Cobalt	14 - 29	26 - 30
Nickel	20 - 59	54 - 61
Copper	35 - 88	86 - 95
Zinc	26 - 91	75 - 88
Lead	ND - 5	ND - 8

The above concentrations appear to be of lithogenic origin and hence can be considered as a background for assessment in future.

4.3.3 Total phosphorus

The concentrations of total phosphorus in sediment generally varied between 658 and 2208 $\mu g\ g^{-1}$ (dry wt) in subtidal sediment. The

variation was in 390 - 2722 $\mu g\ g^{-1}$ (dry wt) range in intertidal sediment. The levels exceeding 1500 $\mu g\ g^{-1}$ appear to be high and can result due to the loads transported through nearby rivers predominantly draining agricultural and forest areas.

4.3.4 PHC

The levels of PHC in subtidal as well as intertidal sediments varied in a narrow range of 0.4 - 3.9 $\mu g\ g^{-1}$ (wet wt) and compared well with the concentrations commonly encountered in unpolluted marine sediments.

4.4. Biological characteristics

Biological characterisation of an area is an essential prerequisite for environmental impact assessment and can be done by selecting a few reliable parameters from a complex ecosystem. Evaluation of biological sensitivity of a wastewater disposal site helps to avoid areas of high productivity and breeding/fishing grounds of economically important species. The baseline information on the production potential of water column and sediment is also required for comparative evaluation of probable changes in the marine environment over a period of time.

The biological parameters considered for the present study were phytoplankton pigments, zooplankton standing stock and population, benthic biomass and population, and fishery potential. The first two reflect the productivity of a water column at primary and secondary levels. Benthic organisms being sedentary animals associated with the

sea bottom, provide information regarding the integrated effects of stress, if any, and hence are good indicators of early warning of potential damage. Experimental trawling was also undertaken to have knowledge of the catch rate, composition and present status of fishery potential. The larval stages of fishes and decapods were identified and quantified to locate the spawning grounds if any, of economically important species. A collective evaluation of all above components is a reliable approach to predict the state of equilibrium of marine life at the disposal site.

4.4.1 Phytoplankton

The levels of chlorophyll *a* (av 1.0 mg m^{-3}) and phaeophytin (av 0.9 mg m^{-3}) were low and marginally varied between stations (Table 4.4.1). The marginally variable nature of pigments between surface and bottom waters revealed the dynamic nature of the coastal system with a well mixed water body. The difference between the flood and ebb concentrations of chlorophyll *a* as well as phaeophytin were also marginal. Over a tidal cycle the concentrations of chlorophyll *a* (0.5 - 1.6 mg m^{-3}) and phaeophytin (0.2 - 1.9 mg m^{-3}) varied in a narrow range. The mean concentration of phaeophytin (0.9 mg m^{-3}) was marginally lower than that of chlorophyll *a* (1.0 mg m^{-3}), thereby indicating that growth and mortality of phytoplankton were well balanced. The present results are comparable with earlier studies (Table 4.4.2) which also revealed low levels of chlorophyll *a* (av 0.6 - 0.8 mg m^{-3}) in the region. The observed low chlorophyll *a* values in the coastal waters off Lakhigam particularly when nutrients are in high

concentrations, can be due to prevailing high suspended load in the water column which limits penetration of sunlight, an essential component for the growth of phytoplankton.

The plankton cell count (Table 4.4.3) varied from 8 x 10^2 l^{-1} to 100 x 10^2 l^{-1} (av 41 x 10^2 l^{-1}) in the coastal waters. The lowest count was encountered at station 1 while the highest value was obtained at station 3. The generic diversity varied from 1 to 8 with an average of 4. The observed diversity was poor and comparable with the earlier results for the region. Major genera encountered were *Coscinodiscus, Thalassiothrix, Nitzschia, Chaetoceros, Fragillaria, Surirella, Bacteriastrum, Amphora, Melosira, Navicula* and *Skeletonema.*

4.4.2 Zooplankton

The zooplankton standing stock (Table 4.4.4) in terms of biomass and population varied widely from 0.4 to 14.7 ml $(100\ m^3)^{-1}$ and from 6.7 x 10^2 to 141.3 x 10^2 $(100\ m^3)^{-1}$ respectively suggesting an overall poor to moderate secondary production potential. Station 1 sustained relatively better zooplankton standing stock especially in terms of biomass [av 8.4 ml $(100\ m^3)^{-1}$] while station 4 recorded the highest mean faunal count of 79 x 10^2 $(100\ m^3)^{-1}$. In general, the coastal waters off Lakhigam revealed poor secondary production (Table 4.4.5). The region was moderately diverse in zooplankton fauna with groups ranging from 4 to 12 (av 9). Copepods dominated the community in 71% of the samples and formed 48 to 85% (av 60 %) of the total count with high percentage at station 2 (av 81.9%). The other dominant

groups encountered occassionally were siphonophores (51.1%) and decapod larvae (71%). The other common groups in the area were chaetognaths, gastropods, ostracods, *Acetes*, ctenophores, polychaetes, and fish eggs and larvae. Fish larvae were represented fairly well in the area.

The study reveals both spatial and temporal variations in zooplankton standing stock and faunal composition. The findings corroborate the results (Table 4.4.6) of earlier studies (1993-94).

4.4.3 Benthos

a) Organic matter

Percent organic matter in the subtidal and the intertidal sediments varied from 0.05 to 1.36 (av 0.3) and 0.08 to 0.97 (av 0.4) respectively. No marked seasonal and regional variability in organic content was noticed. Both subtidal and intertidal regions sustained poor organic matter which could be mainly attributed to the sediment texture and partly to the unstable substratum conditions associated with strong tidal currents.

b) Intertidal fauna

The macrofaunal standing stock (Table 4.4.7) in terms of population and biomass (wet wt) varied from 25 - 1951 m^{-2} (av 431 m^{-2}) and 0.1 - 316 g m^{-2} (av 49 g m^{-2}) respectively in the intertidal area. Among the three transects investigated, transect III sustained the highest mean biomass of 95.7 g m^{-2} while the lowest mean standing stock both

in terms of population (164 m^{-2}) and biomass (8.3 g m^{-2}) was recorded at transect II. The mean faunal counts between transect I (550 m^{-2}) and transect III (581 m^{-2}) were comparable although transect I sustained about an order biomass less than transect III. Invariably the upper intertidal region (above mid-tide level) of all the three transects sustained very rich macrofaunal standing stock (av 988 m^{-2}; 122 g m^{-2}) as compared to the lower intertidal zone (av 90 m^{-2}; 0.5 g m^{-2}). The fauna was chiefly constituted (Table 4.4.8) by crustaceans (46%), polychaetes (32%), and molluscs (15%). Among crustaceans crabs (23%) were dominant than other common groups like amphipods (10%), isopods (11%) and prawns (2%). The faunal composition results revealed dominance of crustaceans at transect I, molluscs and crustaceans at transect II and polychaetes at transect III. However, the crabs were accounted for rich biomass rather than numerical density.

The study revealed considerable spatial variability in intertidal macrofauna. In general, the intertidal area off Lakhigam sustained a rich faunal standing stock especially at the upper intertidal zone as compared with the lower zone. This is comparable with the previous studies (Table 4.4.9) undertaken along the southern portion of the intertidal area of Lakhigam. However, the present study revealed about 25 times more biomass (av 49 g m^{-2}) as compared with southern portion (av 1.9 g m^{-2}) which could mainly be attributed to the prevailing complex coastal dynamics of the region resulting in vast intertidal mud flats along the northern part of Lakhigam. Polychaetes and crustaceans were the major macrofaunal

components (Table 4.4.10) of the intertidal macrobenthos. The present results are comparable with earlier data.

c) **Subtidal fauna**

The subtidal benthic standing stock (Table 4.4.11) in terms of population and biomass varied from 13 - 51 m^{-2} (av 28 m^{-2}) and 0.01 - 0.06 g m^{-2}(av 0.03 g m^{-2}) respectively. The benthic samples could not be obtained from station 2. Stations 1 and 4 revealed relatively better faunal standing stock than the rest. Overall, the region sustained very poor mean benthic standing stock in terms of population and biomass. Polychaetes (55%), amphipods (18%) and insect larvae (27%) were the major components of subtidal benthic organisms (Table 4.4.12). Among them, polychaetes accounted for 100% frequency of occurrence as compared with other two groups (20%). The study revealed very poor subtidal macrofaunal standing stock (av 28 m^{-2}; 0.03 g m^{-2}) as compared to the intertidal macrofauna (av 431 m^{-2}, 49 g m^{-2}) of the region. The subtidal macrofaunal standing stock is closely comparable with the earlier results (Table 4.4.13) for the region. The available informations indicate no significant spatial and temporal variations in subtidal macrofauna. A very poor subtidal macrofaunal standing stock noticed in the region can be due to the prevailing high turbidity and strong tidal currents.

4.4.4 Fishery

Very high tidal amplitude and high turbidity associated with strong currents make trawling or grill-netting for fish, difficult and risky

in the Gulf. Evidently no commercial exploitation of fishery is noticed except for small-scale shore based hand net operations. With special efforts experimental trawling was undertaken for a shorter duration during certain stages of a tide when currents were relatively week. The results are given in Table 4.4.14. In general, the fishery potential of the area is very poor as revealed by the catch per unit effort (CPUE). No appreciable difference in the average catch rate between postmonsoon (2.8 kg h^{-1}) and premonsoon (3.5 kg h^{-1}) was noticed which suggested less seasonal influence over the fishery potential of this region. Overall diversity of fish was low due to prevailing extreme environmental conditions. Fishes (90 - 94%) and crustaceans (6 - 10%) mainly contributed to the total catch. Among the fishes *Harpodon nehereus* (73 - 80%) dominated the catch. The total number of species varied from 7 to 10 with an average of 8 (Table 4.4.14). Other dominant species encountered were *Arius maculatus, Boleophthalmus dentatus, Tryssa mystax, Lepturacanthus savala, Parapenaeopsis* sp, and *Nematopalemon* sp.

Gujarat is a leading state in marine fish production and during 1993-94 the total landing was 6.2 x 10^5 ton (Table 4.4.15). Bharuch district accounted for only 1% of the total landing which clearly indicated very poor fishery potential of the Gulf. The Bombay duck (*Harpodon nehereus)* forms a major fishery (21%) of Gujarat with other groups like croakers (16%), pomfrets (6%) and prawns (5.3%) also contributing to the total catch. The composition (Table 4.4.16) of the marine fish landings of Bharuch (1993 - 1994) indicated that clupeid

(12%), cat fish (10.6%), mullet (8.2%), shark (5.4%), mud skipper (5.6%) and shrimp (32.5%) were the major components. Enquiries with the local fisherman and the Department of Fisheries, Bharuch, indicate that trawlers generally do not operate off Lakhigam and fisheries activities are not dominant in the region.

4.4.5 Breeding and spawning

Extensive and long term field observations are required to identify breeding and spawning grounds of fishes and crustaceans. This was not possible during the present short term investigations. Hence, decapod larvae, fish eggs and fish larvae were studied from zooplankton collections of 1993 - 94 and taken as indices of probable existence of spawning grounds. The fish caught during trawling and the available information on the breeding habits of the species found in the area were considered for the assessment.

a) Decapods

Decapods were common and in abundance occassionally in the zooplankton collections (Tables 4.4.17 and 4.4.18). The decapod larvae were constituted mainly by penaeids and caridean prawns, crabs and stomatopods. The common families and species found were *Metapenaeus affinis*, *Acetes indicus*, *Macrobrachium* sp., Nematopalaemon, Leptochela (Pasiphaeidae), Hippolytidae, Crangonidae and other carideans and crab zoea and megalopa stages. Among Penaeinae, *M. affinis* was the dominant species. *Acetes indicus* were the most abundant with sergestid shrimp, caridean prawns and

Brachyuran crab larvae showing higher incidence during postmonsoon period.

All commercial penaeid prawns of the Indian waters breed in the sea in relatively deeper waters in relation to the area of normal existence of adult prawn. Penaeid prawns have high fecundity which varies with species and size of the prawn. *M.affinis*, *M.dobsoni*, *M.monoceros* and *P.stylifera* breed through out the year with individually delineated peak breeding periods. The eggs are released while swimming near the bottom. The early development takes place in the open sea and the postlarvae enter the estuaries/backwaters to attain the adult characters including secondary sexual characters and return to the sea where maturation of the ovary and subsequent spawning takes place.

Generally, the spawning grounds of penaeid prawns are away from the coast. The spawning ground of *M.dobsoni* is reported to be at 20-22 m depth while that of *M. affinis* is at still deeper waters. Spawning grounds of *M. monoceros* and *P.stylifera* are at 50-65 m and at 18-25 m depth respectively. *M.affinis* and *P.stylifera* prefer areas of soft mud and zones of rich plankton for mating and spawning.

Acetes indicus are common and economically important species of shrimps. They form conspicuous aggregations near the shore and are fished on a large scale during January-April. Fishing grounds of these shrimps are mostly located in calm muddy intertidal zones or waters shallower than 5 m. The life span of *Acetes* is 3-10 months and the

adults die soon after spawning. Breeding is continuous and surface water currents stimulate *Acetes* to swarm in shallow inshore waters when the wind blows moderately towards the land.

b) Fish eggs and fish larvae

Fish eggs were rarely encountered in zooplankton samples (23%). The number of eggs varied from 1 to 4 $(100\ m^3)^{-1}$ during postmonsoon and from 1 to 5 $(100\ m^3)^{-1}$ during premonsoon indicating very poor potential for fish eggs (Tables 4.4.19 and 4.4.20).

Fish larvae varied from 0 to 347 [av 48 $(100\ m^3)^{-1}$] in the region (Tables 4.4.19 and 4.4.20). Percentage contribution of fish larvae to total zooplankton count was invariably less than one in 75% of the samples. Total groups of fish larvae varied from 4 to 20. The standing stock and diversity of fish larvae between post- and pre-monsoon were comparable indicating less seasonal influence in their distribution in the coastal system off Lakhigam. Species composition data revealed (Tables 4.4.19 and 4.4.20) that the species of Gobidae, a non economically important group was dominant as compared with economically important species like *Sardinalla longiceps, S.lile, Pellona sladeni, P.dayi, Thryssa purava, T.mystax, T.dussumieri* and *Hilsa kelee* which were low in numbers. The overall distribution pattern of fish larvae indicated that none of the economically important species were very common in the area except for isolated abundance of carangidae, *S.longiceps, Trichiuridae* and *T.mystax*.

Along the west coast, fishes spawn during monsoon and postmonsoon periods. The number of eggs shed by different species may vary considerably. Even individuals of the same species produce varying number of eggs depending on their age, length, weight and condition of the gonad.

The mud skippers or gobids are not economically important and larvae of this group dominate the area. Early preflexion stages of the group are common suggesting that they are local breeders.

The economically important groups namely Clupidae and Engraulidae though present, their numerical abundance was not sufficient to denote a spawning ground in the area. These fishes are normally associated with regions of high plankton production. Even though the major fishery as per the trawl catch data, showed dominance of *Harpodon nehereus*, occurrence of fish eggs and early larval stages of the species were negligible in the collections. Spawning season of the oil sardine *Sardinella longiceps* is a prolonged one with a certain amount of variation in its duration. In general, it extends from June to October with an intense activity of 2 - 3 months during this period. The fecundity varies between 38,000 and 80,000 ova. Eggs are planktonic and hatching takes place in about 24 h. *H.nehereus* is a continuous breeder with intense activity from October to April and slack from May to September. Breeding of the species is reported to be beyond 75 m. The number of ova produced vary from 14,600 to 1,46,400. In Trichiuridae spawning takes place in May-June and

November-December. Available data indicate that they migrate to deeper waters for spawning.

4.4.6 Comparative ecology

The overall biological characteristics indicate low production potential off Lakhigam. The concentrations of phytoplankton pigments are quite low as compared to the levels in normal coastal waters. The overall conditions are not conducive for the favourable growth of phytoplankton. Zooplankton standing stock is also poor. Considering the quatitative and qualitative nature of zooplankton, the area can be rated as moderate to poor, for these secondary producers. The region also sustains very poor benthic standing stock in terms of population and biomass. Standing stock of intertidal fauna is more in the upper intertidal zone than in the lower regions. The experimental trawling and other information confirms that the area is not a fishing zone for commercial fishes even during the peak fishing season of October.

Decapods are abundant in the area and larvae of economically important penaeid and non-penaeid prawns are common in the samples. However, their numerical abundance is not sufficient enough to support any breeding activity in the area. Generally, the spawning of penaeid prawns are away from the coast at or beyond 20 m depth. The area was very poor in fish eggs. The low population count of economically important larval species of fishes indicate that the area cannot be a breeding ground.

5 POTENTIAL MARINE ENVIRONMENTAL IMPACTS

Major marine operations that may influence coastal ecology during construction and operational phases of the project are wastewater disposal and port terminal.

5.1 Waste disposal

5.1.1 Construction phase:

The complex will generate upto 5300 $m^3 d^{-1}$ of process wastewater which after treatment to meet standards prescribed by GPCB (Table 2.3.1) will be conveyed through a pipeline to a suitable subtidal location and released through a single-pore or multi-pore diffuser. The movement of heavy machinery during construction of approach bund/trestle on intertidal area, and trenching operations for burying the pipelines may cause extensive though localised damage to the intertidal flora and fauna. Deployment of diffuser block may disperse substantial quantities of suspended load that has potential to reduce primary productivity apart from localised destruction of benthic communities.

5.1.2 Operational phase

Probable wastewater characteristics are compared with the mean baseline water quality of Lakhigam in Table 5.1.1. It is clear from the table that the concentrations of certain constituents are much higher than the corresponding levels in seawater. Thus for instance, the levels of oil and grease are about 1000 times more than in seawater. Similar situations prevail in case of comparative levels of most heavy metals.

Hence, the wastewater even though treated, has a potential to deteriorate water quality and in turn expose biota to undesirable levels of pollutants.

Toxicity of wastewater is often assessed through static bioassay in which an organism such as fish is exposed to increasing concentrations of wastewater for a specified period. Wastewater when treated as stipulated may not be toxic to the test organism yet it may not be safe when released since threshold levels for several sensitive organisms and eggs and larvae are much lower and their long exposure may lead to damage. Moreover, several commercially important species such as shell fish bioaccumulate trace constituents particularly heavy metals and organics by thousands of times, in their bodies.

Coastal water of Lakhigam sustains high concentrations of fine particulate suspended matter which may absorb some pollutants from the wastewater and transport them to the sea floor on settling, thus exposing benthic flora and fauna to undesirable levels of pollutants.

The smelter will produce 160,000 t y^{-1} of furnace slag and 500,000 t y^{-1} of phosphogypsum and 70,000 t y^{-1} of fly ash. The solid waste is proposed to be stored in preconstructed dump sites within the complex. Under normal weather conditions the solids are unlikely to be transported to the marine environment, however during periods of occassional heavy downpour during monsoon the overflow from the dump sites may reach the nearby marine areas aided by the natural slope of the terrain. Although major components of the solid waste are

non toxic, presence of trace pollutants such as copper in furnace slag and cadmium and lead in fly-ash can be harmful to sensitive biota. Moreover, the fine solids associated with the overflow may settle on the localised intertidal area smothering benthic biota of affected area.

5.2 Port terminal

The proposed development envisages construction of a jetty (210 x 20 m) to berth upto 30,000 DWT ships, connected to the shore by a 1044 m long piled approach and 1320 m long rubble bund road. The other associated marine structures will include mooring dolphins, bresting dolphins, etc. Large quantities of inorganic chemicals and raw materials such as copper concentrate, rock phosphate, sulphur, coal, phosphoric acid, ammonia etc. will be handled at the jetty.

5.2.1 Construction phase

Construction activities in the subtidal and intertidal areas apart from causing localised destruction of the habitats due to physical stresses, can cause certain indirect effects such as changes in shoreline configuration and circulation pattern and temporary increase in turbidity leading to reduction in photosynthesis.

The most severely affected will be benthic biota which will be destroyed along the pile foundations and rubble bund. The damage though confined and localised is irreversible in some instances. Thus for example, the benthic community along the piled approach and jetty may

reestablish over a period of time once the construction phase is completed, the destruction will be irreversible along the rubble bund. From Section 4.4.3, it is evident that the alignment of approach road is along the transect of low benthic biomass. The higher production is confined to the vast intertidal area north to the proposed jetty, particularly around Dahej creek. The macrobenthic biomass along the proposed jetty varied widely between 0.06 and 40.8 g m^{-2}. Considering that the rubble bund will occupy an area of about 50,000 m^2, the macrobenthic biomass permanently lost will be roughly 500 kg (wet wt).

Any barrier across the natural flow of tidal water can alter littoral transport which may result in erosion of certain nearby areas. Such tendencies have also been revealed by physical model studies.

Hectic construction activities involving driving of piles, movement of heavy construction machinery, dredging operations etc. has a high potential to disperse fine grained sediment in the water column increasing the turbidity which can influence photosynthetic activity apart from increasing BOD. However, as discussed in Section 4.3, the sediment being free from anthropogenic contamination by trace metals and PHC, direct toxic effects due to suspended sediment on biota are unlikely.

5.2.2 Operational phase

Possible marine environmental implications during operational phase are associated with the spillages of raw materials particularly

copper concentrate, rock phosphate and ammonia (occasional imports) during bulk unloading and phosphoric acid during product transfer for export.

The cargo in the loose form will be offloaded with a grab mounted on the jetty. Such an operation is prone to spillage if proper precautions are not taken. The spilled material will settle on the intertidal area or the subtidal region changing the character and composition of the bed material in the affected area over a period of time. Although copper that may leach out slowly may not be toxic to adult fish or shell fish, sensitive life stages such as eggs and larvae may be affected. Moreover, the benthic fauna may be exposed to undesirable levels of copper in the sediment.

Phosphoric acid will be pumped through a pipeline and flexible hose system to ship berthed at the port terminal. Any accidental spillage due to loose hose coupling or rupture of hose may result in contamination of seawater. The maximum quantities of the acid that may be spilled depends on the volume of the hose. This can be of the order of 10 m^3 and 50 m^3 in the worst case scenarios. The consequences of seawater contamination by acid will be sudden decrease in pH and increase in the concentrations of phosphate. Because of its high density (1.8 g cm^{-3}), phosphoric acid will sink through the water column and spread on the sea-bed and eventually will be diluted by tidal currents which are fairly strong. Marine organisms including fishes exposed to the shock of drastic change in pH may die. Benthic fauna will be worst

affected in the area of impact. The damage however will be temporary and original populations may soon be reestablished once the pH returns to normal. Temporary increase in phosphate content may not be a serious consideration since phosphate is nontoxic and area being well flushed, and highly turbid, the primary productivity is unlikely to increase to levels to cause eutrophication around the berth area.

The maximum depths required for spills of phosphoric acid amounting to 10 m^3 and 50 m^3 to sink to attain ambient density were calculated from the relation.

$$D_{max} = A\,(V_s\,g')^{1/4}/(gE)^{1/4}$$

where A = constant

V_s = original volume of spill

E = density gradient within the water column

$$g' = \frac{g\,\Delta P}{P_o}$$

where ΔP = difference between the ambient and spill densities

P_o = density of the ambient at the surface

These depths are calculated to be 31 m for 10 m^3 spill and 46 m for 50 m^3 spill. As the available depth near the jetty head is 18 - 28 m (depending on the tide) the spilled phosphoric acid though diluted will not attain ambient density by the time it sinks to the bottom as evident from the table given below.

	Spill quantity		Density at sea floor	
	10 m^3	50 m^3	10 m^3	50 m^3
Dilution				
Av LW	316	90	1.025	1.031
Av HW	1190	351	1.024	1.025

Although the diluted phosphoric acid may persist as a high density water mass at the bottom till advected and diluted further by currents, it is unlikely to reach the shores under the prevailing tidal circulation which is predominantly in the north-south direction.

At present a low traffic, that too of small crafts, exist in the tidal port of Dahej. However, the traffic along the coast is expected to increase several folds that too of big ships once the proposed industrial developments at Lakhigam get underway. A couple of captive jetties in the mouth of Narmada estuary are planned to serve the petrochemical complex. These jetties alone are expected to handle 1000 vessels every year of sizes in the range 800 to 10,000 DWT. The number of vessels visiting the Indo Gulf jetty will be around 50 y^{-1}. In addition a chemical terminal to receive vessels upto 70,000 DWT is under active consideration, to the south of the captive jetty of Indo Gulf. Hence, probability of ships collision or a freak accident of ship going aground will increase manifolds particularly because of navigational hazards due to shifting sand bars, strong currents and high tidal ranges. An accident involving a ship loaded with liquid cargo has potential to release several

thousand tons of her contents in the marine waters which can cause large scale destruction of aquatic life. Accidents during manoeuvring, berthing and loading - unloading operations can also result in release of substantial quantities of pollutants to the sea.

Other operational releases that can contaminate the coastal waters include domestic and other wastes from ships and shore-based work-force, storm water etc. If not properly managed they can be a source of low level chronic pollution that can be harmful to the local biota, in the long run.

6 MITIGATION MEASURES

6.1 Waste disposal

6.1.1 Construction phase

The pipeline to convey wastewater can be laid along the jetty approach avoiding trenching and laying in the intertidal area. However, due to operational reasons if the pipeline is to be laid under the intertidal area, the destruction of biota will be confined to a narrow corridor of about a couple of meters. Once the pipe laying operation is completed the biota will recover to the original status within a few months.

6.1.2 Operational phase

In view of the probable adverse impact due to release of wastewater in the marine environment, it is necessary that the wastewater release location is carefully selected in a manner that the impacts are considerably minimised.

a) Wastewater release location

In an ideal situation, the wastewater release location should be so selected that the effluent attains high degree of dilution on entering seawater so that the baseline levels are attained close to the disposal location. However, due to the difference in densities of seawater and effluent and considerable time taken for the currents to transport the effluent away, the mixing is not instantaneous. Hence in reality, release of wastewater results in a water mass containing high concentration of effluent near the point of release and the concentration decreases away from the release location. An effective wastewater release system achieves baseline concentrations within a few metres from the release orifice.

The most important design consideration of a marine wastewater disposal scheme is to achieve maximum possible initial dilution by effectively making use of initial inertia and gravity forces associated with discharge velocity and differing densities. Majority of effluents are lighter than seawater. Hence, there is a definite advantage in releasing them through a subsurface outfall. The propagation in a water body of wastewater discharging from a subsurface outfall is subdivided into three successive areas, which differ by the mechanism governing their movement but have no definite boundaries:

(a) Jet area
(b) Plume area
(c) Convective diffusion area

In the plume area, gravity forces due to the differences in densities of the effluent and seawater, outweigh the initial inertia forces. The plume comprises the rising flow upto the point at which it spreads out horizontally. When this occurs at the surface, gravity forces are partly effective in spreading the plume.

In the convective-diffusion area, the contaminated watermass no longer has an inherent source of energy and therefore, its behaviour is governed solely by the prevailing currents and turbulence which mix it with the receiving water thus reducing its concentration. In addition, the plume and convective diffusion areas vary quite appreciably depending on the receiving water density, homogeneity and prevailing currents.

For a plume discharging vertically into a medium of homogeneous density, plume path and mean dilution can be calculated from the relations:

$$R = V/U$$

$$F^2 = V^2/\{g\ (\frac{P - P_o}{P_o})\ D\}$$

$$X = x/(RD)$$

$$A = X + R^2X^2/(2\ F^2)$$

$$z = 1.44\ RDA^{1/3}$$

$$T = RA^{2/3} = 0.48\ z^2/(RD^2)$$

$$r = z/2$$

where U = flow velocity of receiving medium

V = jet discharge velocity

x and z = jet co-ordinates; the origin being at the point of discharge and z being the vertical ordinate

F = Froude density number of jet

T = Mean dilution at height z

D = discharge orifice diameter

P = density of receiving medium

P_o = initial density of effluent

r = jet radius at coordinates x and z.

R, A and X = simplyfying intermediate calculation variables.

Similar calculations can be performed for wastewater heavier than seawater as in the present case. In such situations the effluents should be released near the sea surface so that the wastewater plume attains dilution while sinking through the water column and attains ambient density before it reaches the seafloor.

It is therefore evident that in both situations the height of water column is the deciding factor for initial plume dilution with other parameters remaining constant.

With specific gravity of 1.05, the treated wastewater will be heavier than seawater. Hence, release at the surface will offer definite advantage. Preliminary calculations indicate a depth of 10 m for release

of wastewater to attain desired initial dilution. In the tide dominated coastal region of Lakhigam, initial dilution will vary considerably depending on the rise and fall of water level. Hence it is necessary that required dilution is attained at spring low tides when the height of water column is minimum. From the bathymetry (ELCOME) it is evident that 10 m depth contour runs close to the spring low water line and roughly parallel to the shore. Hence, the wastewater can be released anywhere along the 10 m contour. However, the advantage of the jetty approach can be taken to take the wastewater pipeline and release can be achieved just below the surface of lowest low water spring.

Following values were obtained for a release of wastewater (5300 $m^3\ d^{-1}$) at the surface through a pipeline of 20 cm dia.

x (m)	z (m)	r (m)	T (Times)	Sp.gravity
10.75	1	0.5	4	1.03
4.5	2	1.0	15	1.025
10	3	1.5	33	1.024
17	4	2.0	60	1.0235
25	5	2.5	93	1.0233
33.5	6	3.0	132	1.0232
43.5	7	3.5	182	1.0231
54	8	4.0	238	1.0231
65	9	4.0	238	1.0231
76.5	10	5.0	370	1.0231
89	11	5.5	449	1.0231

x, z, r and T are described for the plume equation discussed earlier. However since the origin is at surface, the z coordinate points downwards. Thus, when released at a height of 10 m from the surface, the wastewater plume will descend through the water column attaining dilution. However, due to strong currents the plume will assume a curved trajectory with a length of 76.5 m from the point of release and will have a diameter of 10 m as it reaches the seafloor in the process attaining dilution by about 370 times. As the mixed water mass reaches the bottom its density would be close to that of ambient seawater. However the mean characteristic dillution would be 250 times.

As evident from Section 4.1.4, the water body is vertically well-mixed. Hence, full water column will be available to effect dilution and there is no possibility of the wastewater plume spreading at an intermediate depth.

Possibility of release of wastewater through a submarine outfall at the bed level was also examined for a release through an orifice of 20 cm at a velocity of 1.7 - 2.0 m s^{-1}. The plume may rise only upto a height of about 1.4 m under the inertia force but due to high specific gravity, it will sink to the bottom attaining a dillution of 25 times, with mean characteristic dilution by only about 17 times.

x (m)	z (m)	T (times)	Sp.gravity
0.2	0.6	1	1.042
2	1.2	6	1.028
4	1.4	7	1.027
6	1.3	8	1.026
7	1.1	10	1.026
8	0.5	18	1.025
8.2	0.1	25	1.024

As the density of the plume on reaching the seafloor will be still higher than the ambient seawater it may persist as a high density watermass that will be advected by the currents, in the process exposing the benthic organisms to higher concentrations of pollutants. The impact of this high density water plume may persist over an area of about 100 m around the outfall orifice. This is an undesirable situation. Hence, release at bed level is not advisable.

Another option is to convey the wastewater through a subsea pipeline upto 10 m depth contour and raise the release orifice above the bed level to take advantage of dilution while the jet rises and the plume descends to the seafloor. Calculations reveal that if the discharge orifice is raised at a height of 2 m from the bed level, the characteristic dilution attained as the plume sinks to the seafloor will be by about 85 times as given below:

x (m)	z (m)	T (Times)	Sp.gravity
0.2	2.6	1	1.042
2	3.2	6	1.028
4	3.4	7	1.027
5	4	21	1.024
8.5	4	42	1.024
14	4	71	1.0233
15	0.0	83	1.0233

However the mean characteristic dillution of the entire jet and plume would be around 55 times only.

i) Thickness of the affected layer

It should be established whether the bottom currents will be capable of transporting away the polluted water sinking to the bed when released through a surface or a subsurface outfall. The approximate thickness H' of seawater layer which may be affected by the effluent can be calculated by using the relation

$$H' = Dq/VO$$

where H' = thickness of the polluted layer

D = mean dilution in the jet or plume

q = effluent discharge

O = plume diameter at the bottom after sinking

V = mean natural flow velocity of seawater across H'

The values obtained for the thickness of the polluted layer as the plume sinks to the bottom, for releases at different heights around station 1 (site A) are as follows:

Location	H' (m)
Release near the seabed	0.7
Release at 2 m above the seabed	1.2
Releae below the sea surface	3.0

In case of release near the seabed, the wastewater will spread along the seafloor as a pool of high density water mass with a thickness of about 0.7 m and the orifice will be within the polluted layer indicating high probability of recirculation of pollutants.

When the release is at a height 2 m above the seabed the thickness of the polluted layer will be around 1.2 m. However, the orifice of release will be above the polluted layer. Hence, the local currents will advect the wastewater spreading it over a larger area fairly efficiently.

Although the thickness of polluted layer will be as high as 3.0 m in case of surface release, this thickness is considerably smaller than the available water depth (10 m). Moreover, the wastewater outfall will be well separated from the polluted layer indicating much better advective transport as the plume descends to the bottom. Also, the quality of water in the polluted layer would be better if the thickness is more. From the foregoing discussion it is obvious that the release just below

the sea surface (lowest low tide spring) at a location where 10 m water depth (below CD) is available can be considered. The preferred site can be below the jetty at Lat 21° 42' 00" and Long 72° 30' 35" (2401785N and 242310E UTM coordinates). This position is marked as A in Figures 1.3.1 and 3.4.1.

ii) Central line diffusion

As the diluted wastewater sinks, it will spread laterally near the bottom depending on currents and diffusion, through a hemispherical pollutant - seawater interface. The central line diffusion which is the measure of concentration/dilution at a radial distance is given by

$$C_{cen} = \frac{I}{2z}\sqrt{\frac{1}{pikvy}}$$

where C_{cen} = central line concentration

I = rate of wastewater flow

z = depth of water

k = coefficient of diffusion

v = root mean square velocity of currents

y = distance from origin

When the plume descends, it will have already attained considerable dilution during sinking. Hence, I can be replaced by I/T where T is the mean characteristics dilution.

The following values were obtained for C_{cen} in terms of kg of wastewater per m^3 of receiving seawater

y (m)	C_{cen}
5	0.29
10	0.20
20	0.15
30	0.10
40	0.07
80	0.05

Hence, when the wastewater is released near the surface and the plume descends to the seafloor, the concentration of wastewater in the plume is expected to be 20 g m^{-3} of seawater at a distance of 10 m from the centre of the plume.

iii) Impact assessment

Probable impact of release of treated wastewater in the coastal sea at site A, on water quality, sediment quality and biological characteristics is predicted on the basis of dilution attained and assuming conservative behaviour of pollutants in the receiving medium. Many pollutants undergo decay or chemical and/or physical changes on entering seawater leading to reduction in their concentrations faster than predicted on the basis of conservative mixing. However, to incorporate changes occurring on release require site specific information on a large number of variables involving detailed field and laboratory studies.

Such studies though desirable are not crucial since concentrations in the receiving medium predicted on the basis of conservative behaviour are invariably higher than actual concentrations which may prevail when a pollutant undergoes changes.

Water quality

It is expected that the wastewater when released through a single orifice it will attain characteristic dilution as follows as the plume sinks to the bed or rises and sinks as the case may be:

Mode of release	Dilution (times)
Release at the surface	310
Release near the seabed	17
Release at 2 m above the seabed	55

The expected concentrations of contaminants as the plume surfaces or sinks are compared with the baseline water quality in Table 6.1.1. The baseline water quality is derived from the actual field studies undertaken during October 95 and other recent data available with NIO.

It is evident from Table 6.1.1 and 6.1.2 that near baseline concentrations are attained in case of surface release while the levels are markedly high for some constituents in case of intermediate release. For bottom release however the concentrations of several constituents are higher. Hence, bottom release is not advisable.

In the case of intermediate release therefore it will be necessary to

enhance dilution by effecting the release through an adequately designed multipore diffuser.

Circulation pattern off Lakhigam is generally parallel to the shore with considerable shoreward transport in the mouth-estuarine zones of Dhadhar and Narmada rivers during flood tide. However, as these estuaries are several kilometres away from the proposed wastewater release location and as the baseline water quality is expected just 10 m away from the release area, the water quality of these two nearby estuaries will be unaffected by the constituents of wastewater. Even in the worst situations of shoreward transport by the shortest distance, the water quality near the shore will not be affected as the location of release is atleast 100 m away from the low tide level.

From the above discussions, it is evident that for surface release and release at 2 m above the bed through an efficient multipore diffuser, the water quality off Lakhigam will not be influenced by the constituents of wastewater.

Sediment quality

Many trace constituents such as heavy metals and organics are scavenged from the water column by suspended matter eventually transporting them to the seafloor on settling. By virtue of high suspended load off Lakhigam a substantial fraction of some constituents will be removed by adsorption and may potentially enrich the sediment with these pollutants.

However, due to strong tidal motions, the particulate matter getting enriched with the anthropogenic pollutants is expected to be dispersed over a very wide area before settling. Hence, it is unlikely that the contaminated suspended load will settle in a small area in quantities to influence the baseline sediment characteristics discussed in Section 4.3.

Biological characteristics

The water quality beyond immediate sphere of influence will more or less remain unaffected due to the release of wastewater. Hence by and large biological characteristics of the region will not be adversely affected. Although, the concentrations of some pollutants may be higher within the plume, these levels are generally much below the threshold concentrations to result in acute toxicity to flora and fauna that may be momentarily trapped in the wastewater plume. As the exposure will be for a short duration, the chances of bioaccumulation are unlikely.

As the character of the sediment and its quality is expected to remain unchanged after release of wastewater, the benthic organisms are unlikely to be adversely affected.

It is therefore considered that the biological characteristics off Lakhigam will remain unaffected due to the release of wastewater. Since the area is not suitable for fishing operations (Section 4.4.4), laying of a diffuser will not be of consequence from the point of view of trawling. However, as the region may experience increase in sea traffic

in future, location of the diffuser should be identified by a suitably designed lighted marker buoy to avoid chances of accidents, if intermediate release option is implemented outside the jetty head.

b) Overflow from dump sites

During monsoon it should be ensured that the overflows from the dump sites do not reach the marine environment.

6.2 Port terminal

6.2.1 Construction phase

The benthic organisms along the rubble bund and pile foundations will be destroyed irreversibly but the loss of 500 kg (wet wt) biomass is insignificant compared to the biomass associated with the vast intertidal expanse of the region.

The probable instability of the shoreline due to the construction of the rubble bund road may be controlled by employing ecofriendly methods such as aforestation. The occurrence of mangroves along Dahej creek suggests that mangrove aforestation can be attempted in suitable localities. A properly conceived mangrove aforestation programme should therefore be considered.

Construction of marine structures leading to increase in turbidity is not a serious consideration in view of the high natural turbidity associated with the coastal water.

6.2.2 Operational phase

The operational philosophy of the terminal should be to integrate various components of marine activities in the design itself aimed at 'zero pollution' during berthing of ships, unloading of raw materials, loading of products etc, under normal conditions. Maximum precautions should be taken to prevent spillages of cargo while unloading. The pumping of liquid products to the ship at the berth should be so designed that in case of any deviation from preset optimum conditions, the pumping stops in a predetermined manner so that quantity of spillages are minimised.

Marine structures, conveyor system and pipelines should be periodically inspected as per the standard protocols and records including those of accidents if any, should be maintained. Because of uneven topography, shifting sand bars and complex silting pattern, the bathymetry particularly around the jetty head should be periodically charted to ensure safe navigation. Channel markers and adequate navigational signals for night navigation should be provided.

Another area that warrants serious attention is to formulate a comprehensive traffic control and management plan for the region as a whole to lower risks of accidents since disaster leading to spillage of thousands of tonnes of bulk chemicals will be highly damaging to the ecology. A comprehensive report on risk analyses of various marine structures including the pipeline should be prepared for efficient operations.

The ships berthing at the jetty should not release the waste generated on board, including solid waste, into the sea. Adequate waste reception facility should be created at the terminal to accept such wastes for treatment and proper disposal. Any activities which will damage the intertidal ecosystem beyond the jetty corridor should be strictly prohibited.

Adequate civic amenities such as toilets, bathrooms, canteen etc. should be made available to the operational staff including workers at the terminal. Domestic waste from these facilities should not be released to the sea.

If bunkering is provided at the terminal, adequate precautions should be incorporated to prevent spillages of petroleum products.

7 MANAGEMENT OF MARINE ENVIRONMENT

Till recently the coastal belt between Narmada estuary and Dhadhar creek was underdeveloped and the nearshore waters were free from direct anthropogenic influences. The scenario is changing rapidly with the plans for industrialisation of the area. Evidently the region is expected to receive wastewaters (treated) from nearby industries. When the proposed port terminals are constructed, the ship traffic will undoubtedly increase many folds. Many of these ships are expected to carry bulk chemicals and petroleum products rendering the area vulnerable to anthropogenic stresses. Proper strategy should therefore be evolved to ensure the health of the marine environment. This will

require establishment of baseline quality, preparation of contingency plans for control of spillages of chemicals, periodic monitoring of coastal waters etc. for the area as a whole.

7.1 Baseline quality criteria

The coastal water are subject to temporal as well as spatial variations which can be considerable in a tide dominated region receiving freshwater inflows, such as Lakhigam. These changes should be clearly understood to evolve dependable criteria for water quality, sediment quality and biological characteristics and their temporal and spatial variabilities. Intertidal regions should also be considered for baseline criteria. A well integrated baseline data collection programme should be designed and implemented. It will be necessary to undertake monthly collections at predetermined grid of stations in an area of about 400 km^2. A few of these stations should be sampled over a tidal cycle.

7.2 Contingency plan

The probability of spillages of liquid chemicals (phosphoric acid, ammonia, petroleum products, caustic lye etc) that will form bulk of the cargo transported by ships, demands that a workable contingency plan involving the major establishments in the region is prepared in advance and available for implementation when the industries become operational.

Contingency plan for the control of spills of petroleum products may be easier to prepare with the world-wide knowledge available on

the subject. It is necessary to integrate the local contingency plan for the area with the National Oil Spill Control Contingency Plan. However, it should be clear while preparing local contingency plan that the highly dynamic coastal environment off Lakhigam is unsuitable for recovery measures such as containment by booms and removal by skimmers.

7.3 Post-project monitoring

In order to ensure that there is no deterioration in marine environmental quality, during operation phases of the projects at Lakhigam, and necessary remedial measures are taken whenever warranted, it is necessary to undertaken marine environmental monitoring. It is desirable that institutional requirements and monitoring strategy in general terms are identified so that the required provisions can be made to facilitate successful undertaking of the monitoring programme.

Marine environmental monitoring is a specialised field requiring well trained seaworthy marine scientists for meaningful and reliable results. Being a multidisciplinary science, inputs from physical oceanography, marine chemistry, marine biology and marine geology in an integrated set-up are a prerequisite for success of such a programme. It is unlikely that an industry will maintain a laboratory with trained marine scientists and other infrastructural facilities like boat, sampling gear, survey experiments etc for the purpose of monitoring. It may be therefore appropriate to engage an independent agency having adequate and proven expertise to undertake monitoring on behalf of industries.

Each major industry however should have a core group of trained scientists/engineers who will be responsible for (a) dealing with emergency situations, (b) routine spot monitoring from a fixed platform such as jetty, (c) routine monitoring of designated experimental mangrove areas, (d) laboratory bioassay and, (e) coordinating monitoring programme. requirements for comprehensive marine monitoring in terms of sampling stations, monitoring frequency and parameters to be monitored are given below:

a) Sampling stations

Sampling stations should include one each near the effluent release locations of industries alongwith a suitable grid of stations to be decided on the basis of circulation pattern and tidal flows. Some of these locations will have to be monitored over a tide cycle to evaluate tidal variabilities of water quality and biological parameters.

Representative areas of mangroves should be carefully selected and designated as experimental sites for long-term monitoring.

b) Frequency

After a proper baseline is established, the monitoring programme should be activated prior to the operational phase of industries for comparison and to delineate natural variations if any with respect to the baseline. The programme of monitoring may be phased out as follows:

First monitoring	-	Prior to operational phase
Second monitoring	-	After 3 months from commencement of operation.
Third monitoring	-	After 6 months from commencement of operation.
Fourth monitoring	-	After 12 months from commencement of operations.
General monitoring	-	Once every year from completion of fourth phase of monitoring.

c) Parameters to be monitored

Water quality: Water samples obtained from 3 levels in the vertical when the depth exceeds 10 m, to be analysed for temperature; pH; salinity; dissolved oxygen; biochemical oxygen demand (or total organic carbon); nitrate; nitrite; ammonia; dissolved phosphate; petroleum hydrocarbons; phenols, toxic metals; bacterial populations.

Sediment quality: Grain size; total organic carbon; total phosphorous; chromium; nickel; copper; zinc; cadmium; lead; mercury; petroleum hydrocarbons. Intertidal sediment should also be sampled and analysed.

Biological characteristics: Primary productivity; phytoplankton population; biomass, population and group diversity of zooplankton; biomass, population and group diversity of benthos (including intertidal), fish quality.

Mangroves of designated areas: Population density; growth; species diversity; sediment characteristics.

Bioassay: Static bioassay to be undertaken for the wastewaters being released, preferably with a selected species of fish from the Gulf.

8 RECOMMENDATIONS

a) Treated wastewater (5300 m^3 d^{-1}) meeting GPCB standards can be released at 10 m depth contour (below CD). The options are (i) surface release just below the lowest low tide level and (ii) intermediate release at 2 m above the seafloor. The first option has definite advantages and should be preferred. The site recommended for release is at Lat 21° 42' 00"; Long 72° 30' 35" (2401785 N and 242310 E in UTM coordinates). The treated wastewater when release as suggested, is unlikely to have any adverse impact on marine ecology.

b) It should be ensured that the monsoonal overflows from dump-sites of solid waste do not flow to the coastal waters.

c) Mangrove aforestation in preselected areas may be considered on experimental basis aimed at enhancing the stability of the shoreline. If successful the programme should be implemented on a wider scale.

d) Loading and unloading operations at the jetty should be so designed that spillages of cargo are prevented under normal operating conditions.

e) Marine structures, conveyor systems, pipelines etc should be periodically inspected as per standards protocols and records maintained.

f) Bathymetry, particularly around the jetty head should be periodically charted to ensure safe navigation.

g) Comprehensive sea-traffic control and management plan for the region as a whole should be evolved to lower risks of accidents involving ships. A ship disaster leading to spillage of thousands of tonnes of bulk chemicals will be highly damaging to the marine ecology.

h) Adequate waste reception facility should be created at the terminal for ships to transfer their waste for further treatment and disposal.

i) Sufficient civic amenities should be provided to the operational staff at the terminal. The wastes from these amenities should not be released to the sea.

j) If bunkering is provided at the terminal, necessary precautions should be incorporated to prevent spillages of petroleum products.

k) Marine environmental management plan that should include baseline quality criteria, contingency plan in the event of chemical spillages and scheme for post project monitoring should be evolved and implemented on the lines given in the report.

Table 2.3.1: Standards set by the Gujarat Pollution Control Board for release of wastewater from Indo-Gulf in the sea off Lakhigam.

Parameters	Concentration (mg l^{-1})	
	Permissible limit (mg l^{-1})	Anticipated limit
pH	6.5-8.5*	--
Oil & grease	10	
Suspended solids	30	
Total Chromium (as Cr)	0.2	
Manganese (as Mn)	2	
Nickel (as Ni	2	0.1
Copper (as Cu)	1	0.1
Zinc (as Zn)	1	0.1
Cadmium (as Cd)	0.2	0.1
Lead (as Pb)	0.1	0.1
Mercury (as Hg)	0.01	0.01
Iron (as Fe)	1	3
Cobalt (as Co)	–	0.1
Arsenic (as As)	–	0.2
Antimony (as Sb)	–	0.2
Bismuth (as Bi)	–	0.1
Selenium (as Si)	–	0.1
Total Heavy Metals	7	4.21
Phosphate (as P)	5	5
Flouride (as F) (At the outlet of Flouride removal unit)	10	–
Flouride (as F) (at final outlet)	1.5	–

* No unit

Table 4.2.1: Water quality at Station 1 (October 95)

Parameter		Max	Min	Mean
Water temperature (°C)	S	31.7	31.7	31.7
	M	31.7	31.6	31.7
	B	31.7	31.6	31.7
Air temperature (°C)		36.0	36.0	36.0
pH	S	7.8	7.8	7.8
	M	7.9	7.8	7.9
	B	7.9	7.9	7.9
Suspended solids (mg l^{-1})	S	1402	1402	1402
	M	3766	3766	3766
	B	3708	3708	3708
Salinity (ppt)	S	25.6	25.5	25.6
	M	25.6	25.5	25.6
	B	25.6	25.3	25.5
DO (mg l^{-1})	S	6.6	6.6	6.6
	M	6.9	6.9	6.9
	B	7.5	6.6	7.1
BOD (mg l^{-1})	S	0.7	0.7	0.7
	M	1.8	1.8	1.8
	B	1.9	1.9	1.9
PO_4-P (µg l^{-1})	S	45	27	36
	M	51	45	48
	B	60	56	58
NO_3-N (µg l^{-1})	S	555	511	533
	M	522	518	520
	B	547	518	533
NO_2-N (µg l^{-1})	S	5	4	5
	M	6	4	5
	B	7	6	7
NH_4-N (µg l^{-1})	S	484	143	314
	M	714	97	406
	B	115	8	62
Phenols (µg l^{-1})	S	50.8	50.8	50.8
PHC (µg l^{-1})	S	5.0	5.0	5.0

Table 4.2.2: Water quality at station 2 (October 95)

Parameter		Max	Min	Mean
Water temperature (°C)	S	31.9	31.9	31.9
	M	31.7	31.7	31.7
	B	31.8	31.8	31.8
Air temperature (°C)		35.5	35.5	35.5
pH	S	7.9	7.9	7.9
	M	7.9	7.9	7.9
	B	7.9	7.9	7.9
Suspended solids (mg l^{-1})	S	394	394	394
	M	-	-	-
	B	1692	1692	1692
Salinity (ppt)	S	25.6	25.3	25.5
	M	25.5	25.3	25.4
	B	25.5	25.3	25.4
DO (mg l^{-1})	S	6.2	3.4	4.8
	M	5.9	5.3	5.6
	B	6.6	6.2	6.4
BOD (mg l^{-1})	S	1.2	1.2	1.2
	M	1.8	1.8	1.8
	B	1.8	1.8	1.8
PO_4-P (µg l^{-1})	S	46	39	43
	M	51	45	48
	B	55	42	49
NO_3-N (µg l^{-1})	S	542	505	524
	M	543	500	522
	B	495	475	485
NO_2-N (µg l^{-1})	S	5	4	5
	M	5	3	4
	B	6	3	5
NH_4-N (µg l^{-1})	S	134	81	108
	M	78	10	44
	B	288	81	185
Phenols (µg l^{-1})	S	34.5	34.5	34.5
PHC (µg l^{-1})	S	5.3	5.3	5.3

Table 4.2.3: Water quality at station 3 (October 95)

Parameter		Max	Min	Mean
Water temperature (°C)	S	32.5	31.0	32.2
	M	33.0	31.0	31.5
	B	32.2	30.5	31.8
Air temperature (°C)		32.5	31.0	31.6
pH	S	7.8	7.7	7.8
	M	7.8	7.8	7.8
	B	8.1	7.8	7.9
Suspended solids (mg l^{-1})	S	275	17	146
	M	268	30	149
	B	376	215	295
Salinity (ppt)	S	26.8	25.8	26.3
	M	27.1	26.1	26.4
	B	27.4	26.4	26.8
DO (mg l^{-1})	S	6.2	5.8	5.9
	M	6.4	5.5	6.0
	B	6.4	5.9	6.1
BOD (mg l^{-1})	S	1.0	< 0.2	0.5
	M	0.3	< 0.2	0.2
	B	2.9	< 0.2	1.5
PO_4-P (µg l^{-1})	S	122	59	88
	M	142	74	100
	B	147	73	106
NO_3-N (µg l^{-1})	S	515	407	458
	M	504	416	464
	B	513	389	445
NO_2-N (µg l^{-1})	S	18	4	8
	M	16	5	9
	B	19	7	14
NH_4-N (µg l^{-1})	S	3	ND	2
	M	27	3	8
	B	34	ND	18
Phenols (µg l^{-1})	S	5.3	ND	2.7
PHC (µg l^{-1})	S	7.4	2.3	4.9

Table 4.2.4: Water quality at station 4 (October 95)

Parameter		Max	Min	Mean
Water temperature (°C)	S	32.0	30.5	31.2
	M	31.8	30.5	31.1
	B	32.0	30.5	31.3
Air temperature (°C)		35.0	26.0	32.0
pH	S	8.0	7.7	7.9
	M	8.0	7.8	7.9
	B	8.0	7.8	7.9
Suspended solids (mg l^{-1})	S	426	300	363
	M	2303	1061	1682
	B	3093	1782	2438
Salinity (ppt)	S	28.1	26.4	27.2
	M	28.1	26.4	27.2
	B	28.1	26.4	27.3
DO (mg l^{-1})	S	7.8	5.9	6.7
	M	7.8	4.1	6.5
	B	7.2	5.6	6.6
BOD (mg l^{-1})	S	5.6	2.7	4.2
	M	1.7	1.1	1.4
	B	0.8	<0.2	0.5
PO_4-P (µg l^{-1})	S	116	30	47
	M	64	45	58
	B	128	48	72
NO_3-N (µg l^{-1})	S	524	414	470
	M	632	393	482
	B	558	398	487
NO_2-N (µg l^{-1})	S	24	4	8
	M	9	5	7
	B	25	5	10
NH_4-N (µg l^{-1})	S	8	2	5
	M	11	1	4
	B	37	1	11
Phenols (µg l^{-1})	S	55.2	ND	27.6
PHC (µg l^{-1})	S	5.8	1.8	3.8

Table 4.2.5 Water quality at station 5 (October 95)

Parameter		Max	Min	Mean
Water temperature (°C)	S	30.2	30.0	30.1
	M	31.0	31.0	31.0
	B	31.2	31.0	31.1
Air temperature (°C)		29.0	28.8	28.9
pH	S	7.9	7.9	7.9
	M	7.9	7.9	7.9
	B	7.9	7.9	7.9
Suspended solids (mg l^{-1})	S	552	552	552
	M	2745	2745	2745
	B	1661	1661	1661
Salinity (ppt)	S	27.8	27.3	27.6
	M	27.9	27.6	27.8
	B	28.1	27.9	28.0
DO (mg l^{-1})	S	6.2	6.2	6.2
	M	6.6	6.6	6.6
	B	7.2	6.9	7.1
BOD (mg l^{-1})	S	1.5	1.5	1.5
	M	1.9	1.9	1.9
	B	1.8	1.8	1.8
PO_4-P (µg l^{-1})	S	88	36	62
	M	56	45	51
	B	50	46	48
NO_3-N (µg l^{-1})	S	501	460	481
	M	501	440	471
	B	552	507	530
NO_2-N (µg l^{-1})	S	5	5	5
	M	7	4	6
	B	6	4	5
NH_4-N (µg l^{-1})	S	68	11	40
	M	376	3	190
	B	6	2	4
Phenols (µg l^{-1})	S	9.5	9.5	9.5
PHC (µg l^{-1})	S	3.3	3.3	3.3

Table 4.2.6: Water quality at station 6 (October 95)

Parameter		Max	Min	Mean
Water temperature (°C)	S	30.5	30.4	30.5
	M	30.7	30.3	30.5
	B	30.8	30.7	30.8
Air temperature (°C)		28.4	28.3	28.4
pH	S	7.9	7.9	7.9
	M	7.9	7.9	7.9
	B	7.9	7.9	7.9
Suspended solids (mg l^{-1})	S	902	902	902
	M	1564	1564	1564
	B	1928	1928	1928
Salinity (ppt)	S	27.3	27.3	27.3
	M	27.6	27.3	27.5
	B	27.6	27.5	27.6
DO (mg l^{-1})	S	6.6	6.2	6.4
	M	6.6	5.9	6.3
	B	6.9	6.2	6.6
BOD (mg l^{-1})	S	0.8	0.8	0.8
	M	1.8	1.8	1.8
	B	1.9	1.9	1.9
PO_4-P (µg l^{-1})	S	55	32	44
	M	47	39	43
	B	55	46	51
NO_3-N (µg l^{-1})	S	507	467	487
	M	531	447	489
	B	472	459	466
NO_2-N (µg l^{-1})	S	5	5	5
	M	7	5	6
	B	6	4	5
NH_4-N (µg l^{-1})	S	ND	ND	ND
	M	ND	ND	ND
	B	11	8	10
Phenols (µg l^{-1})	S	ND	ND	ND
PHC (µg l^{-1})	S	1.7	1.7	1.7

Table 4.2.7: Water quality at station 5 (October 93)

Parameter		Max	Min	Mean
Water temperature (°C)	S	32.0	32.0	32.0
	M	31.0	31.0	31.0
	B	31.0	31.0	31.0
Air temperature (°C)		33.0	32.0	33.0
pH	S	7.8	7.8	7.8
	M	7.8	7.8	7.8
	B	7.8	7.8	7.8
Suspended solids (mg l^{-1})	S	78	78	78
	M	802	802	802
	B	5848	5848	5848
Salinity (ppt)	S	27.7	26.4	27.1
	M	27.7	27.7	27.7
	B	27.7	26.8	27.3
DO (mg l^{-1})	S	4.0	2.4	3.2
	M	5.6	4.5	5.1
	B	5.0	3.2	4.1
BOD (mg l^{-1})	S	<0.2	<0.2	<0.2
	M	1.1	1.1	1.1
	B	<0.2	<0.2	<0.2
PO_4-P (µg l^{-1})	S	50	ND	25
	M	88	18	53
	B	59	59	59
NO_3-N (µg l^{-1})	S	729	632	681
	M	660	636	645
	B	767	665	716
NO_2-N (µg l^{-1})	S	3	3	3
	M	3	3	3
	B	5	3	4
NH_4-N (µg l^{-1})	S	11	7	9
	M	15	12	14
	B	35	22	29
Phenols (µg l^{-1})	S	ND	ND	ND
PHC (µg l^{-1})	S	41.8	41.8	41.8

Table 4.2.8: Water quality at station 6 (October 93)

Parameter		Max	Min	Mean
Water temperature (°C)	S	32.0	31.0	32.0
	M	32.0	32.0	32.0
	B	31.1	31.0	31.1
Air temperature (°C)		33.0	32.0	33.0
pH	S	7.8	7.8	7.8
	M	7.8	7.8	7.8
	B	7.8	7.8	7.8
Suspended solids (mg l^{-1})	S	260	260	260
	M	353	353	353
	B	3744	3744	3744
Salinity (ppt)	S	27.7	26.8	27.3
	M	27.7	27.7	27.7
	B	29.0	27.7	28.4
DO (mg l^{-1})	S	4.8	4.8	4.8
	M	4.8	4.8	4.8
	B	4.8	4.0	4.4
BOD (mg l^{-1})	S	3.0	3.0	3.0
	M	2.7	2.7	2.7
	B	<0.2	<0.2	<0.2
PO_4-P (µg l^{-1})	S	162	39	101
	M	52	52	52
	B	124	38	81
NO_3-N (µg l^{-1})	S	643	617	630
	M	736	736	736
	B	645	567	606
NO_2-N (µg l^{-1})	S	3	3	3
	M	3	3	3
	B	8	3	6
NH_4-N (µg l^{-1})	S	13	8	11
	M	12	12	12
	B	58	8	33
Phenols (µg l^{-1})	S	ND	ND	ND
PHC (µg l^{-1})	S	4.0	4.0	4.0

Table 4.4.1: Distribution of chlorophyll *a* (mg m^{-3}) and phaeophytin (mg m^{-3}).

Station	Date	Time	Depth	Chlorophyll *a*	Phaeophytin
1	11.10.95	1300	S	0.5	0.8
			B	1.1	1.3
		1330	S	0.5	1.3
			B	1.6	0.7
2	11.10.95	1430	S	0.5	0.2
			B	1.1	1.6
		1500	S	0.5	0.2
			B	1.6	0.3
3	17.10.95	1300	S	1.6	0.3
			B	1.1	0.8
		1500	S	0.5	1
			B	1.6	1
		1700	S	1.1	1.9
			B	1.6	0.6
4	13.10.95	0730	S	0.5	1.3
			B	1.1	0.8
		0930	S	0.5	0.2
			B	0.5	1.7
		1130	S	1.1	0.4
			B	1.6	0.3
		1330	S	1.1	0.8
			B	1.6	0.6
		1530	S	1.1	0.2
			B	1.6	1
		1730	S	1.1	1.6
			B	1.6	1.8

Table 4·4·1 (contd.)

5	11.10.95	0715	S	0.5	0.2
			B	1.1	0.8
		0730	S	0.5	0.2
			B	1.6	0.3
6	11.10.95	0630	S	0.5	0.2
			B	0.5	0.2
		0700	S	1.1	0.8
			B	1.6	1.4

Table 4.4.2: Comparison of phytoplankton pigments between 1993-94 and 95 (Average in parenthesis).

	Chlorophyll *a* (mg m^{-3})		Phaeophytin (mg m^{-3})	
	Surface	Bottom	Surface	Bottom
October 93	0.5 - 1.60 (0.8)	0.5 - 1.1 (0.8)	0.2 - 0.6 (0.4)	0.4 - 1.0 (0.6)
February 94	0.5 - 1.1 (0.8)	0.5 - 1.1 (0.6)	0.2 - 1.0 (0.5)	0.4 - 1.3 (0.9)
October 95	0.5 - 1.6 (0.8)	0.5 - 1.6 (1.3)	0.2 - 1.9 (0.8)	0.2 - 1.6 (0.9)

Table 4.4.3: Distribution of phytoplankton population (no x 10^2 l^{-1}).

Station	Date	Time	Depth	Phyto-plankton population	Total No. of genera	Dominent genera
1	11.10.95	1300	S	8	1	*Coscinodiscus*
			B	48	3	*Thalassiothrix, Nitzschia, Coscinodiscus*
2	11.10.95	1430	S	20	3	*Cosinodiscus, Thalassiosira, Nitzschia*
			B	40	2	*Coscinodiscus, Thalassiosira*
3	17.10.95	1300	S	100	8	*Nitzschia, Thalassiothrix, Chaetoceros*
			B	44	3	*Fragilaria, Surirella, Coscinodiscus*
		1700	S	12	4	*Bacteriastrum, Biddulphia, Hemiaulus*
			B	68	6	*Nitzschia, Amphora, Melosira*
4	13.10.95	0700	S	12	3	*Bacteriastrum, Coscinodiscus, Nitzschia*
			B	40	3	*Fragillaria, Thalassiosira, Nitzschia*
		1330	S	88	6	*Skeletonema, Coscinodiscus, Nitzschia*
5	11.10.95	0715	S	24	3	*Navicula, Nitzschia, Thalassiothrix*
6	11.10.95	0630	S	24	2	*Fragillaria*

Table 4.4.4 (contd.)

5	11.10.95 0715	2.7	6.7	10	Copepods (41.7), chaetognaths (29.9), siphonophores (20.9), decapod larvae (5.9), polychaetes (0.4)
	0730	2.5	40.9	12	Copepods (61.8), siphonophores (33.7), chaetognaths (1.8), decapod larvae (1.4), fish larvae (0.4)
6	11.10.95 0630	0.6	25.5	10	Siphonophores (51.1), copepods (28.1), chaetognaths (14.3), decapod larvae (5.4)
	0700	2.5	25.0	10	Siphonophores (42.1), copepods (28.1), decapod larvae (24.6), chaetognaths (4.0)

Table 4.4.4: Distribution of zooplankton .

Station	Date & time	Biomass ($ml(100m^3)^{-1}$	Population (no x $10^2(100m^3)^{-1}$	Faunal groups (no)	Major groups (Percentage in paranthesis)
1	11.10.95 0930	14.7	73.8	11	Copepods (67.3), siphonophores (15.9), chaetognaths (8.3), decapod larvae (6.8), fish larvae (0.9)
	1330	2.1	13.8	9	Copepods (51.9), chaetognaths (21.6), decapod larvae (13), gastropods (8.6), siphonophores (4.3), fish larvae (0.4)
2	11.10.95 1430	1.9	82.5	7	Copepods (78.7), siphonophores (8.3), chaetognaths (6.2), decapod larvae (6.2), fish larvae (0.6)
	1500	3.9	69.4	9	Copepods (85.1), decapod larvae (6.5),chaetognaths (4.9), gastropods (1.9), siphonophores (0.6)
3	17.10.95 1300	0.4	12.9	4	Copepods (60.8), chaetognaths (17.4), decapod larva (13.1), siphonophores (8.7)
	1400	0.7	25.5	9	Copepods (52.7), decapod larvae (33.8), chaetognath (9.3) ostracods (1.6), fish larvae (1.5)
4	13.10.95 0730	2.2	141.3	9	Siphonophores (49.3), decapod larvae (32.9), copepods (16.4), Cheognaths (1.0), *Acetes* (0.1)
	1030	1.8	110.7	8	Decapod larvae (71.1), copepods (25.5), siphonophores (2.2), ctenophores (0.4), fish eggs (0.2), ostracods (0.2)
	1330	0.6	26.4	6	Copepods (49.7), siphonophores (24.8), chaetognaths (12.4), decapod larvae (12.4), fish larvae (0.5)
	1630	2.9	38.6	10	Copepods (48.2), decapod larvae (32.1), siphonophores (16.1), chaetognaths (1.4), ostracods (0.3)

Table 4.4.5: Mean zooplankton standing stock and faunal groups.

Station	Biomass [ml $(100\ m^3)^{-1}$]	Population [no x $10^2(100\ m^3)^{-1}$]	Faunal group (no.)
1	8.4	43.8	10
2	2.9	76	8
3	0.6	19.2	7
4	1.8	79.2	8
5	2.6	23.8	11
6	1.6	25.2	10

Table 4.4.6: Comparison of zooplankton standing stock between 1993-94 and 95 (Average in parenthesis)

	Population [no $(100m^3)^{-1}$]	Biomass [ml $(100m^3)^{-1}$]	Total groups (no)
October 93	1644 - 12408 (6617)	1.7 - 5.9 (3.3)	11 - 15 (13)
February 94	924 - 4800 (2805)	0.9 - 11.5 (3.7)	6 - 9 (8)
October 95	1920 - 7920 (4453)	0.6 - 8.4 (2.9)	7 - 11 (9)

Table 4.4.7: Distribution of intertidal macrofaunal population (no.m^{-2}) and biomass (g m^{-2} ; wet wt).

Location	Transect I		Transect II		Transect III	
	Population	Biomass	Population	Biomass	Population	Biomass
A	75	0.45	77	0.59	200	0.1
B	100	0.57	51	0.1	39	0.97
C	1052	36.2	589	40.8	215	0.4
D	1106	174.2	25	0.2	1951	316.5
E	415	3.5	75	0.06	502	160.3

A —> E : Lowest low water spring (LLWS) —> Highest high water spring (HHWS)

Table 4.4.8: Composition (no m^{-2}) of intertidal macrofauna.

Location	Polychaetes	Amphipods	Isopods	Prawns	Crabs	Bivalves	Insect larvae	Nemertines	Miscellaneous
Transect I									
A	100	150	38	--	63	13	--	38	13
B	25	238	100	13	775	25	--	---	--
C	--	25	613	--	225	163	13	--	--
D	100	--	--	--	--	--	--	--	--
E	--	75	--	--	--	--	--	--	--
Transect II									
A	13	--	--	13	--	--	13	--	38
B	25	--	--	13	--	--	--	---	13
C	13	100	38	--	138	250	50	--	--
D	25	--	--	--	--	--	--	--	--
E	50	--	--	--	--	25	--	--	--
Transect III									
A	200	--	--	--	--	--	--	--	--
B	--	--	13	13	--	--	--	---	13
C	13	50	13	38	--	38	--	38	25
D	1875	--	--	--	--	63	--	--	13
E	13	--	13	--	400	13	--	38	25

A---> E : LLWS ----> HHWS

Table 4.4.9: Comparison of intertidal macrofaunal mean standing stock during 1993-94 and 95.

	Population (no m^{-2})	Biomass (g m^{-2})
October 93		
Upper intertidal	469	3.1
Lower intertidal	212	0.6
March 94		
Upper intertidal	2988	3.2
Lower intertidal	792	0.7
October 95		
Upper intertidal	659	81.3
Lower intertidal	90	0.5

Table 4.4.10: Comparison of intertidal macrofaunal composition (%) of dominant groups during 1993-94 and 95.

Group	1993/94	1995
Polychaetes	52.5	32
Crustaceans	45	46
Molluscs	1.5	15
Others	1	7

Table 4.4.11: Subtidal macrofaunal population (no m^{-2}) and biomass (g m^{-2})

Station	Population	Biomass
1	51	0.04
2	–	–
3	25	0.01
4	38	0.06
5	13	0.02
6	13	0.01

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Table 4.4.12: Composition (no m^{-2}) of subtidal macrofauna .

Fauna	Station				
	1	3	4	5	6
Polychaetes	13	25	13	13	13
Amphipods	--	--	25	--	--
Insect larvae	38	--	--	--	--

Table 4.4.13: Comparison of subtidal macrofaunal standing stock between 1993-94 and 95.

	Population (no m^{-2})	Biomass (g m^{-2})
October 93	3-31 (17)	0.01-0.02 (0.01)
March 94	12-26 (19)	0.03-0.08 (0.05)
October 95	13-51 (28)	0.01-0.06 (0.03)

Table 4.4.14: Trawl catch data off Lakhigam.

Season	Tide	Catch rate (Kg h^{-1})	Total species	Species composition (%)
Postmonsoon	Flood	3	9	*Harpodon nehereus* (73.3), *Nematopalaemon* sp. (6.7), Crab (6.7), *Coilia dussumieri* (3.3), *Arius* sp. (3.3), *Parapenaeopsis sculptilus* (3.3), *Ilisha megaloptera* (1.7), *Thryssa mystax* (1.0), *Mugil* sp. (0.7).
Postmonsoon	Ebb	2.5	10	*Harpodon nehereus* (80.0), *Tryssa mystax* (4.8), *Arius* sp. (2.7), *Lepturacanthus savala* (2.7), *Parapenaeopsis sculptilis* (2.7), *Nematopalaemon* sp. (4.1), *Cynoglossus macrolepidotus* (1.0), *Metapenaeus* sp. (1.0), *Parapenaeopsis stylifera* (1.0).
Premonsoon	Flood	1.2	8	*Arius maculatus* (4), *Harpodon nehereus* (52), *Boleophthalmus dentatus* (13), *Thryssa mystax* (4), *Ilisha megaloptera* (1), *Parapenaeopsis* sp (16), *Exopalaeomon stylifera* (8), *Acetes indicus* (2).
Premonsoon	Ebb	5.9	7	*Arius maculatus* (85), *Harpodon nehereus* (7), *Boleophthalmus dentatus* (0.5), *Parapenaeopsis* sp (3), *Exopalaeomon stylifera* (2), *Acetes indicus* (2), Crab (0.5).

Table 4.4.15: Yearwise fish production of Gujarat state

Year	Marine fish landings of Gujarat ($x10^3$ t y^{-1})	Marine fish landings of Bharuch dist. ($x10^3$ t y^{-1})	Percentage of state production	Inland fish production of Bharuch ($x10^3$ t y^{-1})
1976-77	225.38	1.03	0.46	9.92
1977-78	176.9	1.1	0.62	7.82
1978-79	229.97	1.69	0.73	8.98
1979-80	206.75	1.16	0.56	8.9
1980-81	218.87	1.7	0.78	9.69
1981-82	220.61	1.29	0.58	12.91
1982-83	192.67	1.11	0.58	13.33
1983-84	223.29	2.59	1.16	12.74
1984-85	290.71	1.58	0.54	12.37
1985-86	306.58	0.71	0.23	12.29
1986-87	315.94	1.43	0.45	11.83
1987-88	327.56	1.86	0.57	12.57
1988-89	414.08	1.91	0.46	11.15
1989-90	432.36	2.11	0.49	13.96
1990-91	500.46	2.11	0.42	28.77
1991-92	530.02	2.32	0.44	17.71
1992-93	669.1	2.43	0.36	23.06
1993-94	619.84	3.07	0.5	26.63

Source: Department of Fisheries, Bharuch

Table 4.4.16: Fish landings (average) for Bharuch district (t y^{-1})

Name of Fish	1988-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94
White pomfret	-	0.06	-	-	-	-	-	-
Bombay duck	313.36	417.17	330.06	409.17	395.89	351.94	253.62	306.7
Jew fish	0.96	-	-	-	-	-	-	-
Hilsa	0.3	4.65	-	-	-	-	-	-
Other clupeids	51.12	75.27	100.74	112.44	138.96	190.95	272.68	364.22
Coilia	0.67	10	2.58	5.47	0.92	11.25	15.71	8.06
Shark	49.1	64.44	76.39	85.05	65.67	113.11	118.23	161.54
Mullet	41.09	60.35	71.6	80.6	110.4	163.22	169.47	246.5
Cat fish	96.7	325.74	162.28	168.28	153.25	220.98	246.05	318.23
Eel	-	4.34	0.12	-	2.16	-	-	-
Leather jacket	33.39	26.04	41.81	40.28	4.97	-	-	-
Ribbon fish	0.05	-	-	-	-	-	-	-
Silver bar	-	-	-	1.39	-	-	-	-
Perches	-	-	1.39	-	-	-	-	-
Shrimps	529.32	741.75	875.52	58.9	800.63	263.93	777.24	976.19
Prawns (Medium)	18.55	1.71	18.63	5.4	-	-	-	-
Crabs	0.3	-	-	0.3	2.46	2.37	1.4	-
Levta	25.33	80.49	83.61	107.15	112.4	103.43	122.94	168.89
Miscellaneous	215.27	268.57	255.81	289.44	323.54	397.44	448.43	517.49

Source: Department of fisheries, Bharuch.

Table 4·4·16 (contd.)

Crabs	0.3	-	-	0.3	2.46	2.37	1.4	-
Levta	25.33	80.49	83.61	107.15	112.4	103.43	122.94	168.89
Miscellaneous	215.27	268.57	255.81	289.44	323.54	397.44	448.43	517.49

Source: Department of fisheries, Bharuch.

Table: 4.4.17: Distribution and abundance of decapod larvae off Lakhigam.

Parameter	Postmonsoon	Premonsoon
Total count [no $(100m)^{-3}$]	74-3074	170-1698
Average	1385	703
Percentage* (%)	4.5 - 24.8	3.5 - 51.9
Average (%)	15.2	31
Total groups	6	9
Species composition (%)	*Metapenaeus affinis* (30.6), *Acetes indicus* (43.6), Palaemonid (16.7), Hipploytid (3.4), Crabzoea and megalopa (5.6), Leptochela (0.1)	*A.indicus* (43.0), Crabzoea and megalopa (24.4), Palaemonid (16.0), Caridea (10.8), *M.affinis* (2.5), Pandalid (1.7), Hippolytid (1.3), Alima of Stomatopada (0.2), Crangonid (0.1).

Table 4.4.18: Distribution and abundance of decapod larvae off Luhara

Parameter	Postmonsoon	Premonsoon
Total count [no $(100m)^{-3}$]	42-11045	10-2969
Average	2749	324
Percentage (%)	0.6-88.2	0.2-91.3
Average (%)	27.1	28.1
Total groups	9	6
Species composition (%)	*Acetes indicus* (42.9) Crabzoea and megalopa (24.4) Palaemonidae (16.0) Caridea (10.9) *Metapenaeus affinis* (2.5) Pandalid (1.7) Hippolytid (1.3) Alima of Stomatopoda (0.2) Crangonid (< 0.05)	*Metapenaeus affinis* (45.1) Crabzoea and megalopa (41.4) *Macrobrachium* (12.0) *Acetes indicus* (0.9) *Nematopalaemon* (0.3) Leptochela (0.3)

Table 4.4.19: Distribution and abundance of fish eggs and larvae off Lakhigam.

Parameter	Postmonsoon	Premonsoon
Fish eggs		
Total Count (no $100m^{-3}$)	1	2-4
Average	1	3
Percentage (%)	0.01-0.06	0.04-0.43
Average (%)	0.03	0.18
Fish larvae		
Total count (no $100m^{-3}$)	6-147	4-28
Average (%)	71	10
Percentage (%)	0.04-4.5	0.08-0.78
Average	2.3	0.38
Total groups	15	9
Species composition (%)	*Microgobius thalassinus* (36.5) *Cother clupeids (14.5)* *Periophthalmus koclreuteri* (13.1) *Apocryptus lanceolatus* (8.5) *Boleophthalmus dussumieri* (5.7) *Thryssa purava* (5.7) Hisla kelee (1.7) *Boleophthalmus tenuis* (3.2) *Sardinella longiceps* (2.1) *Boleophthalmus glaucus* (2.1) Trichiuridae (2.1) *Sardinella lile* (0.7) *Pellona dayi* (0.7) *Thryssa mystax* (0.7) *Boleophthalmus viridis* (0.4)	*Gobiidae (63.5)* (others) Engraulidae (7.3) *Gobius planiceps* (7.3) *Thryssa purava* (4.9) *Microgobius thalassinus* (4.9) *Boleophthalmus dussumieri* (4.9) *Scorpaeinidae* (2.4) *Clupeidae* (2.4) *Pellona dayi (2.4)*

Table 4.4.20: Distribution and abundance of fish eggs and larvae off Luhara

Parameter	Postmonsoon	Premonsoon
Fish eggs		
Total count (no $100m^{-3}$)	4	1-5
Average	--	2.7
Percentage (%)	0.02	0.04-0.68
Average (%)	--	0.2
Fish larvae		
Total count (no $100m^{-3}$)	6-347	1-334
Average	67	39.4
Percentage (%)	0.01-5.86	0.01-21.4
Average (%)	1.1	4
Total groups	25	10
Species composition (%)	*Boleophthalmus dussumieri* (21.3) *B. viridis* (11.8) *Thryssa purava* (10.6) *Microgobius thalassinus* (10.4) *Sardinella longiceps* (8.2) *B.glancus* (1.7) Carangidae (6.9) Pellona dayi (5.9) *Hilsa kelee* (5.5) Clupeidae (others) (2.5) *S.lile* (1.7) *Gobioidus anguillaris* (1.7) *Pellona sladeni* (1.6) *Thryssa mystax* (1.4) *Periophthalmus koclreuteri* (1.2) *Spratelloides gracilis* (0.4) *Sardinella melanura* (0.2) Engraulidae (0.2) *Scatophagus argus* (0.2) Gobiidae (others) (0.2) *Thryssa dussumieri* (0.1) *Apocryptus rictuosus* (0.1) *Trichiuridae* (0.1) *Triacanthus brevirostris* (0.1) *Harpodon nehereus* (0.1)	Gobiidae (55.4) *T.mystax* (28.3) *B.dussumieri* (10.3) *Thryssa purava* (2.9) Engraulidae (1.4) Gobius planiceps (0.7) *Microgobius thalassirus* (0.4) Pellona dayi (0.2) *Johnius axillaris* (0.2) Epigonidae (0.2)

Table 5.1.1: Comparison of probable wastewater characteristics and baseline water quality off Lakhigam. (All values in mg l^{-1} except for pH).

Parameter	Wastewater	Seawater baseline
pH	5.5 - 9.0	7.9
Suspended solids	100	1495
Oil & grease	10	0.027
BOD	30	2
COD	100	3
Ammoniacal nitrogen	50	0.02
Free ammonia (as NH_3)	5	0.02
Total residual chlorine	1	0
Total dissolved solids	2100	31800
Phenolic compounds	1	0.004
Cyanides (as CN)	0.2	0
Flourides (as F)	1.5	1.2
Phosphates (as P)	5	0.06
Sulphides (as S)	2	0
Boron (as B)	2	3.86
Arsenic (as As)	0.2	0.0005
Mercury (as Hg)	0.01	0.0001
Lead (as Pb)	0.1	0.003
Cadmium (as Cd)	1	0.0005
Hexavalent chromium (as Cr^{+6})	0.1	0
Total chromium (as Cr)	2	0.0005
Copper (as Cu)	3	0.02
Zinc (as Zn)	5	0.05
Nickel (as Ni)	3	0.0005
Pesticides	Absent	–

Table 6.1.1: GPCB standards and predicted concentrations of some contaminants in seawater for different modes of release.

Parameter	GPCB standard	Seawater baseline	Predicted concentration for release at		
			Surface	Bed	2 m above bed
pH	6.5-8.5	7.9	–	–	–
Oil & grease	10	0.03	0.05	0.62	0.21
Suspended solids	30	1500	1500	1414	1473
Total chromium	0.2	0.0005	0.0009	0.012	0.004
Manganese	2.0	0.005	0.009	0.122	0.041
Nickel	2.0	0.0005	0.0009	0.118	0.037
Copper	1.0	0.01	0.01	0.07	0.028
Zinc	1.0	0.02	0.02	0.08	0.038
Cadmium	0.2	0.0005	0.0009	0.0122	0.004
Lead	0.1	0.003	0.003	0.009	0.005
Mercury	0.01	0.0001	0.0001	0.0007	0.0003
Iron	1.0	0.01	0.01	0.07	0.028
Phosphate-P	5.0	0.06	0.07	0.35	0.15
Fluoride	1.5	1.2	1.2	1.22	1.21

All values except pH are in mg l^{-1}

Table 6.1.2: Predicted concentrations of some contaminants in seawater for different modes of release after reaching the bottom at different distances.

Parameter	Surface release		Release at seabed		Release 2 m above seabed	
	At 10 m	At 50 m	At 10 m	At 50 m	At 10 m	At 50 m
Oil & grease	0.034	0.031	0.16	0.06	0.07	0.039
Suspended solids	1500	1500	1481	1496	1494	1499
Total chromium	0.0006	0.0005	0.003	0.0011	0.0012	0.0007
Manganese	0.006	0.0052	0.031	0.011	0.0131	0.0067
Nickel	0.0006	0.0005	0.0268	0.0062	0.0087	0.0023
Copper	0.01	0.01	0.023	0.013	0.014	0.011
Zinc	0.02	0.02	0.033	0.023	0.024	0.021
Cadmium	0.0006	0.0005	0.0031	0.0011	0.0013	0.0007
Lead	0.003	0.003	0.0043	0.0033	0.0036	0.0031
Mercury	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001
Iron	0.01	0.01	0.023	0.013	0.014	0.11
Phosphate-P	0.061	0.06	0.124	0.074	0.08	0.064
Fluoride	1.2	1.2	1.2	1.2	1.2	1.2

All values except pH are in mg l^{-1}

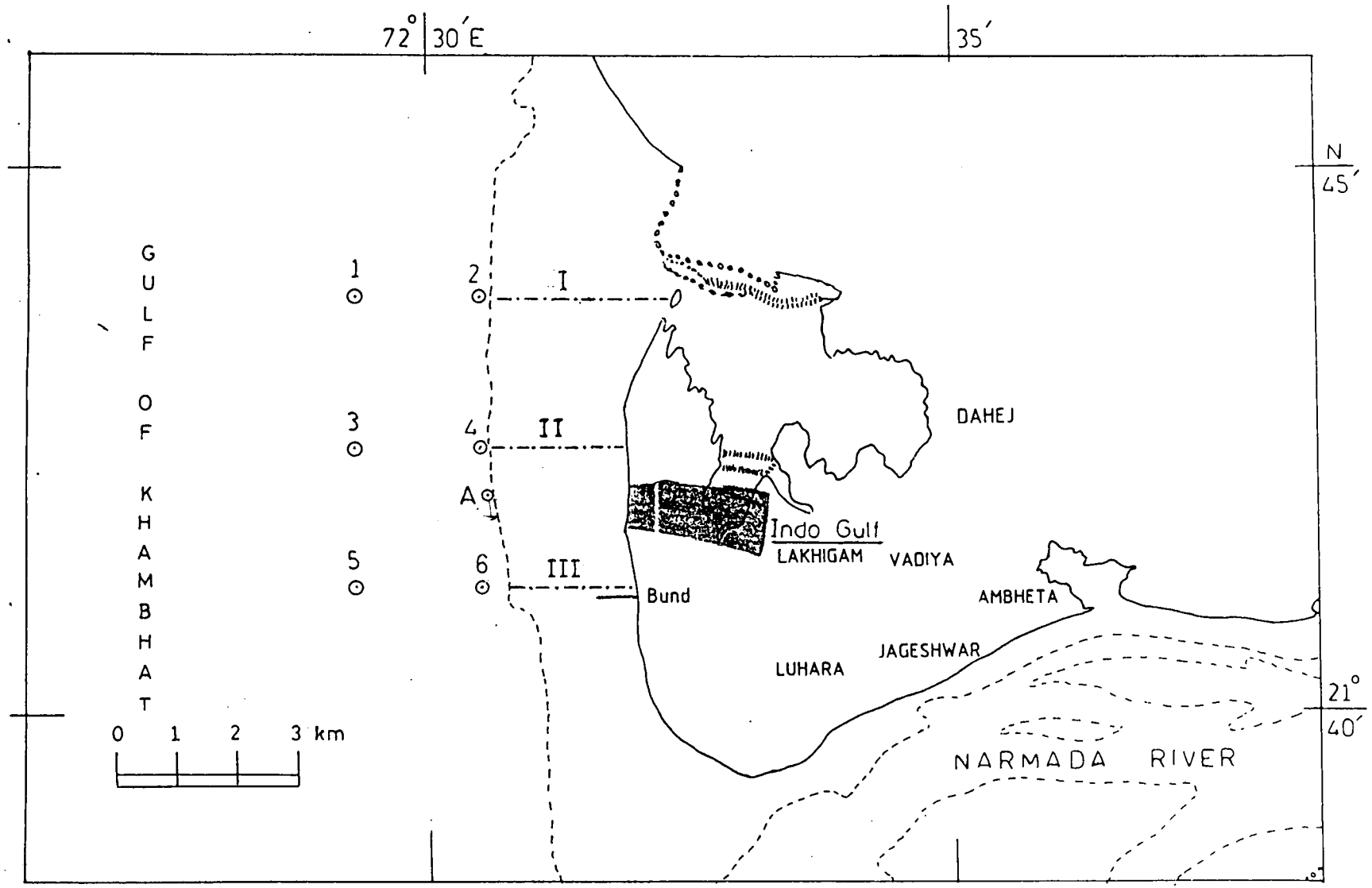


Fig 1·3·1 Location of stations

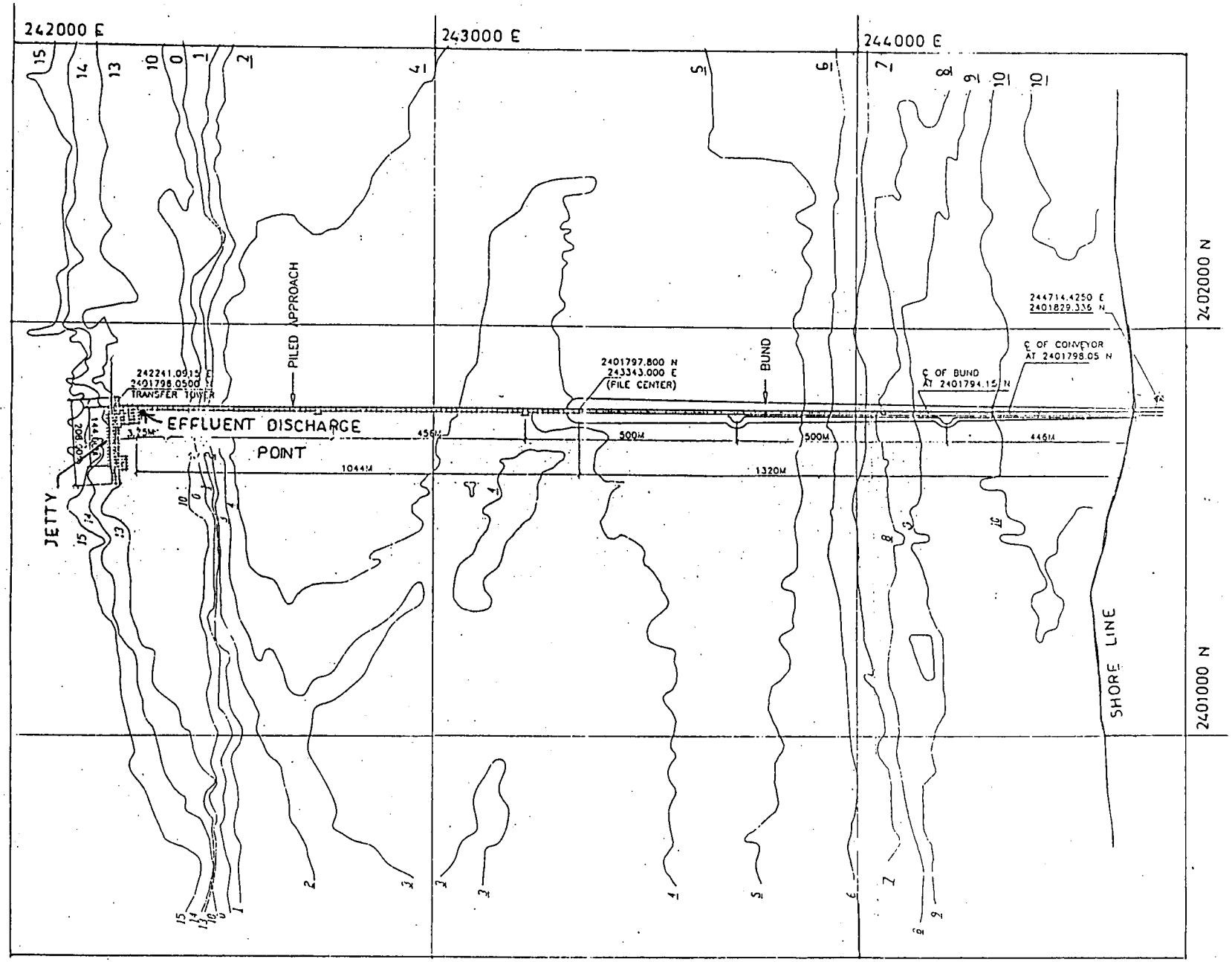


Figure 3·4·1 Jetty alignment and proposed location for release of wastewater

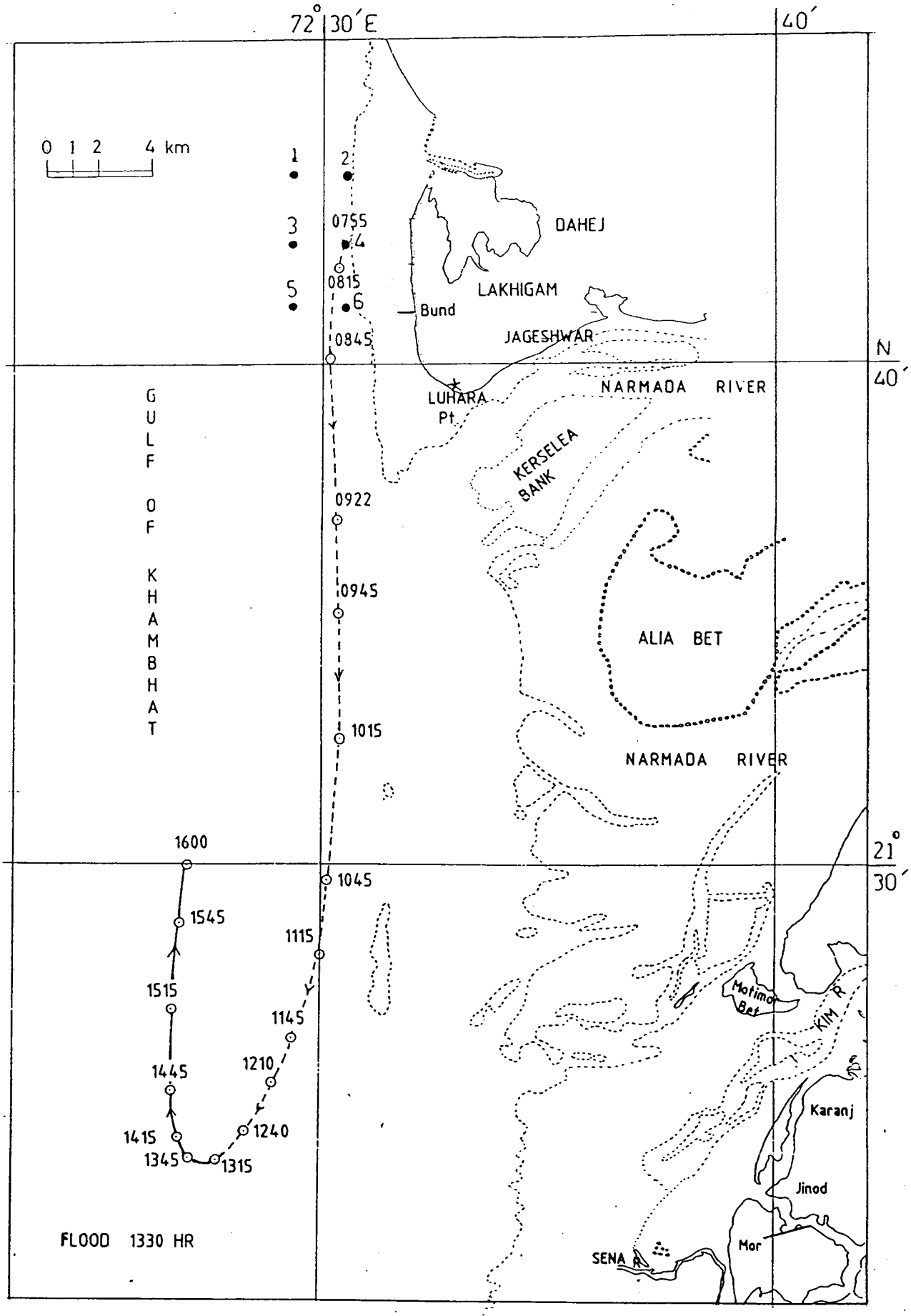


Figure 4·1·1 Drogue path on 12·10·1995

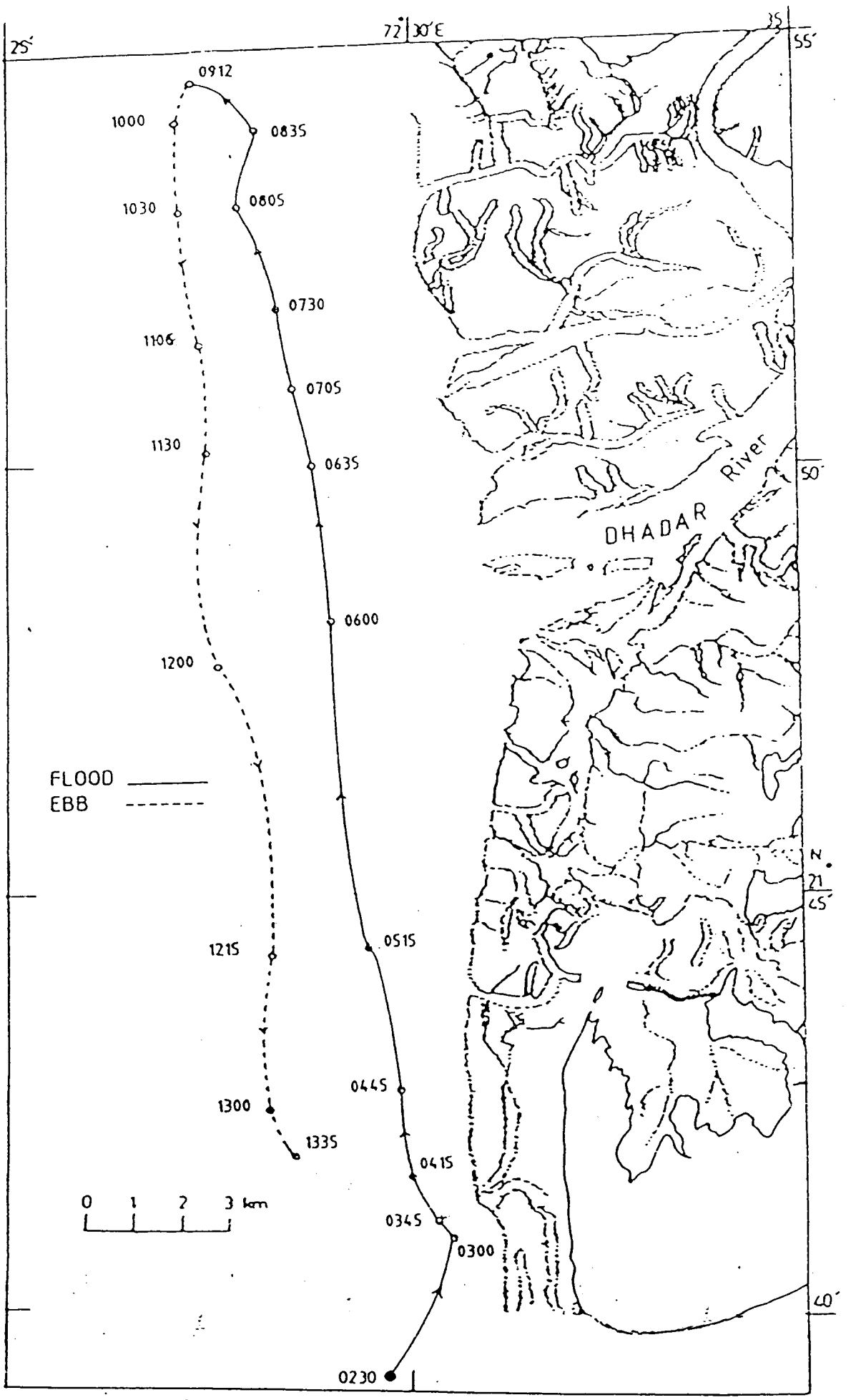


Fig 4·1·2 Drogue path on 6.11.1993

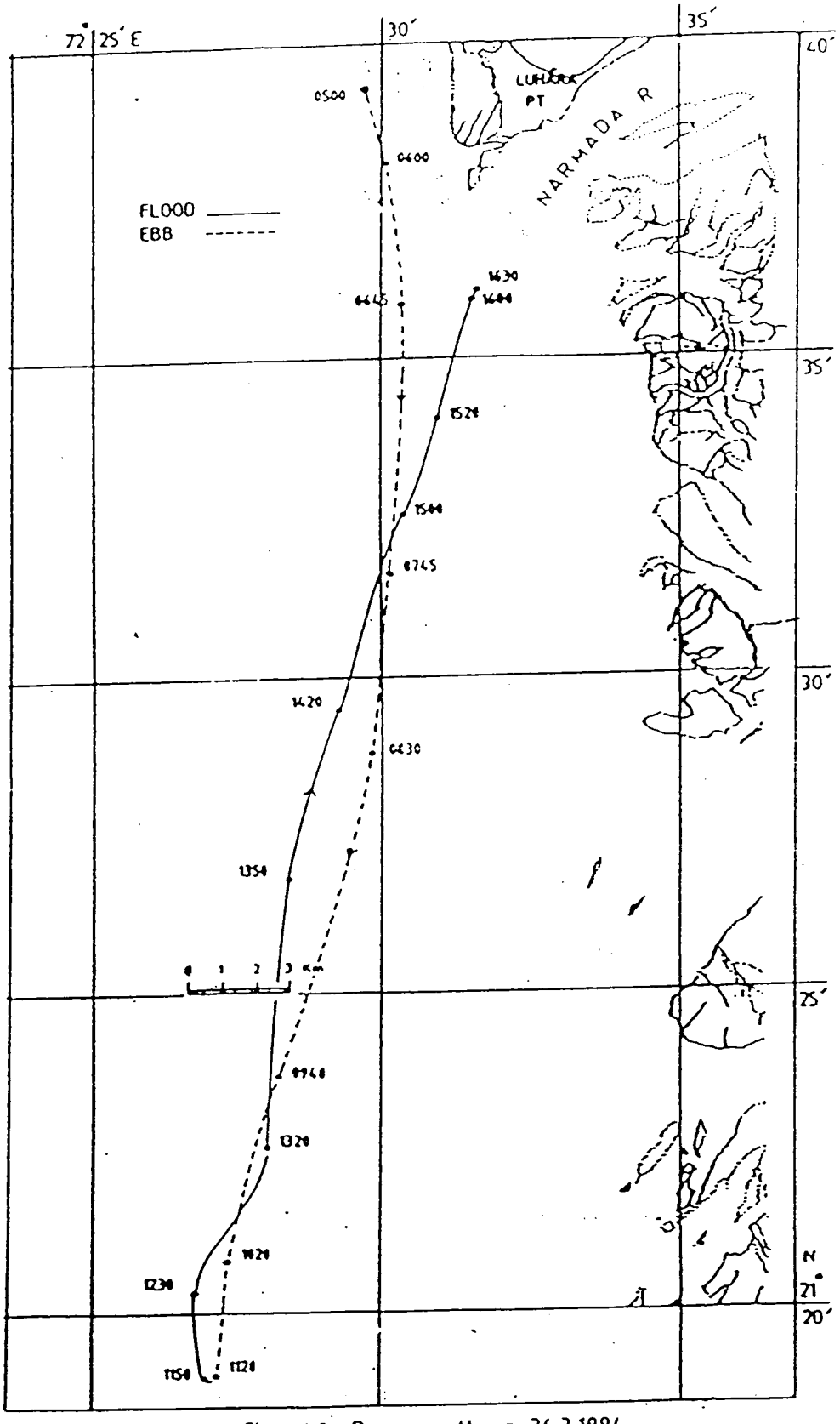


Fig 4·1·3 Drogue path on 26.2.1994

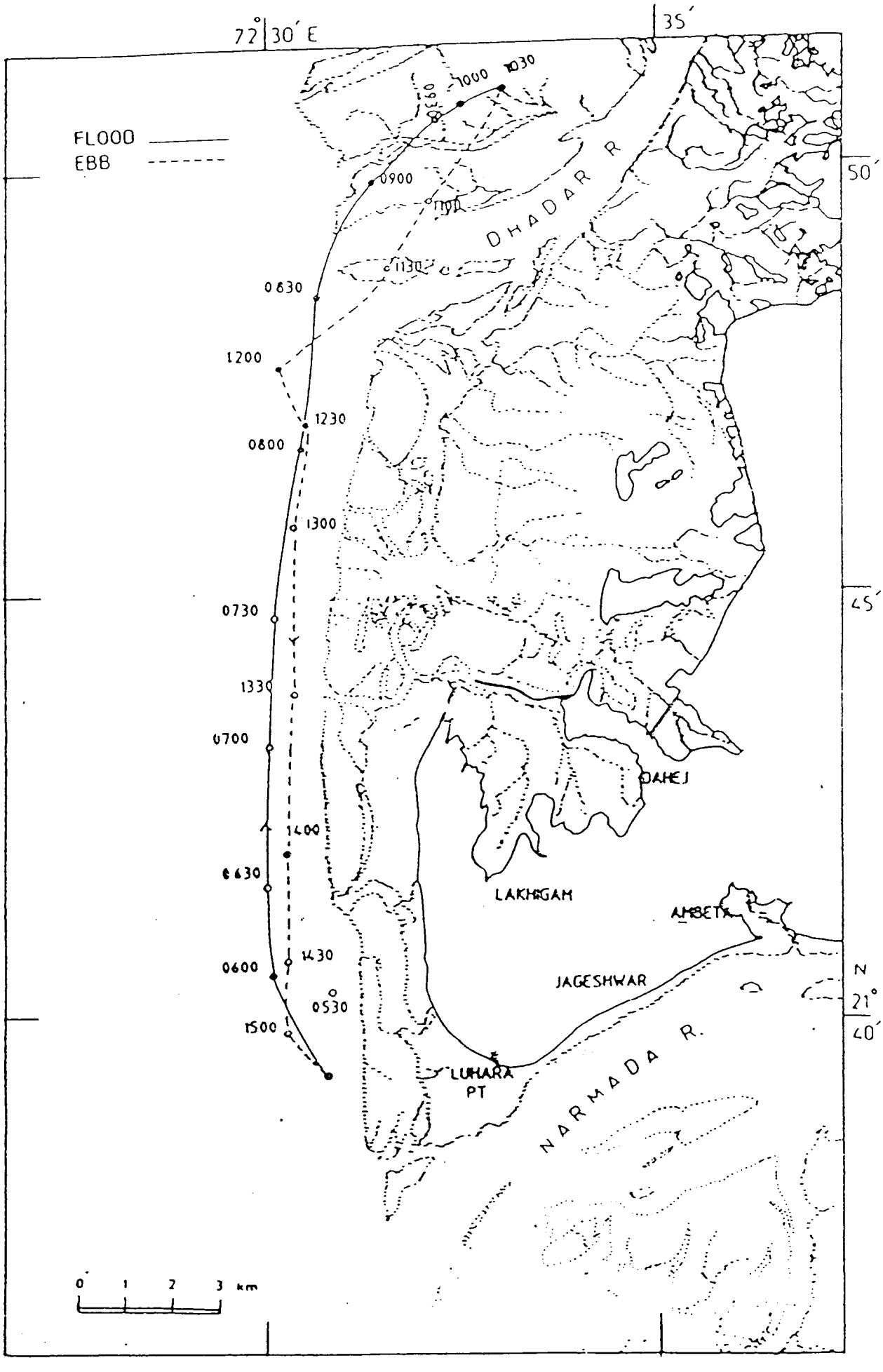


Fig. 4·1·4 Drogue path on 5.3.1994

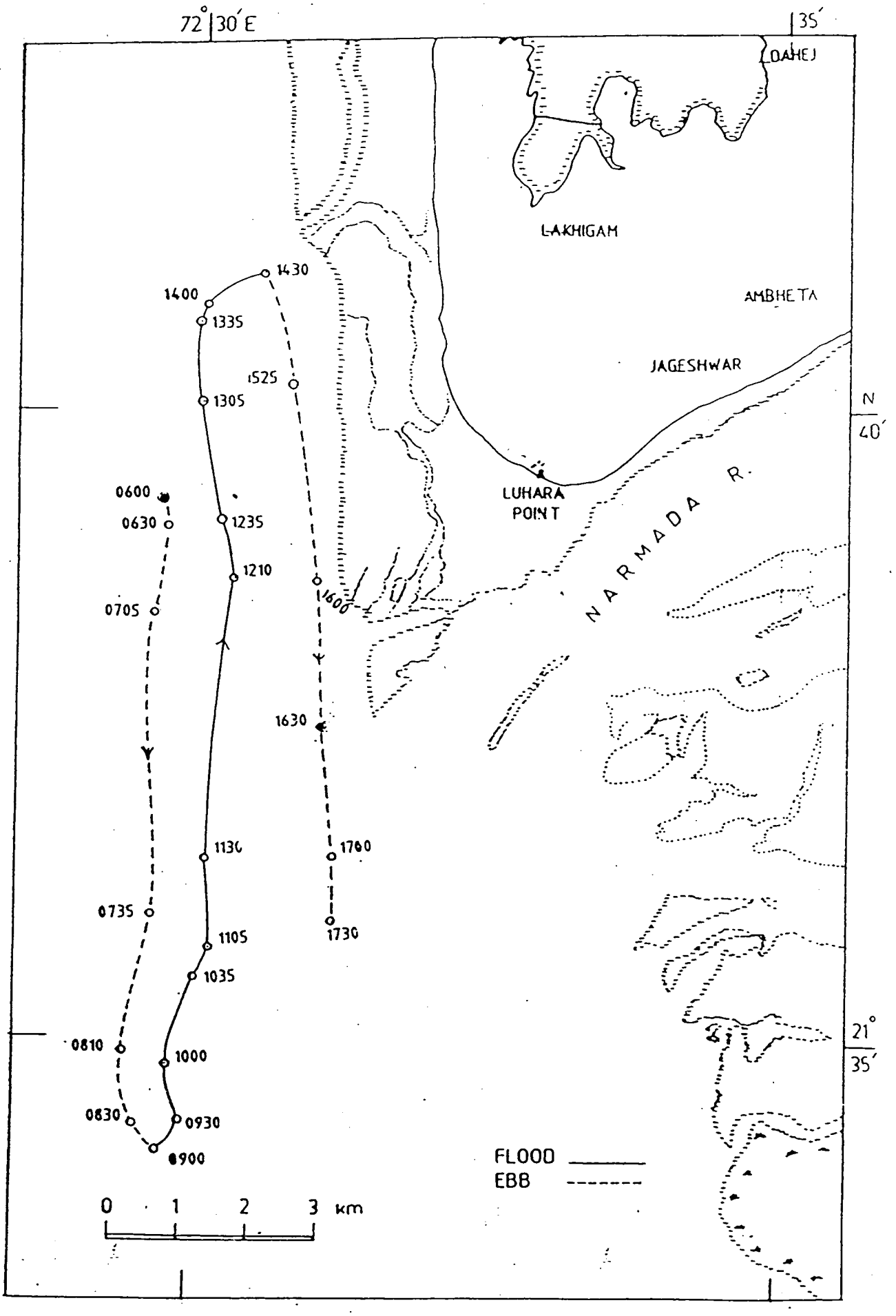


Fig 4·1·5 Drogue path on 7.3.1994

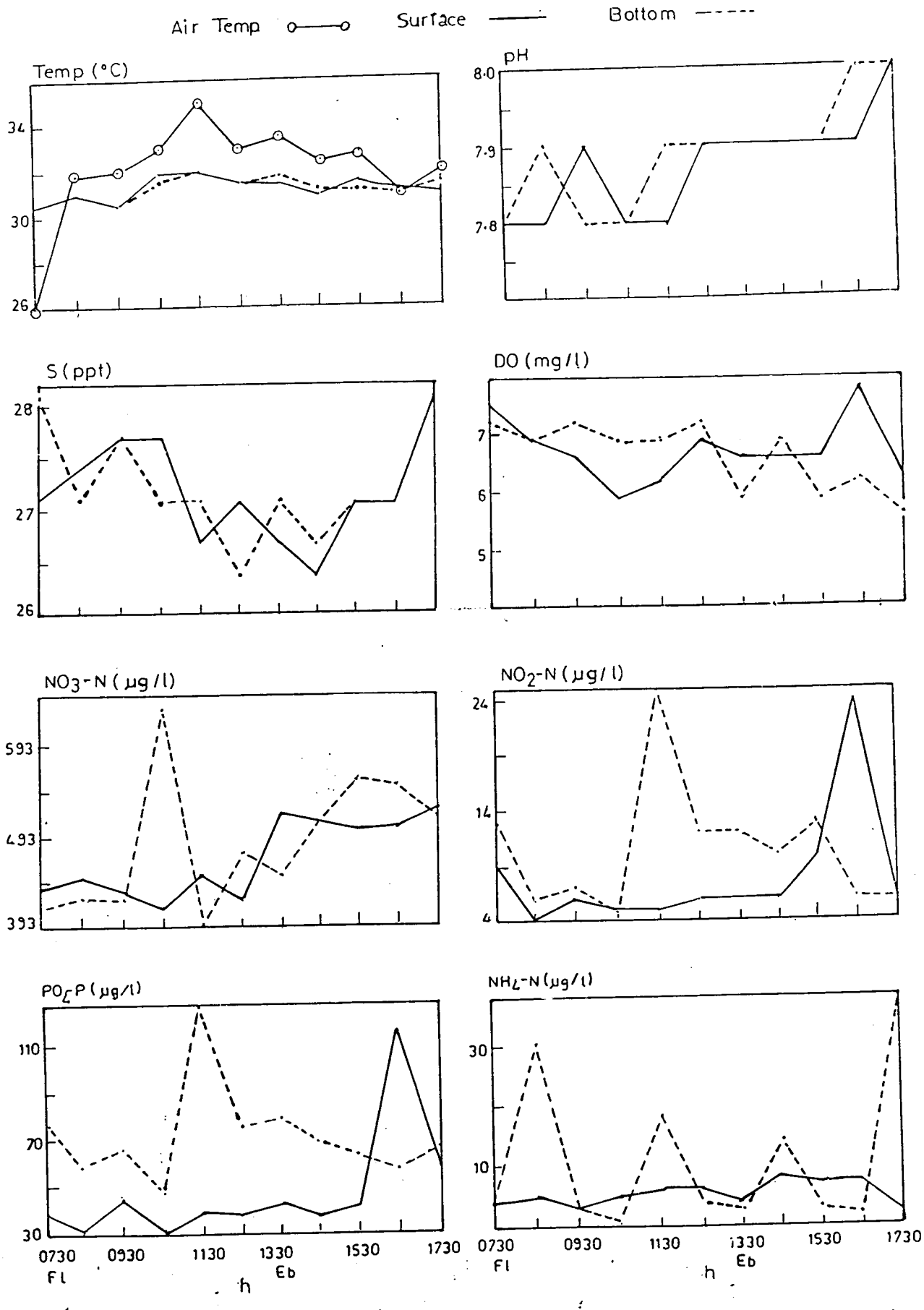


Fig 4·2·1 Variations of some physico chemical parameters at Station 4 on 13·10·1995

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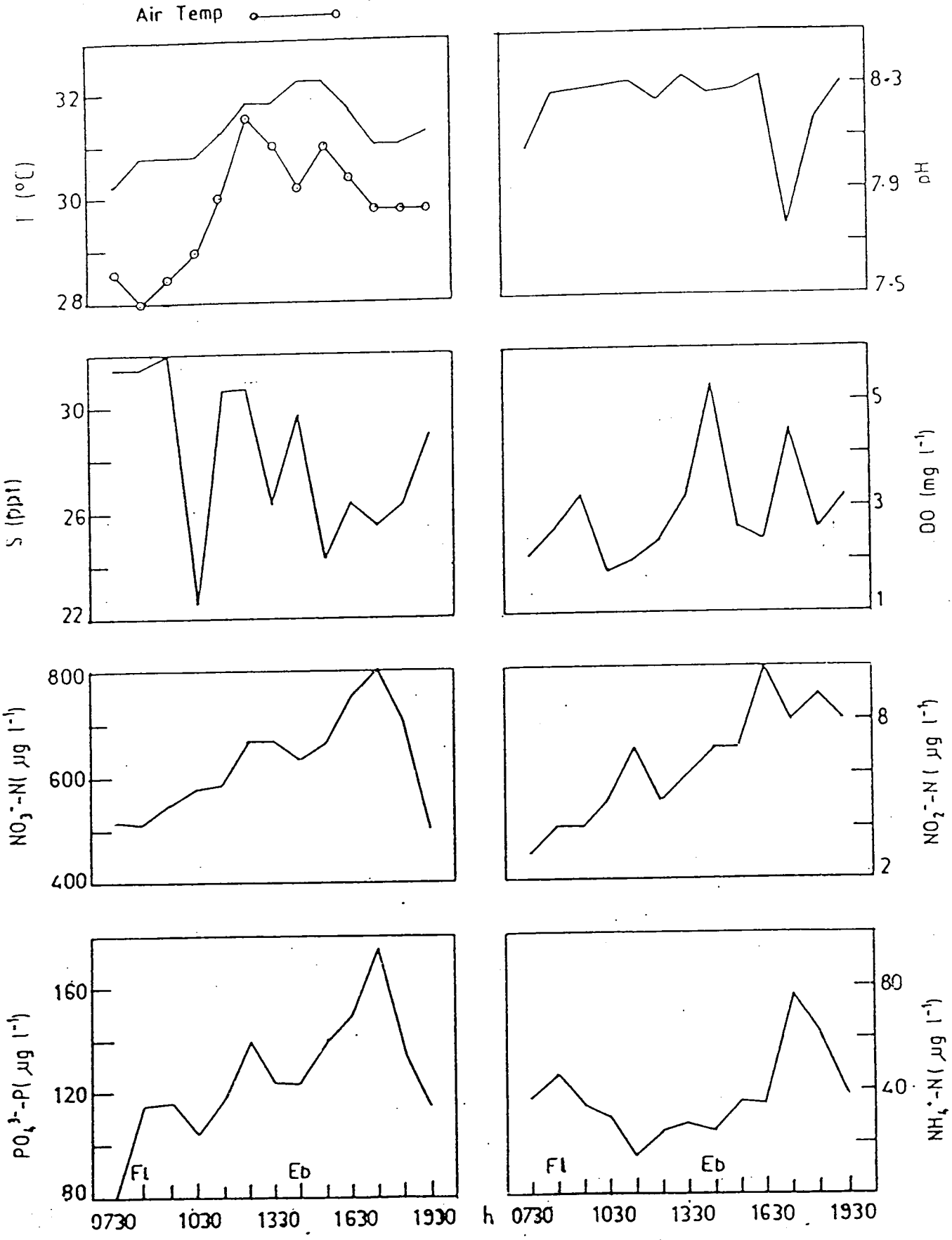


Fig 4·2·2 Variations of some physico-chemical parameters off Lakhigam on 21·10·1993

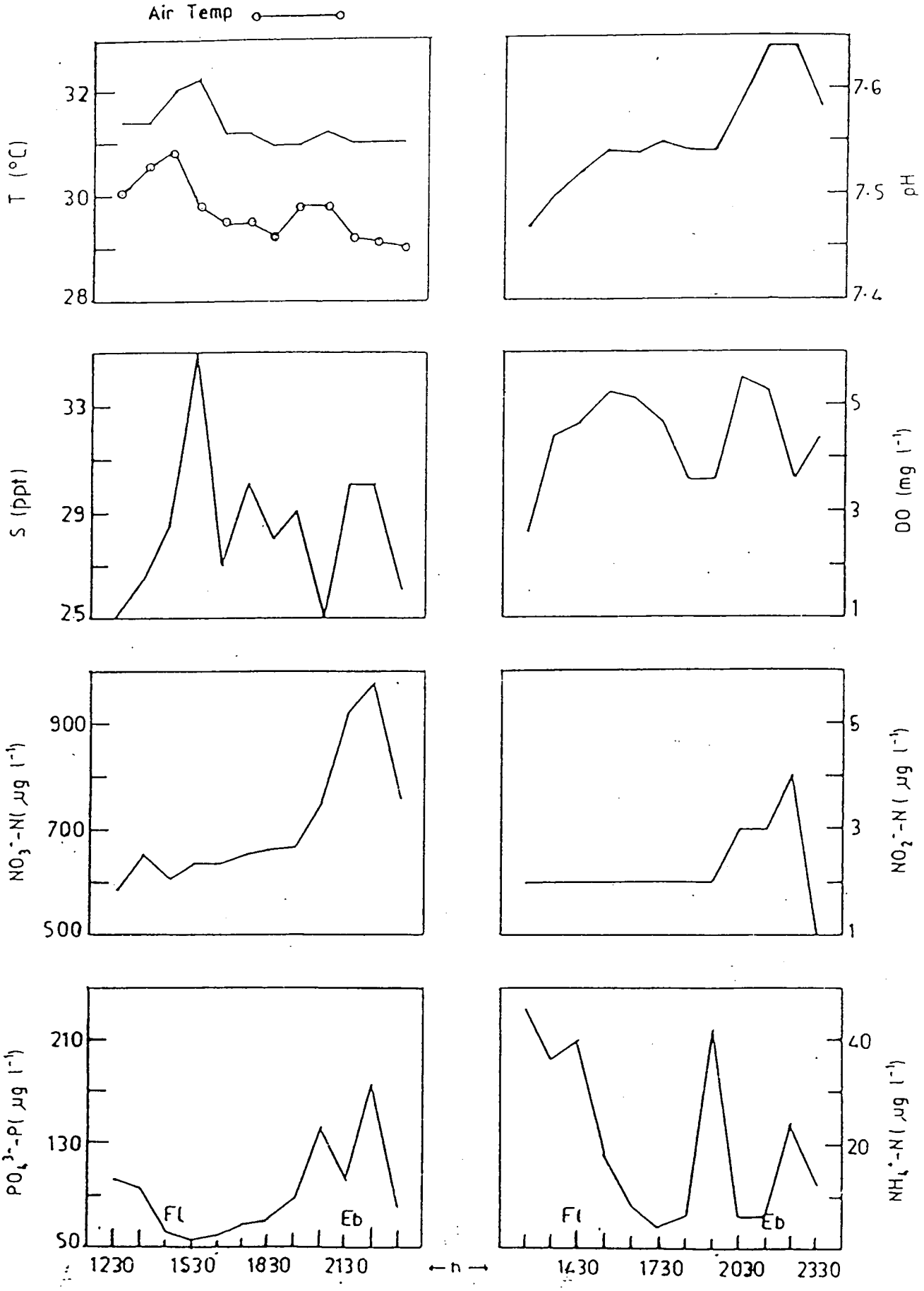
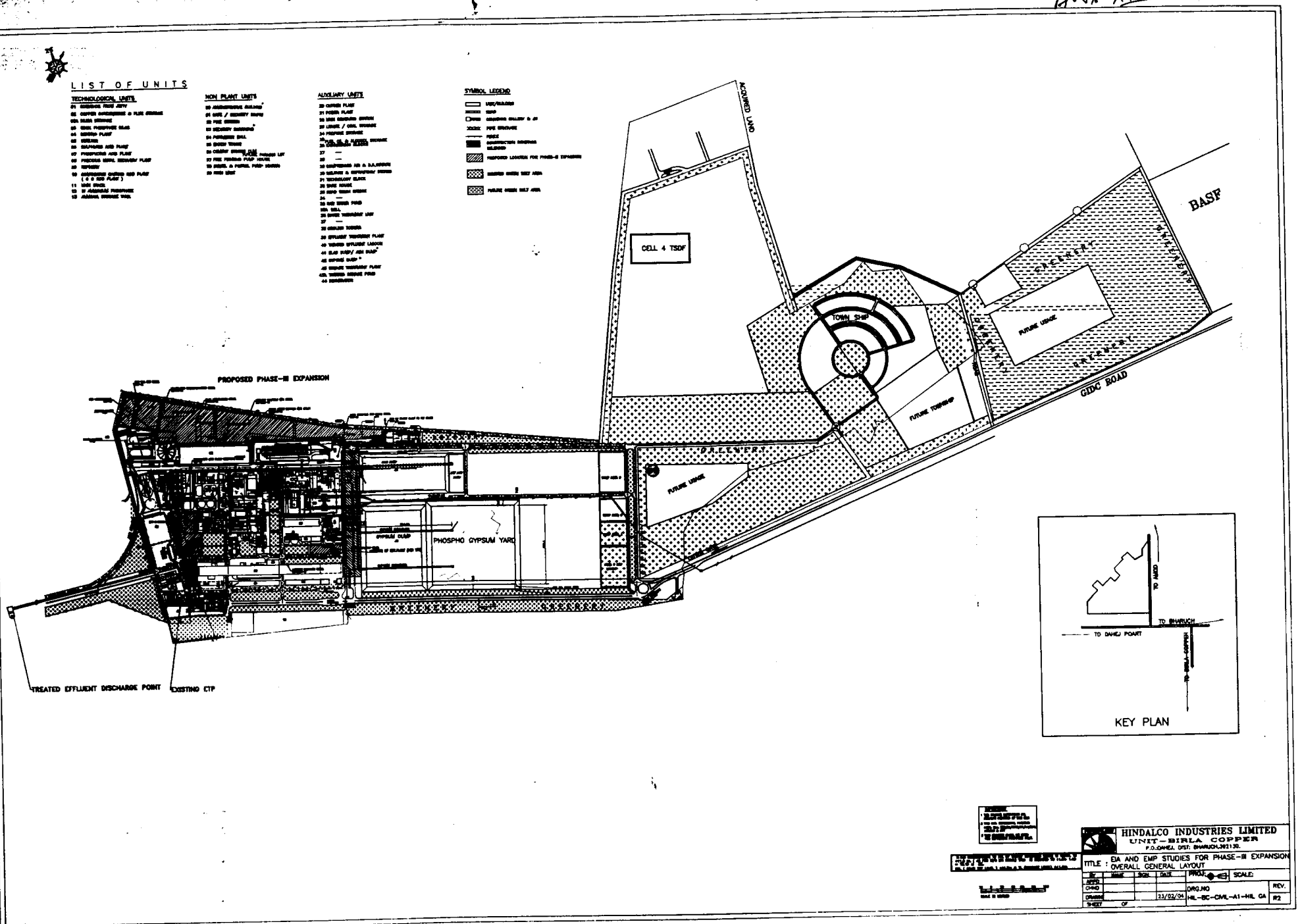


Fig 4·2·3 Variations of some physico-chemical parameters off Lakhigam (26·10·1993)


LIST OF UNITS
TECHNOLOGICAL UNITS
NON PLANT UNITS
AUXILIARY UNITS
SYMBOL LEGEND
ACQUIRED LAND
CELL 4 TSDF
BASF
GREENERY
TOWN SHIP
FUTURE USAGE
FUTURE TOWNSHIP
GIDC ROAD
PROPOSED PHASE-III EXPANSION
PHOSPHO GYPSUM YARD
GYPSUM DUMP
TREATED EFFLUENT DISCHARGE POINT
EXISTING ETP
TO BHARUCH
TO DAHEJ PORT
TO BIRLA COPPER
KEY PLAN
HINDALCO INDUSTRIES LIMITED
UNIT-BIRLA COPPER
P.O.DAHEJ, DIST: BHARUCH-392130.
TITLE : EIA AND EMP STUDIES FOR PHASE-III EXPANSION
OVERALL GENERAL LAYOUT
SCALE:
ORG.NO
HIL-BC-CIVIL-A1-HIL GA
REV.
R2
23/02/94

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Annexure-6

No. J-11011/7/94-IA.II[I]
Government of India
Ministry of Environment & Forests

Paryavaran Bhavan,
CGO Complex, Lodi Road,
New Delhi - 110 003.

Dated 3rd January, 2000.

To,

M/s Indo Gulf Corporation Ltd.
[Unit Birla Copper],
309, World Trade Centre,
Barakhamba Road,
New Delhi - 110 001.

[Atten: Shri R. Vaidyanathan, Joint Executive President]

Sub: Transfer of Jetty Licence of IGCL in favour of M/s Dahej Harbour Infrastructure Limited - regarding.

Sir,

This has reference to your communications No. IGCL/BC/JETTY/DO/99 dated 24th September 1999 and No. BC/DO/MOEF/99 dated 20th December 1999 seeking Ministry's approval for transferring the environmental clearance granted to captive jetty facilities at Dahej [in respect of the copper smelter project] in favour of M/s Dahej Harbour Infrastructure Limited P.O. Dahej, Lakhigam, District Bharuch, Gujarat.

The matter has been examined and interalia it has been noted that M/s DHIL, a Registered Company under Companies Act, 1956 has given an undertaking to comply with the terms and conditions imposed by the Ministry vide clearance letter No. J-11011/7/94-IA.II[I] dated 14th March 1995 and as applicable in conformity with CRZ regulations and that Gujarat Maritime Board has transferred the licence regarding the administration, development and operation of port facilities of the said captive jetty to M/s DHIL vide its letter of 2nd August 1999.

Subject to the above, the earlier clearance granted to Captive Jetty is transferred in the name of M/s DHIL. M/s DHIL should submit six-monthly reports on the compliance of environmental terms and conditions to this Ministry [Regional Office at Bhopal].

Yours faithfully,

(Dr. N.H. Hosabettu)
Addl. Director [S]

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MARINE ENVIRONMENT MONITORING FOR IN THE INSHORE WATERS OF GULF OF KHAMBHAT, OFF DAHEJ PLANT, SURROUNDING TO EFFLUENT DISCHARGE POINT OF HINDALCO INDUSTRIES LIMITED (UNIT: BIRLA COPPER), DAHEJ

DRAFT REPORT

Project Coordinator

Dr. Jayendra. Lakhmapurkar

Study Team

Dr. Deepa Gavali

Mr. Bhupindra Patel

January 2025

ACKNOWLEDGEMENTS

With immense pleasure and thanks we record our heartfelt appreciation to

- *Sachin Sharma (HOD Env.), for valued guidance and support in successfully organizing the field activity.*
- *Mr. Dharmesh Golwala (Sr. Engineer) Hindalco Industries Ltd. for their technical help during the project duration.*
- *Last but not least, Boatman-Babubhai and his crew members for their valued assistance during sampling.*

EXECUTIVE SUMMARY

1 Gujarat Ecology Society (GES) is engaged in regular monitoring of the marine environment around submarine outfalls and jetty installations of Hindalco Industries Ltd. (Unit: Birla Copper). The present study was carried out during the post-monsoon season in December 2020.

2 Three transects between, 21˚40′ N to 21˚43′ N latitudes and 72˚ 28′ to 72˚ 31′ E longitudes were taken covering 10 Km^2 during both tides. A total of six stations were sampled representing upstream and downstream of jetty and discharge point of Birla Copper Ltd. Physico-chemical and biological parameters were studied at these stations.

3 Water samples were collected from the surface, middle, and close to the bottom at all sampling points. Parameters like temperature and pH were recorded at the field itself. Samples were preserved for DO/BOD studies. Sediments were collected from stations 2, 4, 5 and 6 for lab analysis. Phytoplankton, Zooplankton, and benthic samples were collected and preserved for lab analysis of biota.

4 Routine parameters Total Suspended Solids, DO, BOD, Salinity, PO_4–P, Total Phosphorus, NO_3–N, NO_2–N, and Total Nitrogen were carried out at the GES laboratory. Heavy metals (Cu, Cd, Cr, Zn, Hg, Pb & Ni) were analyzed using AAS. Phytoplankton and Zooplankton were isolated for identification and quantification like wet biomass, numerical density, species composition and species diversity. Benthos was examined for enumerating diversity. The sediment samples were examined for total organic carbon, texture and heavy metals (Cu, Cd, Cr, Zn, Hg, Pb & Ni).

5 Water temperature varied from 21°C to 27.5°C during both tides. The turbidity ranged from 200 NTU to 1800 NTU, indicative of high turbidity, which is the general character of the Gulf waters. pH was in the efficient buffering range of the sea and the environment with a characteristic alkaline (8.13 to 8.20) water column nature. The salinity varied in the wide range of 28.18 ppt and 32.02 ppt.

6 The average TSS value of surface samples in the low tide was 0.51 g/l while that during the high tide was 0.49 g/l. There was no major difference between the high tide and low tide.

7 The Dissolved Oxygen (DO) content showed that the study area is well-oxygenated (3.60 to 5.06 mg/l) during the high tide. While during the low tide oxygen levels reported were 5.52 to 9.23 mg/l.

8 The ammonical nitrogen ranged between 0.23 to 0.60 mg/l, under the prescribed limit of GPCB. Nitrates and Nitrites content indicated the presence of more nitrates (mean concentration: 0.02 mg/l) compared to nitrites (min: 0.09 mg/l, max: 0.29 mg/l). This is indicative of good health and oxidizing conditions that prevail in the environment. The Total nitrogen ranged between 0.51 mg/l to 0.75 mg/l.

9 Inorganic phosphates, which are an assimilative form to organisms for tissue built-up were found in the range of 0.04 to 0.29 mg/l. Whereas, the total phosphate recorded was in the range of 0.22 and 0.50 mg/l.

10 The highest Chlorophyll *a* value was reported from station 2(1.43 mg/l) followed by station 6 (1.398 mg/l) during the high tide. Even during the low tide the Chlorophyll *a* ranged between 1.327 mg/l to 1.338 mg/l. The waters of the gulf are productive and supported by low pheophytin values.

11

12 A total of 21 phytoplankton species was reported in the present study. *Navicula spp*, *Coscinodiscus gigas* and *Surirella spp* are the most common species reported from all the sampled stations. The species reported largely belonged to Bacillariophyceae group. The phytoplankton density was reported high at station 5 (10.86 individuals/l) and low density (5.67 individuals/l) was reported at station 2. The phytoplankton density was reported high during the low tide as compared to the high tide. There is more productivity during the low tide because of high light penetration.

13 A total number of 37 zooplankton species belonging to different groups was reported in the present study. *Clausocalanus* sp, *Oithona sp.* and Polychaete larva were reported from all the stations. This indicates the presence of the species in the area irrespective of the open waters or estuary part. The group Calanoida, Copepoda, and Decapoda is represented in all the sampling sites. The zooplankton density was high at stations 4 and 6 during the high tide whereas during the low tide, the zooplankton density was high at station 1. Stations 4 and 6 are close to the shoreline.

14 There was a low catch in the year 2020 -21 (2191 M.T). This is largely due to COVID 19 and the lockdown period from April to May that had an impact on fish catch). Levta is the major fishery of the region and the vast mudflats of the Gulf of Khmabhat support *levta* fishery. Bombay duck, Shrimps, and crabs are the other contributors to the Fishery of the region.

15 The 96 hrs static bioassay test on fish guppy at the industrial site was carried out by Birla Copper Ltd. The results showed 96% survival in 96 hrs, indicating good quality of effluents.

16 The mangroves found near the Birla Copper jetty were dominated by *Avicennia marina,* which is the most common and dominating species of the Gulf of Khambhat. Birds like egrets and herons were noticed in the mangroves.

17 Three Dolphin were sighted at the time of the sampling and this indicates the presence of good productive waters.

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ABBREVIATIONS

DO	Dissolved Oxygen
ECLO	*Escherichia coli* like organisms
MT	Metric Ton
NO_2-N	Nitrite Nitrogen
NO_3-N	Nitrate Nitrogen
PALO	*Pseudomonas aerugionosa* like organisms
PKLO	Proteus/Klebsiella like organisms
PO_4-P	Inorganic Phosphate
ppm	Parts per Million
SFLO	*Streptococcus faecalis* like organisms
SHLO	*Shigella* like organisms
SLO	*Salmonella* like organisms
TSS	Total suspended Solids
TVC	Total viable count
VCLO	*Vibrio cholerate* like organisms
VLO	*Vibrio* like organisms

1 INTRODUCTION

1.1. BACKGROUND

The Gulf of Khambhat with high tidal amplitude and energy conditions assisted in the development of jetties for medium and large ships. At present, this region has become a hub for industrial development. The port facility has helped in the establishment of industries RPCL, GACL, Hindalco Industries Limited **(**Birla Copper unit), Gujarat Narmada Valley Fertilizer CO. Ltd (GNFC), Gujarat Chemical Port Thermal Company Ltd (GCPTCL), Petronet LNG unit, and others. The Government of Gujarat established Gujarat PCPIR (GPCPIR) at Dahej which is spread over 453 sq. km. 44 villages fall within the PCPIR area under the jurisdiction of GIDC and Gram Panchayats, covering an area of 45,295 ha including 3988 ha under CRZ. The land-use pattern study noted that the industrial area in the PCPIR region has increased from 1939.2 ha (2011) to 3078.6 ha (2013). The presence of industrial clusters with their treated wastewater in the Gulf of Khambhat will impact the water quality in the long run.

Hence, the MoEF & CC, Government of India has made it mandatory to regularly monitor the marine waters at the outfall point of the industries. In this regard, Hindalco Industries Limited has allotted the job of monitoring marine waters to the Gujarat Ecology Society. GES is the prime agency in Gujarat working on several issues related to the coastal and marine environment of the state and has been monitoring Birla Copper since 2000.

Coastal monitoring was undertaken through the quantification of water, sediment, biological characteristics, and heavy metals.

1.2 SCOPE OF THE STUDY

1. Marine Environmental monitoring round (One set) to fill full condition of MoEF
2. A minimum of six sampling stations will be fixed in seawater upstream and downstream of Birla Copper's effluent discharge point, including the intertidal area.

3. At each station, the seawater samples will be collected near the surface of the seawater and above the seafloor as well as midway between these two positions, where water depths exceed 5 m except at inter-tidal areas where only surface samples will be collected. Sampling of seawater for low tide and high tide.
4. At each sampling station sediment samples will be collected to study benthic fauna.
5. Seawater samples to be analyzed for

- *Physio-chemical parameters:*

  Seawater and air temperature, depth, turbidity, total suspended solids, salinity, pH, dissolved oxygen, NH_4-N, NO_2-N, NO_3-N, Total -N, PO_4-P, Total -P, Chlorophyll-*a*, pheophytin, Heavy metals.

  Phytoplankton:

  Phytoplankton count, major genera and generic diversity.

- *Zooplankton:*

  Zooplankton count, fresh weight, dry weight and volume of zooplankton, major genera of zooplankton and group diversity.

- *Bacteriological parameters:*

  Only surface water & sediment samples from all sampling stations will be analyzed;

  Total viable count, Total Coliform, *E.coli, Shigella, Salmonella, Proteus Klebsiella, Vibrio cholerae, Vibrio parahaemolyticus* and other *Vibrio* sp., *Pseudomonas aeruginosa* and *Streptococcus faecalis.*

6. Sediment samples to be analyzed for :

- ***Physico-chemical Parameters***

  Texture, TOC and heavy metals

- *Benthic fauna:*

Numerical and biomass density per unit area, identification of species and species diversity.

7. Data on Fishing resources and fish landings will be collected from authentic sources or agencies. Bioassay tests will be conducted on the seawater near the discharge point.
8. To analyze and evaluate any impacts on the marine wildlife of the region.
9. Observations of *Mangrove vegetation*, wherever extant in the vicinity of the observed area to be studied for population density, growth, and species diversity.
10. To prepare EMP to mitigate identified impacts.

2 STUDY AREA

The Gulf of Khambhat is funnel-shaped as a bay on the Arabian Sea coast of India, on the western shelf of India. The Gulf has a North-South alignment as it lies between 21°00' to 22°25' N Latitude and 71°45' to 72°53' E Longitude. The Gulf of Khambhat covers about 3,120 sq. km. It is 70 km wide and 130 km long (Vora et al., 1980). Major rivers draining Gujarat are the Narmada, Tapti, Mahi and Sabarmati which form estuaries in the gulf.

The Gulf experiences semi-arid to sub-humid climatic conditions. The Bharuch region receives an average annual rainfall of 1100 mm with 45 rainy days. The atmospheric temperature over the Gulf varies between 13° and 40° C.

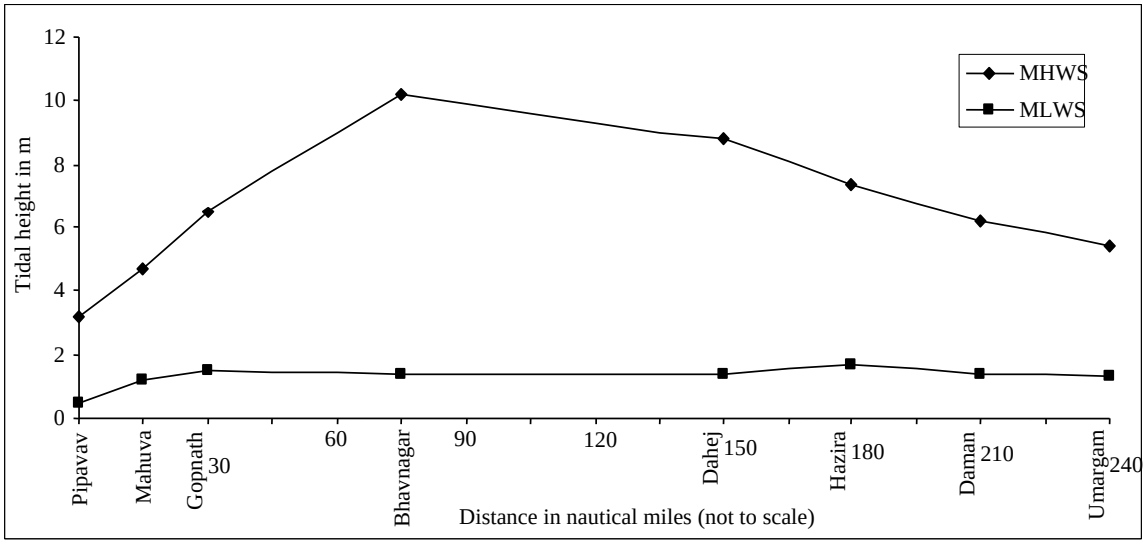
The bathymetry of the gulf bottom is seen to comprise of large number of shoals, underwater ridges and deep channels. These features represent the continuous accumulation and distribution of sediment load by tidal currents with some control of the tectonics of the Cambay basin. Geologically the region includes the Cambay basin. It is a narrow half-graben trending roughly NNW-SSE filled with Tertiary sediments with rifting due to extensional tectonics.

A number of estuaries, islands, mudflats, cliffs, salt marshes and mangrove swamps, etc, mark the coast of the Gulf. The inner shelf is characterized by uneven seafloor topography. Entire banks surrounding the Gulf area are bordered with large tidal flats nested into numerous tidal creeks. The large intertidal results of high net transport of sediments towards land/coast. The sediments brought by various rivers during monsoon remain in suspension and start settling down at the onset of winter (Natak and Sahay 1985).

The Gulf of Khambhat has semi-diurnal tides (M2 – type), with a mean amplitude of 8.0 m above the *chart datum* (Nayak and Shetye 2003), a large diurnal inequality and varying amplitude – which decreases from north to south along both the coasts. Because of its unique position – nearness to the Tropic of Cancer, funnel shape of the Gulfs.

Due to the large tidal range, strong currents are observed in the Gulf, which provided a mechanism for the transport of sediments in suspended mode (Unnikrishnan *et al.* 1999). High-water Spring (MHWS) of 4.7m at Mahuva Bandar rises to 6.5m at Gopnath Point to 10.2 m at Bhavnagar (Figure 1, Table 1). The MHWS at Luvara Point is 8.8 m and is 7.4 m at Hazira. The maximum spring tide recorded at Bhavnagar is 12.5m which is the second-highest tide recorded anywhere in the world (around 17m at the Bay of Fundy on the Newfoundland coast of Canada is the highest).

Fig 1: Tidal heights and ranges in the Gulf



During the SW monsoon, the coastal surface currents along the West coast of Saurashtra flow alongshore directed northwards. At a distance of 3-5 km from the coast the alongshore current develops a shoreward component. This phenomenon reverses during NE monsoon when the alongshore current flow equator wards and its perpendicular component gets directed away from the shore. Currents in the Gulf, though tidal, are monsoonal in origin.

Maximum flood velocities during spring tide are of the order of 1.7 – 3.9 m s^{-1} (3.31 – 7.59 knots). Maximum flood velocities during neap tide are 0.7 – 2.5 m s^{-1} (1.34 – 4.86 knots).

Table 1 Tidal levels referred to chart datum in the Gulf of Khambhat

Place	MHHW	MLLW	MHWS	MLWS
Pipavav Bandar	3.2	0.5	-	-
Mahuva Bandar	-	-	4.7	1.2
Gopnath Point	-	-	6.5	1.5
Bhavnagar	-	-	10.2	1.4
Luhara Point	-	-	8.8	1.4
Hazira	-	-	7.4	1.7
Daman	-	-	6.2	1.4
Umargam	-	-	5.4	1.3

Heights of tides in metres above c*hart datum* (GTS)
MHHW – Mean Higher High Water
MLLW – Mean Lower Low Water

Source: Hydrographic charts 201, 203, 256

Recently freshwater inflow into the Gulf reduced significantly, particularly after the final rise of the Narmada Dam in 2014 (from 121.92 m to 138.68 m) the outflow has reduced drastically at Garudeshwar from 76437.36 MCM (2013) to 16840.21 MCMC (2015). This has increased TDS in the groundwater and coastal soil. Reduced inflow has also affected the breeding and migration of the Hilsa fishery.

The Gulf of Khambhat is quite an active maritime area with a lot of development. The Gulf provides an easy opening to the sea and means of transportation for the industries situated around it. The presence of different geomorphic features, their location, association, and processes, such as sediment transport and concentration has a larger influence on industrial and commercial activities.

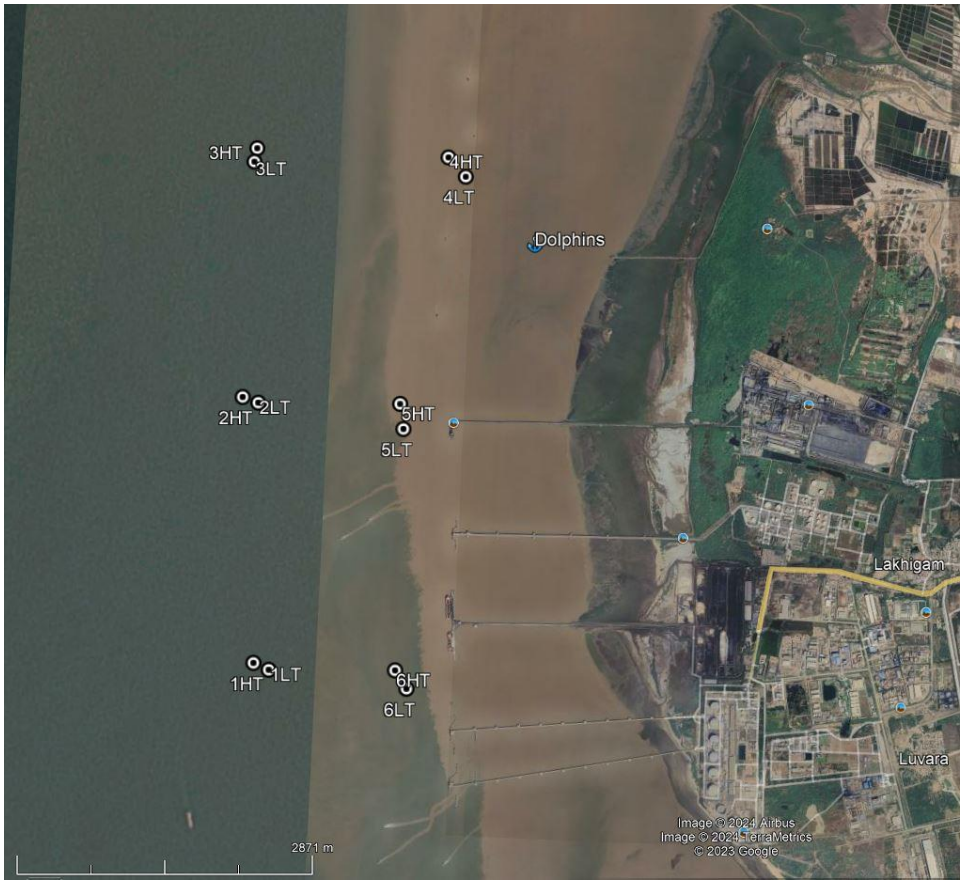
Birla Copper, Hindalco's copper unit, is located at Dahej in the Bharuch district of Gujarat, India. This is one of the largest single-location copper smelters with integrated port facilities. The copper unit at Dahej comprises copper smelters, backed by a captive power plant, oxygen plants, by-products plants, utilities, and a captive jetty.

3 MATERIALS AND METHODS

3.1 SAMPLING

The samplings were carried out during a Low tide and a High tide phase using a fishing boat at 6 stations (Figure 2). Coastal water samples were collected using a Niskin all PVC water sampler. Immediately upon collection samples were fixed for estimation of Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD). The samples for BOD and Chlorophyll were stored in amber glass bottles. A portion of water samples was treated with 1% mercuric chloride solution and stored for the analysis of nutrients and other chemical parameters. An aliquot of the water sample was acidified with 10% HNO_3 for heavy metal analysis.

Figure 2 GPS locations of sampling stations



GPS locations of sampling stations

Stations	High tides	Low tides
1	21°40'45.60"N 72°29'28.02"E	21°40'43.62"N 72°29'33.31"E
2	21°42'9.27"N 72°29'19.74"E	21°42'7.63"N 72°29'25.16"E
3	21°43'29.23"N 72°29'20.33"E	21°43'24.85"N 72°29'19.59"E
4	21°43'28.36"N 72°30'26.37"E	21°43'22.30"N 72°30'32.62"E
5	21°42'8.78"N 72°30'13.63"E	21°42'0.86"N 72°30'15.15"E
6	21°40'44.80"N 72°30'16.06"E	21°40'39.20"N 72°30'20.19"E

The samples were analyzed for the following parameters at the GES laboratory following internationally standard techniques (Strikland and Parsons, 1965; IOC, 1985) and accepted by MoEF, GPCB, CPCB, etc., as detailed here.

3.2 ANALYTICAL METHODS

Physico-chemical parameters

Temperature (°C)

Atmospheric and seawater temperatures were measured using a standard mercury thermometer Zeal make (0 – 50 °C)

pH

The seawater pH was measured immediately after collection by using Cyberscan 100 digital auto meter.

Salinity (ppt)

The salinity was determined by multiplying the values of chlorinity by 1.80655.

Dissolved oxygen (DO) (mg/l)

The first sample of seawater drained from the water sampler was always used for DO estimation. A 60 ml glass bottle was filled with water, after an equal volume flowed over, taking care that no air bubble is formed or trapped. 0.5 ml each of Winkler reagent A (Manganous Chloride) and Winkler B (Alkaline Iodide) were added to the sample, shaken well and preserved for analysis in the shore laboratory. The precipitate was dissolved in dilute hydrochloric acid and the liberated iodine was titrated against sodium thiosulphate using starch as an indicator.

***Total Suspended Solids (TSS)* (g/l)**

The TSS was measured by filtering a known volume of sample through a pre-weighed 40-micron Whatman glass fiber filter paper (GF/C) using a Millipore filtering system. The filter paper was then dried at a low temperature to constant weight. The difference in the weight is equivalent to the number of suspended solids in a unit volume of water.

Nitrite-Nitrogen (NO_2-N) (mg/ l)

Nitrite in seawater, when treated with sulphanilamide in an acid solution, results in a diazo-compound. This is then allowed to react with N (1-Naphthyl)-ethylene diamine dihydrochloride to form a pink-coloured azo dye, the extinction of which was measured at 543 nm using a UV- visible spectrophotometer.

***Nitrate-Nitrogen (NO_3-N)* (mg/ l)**

The nitrate is quantitatively reduced to nitrite by passing the ammonium chloride buffered seawater sample through a column packed with amalgamated cadmium. The nitrite thus obtained was measured as nitrite-nitrogen (NO_2-N) as above and the corresponding nitrate content was calculated after correcting for the initial nitrite.

***Total Nitrogen* (mg/ l)**

The filtered seawater sample was oxidized with the help of a strong oxidizing agent (alkaline persulphate) by autoclaving in a closed condition. Organically bound nitrogen was completely decomposed to nitrate during alkaline persulphate digestion. The oxidized samples were passed through the cadmium column to reduce the nitrate to nitrite as per the procedure for nitrate-nitrogen. The nitrite thus obtained was measured as nitrite-nitrogen (NO_2-N) as above and the corresponding total nitrogen content was calculated. Deducting NO_3-N and NO_2-N values from Total-N we can obtain values for NH_4^+-N + Organic-N. NH_4^+– N content of coastal Arabian Sea water is generally low. This difference can, therefore, be taken as Organic-N, at least at a first approximation.

Phosphate-Phosphorous (PO_4-P) **(mg/ l)**

Phosphate is allowed to react with an acidified molybdate reagent and the resultant phosphomolybdate is reduced with ascorbic acid to give a blue complex. The optical density of this complex was then photometrically measured at 880 nm.

Total Phosphorous **(mg/ l)**

For the measurement of Total Phosphorous, an unfiltered seawater sample is oxidized with the help of a strong oxidizing agent (alkaline persulphate) by autoclaving in a closed condition. The organic form of phosphate and also its inorganic form in lower oxidation states are finally oxidized to inorganic phosphate. The further procedure is as under Phosphate-Phosphorous.

Chlorophyll-a and Phaeophytin

The water samples are filtered through a nylon cloth (0.3 mm mesh) followed by a membrane filter (0.45 µm pore size), after adding 3 drops of 1% magnesium carbonate. The separated phytoplankton are extracted with 90% acetone. Chlorophyll-*a* and Pheophytin are extracted by centrifugation and estimated spectrophotometrically by determining optical densities at 750 (turbidity blank) and 665 nm before and after acidification.

Biological parameters

Phytoplankton

Phytoplankton samples are collected by a standard IIOE phytoplankton net from the surface water during the Low and High tidal phases at different stations.

Phytoplankton in thirty liters of seawater was concentrated to 250ml by filtering and preserved by adding 5ml of 40% formalin and 2 ml Lugol's iodine. In the laboratory, the samples are concentrated by a centrifuge and made up to the final volume of 25ml. The finally concentrated samples are preserved in 4% formalin prepared in seawater. These samples are subjected to qualitative and quantitative evaluation of phytoplankton. For the quantitative estimation, a Sedgwick Rafter Counting Cell is

used and quality is identified up to species level under a binocular microscope following standard monographs on taxonomy (Husted 1930, Pergallo 1965).

Zooplankton

Zooplankton samples were collected by surface hauls by using a Heron-Tranter plankton net with a mesh size of 300µ for 10 minutes at a speed of 2 knots/hour. The samples are preserved in 4% formalin. The wet weight of the zooplankton is determined after washing the zooplankton with distilled water and thereafter filtering through filter paper. The dry weight is determined by drying the filtered samples in a hot air oven at 70° C till it achieves a constant weight. The results are recorded in mg/100m^3 of seawater (dry weight). Zooplankton volume is measured by the displacement method. In this method, zooplankton was filtered and blotted with filter paper and the mass is transferred to a measuring cylinder having a known volume of 4% formalin prepared in seawater. The rise in the level of seawater in the measuring cylinder is recorded. The difference between the final and initial readings gives the volume of zooplankton. The results are expressed as ml/100m^3 of seawater. The numbers of zooplankton in the samples are counted by using a Sedgwick Rafter Counting Cell. Zooplankton is identified up to species level, wherever possible, under a binocular microscope by referring to standard manuals.

Sediments

Sediment samples were collected from various stations by Van Veen grab sampler. The samples were analyzed for texture, grain size, organic carbon, and selected heavy metals (Ni, Cd, Cr, Cu, Zn, Pb& Hg).

Texture and Grain size

Sediment texture, sand, silt and clay are fractionated as per the Wentworth scale classification. For further analysis of the silt-clay fraction, pipette analysis was followed. The process involves the initial splitting of sediment into a sand fraction (>63µ) and silt clay fraction (<63µ), by the wet sieving method. A known weight of sediment (approx. 25g) is dispersed in sodium hexametaphosphate $(NaPO_3)_6$ (6.2g/l) by soaking overnight. This is sieved through a test sieve (<63µ) and the residue is a

sand fraction. The particles which passed through the sieves are analyzed for silt and clay by pipette analysis method.

Organic carbon

Organic carbon in sediment is estimated by the method described by El Wakeel and Riley. Oxidation of dried sediment samples with chromic acid is carried out at 100^0C for 15 minutes. The excess chromic acid is titrated against 0.2 N Ferrous-Ammonium Sulphate (FAS) using Ferrous-Phenanthroline as an indicator.

Benthic fauna

The sediment samples are sieved through 1mm and 63µ mesh sieves by adding copious amounts of water for separating macro - and meiobenthic fauna respectively. The organisms retained in the sieve are preserved in 4% formalin and are identified up to the species level. The numerical density and biomass are estimated for phytoplankton. But in the present study, the numerical density and biomass could not be estimated because of the relatively very low amount of sample volume.

Bacteriological Analysis

Water: Water samples for the bacteriological parameters are collected with Zobell's Microbial samplers. This sampler is a must whenever we have to collect samples at different depths. However, the surface water samples are preserved for further analysis using sterilized glass stoppered bottles in the present study.

Sediments: Even though there are few microbiological samplers available for sampling, for routine use, Peterson's grab sampler is normally sufficient. It was used for the sample collection. The central portion of the sediment sample was removed with a sterile spatula and kept in sterile Petri dishes (disposable).

The water and sediment samples so collected are preserved in ice (4 ^{o}C) till reaching the laboratory. The analysis is carried out immediately.

Methodology of culturing Microbes

The seawater samples collected in sterilized glass stoppered bottles are filtered through sterile Whatman No. 1 filter paper. Surface plating technique was used for

the analysis wherein 0.1 - 0.3 ml of samples are pipetted separately in triplicates on to the surface of the respective medium in sterile disposable polycarbonate Petri dish. These samples are spread uniformly with a sterile glass spreader and left at room temperature for about 30 min. for the samples to get absorbed by the medium. The Petri plates are then inverted, stacked in lots of 5, covered with Kling wrapper and incubated at room temperature (28^{o} C) for 24 – 48 hrs. After the required incubation period, the plates are taken out and the presumptive identification are made based on the appearance, size, and colour of the colonies and the populations are expressed in CFU/ml. The results are recorded after the 48^{th} hour of inoculation (DOD, 1998).

The table shows mediums that are used for the culture and identification of microbes based on the size, form, shape and colour of the colonies.

Identification of microbes based on the size, form, shape, and color of the colonies grown on respective media

S. No.	Cultured organism	Medium used	Colony color
1.	*Shigella*-like organisms (SHLO)	XLD Agar	Red colonies
2.	*Salmonella*-like organisms (SLO)	XLD Agar	Red colonies with black center
3.	Proteus/Klebsiella like organisms (PKLO)	XLD Agar	Yellow colonies
4.	*Vibrio cholerate*-like organisms (VCLO)	TCBS Agar	Yellow colonies (Round, raised, 2-3 mm dia)
5.	*Vibrio parahaemolyticus*-like organisms (VPLO)	TCBS Agar	Bluish, Green (Punctate, < 2 mm dia)
6.	*Vibrio*-like organisms (VLO)	TCBS Agar	All other colonies in the media
7.	Total Viable Count (TVC)	Nutrient Agar	All colonies appearing on this medium
8.	*Pseudomonas aerugionosa* like organisms (PALO)	Cetrimide Agar	All colonies appearing on this medium
9.	*Streptococcus faecalis* like organisms (SFLO)	Enterococcus Agar	Maroon colored colonies

DOD, (1998)

Bioassay test

Bioassay test was performed at the laboratory of Hindalco Industries following the standard methods.

4 SEA WATER SAMPLES

4.1 Physico-chemical parameters

Temperature

The ambient air temperature varied in the range of 24°C to 30°C. The air temperature was higher for the low tide sampling as the sampling was undertaken in the afternoon.

The water temperature varied from 22.5°C to 28°C during both tides (Table 2 & 3). The average water temperature was low during the high tide (24°C) as compared to low tide (28.1°C). The water temperatures recorded were high as compared to previous years, indicative of global rise in sea temperature.

Turbidity

The turbidity of the water column ranged from 21 NTU to 136 NTU during high tide (Table 2) and 2 to 102 NTU during low tide (Table 3). The turbidity was reported high during the high tide because of higher currents prevelant in the sea and the presence of suspended particles in the water column.

pH

The average concentration of Hydrogen ions (pH) in the water column during the low tide phase ranged between 7.55 and 7.61 (Table 3). During the high tide phase, pH values varied from 7.46 to 7.59 (Table 2). The pH of the water column declined from surface to bottom during both tides. The pH values were coherent with the past records and no anomaly was observed.

Salinity

The salinity during the high tide phase varied from 25.62 ppt to 32.02 ppt (Table 2). The salinity in the water column declined from surface to bottom sampling. The water salinity during the low tide ranged from 17.29 ppt to 35.22 ppt (Table 3). Depth-wise salinity data shows that the salinity of the surface samples was more than that of the bottom samples. The salinity values reported in the present study are less than that of the 2022 sampling (GES 2023). The presence of fresh water flow from the river as a result of high high rainfall in the year 2024 have resulted in lower salinity values.

Table 2: Physicochemical parameters of water samples taken during high tide

Station	Water layer	Wtm (°C)	Atm (°C)	DO (mg/l)	pH	Salinity (ppt)	TSS (g/l)	Turb (NTU)	PO4 (mg/l)	TP (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	NH_4 (mg/l)	TN (mg/l)
1	Surface	23	24	3.95	7.52	29.46	1.01	33	0.11	0.19	0.02	0.151	0.081	0.253
	Middle	23	24		7.51	32.02	0.96	113	0.11	0.11	0.03	0.248	0.053	0.328
	Bottom	22.5	24		7.46	25.62	0.97	85	0.11	0.19	0.05	0.187	0.065	0.300
2	Surface	23	24	3.39	7.59	25.62	0.96	105	0.09	0.15	0.01	0.204	0.063	0.277
	Middle	23	24		7.57	32.02	0.98	65	0.11	0.13	0.01	0.277	0.024	0.311
	Bottom	23	24		7.56	19.21	0.96	61	0.13	0.27	0.01	0.224	0.117	0.350
3	Surface	24	25	4.52	7.59	28.82	0.90	21	0.11	0.16	0.02	0.199	0.076	0.289
	Middle	24	25		7.54	25.62	1.02	125	0.09	0.17	0.04	0.249	0.057	0.350
	Bottom	23.5	25		7.55	25.62	0.99	123	0.13	0.24	0.01	0.210	0.054	0.277
4	Surface	24	26	5.08	7.59	25.62	1.01	123	0.09	0.20	0.02	0.230	0.076	0.327
	Middle	24	26		7.51	19.21	0.97	85	0.08	0.39	0.02	0.146	0.010	0.175
	Bottom	24	26		7.5	32.02	0.98	83	0.09	0.47	0.06	0.189	0.441	0.688
5	Surface	25	27	4.52	7.54	23.06	0.99	136	0.12	0.21	0.03	0.217	0.129	0.376
	Middle	25	27		7.53	25.62	0.97	105	0.12	0.27	0.01	0.162	0.072	0.247
	Bottom	24.5	27		7.54	26.26	1.01	100	0.10	0.28	0.06	0.214	0.038	0.312
6	Surface	26	27.5	5.19	7.56	31.38	0.98	42	0.11	0.12	0.03	0.221	0.050	0.298
	Middle	26	27.5		7.53	32.02	0.99	40	0.07	0.36	0.04	0.200	0.048	0.283
	Bottom	25	27.5		7.49	25.62	0.96	38	0.35	0.49	0.08	0.233	0.081	0.253

Table 3 Physicochemical parameters of water samples taken during low tide

Station	Water layer	Wtm (°C)	Atm (°C)	DO (mg/l)	pH	Salinity (ppt)	TSS (g/l)	Turb (NTU)	PO4 (mg/l)	TP (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	NH_4 (mg/l)	TN (mg/l)
1	Surface	27	28	4.52	7.56	35.22	1.00	2	0.09	0.17	0.01	0.171	0.009	0.321
	Middle	27	28		7.55	25.62	1.01	45	0.10	0.14	0.08	0.151	0.057	0.237
	Bottom	27	28		7.65	38.43	1.00	45	0.11	0.13	0.02	0.139	0.064	0.295
2	Surface	27	28.5	3.95	7.61	19.21	0.99	1	0.10	0.19	0.01	0.160	0.061	0.222
	Middle	27	28.5		7.59	26.26	0.99	20	0.09	0.16	0.04	0.155	0.091	0.257
	Bottom	27	28.5		7.55	28.18	1.00	80	0.10	0.20	0.02	0.239	0.068	0.260
3	Surface	28	29	5.65	7.66	19.21	1.07	10	0.11	0.14	0.03	0.165	0.021	0.283
	Middle	28	29		7.56	23.06	1.00	102	0.11	0.32	0.02	0.168	0.066	0.259
	Bottom	28	29		7.57	19.21	0.98	73	0.11	0.33	0.03	0.151	0.067	0.259
4	Surface	29	29.5	4.52	7.61	17.29	0.96	77	0.10	0.48	0.02	0.184	0.075	0.257
	Middle	29	29.5		7.58	22.41	1.01	54	0.08	0.65	0.02	0.149	0.053	0.257
	Bottom	29	29.5		7.56	17.93	0.98	44	0.12	0.18	0.08	0.220	0.086	0.259
5	Surface	29	30	4.52	7.62	18.57	1.01	10	0.12	0.20	0.01	0.209	0.002	0.300
	Middle	29	30		7.58	18.57	0.98	20	0.09	0.22	0.06	0.157	0.037	0.258
	Bottom	29	30		7.61	17.93	1.00	77	0.04	0.20	0.02	0.249	0.044	0.258
6	Surface	29	30	4.52	7.6	20.49	1.01	92	0.04	0.20	0.01	0.157	0.010	0.262
	Middle	29	30		7.59	19.21	1.01	79	0.28	0.39	0.03	0.153	0.096	0.262
	Bottom	29	30		7.56	18.57	1.01	85	0.10	0.39	0.04	0.136	0.074	0.259

Total suspended solids (TSS)

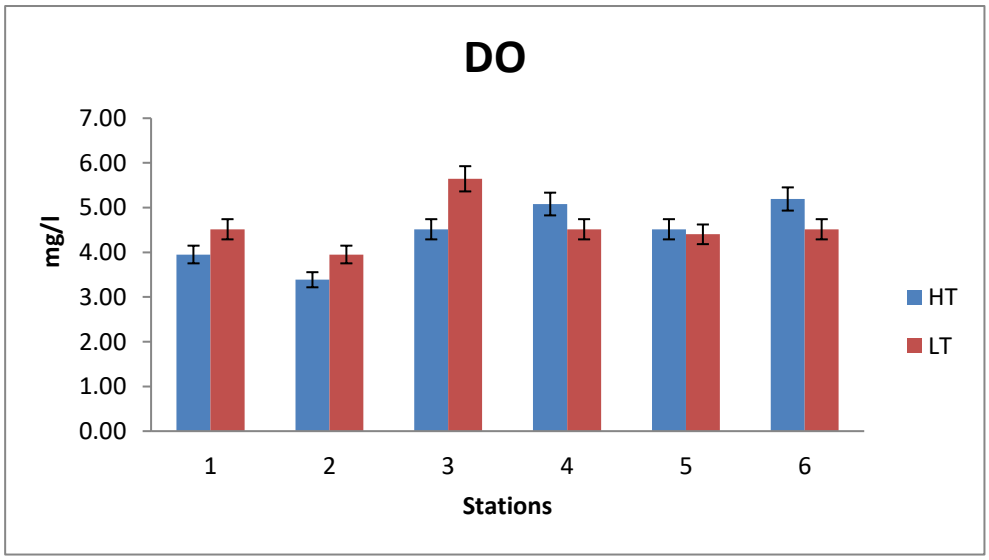
During high tide phase TSS values varied between 0.96 g l^{-1} to 1.02 g l^{-1}. The TSS of the bottom samples was higher as compared to the surface samples at stations 3 and 5, while at other stations surface samples reported higher TSS (Table 2).

During the low tide phase the TSS values ranged between 0.96 g/l to 1.01 g/l at (Table 3). The average TSS value of surface samples in the low tide was 1.0 g/l. The TSS values was reported higher as compared to 2022 sampling (GES 2023). The higher TSS value during the low tide is attributed to presence of untereated sewage released form the nearby industrial area.

Dissolved oxygen concentration (DO)

The amount of dissolved oxygen (DO) is a major factor affecting the diversity and abundance of species in sea water. The average dissolved oxygen concentration in the waters collected during the High Tide phase varied between 3.39 mg/l at station 2 to 5.19 mg/l at station 6 (Table 2). The DO concentration in the waters collected during the Low Tide phase ranged between a minimum of 3.95 mg/l at station 2 to a maximum of 5.65 mg/l at station 3 (Table 3). The average DO was higher in the high tide (4.44 mg/l) as compared to the low tide (4.61 mg/l). There is no substantial difference between the DO levels of high tide and low tide (Figure 3). The inflow of fresh water and good monsoons of 2024 has impacted the water quality status.

Figure 3 Variation DO during High and low tides in the sampling stations



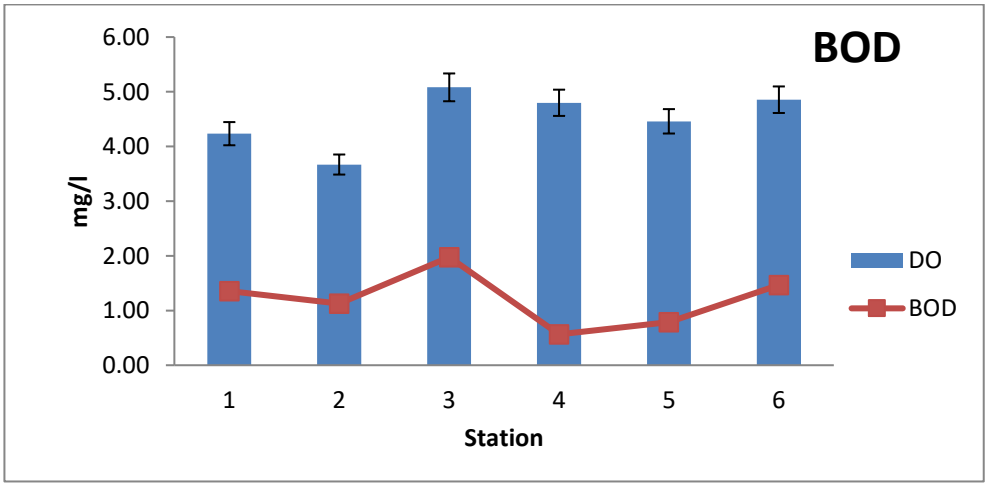
Biological Oxygen Demand

Biological Oxygen Demand (BOD_5) was ND at station 5 and a maximum (2.26 mg/l) at station 3 was reported during the high tide phase (Table 2). The BOD levels during the low tide phase ranged between ND at station 4 to 1.69 mg/l at stations 2, 3, and 5 (Table 3). These ranges are within the permissible limits of natural seawater.

There is not much variation in average BOD between high tide (1.24 mg/l) and low tide (1.20 mg/l). The DO and BOD values were in tune with each other during both tides (Figure 4). BOD also followed the trend observed in DO and values were high in outer gulf samples during both high as well as low tide.

The minimum BOD level required to maintain marine water free from pollution caused by sewage and decomposable wastes is 5 mg/l (CPCB guidelines). The presence of low BOD indicates the presence of high organic carbon. The Biochemical Oxygen Demand was observed to be < 3 mg/l at all the stations of the studied area. The biological oxygen demand was similar as compared to earlier year studies. BOD values in the area are indicative of water deterioration possibly due to the release of sewage.

Figure 4 Variation in DO and BOD in the sampling stations



Ammonical nitrogen

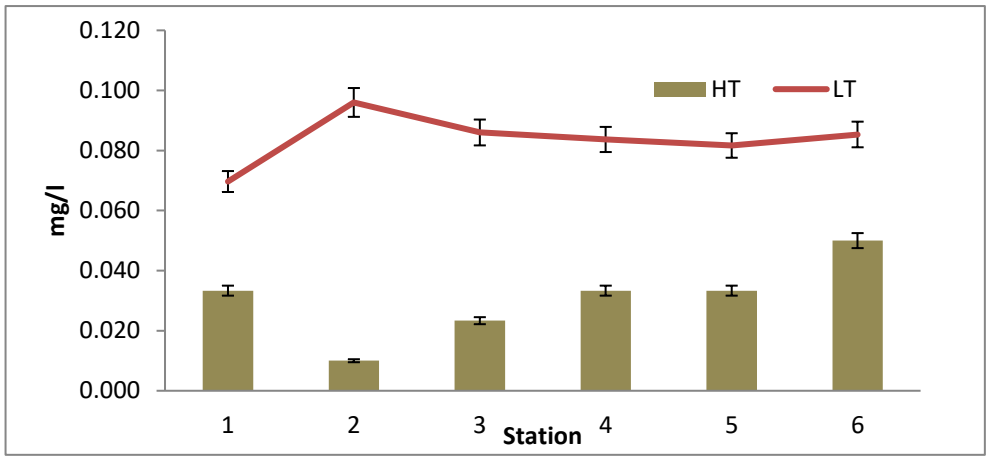
The ammonical nitrogen during high tide ranged between 0.017 mg/l at station 6 to 0.535 mg/l, at station 4. During low tide it varied from 0.01 mg/l (Station 4) to (0.007 mg/l) at station 1. In general ammonical nitrogen is under the prescribed limit of GPCB (50 mg/l for coastal and marine areas) at all the stations. Station 4

lies upstream of the outfall point of Birla Copper and is influenced by the release of waste from the industrial cluster present close by.

Nitrite and nitrate nitrogen

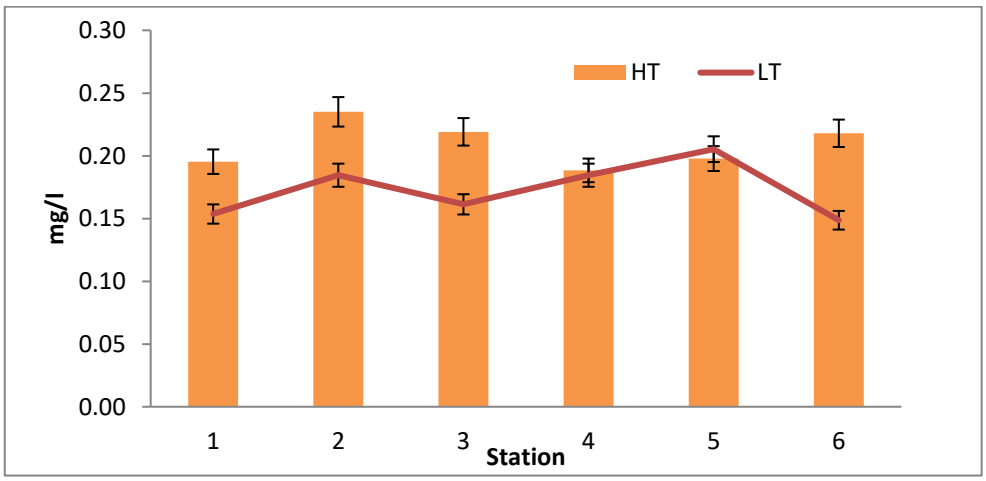
Nitrite and nitrate are important nutrients for their role in primary productivity being part of the photochemical processes taking place in phytoplankton (primary producers). The nitrite concentration during both tides varied from 0.01 mg/l to 0.08m g/l, with higher values during the low tide (Figure 5). The values were much below the permissible limits by CPCB for marine waters (10 mg/l).

Figure 5 Nitrite concentration during High Tide & Low Tide



Nitrate nitrogen concentration during high tide was found minimum (0.05 mg/l) at station 1 and maximum (0.108 mg/l) at station 2 (Table 2). During the low tide, the Nitrate nitrogen concentration was found minimum (0.051 mg/l) at station 1 and the maximum average (0.087 mg/l) was recorded at station 4 (Figure 6). However, the values are below the prescribed norms of CPCB.

Figure 6 Nitrate concentration during High Tide & Low Tide

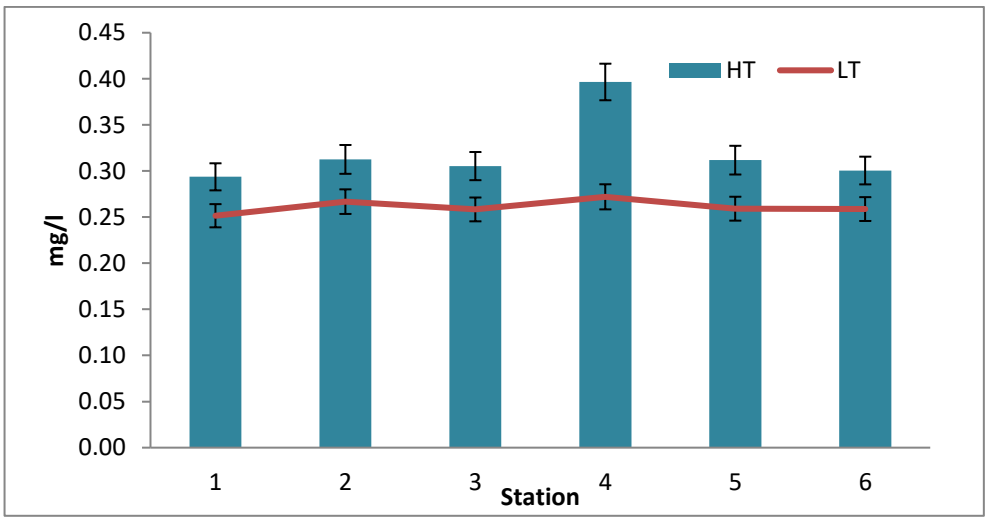


The Nitrate concentration was higher than that of Nitrite. This is mainly because of the quick oxidation of Nitrites into Nitrates. There was uniform pattern in the nitrate content during the high tide and low tide at all the stations. High oxygen levels also facilitated conversion of nitrite to nitrate. Nitrate levels were coherent with the earlier findings of Swami *et al.,* (2000) and Nayar *et al* (2000) and previous years of monitoring in the Gulf area.

Total nitrogen

The average Total nitrogen during high tide ranged between 0.68 mg/l (station 4) to 0.20 mg/l (station 6) (Table 2). During low tide, TN ranged between 0.135 mg/l (station 6) to 0.222 mg/l (station 1) (Table 3). The TN was higher during high tide at station 2 and the station is located outside towards the open sea (Figure 7).

*Figure 7 Total Nitrogen (*mg/l*) during High Tide & Low Tide*



Organic phosphate

Phosphate play vital role in metabolic needs of phytoplankton and autotrophic bacteria.

The organic phosphate (PO4-P) during the high tide phase was recorded 0.16 mg/l to 0.20 mg/l throughout the studied area (Table 2). During low tide the values of organic phosphate ranged from 0.18 mg/l to 0.20 mg/l. The average phosphates concentration was 0.18 mg/l during both tides, indicating no major difference in the organic phosphates between the tides.

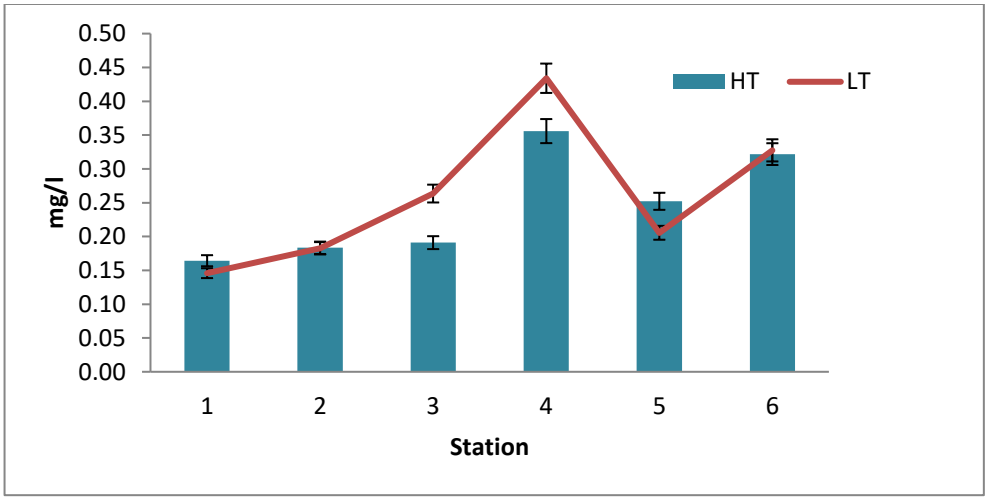
‘

Total phosphate

Figure 7 illustrates the total phosphate (TP) during the high tide phase was recorded at 0.12 to 0.46 throughout the studied area (Table 2). The low tide TP values were on the higher side as compared to high tide at stations 3 and 4 (Table 3). While, at other stations, TP values were comparable with the high tide values. Station 3 and 4 lie on the upstream of the Birla copper outfall point and the higher values are attributed to the release of effluents in the region by other industries. However, the Total Phosphates level was within the prescribed limits of GPCB (Nayar *et al* 2000).

The total phosphates level was lower as compared to previous studies (GES 2005, 2009, 2011, 2014, 2019, 2022).

Figure. 8 Total Phosphate concentrations (mg/l) *during High Tide & Low Tide*



4.2 Chlorophyll *a* and pheophytin

Chlorophyll *a* is indicator of primary productivity and in the present sampling, the highest value was reported from station 6 (0.454 mg/l) followed by station 4 and 5 (0.371 mg/l) during the high tide (table 4). The Chlorophyll *a* values were lower than the previous years indicative of less productivity. In case of low tide, Chlorophyll *a* values were recorded high at sation 4 (1.135 mg/l) followed by station 2 (0.566 mg/l). Station 4 is nearshore station and close to mangroves which has influenced the higher chlorophyll values.

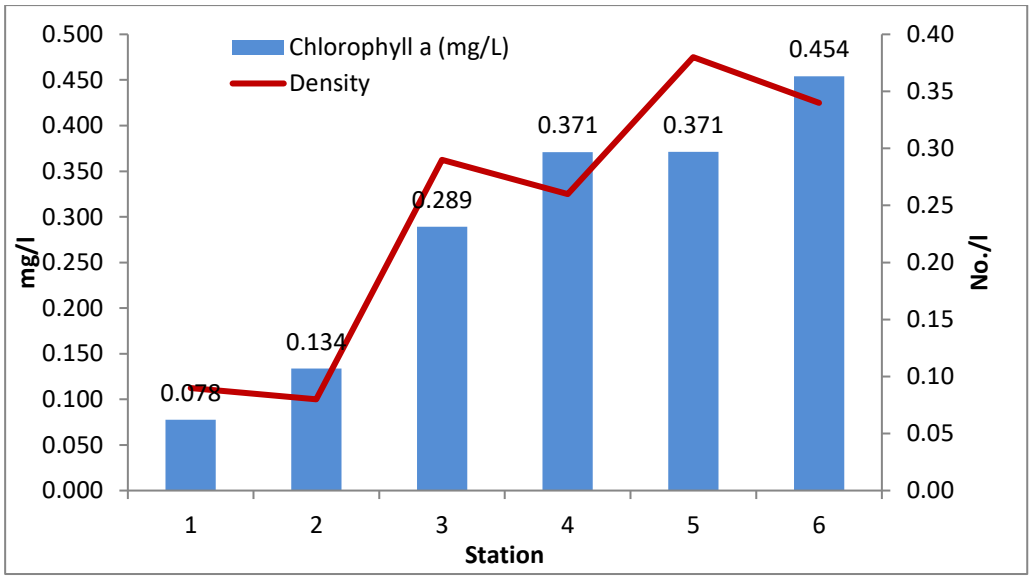
Pheophytin values are indicatives of amount of dead phytoplankton cells present in the water column. The values were too low during both the high tide and low tide samples.

Table 4: Chlorophyll a and pheophytin values at the sampling stations during high and low tide

Samples	Chlorophyll *a* (mg/l)	Pheophytin (mg/l)
High tide		
1	0.078	0.012
2	0.134	0.003
3	0.289	0.014
4	0.371	0.027
5	0.371	0.034
6	0.454	0.004
Low Tide		
1	0.325	0.002
2	0.566	0.002
3	0.452	0.003
4	1.135	0.007
5	0.404	0.012
6	0.647	0.008

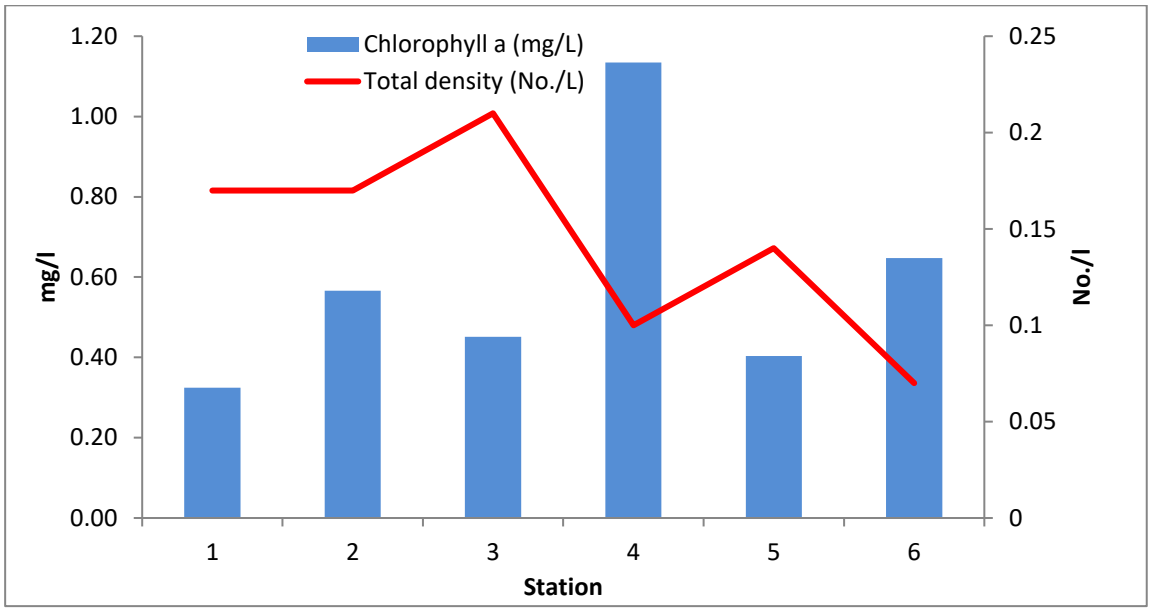
Chlorophyll *a* value is directly propotional to the phytoplankton density. In the present study, there is a direct correlation between both variables. In the case of station 5, the density is high as compared to the Chlorophyll *a* value, largely due to dominance of Bacillariophyceae members at station 5. Bacillariophyceae members are diatoms and have low Chlorophyll *a* value as compared to the chlorphyceae members.

Figure 9: Relation between chlorophyll a and phytoplankton density during the high tide



During the low tide, the chlorophyll content was high at station 4 as compared to other stations. Station 4 is located close to the Dhadhar mouth of the river and has estuarine characteristics, which is responsible for higher productivity (Figure 10).

Figure 10: Relation between chlorophyll a and phytoplankton density during the low tide



Pheophytin values during both tides were recorded low and indicated the absence of dead cells or phytoplankton (Table 4). This implies that the water quality is good and sustains phytoplankton. Higher pheophytin value was recorded at station 4 and being close to the coast showed stress conditions as compared to other sites.

4.3 Phytoplankton

During high tide a total of 21 phytoplankton species was reported in the present study distributed among the sampled stations (Table 7). The species number was reported high at station 6 (11 spp.), followed by station 4 (10 spp.), Stations 1 & 3 (9 spp.). *Navicula spp*, *Coscinodiscus gigas* and *Surirella spp* are the most common species reported from all the sampled stations. The species reported largely belonged to Bacillariophyceae group.

Table 5 Phytoplankton composition, density during high tide

	1	**2**	**3**	**4**	**5**	**6**
Amphora spp.	**0.01**	**0.02**		**0.01**		
Asterionella						
Biddulphia aurita	0.01	0.01	0.02	0.01		
Biddulphia mobilensis	0.01	0.01	0.02	0.01	0.04	0.09

Ceratium spp			0.01			0.01
Closterium					0.01	
Chlorella				0.02		
Coscinodiscus occulus	0.01					
Coscinodiscus viridus			0.02		0.01	
Ditylum sol				0.01	0.01	0.01
Navicula	0.01	0.03	0.11	0.08	0.06	0.1
Nitzschia	0.01		0.05	0.04	0.06	0.05
Pinnularia spp	0.01		0.03	0.01	0.09	
Surirella spp	0.03	0.03		0.04	0.07	0.05
Syndera spp.			0.03	0.04	0.03	0.03
No. of species	**7**	**4**	**8**	**9**	**9**	**7**
Total density (No./L)	**0.09**	**0.08**	**0.29**	**0.26**	**0.38**	**0.34**
Chlorophyll a (mg/L)	**0.078**	**0.134**	**0.289**	**0.371**	**0.371**	**0.454**
Pheophytin (mg/L)	**0.012**	**0.003**	**0.014**	**0.027**	**0.034**	**0.004**

The phytoplankton density was reported high at station 5 (10.86 individuals/l) followed by at station 3 (7.73 individuals/l). Station 2 reported a low density (5.67 individuals/l) among all the sampled stations.

During **low tide,** around 24 phytoplankton species were reported in the sampled stations. The species diversity was reported high at station 2 & 5 (10 species), followed by station 4 & 6 (9 species), stations 1& 3 (8 species) (Table 6). *Coscinodiscus gigas* and *Navicula* spp were reported from all the sampling stations.

Table 6 Phytoplankton composition, and density, during Low tide

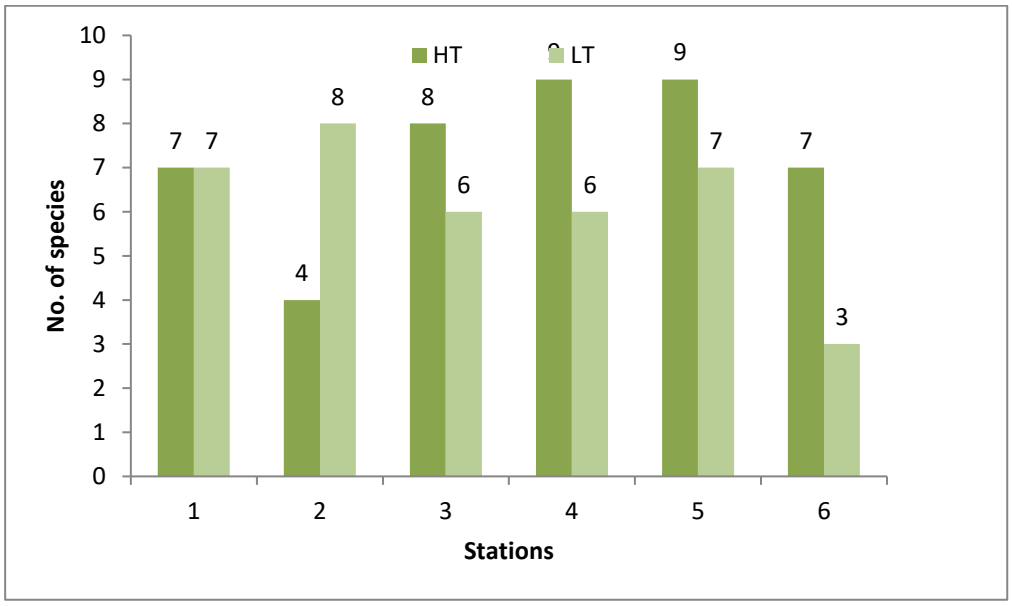
		1	**2**	**3**	**4**	**5**	**6**
1	*Asterionella*		0.01				
2	*Biddulphia aurita*	0.04	0.01	0.06			
3	*Biddulphia mobilensis*			0.02		0.02	0.02
4	*Ceratium*	0.01					
5	*Coscinodiscus gigas*		0.01		0.01		
6	*Coscinodiscus occulus*				0.01	0.01	
7	*Coscinodiscus viridus*		0.02				
8	*Ditylum*	0.01					
9	*Fragillaria*				0.04	0.01	
10	*Navicula*	0.05	0.03	0.03	0.02	0.04	0.04
11	*Nitzschia*	0.03		0.01		0.03	
12	*Pinnularia spp*	0.02					

13	*Pleruosigma*		0.02		0.01		
14	*Surirella spp*	*0.01*	0.04	0.06	0.01	0.02	0.01
15	*Syndera spp.*		0.03	0.03		0.01	
16	**No. of species**	**7**	**8**	**6**	**6**	**7**	**3**
17	**Total density (No./L)**	**0.17**	**0.17**	**0.21**	**0.1**	**0.14**	**0.07**
18	**Chlorophyll a (mg/L)**	**0.32**	**0.57**	**0.45**	**1.13**	**0.40**	**0.65**
19	**Pheophytin (mg/L)**	**0.002**	**0.002**	**0.003**	**0.007**	**0.012**	**0.008**

Chlorophyll *a* content was reported high at station 2 (1.714 mg/l) followed by station 1 (1.706 mg/l). The abundance of *Coscinodiscus gigas* spp at station 2 accounted for the presence of higher chlorophyll. The pheophytin values ranged from 0.107 mg/l (station 4) to 0.036 mg/l (station 5). The values reported were low indicative of low pheophytin production indicative of productive waters.

Phytoplankton species diversity differed between the tides for sampled stations. The number of phytoplankton species reported ranged from 8 to 11 during the high and low tides. A higher diversity of phytoplankton species was reported during the high tide from station 6. However, during the low tide, the highest number of species was reported from stations 2 & 5 (Table 8). These stations are close to the land and the presence of species indicates good water quality.

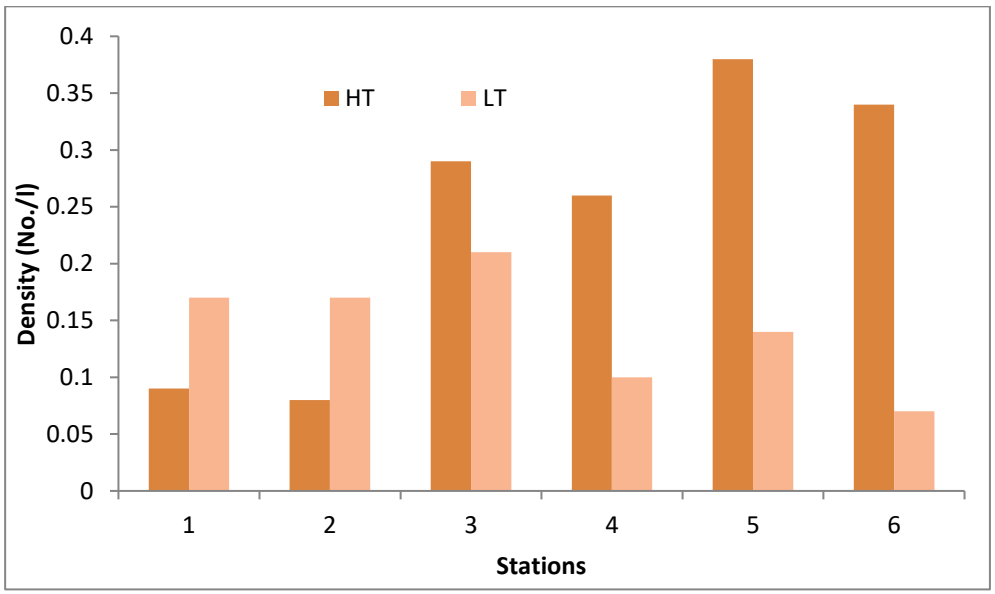
Figure 11 Phytoplankton diversity at sampled stations during high and low tide



The phytoplankton density was reported high during the low tide as compared to the high tide (Figure 12). There is more productivity during the low tide because of high light penetration. Station 5 reported the highest density during both the tides

indicating good productivity. This site is close to the discharge point and productivity indicates low pollution.

Figure 12 Phytoplankton density at sampled stations during high and low tide



4.5 ZOOPLANKTON

A total number of 19 species belonging to different groups was reported during the high tide (Table 7). An equal distribution of 9 species was reported from the sampled stations except stations 2 and 3, which recorded 6 and 8 species respectively. Both stations 2 and 3 are in the mouth of the river and have recorded higher zooplankton volume as compared to other stations. The presence of Nauplius larvae of both barnacles and crustaceae has dominated the waters in the high tide.

Table 7 Species distribution of zooplankton during the high tide

	1	**2**	**3**	**4**	**5**	**6**
Calanoida						
Acartia sp	P				P	P
Acartiella sp				P		
Centropages sp.				P		
Clausocalanus sp						
Eucalanus sp	P	P				
Euchaeta sp	P					
Labidocera sp				P		
Other Calanoida	P	P		P		P
Copepods						

Nauplius larva of Cyclopoida			P			
Cyclops sp		P	P		P	
Mysis larva	P		P	P	P	P
Oithona sp (Cyclopoida)						P
Other Cyclopoida	P	P	P	P		P
Decapods						
Nauplius larva (Barnacles)	P	P	P	P	P	P
Nauplius larva (Crustacea)	P		P	P	P	
Zoea larva	P		P	P	P	P
Diphyes sp (Crustacea)						
Annelida					P	
Polychaete larva					P	P
Fish larva		P	P		P	P
Total Species (no.)	**9**	**6**	**8**	**9**	**9**	**9**
Vol/vol (No./100)	0.10	1.00	0.60	0.30	0.20	0.20
Fwt (mg/100m^3)	350	410	180	60	80	190
Dry wt (mg/100m^3)	210	246	108	36	48	114

The group Calanoida, Copepoda, and Decapoda is represented in all the sampling sites (Table 8). Fish larvae were dominating at stations 2 and 3 .

Table 8 Occurrence and distribution of different zooplankton groups during the high tide

	Stations					
Group	**1**	**2**	**3**	**4**	**5**	**6**
Calanoida	55.56	66.67	37.50	55.56	33.33	44.44
Copepods	66.67	116.67	62.50	22.22	33.33	33.33
Decapods	33.33	33.33	50.00	22.22	22.22	33.33
Fish larvae		66.67	37.50		11.11	11.11
Foraminifera						11.11
Mollusca						11.11

During the low tide around 19 zooplankton species were reported from all the stations belonging to copepods, calanoida and Cladocera group (Table 9). Among the copepod group *Cyclopoida* was reported from all the sampling stations. Within the decapoda group *Nauplius larva (Barnacles)* was reported from all the sampling stations. The fish larva was reported from all the sampling stations.

Table 9 Species distribution of zooplankton during the low tide

	Groups	Stations					
		1	**2**	**3**	**4**	**5**	**6**
	Calanoida						
1	*Acartia* sp	P	P	P	P		
2	*Clausocalanus* sp	P	P	P			P
3	*Eucalanus sp*		P	P			
4	*Other Calanoida*		P				
5	*Euchaeta sp*		P				
	Copepods						
6	*Microsetella* sp (Harpacticoida)						P
7	*Oithona sp (Cyclopoida)*					*P*	P
8	*Other Cyclopoida*	P		P	*P*	P	P
9	*Mysis larva*		P				P
10	*Cyclops sp*		P	P	P		P
	Decapods						
11	Nauplius larva (Crustacea)	P	P	P	P	P	P
12	Nauplius larva (Barnacles)		P		P	P	P
13	Zoea larva		P (Brachyuran)		P	P	P
14	Unidentified Crustacean Larva		P		P	P	
	Annelida						
15	Polychaete larva	P		P			P
	Marine worms						
16	*Sagitta sp* (arrow worm)	P	P	P			
17	**Fish larva**	P	P	p	P	P	P
18	**Sponge Spicules**	P					
19	*Cladocera sp.*		P				
	Total Species (no.)	**8**	**14**	**8**	**8**	**7**	**11**
	Vol/vol (No./100)	0.30	0.60	0.10	0.50	0.10	0.10
	Fwt (mg/100m^3)	230	560	180	480	110	160
	Dry wt (mg/100m^3)	138	336	108	288	66	96

During the low tide distribution of various zooplankton groups varied between the stations (Table 10). Calanoida and Decapods were the dominant group reported in

all the stations. A sponge spicule was reported from station 4, which is close to near shore.

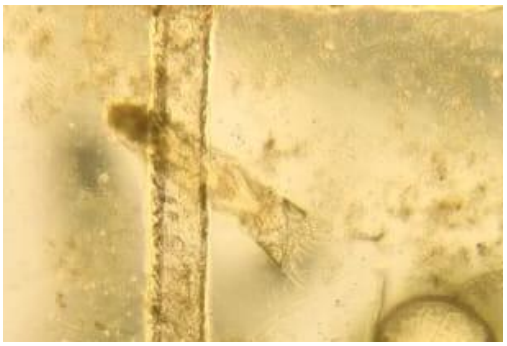
Table 10 Occurrence and distribution of different zooplankton groups during the low tide

	Stations					
% distribution	**1**	**2**	**3**	**4**	**5**	**6**
Calanoida	50.00	57.14	62.50	62.50		18.18
Copepods	37.50	28.57	37.50	37.50	42.86	63.64
Decapods	25.00	28.57	25.00	37.50	57.14	27.27
Fish larvae	25.00	21.43	25.00	12.50	14.29	9.09
Sponge spicule				12.50		

Figure 13: Pictures of zooplankton as clicked using microscope.







5 SEDIMENTS

During the present sampling sediment of stations 2, 4, 5, and 6 only could be collected. Strong currents and hard bottom samples made it difficult to collect sediment from 1 and 3 stations. Sediment samples collected were analyzed for Texture, Organic carbon, and Heavy Metals.

5.1 Texture and Grain Size Distribution

The grain size distribution indicates that the sediment is sandy in nature with around 80% of sand particles. Station 4 (77% sand, 23% silt), Station 5 (84% sand, 16% silt), Station 6 (89% sand, 11% silt) dominated by sand. Station 2 showed some 25% silt and 75% sand.

5.2 Organic Carbon

The organic carbon content in the sediment was low and ranged from 1.52 to 2.34 mg/l (Table 11). The sandy nature of the sediment accounted for low organic carbon.

Table 11: Organic carbon in the sediments

Sr No.	Organic carbon (mg/g)
2	2.34
4	1.87
5	1.76
6	1.52

6 FISHERY AND BIOASSAY

6.1 Fishery

A steady increase in fish production was observed from 2020-21 to 2023-24.

Table 12 Marine Fish production (M.T) in the last 9 years in Bharuch

Year	Fish production (MT)
2011-12	6405
2012-13	4793
2013-14	4045
2014-15	3453
2015-16	3583
2016-17	3616
2017-18	4842
2018-19	4981
2019-20	5150
2020-21	2191
2021-22	3350
2023-24	3271

Source: Fisheries Department, GOG

The fish caught in the region included Bombay duck, shrimp, and crab (Table 20). Catfish and mullets are the other fishery in the region. Comparing the last 5 years data on fish production has revealed that there is an increase in catfish production and zero catch of pomfret from the region.

Table 13: Fish catch for important fishery (2023-24)

Species	**Production (MT)**
Bombay duck	575
Catfish	197
Mullets	252
Eel	168
Shrimp	431
Prawns (medium)	281
Prawns (jumbo)	238
Crab	377
Levta	108

Source: Fisheries department, GOG

7 MANGROVE VEGETATION

Mangrove vegetation was present on the northern side of the Birla Copper jetty. *Avicenia marina,* called '*Tawar'* locally was the dominant species present. The height of the mangroves ranged between 0.6 to 4.5mts and giving a stunted appearance. The girth of the mangroves varied from 3-20 cm. Birds like egrets, herons were noticed in the mangroves. On the opposite side of the jetty against the thickest few saplings of *A. marina* could be observed.



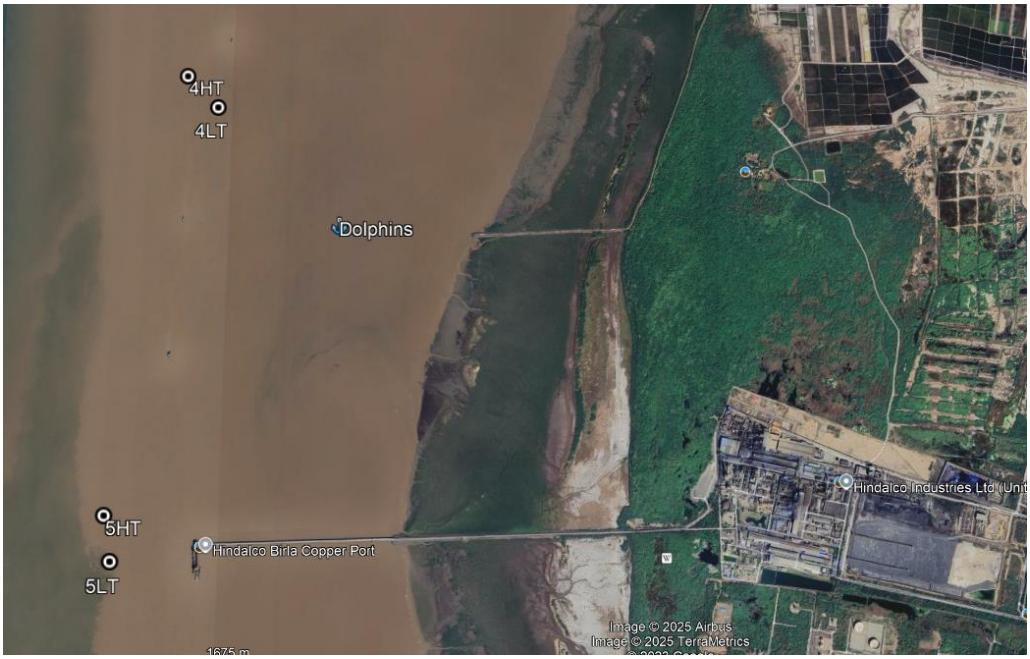


Though the mangroves were present close to the premises of the industrial area no major external symptoms due to air pollution was observed. This showed that BC maintained strict discharge norms and have upgraded technology to reduce air pollution. However, it was observed that sediment is becoming sandy which is not favored by the mangroves. This is of concern for their long-term survival.

8 WILD LIFE: DOLPHINS

The fish of the region also occasionally attract mammalian species, as a Dolphin was sighted during high tide in North the close to the Birla Copper Jetty (Figure 14). Dolphins enter the inner Gulf with high tide and move southward with the low tide, during which they feed on fish and prawns.

Figure 14 Location of dolphins sighing during the present study





Prawn cought in zooplankton net

9 CONCLUDING REMARKS

The present monitoring indicated that the water is well oxygenated (DO: 3.60 mg l^{-1} to 5.06 mg l^{-1}). Other parameters like nutrient and heavy metals are also within the permissible limits prescribed by GPCB. The results related to biological parameters like phytoplankton, zooplankton, benthos etc are well comparable with previous monitoring studies (GES 2019-20). This suggests that the Gulf of Khambhat ecosystem is stable and no change over the last decade was observed. The operational protocol set by Hindalco Industries Ltd, Dahej is working in good condition and there is no requirement of suggestions for mitigation strategies.

Plates



Water sampling - Niskin



phytoplankton sampling

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File No. Q-15017/9/2020-CPW
Government of India
Ministry of Environment, Forest & Climate Change
(CP Division)

IInd Floor Prithvi Wing,
Indira Paryavaran Bhawan,
Jorbagh Road, Aliganj,
New Delhi-110 003

Dated: 1st November, 2024

To,

The Member Secretary
Central Pollution Control Board,
Parivesh Bhawan, East Arjun Nagar,
Delhi-110032

Subject: Study titled "Prediction of Impact on Aquatic Environment due to Increase in COD Limit in Marine Discharge near Kantianjal, Gulf of Khambhat, Gujarat" - reg.

Sir,

This is with reference to the notification of Environmental Standards of Common Effluent Treatment Plants (CETP) into deep sea under Environment (Protection) Rules, 1986.

2. The DMAI (Dye Manufacturers Association of India) had submitted a representation for increase in COD limit for CETP effluents citing technical difficulties. Consequently, a Study for prediction of impact on Aquatic Environment due to increase in COD limit was assigned to CSIR-Central Salt and Marine Chemicals Research Institute (CSMCRI) & National Institute of Oceanography (NIO) by CPCB. The report suggested to relax the norms temporarily and recommended for further prototype study under actual discharge conditions, to be completed within six months.

3. The report submitted by CSMCRI to CPCB was discussed in the Peer & Core committee meeting dated 20.09.2024. Based on the recommendations of the Committee, CPCB proposed following values of parameters to be temporarily allowed for 6 months' experimental period at the discharge point of Narmada Clean Tech Limited (NCTL) CETP.

Industry	Parameters	Proposed Standards
CETP		Into Sea (mg/l)
Treated Effluent Quality Standards	COD	1000 mg/l*
	BOD	200 mg/l*
	Ammonical Nitrogen	100 mg/l*

* Discharge of treated effluent into sea shall be through proper marine outfall. The existing shore discharges shall be converted to marine outfalls. Only in cases where the marine outfall provides a minimum initial dilution of 250 times and above is achieved at the point of discharge (DP) and 1500 times (minimum) at 100 m away from DP.

4. The matter was examined in the Ministry and it was decided that for carrying out the prototype experiment as suggested above, Gujarat Pollution Control Board may relax the standards regarding parameters of CETP as given at para 3 above for study site located at Gulf of Khambat for a period of 6 months from the date of commencement of the study (copy enclosed). Therefore, CPCB is requested to further commission the study so as to ensure that the experiment completed within the stipulated time.

Yours faithfully,

Sonu Singh

(Dr. Sonu Singh)
Scientist 'E'
E-mail: sonu.singh@nic.in