



PART-A

Chapter-1: Air Quality Monitoring and Micro-Meteorology

1.1 Introduction

Jawaharlal Nehru Port (JN Port) is one of the thirteen major ports of India, located on the east side of Mumbai Harbour adjoining the main land of the West Coast of India.

As per the Environmental Management Plan Air Monitoring has been done at three fixed stations in Port area and one moving station at Elephanta Caves.

The main objectives of air quality monitoring survey are:

- To determine the status of existing ambient air quality levels in the port and to compare it with CPCB specified standards as well as earlier surveys.
- To identify possible mitigation measures, as appropriate, based on the findings of current month survey.

The air quality parameters which are relevant to the port activity and mentioned in the National Ambient Air Quality Standards (NAAQS) are monitored. Sampling frequency is twice a week at the three stations and once a month at the moving station (EC). Seven major pollutants viz., Total Suspended Particulates (TSP), Respirable Particulate Matter (PM₁₀), and Oxides of Nitrogen, Sulfur Dioxide, Ammonia, Carbon Monoxide and Carbon Dioxide are monitored at four monitoring stations viz., Liquid Chemical Terminal / Indian Molasses Company (IMC), POC Building (POC), Residential Colony of JNPT (RC) and Elephanta Caves (EC) for the month of February, 2013 Table A.1 gives the station name and its location with respect to prominent structures for the purpose of identification. The locations of all the stations for air quality monitoring are shown in MAP 1.

Table A.1
Description of Air Quality Monitoring Stations

Stations	Location
RC	At JNPT residential township
IMC	At IMC compound in Liquid Chemical Terminal area
POC	Near Port Operation Centre (POC)
EC	At the Elephanta at MTDC Chalukya restaurant terrace (facing BARC)



1.2 Air Quality Monitoring Methodology for Stations

Frequency of monitoring in RC, IMC and POC is twice in a week and at EC was once in a month. Duration of monitoring at RC, IMC, POC and EC was of 8 hours each in 24-hour sampling period for gaseous monitoring and continuous 24 hour sampling for TSP and RSPM samples. After a continuous operation of eight hours of the sampler, the reagents (for the gaseous samples) were replaced to obtain three samples per day for each gaseous parameter. The filter paper and cyclone cup was used for a period of 24 hrs to obtain one sample of TSP and RSPM per day.

1.3 Results and Discussion

Tables A.2, A.3 and A.4 provide the results for the parameters sampled at RC, IMC and POC stations for February, 2013 respectively. Table A.5 shows results of air pollutant concentration at Elephanta Island during 26th to 27th February, 2013.

The results of air monitoring at RC station are as follows.

Table A.2:
Maximum and Minimum concentration of various parameters at RC station.

Parameters	Maximum	February, 2013	Minimum	February, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	170	11 th to 12 th	111	01 st to 02 nd	200
PM ₁₀	71	07 th to 08 th	60	01 st to 02 nd	100
NO _x	21.1	11 th to 12 th	2.7	01 st to 02 nd	80
SO ₂	5.1	7 th to 8 th & 11 th to 12 th	1.2	1 st to 2 nd & 21 st to 22 nd	80
NH ₃	42.7	1 st to 2 nd	6.9	25 th to 26 th	400
CO	1.73	21 st to 22 nd	1.60	4 th to 5 th & 25 th to 26 th	2mg/m ³
CO ₂	305	11 th to 12 th	301	7 th to 8 th	-

The values for TSP and PM₁₀ were below the prescribed limit during whole sampling period in the month of February, 2013.



The results of air monitoring at IMC station are as follows:

Table A.3:
Maximum & Minimum concentration of various parameters at IMC station.

Parameters	Maximum	February, 2013	Minimum	February, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	226	14 th to 15 th	187	18 th to 19 th	200
PM₁₀	114	14 th to 15 th	89	18 th to 19 th	100
NO_x	31.6	25 th to 26 th	11.7	04 th to 05 th	80
SO₂	7.7	21 st to 22 nd	1.3	07 th to 08 th & 18 th to 19 th	80
NH₃	46.9	14 th to 15 th	11.3	25 th to 26 th	400
CO	1.80	1 st to 2 nd	1.64	7 th to 8 th	2mg/m ³
CO₂	314	11 th to 12 th	306	18 th to 19 th	-

The values for TSP and PM₁₀ were above the prescribed limit during sampling period most of the time in the month of February, 2013.

The results of air monitoring at POC station are as follows.

Table A.4:
Maximum & Minimum concentration of various parameters at POC station.

Parameters	Maximum	February, 2013	Minimum	February, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	188	11 th to 12 th	149	18 th to 19 th	200
PM₁₀	90	11 th to 12 th	63	18 th to 19 th	100
NO_x	25.5	21 st to 22 nd	7.2	07 th to 08 th	80
SO₂	7.7	11 th to 12 th	1.2	07 th to 08 th & 21 st to 22 nd	80
NH₃	52.4	07 th to 08 th	8.6	21 st to 22 nd	400
CO	1.81	14 th to 15 th & 25 th to 26 th	1.62	4 th to 5 th	2mg/m ³
CO₂	316	11 th to 12 th	306	1 st to 2 nd & 21 st to 22 nd	-

The values for TSP and PM₁₀ were below the prescribed limit during the whole month of February, 2013.



Table A.5 provides the results of the air quality parameters at Elephanta Island station during 26th to 27th February, 2013. The concentration of TSP and PM₁₀ was found to be 76 µg/m³ and 40 µg/m³ respectively. The concentration range of NO_x, SO₂, NH₃, CO & CO₂ was found to be in the range of 4.1 to 8.0 µg/m³, 2.5 to 3.9 µg/m³, 27.3 µg/m³ to 34.6 µg/m³, 1.62 mg/m³ to 1.68 mg/m³ and 302 ppm to 304 ppm respectively. The concentration of TSP, PM₁₀ and all gaseous pollutants were found to be below than the prescribed CPCB standard at EC station for the month of February, 2013.

Table A.5

Results of Air Pollutant Concentration at Elephanta Island During 26th to 27th February, 2013

STATION	DATE	TIME (Hrs)	TSP µg/m ³	PM ₁₀ µg/m ³	NO _x µg/m ³	SO ₂ µg/m ³	NH ₃ µg/m ³	CO mg/m ³	CO ₂ ppm
STANDARD	→		100 µg/m ³	100 µg/m ³	80 µg/m ³	80 µg/m ³	400 µg/m ³	2.0 mg/m ³	-
EC	26/02/13	2:00-8:00	76	40	8.0	2.6	27.3	1.62	302
	27/02/13	8:10-6:10			6.0	2.5	34.6	1.66	302
	27/02/13	6:15-2:15			4.1	3.9	32.6	1.68	304

EC-ELEPHANTA CAVES

(*) indicates the value is above the prescribed CPCB Standard

Table A.6

Monthly Average Values of Air Pollutant Concentration at Various Stations of JNP Area during the Month of February, 2013 and their Respective CPCB Standards

STATION	TSP µg/m ³	PM ₁₀ µg/m ³	NO _x µg/m ³	SO ₂ µg/m ³	NH ₃ µg/m ³	CO mg/m ³
Industrial areas						
NAAQ STDS.	200	100	80	80	400	2.0
IMC	205±13	100±8	20.4±6.1	4.1±1.7	28.0±10	1.72±0.04
POC	170±14	77±9	14.7±5.2	2.7±1.5	23.7±10	1.73±0.06
Residential and Rural Areas						
NAAQ STDS.	200	100	80	80	400	2.0
RC	147±20	66±4	8.9±4.9	2.2±1.2	20.9±8.6	1.66±0.04
Sensitive Areas						
NAAQ STDS.	100	100	80	80	400	2.0
EC	76	40	6.0	3.0	31.5	1.65

Values as mean ± std deviation

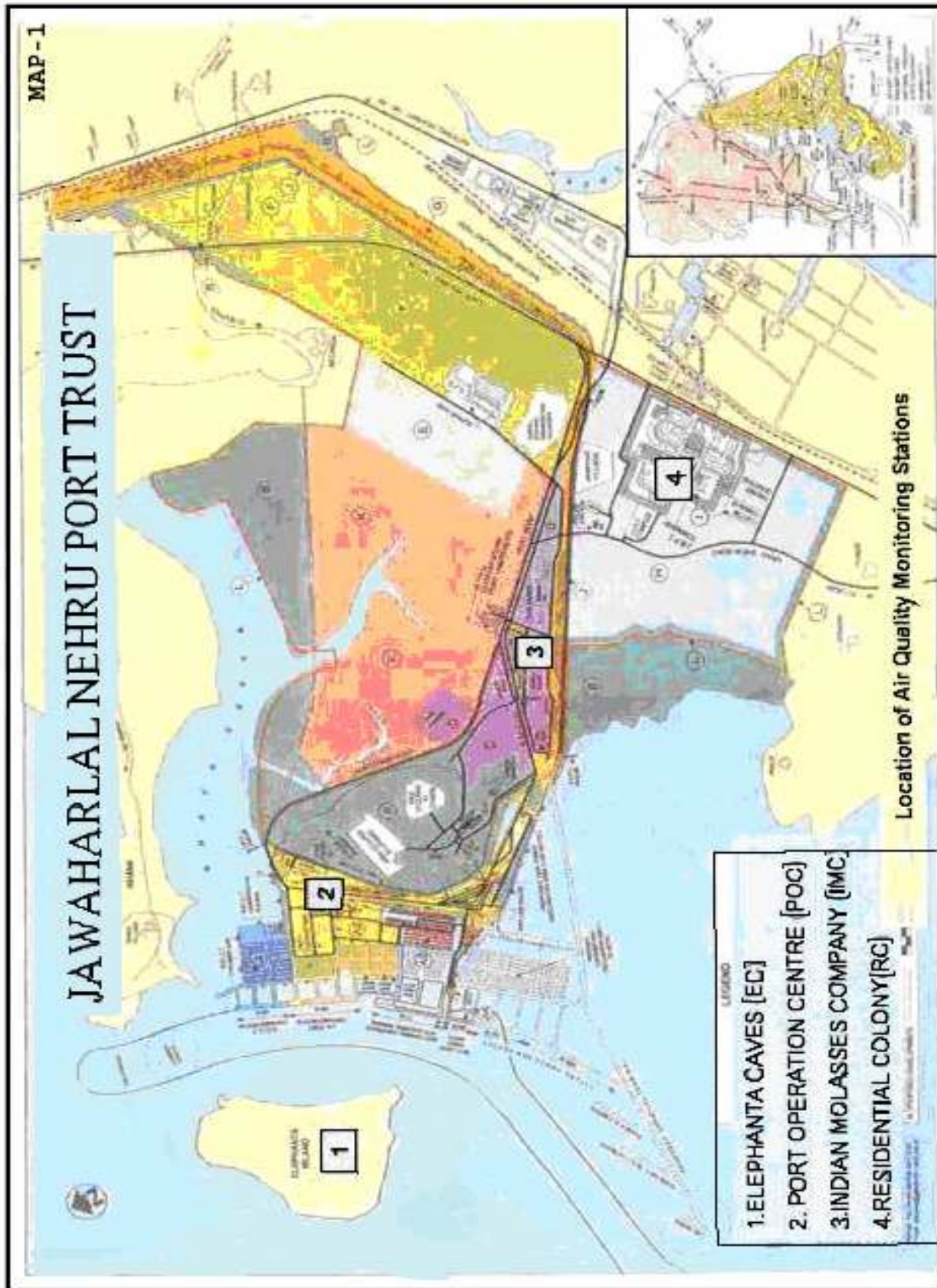




Table A.7
Results of Air Pollutant Concentration at RC Station of JNP Area during the Month of February, 2013

SR. NO	STATION	DATE	TIME (Hrs)	TSP ($\mu\text{g}/\text{m}^3$)	PM ₁₀ $\mu\text{g}/\text{m}^3$	NO _x $\mu\text{g}/\text{m}^3$		SO ₂ $\mu\text{g}/\text{m}^3$		NH ₃ $\mu\text{g}/\text{m}^3$		CO mg/m^3	CO ₂ ppm
						8 hr	24 hr Avg	8 hr	24 hr Avg	8 hr	24 hr Avg		
STANDARD				200 $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$	80 $\mu\text{g}/\text{m}^3$		80 $\mu\text{g}/\text{m}^3$		400 $\mu\text{g}/\text{m}^3$	2.0 mg/m^3	2.0 mg/m^3	-
1	RC-I	01/02/13	03:30-11:30	111	60	2.7	4.7	1.2	1.7	20.5	31.5	1.63	302
		02/02/13	11:30-07:30			4.4		1.3		42.7		1.71	
		02/02/13	07:30-03:30			7.2		2.6		31.4		1.68	
2	RC-II	04/02/13	03:30-11:30	135	64	3.0	4.3	1.3	1.8	20.7	20.1	1.66	303
		05/02/13	11:30-07:30			4.0		1.4		12.5		1.60	
		05/02/13	07:30-03:30			5.7		2.9		27.0		1.63	
3	RC-III	07/02/13	03:30-11:30	164	71	8.6	11.0	1.4	2.6	26.5	26.8	1.61	301
		08/02/13	11:30-07:30			9.9		1.3		24.8		1.72	
		08/02/13	07:30-03:30			14.4		5.1		29.0		1.70	
4	RC-IV	11/02/13	03:30-11:30	170	70	21.1	19.6	3.8	4.3	23.6	23.0	1.69	305
		12/02/13	11:30-07:30			18.5		3.9		20.5		1.64	
		12/02/13	07:30-03:30			19.2		5.1		24.8		1.64	
5	RC-V	14/02/13	03:30-11:30	140	66	6.6	6.9	2.9	1.8	11.3	14.5	1.66	303
		15/02/13	11:30-07:30			7.3		1.4		11.3		1.62	
		15/02/13	07:30-03:30			6.8		1.3		20.9		1.61	
6	RC-VI	18/02/13	03:30-11:30	139	64	7.7	7.2	1.3	2.1	9.9	17.9	1.67	304
		19/02/13	11:30-07:30			6.4		2.3		31.4		1.68	
		19/02/13	07:30-03:30			7.6		2.6		12.4		1.62	
7	RC-VII	21/02/13	03:30-11:30	167	68	12.8	10.6	2.6	1.7	22.3	19.9	1.73	304
		22/02/13	11:30-07:30			9.0		1.2		19.9		1.71	
		22/02/13	07:30-03:30			10.0		1.3		17.4		1.69	
8	RC-VIII	25/02/13	03:30-11:30	150	67	7.4	6.9	1.3	1.7	24.8	13.6	1.72	303
		26/02/13	11:30-07:30			6.5		1.4		9.0		1.70	
		26/02/13	07:30-03:30			6.7		2.6		6.9		1.60	



Table A.8
Results of Air Pollutant Concentration at IMC Station of JNP Area during the Month of February, 2013

SR. NO	STATION	DATE	TIME (Hrs)	TSP ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)	NO _x $\mu\text{g}/\text{m}^3$		SO ₂ $\mu\text{g}/\text{m}^3$		NH ₃ $\mu\text{g}/\text{m}^3$		CO mg/m ³	CO ₂ ppm
						8 hr	24 hr Avg	8 hr	24 hr Avg	8 hr	24 hr Avg		
STANDARD	→			200 $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$		80 $\mu\text{g}/\text{m}^3$		80 $\mu\text{g}/\text{m}^3$		400 $\mu\text{g}/\text{m}^3$	2.0 mg/m ³	-
1	IMC-I	01/02/13	03:00-11:00	206	100	14.6	16.9	5.1	3.5	32.3	36.3	1.80	307
		02/02/13	11:00-07:00			18.1		2.9		40.4		1.69	
		02/02/13	07:00-03:00			17.9		2.6		36.4		1.72	
2	IMC-II	04/02/13	03:00-11:00	222	110	14.7	16.5	3.9	3.1	23.8	26.9	1.78	306
		05/02/13	11:00-07:00			11.7		2.8		22.1		1.79	
		05/02/13	07:00-03:00			23.0		2.6		34.8		1.70	
3	IMC-III	07/02/13	03:00-11:00	195	97	23.3	21.8	1.3	3.3	15.3	18.1	1.64	311
		08/02/13	11:00-07:00			25.1		2.8		16.5		1.74	
		08/02/13	07:00-03:00			17.1		5.7		22.3		1.69	
4	IMC-IV	11/02/13	03:00-11:00	207	101	14.4	14.5	5.2	5.5	41.8	33.7	1.67	314
		12/02/13	11:00-07:00			15.6		5.1		33.5		1.75	
		12/02/13	07:00-03:00			13.5		6.3		25.8		1.72	
5	IMC-V	14/02/13	03:00-11:00	226	114	14.4	16.8	6.4	5.7	46.9	40.0	1.74	312
		15/02/13	11:00-07:00			24.0		5.7		34.5		1.71	
		15/02/13	07:00-03:00			12.0		5.1		38.6		1.66	
6	IMC-VI	18/02/13	03:00-11:00	187	89	26.6	26.5	3.8	2.6	21.1	27.4	1.68	306
		19/02/13	11:00-07:00			25.6		1.3		40.6		1.67	
		19/02/13	07:00-03:00			27.3		2.6		20.5		1.70	
7	IMC-VII	21/02/13	03:00-11:00	200	97	27.4	25.4	3.9	5.4	23.7	18.2	1.75	308
		22/02/13	11:00-07:00			30.5		7.7		14.9		1.79	
		22/02/13	07:00-03:00			18.4		4.6		16.1		1.71	
8	IMC-VIII	25/02/13	03:00-11:00	199	92	31.6	24.7	5.7	3.7	11.3	23.5	1.72	309
		26/02/13	11:00-07:00			17.2		2.6		28.8		1.69	
		26/02/13	07:00-03:00			25.3		2.8		30.4		1.74	



Table A.9
Results of Air Pollutant Concentration at POC Station of JNP Area during the Month of February, 2013

SR. NO	STATION	DATE	TIME (Hrs)	TSP ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)	NO _x $\mu\text{g}/\text{m}^3$		SO ₂ $\mu\text{g}/\text{m}^3$		NH ₃ $\mu\text{g}/\text{m}^3$		CO mg/m ³	CO ₂ ppm
						8 hr	24 hr Avg	8 hr	24 hr Avg	8 hr	24 hr Avg		
STANDARD	D			200 $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$		80 $\mu\text{g}/\text{m}^3$		80 $\mu\text{g}/\text{m}^3$		400 $\mu\text{g}/\text{m}^3$	2.0 mg/m ³	-
1	POC-I	01/02/13	02:30-10:30			10.0		3.9		22.8		1.67	
		02/02/13	10:30-06:30	187	88	10.8	10.3	2.6	2.9	25.1	26.1	1.63	306
		02/02/13	06:30-02:30			10.0		2.3		30.3		1.67	
2	POC-II	04/02/13	02:30-10:30			9.7		2.8		33.1		1.62	
		05/02/13	10:30-06:30	169	79	10.8	10.5	1.4	2.3	20.1	26.8	1.71	309
		05/02/13	06:30-02:30			10.9		2.6		27.3		1.73	
3	POC-III	07/02/13	02:30-10:30			15.8		1.2		11.3		1.78	
		08/02/13	10:30-06:30	175	76	13.0	12.0	1.3	1.2	52.4	32.8	1.80	311
		08/02/13	06:30-02:30			7.2		1.2		34.7		1.70	
4	POC-IV	11/02/13	02:30-10:30			18.8		7.7		13.8		1.79	
		12/02/13	10:30-06:30	188	90	25.3	20.5	3.8	4.3	37.2	21.5	1.74	316
		12/02/13	06:30-02:30			17.3		1.3		13.5		1.72	
5	POC-V	14/02/13	02:30-10:30			10.7		2.5		19.0		1.76	
		15/02/13	10:30-06:30	153	66	10.3	11.0	2.6	3.4	21.7	22.2	1.81	314
		15/02/13	06:30-02:30			12.1		5.1		26.1		1.77	
6	POC-VI	18/02/13	02:30-10:30			13.2		1.3		17.4		1.70	
		19/02/13	10:30-06:30	149	63	15.9	16.9	2.8	2.3	35.9	25.3	1.63	312
		19/02/13	06:30-02:30			21.6		2.9		22.6		1.68	
7	POC-VII	21/02/13	02:30-10:30			14.3		1.2		23.4		1.69	
		22/02/13	10:30-06:30	166	75	25.5	20.7	3.8	2.5	8.6	17.6	1.74	306
		22/02/13	06:30-02:30			22.3		2.6		20.9		1.79	
8	POC-VIII	25/02/13	02:30-10:30			9.9		3.5		12.5		1.81	
		26/02/13	10:30-06:30	174	77	18.9	15.5	2.5	2.7	13.6	17.4	1.78	308
		26/02/13	06:30-02:30			17.6		2.8		26.1		1.77	



1.4 Conclusions and Mitigations Measures

Table A.6 shows the overall average values of TSP, PM₁₀ and all gaseous pollutants at all three sampling stations.

CPCB standards for ambient air quality for different areas are given in Table A. 6. All pollutants were found within prescribed limits at all station except IMC for TSP and PM₁₀ for the month of February 2013.

The following mitigation measures can be taken to reduce high TSP and PM₁₀ levels in and around the port area during construction time:

- Cleaning of paved and unpaved roads regularly to remove spillage of earth/soil material during transportation.
- Maintaining road pavement at IMC area regularly or using paver blocks as far as possible wherever heavy loads movement occurs.
- Spraying water on dusty road surfaces on regular intervals with more frequency in noon hours at various locations and all construction areas to avoid re-suspension.
- Good housekeeping during road cleaning to avoid dust resuspension by transportation of heavy vehicles.
- Increasing the plantations in and around the port area as well as developing and maintaining thick green cover on both sides of the roads and tank farms.
- Regular PUC check up and maintenance of vehicles plying in the port.



Meteorological Data

1.5 Introduction

Meteorological parameters characterize the dilution capacity of pollutants in the atmosphere of a region. Air pollution in a coastal region has typical characteristics on account of the specific meteorological factors due to land–sea interface. Hence, collection of meteorological data is important for any air monitoring programme. A meteorological station can be installed to simultaneously monitor wind direction, wind velocity, atmospheric temperature, relative humidity, rainfall and solar radiation and record these on real time basis. Meteorological factors change hourly, daily, monthly, yearly and season wise. Analysis of meteorological parameters can help in interpretation of air pollution concentration data. The relation between meteorological parameters and air quality is given in Table A.10

1.6 Description of Meteorological Station

The meteorological station has been installed at Port Operation Centre (about 800 m away from the berths) in Jawaharlal Nehru Port. The height of the station is 20 m above sea level. The geographical location of the weather station is longitude of 72° 57' 14.7" East and latitude of 18° 56' 54.0" North. Micro processor based automatic weather station developed by Dynalab (India) Ltd. is used for collection of meteorological data which is measured on hourly basis and stored in the memory module. The stored data are transferred to a desktop computer regularly. The station has sensors for measuring Relative Humidity is measured with the help of hygrometer. The humidity sensor is a thin film capacitor element. Water molecule from the air absorbed by dielectric polymer through a thin film metal electrode and this causes a capacitance change proportional to Humidity.



Table A.10
Relation between meteorological parameters and air quality

Sr. No.	Meteorological parameter	Impact on Air Quality
1.	Wind speed	Higher the wind velocity more the dilution of pollutants and lesser the concentration
2.	Wind direction	Wind direction determines the direction and location of impact of pollutants
3.	Rainfall	Removes pollutants by scavenging
4.	Temperature and Relative Humidity	Effects the stability and hence dilution of pollutants through mixing height and ventilation coefficient
5.	Mixing Height	Higher the mixing height more the vertical mixing of pollutants, so lower the concentration
6.	Ventilation coefficient	Higher the ventilation coefficient lesser the pollution potential and better the air quality

1.7 Description of Sensors

1.7a Wind Speed Sensor: 3 Cup Anemometer

- Range: 0 to 65 meter/sec.
- Accuracy: Better than 0.5 m/s

Principle of Operation:

Wind speed is measured with anemometer. When rotated by wind, a chopper on the anemometer shaft interrupts an infra-red light beam 18 times per revolution, generating pulses from a phototransistor. The signal is amplified and frequency is proportional to wind speed.

1.7b Wind Direction Sensor: Wind Vane

- Range; 0 to 357 degree
- Accuracy: +/- 3 degree

Principle of Operation:

Wind detection is reported by direction from which it originates. It is measured with the help of a wind vane. The end of the wind vane, which offers the greatest resistance to the motion of the air, moves to the downwind position. Resistance is proportional to the position of the wind vane.



1.7c Air Temperature Sensor: Standard Platinum RTD element (Pt 1000) is mounted inside weather shield

- Range: -40 to +60 °C
- Accuracy: 0.2 °C
- Resolution: 0.1 °C

Principle of Operation:

The sensor used is an RTD (PT 1000). Here the resistance of the element varies with temperature, approximately $3.9 \Omega/^{\circ}\text{C}$. This is converted to a voltage in the single conditioner inside the data logger from -40 °C to +60 °C.

1.7d Relative Humidity Sensor: Solid state capacitive sensor

- Range:: 0 to 99 %
- Accuracy: ± 3 % of full-scale reading
- Resolution: 0.1 %

Principle of Operation:

Relative Humidity is measured with the help of hygrometer. The humidity sensor is a thin film capacitor element. Water molecule from the air absorbed by dielectric polymer through a thin film metal electrode and this causes a capacitance change proportional to Humidity.

1.7e Rainfall Sensor: Tipping Bucket Rain gauge

- Capacity: Unlimited
- Accuracy: 1 mm
- Resolution: 0.5 mm

Principle of Operation:

It uses tipping bucket mechanism to produce a contact closure every time it receives a predetermine quantity of rainfall (**16.2 cc of water for 0.5 mm of rain**)

1.7f Solar Radiation Sensor: 100 element thermopile

- Spectral range: 0.3 to 3 μmeter
- Sensitivity: 4 milli Volt /kWm²
- Max. intensity: >200 m W/cm.

Principle of Operation:

The pyranometer measures the radiation received on a horizontal surface from both the sun and sky. The difference in temperature of the two sides of thermocouple gives the intensity of solar radiation.



1.8 Results and Discussion:

Table A.11 shows the daily average values of wind speed, ambient temperature, relative humidity and solar radiation while Table A.12 shows the daily rainfall recorded for the month of February, 2013 in JN Port respectively.

1.8a Wind speed:

The monthly average wind speed for February, 2013 was found to be 2.4 m/s. The maximum hourly average wind speed recorded was 6.0 m/s at 16:00 hrs on 16th February, at 0:00 hrs on 18th February and at 8:00 & 15:00 hrs on 28th February, 2013. As compared to the previous month (January, 2013) higher values of hourly average wind speed were recorded during night as well as during daytime. Transport and dispersion of air pollutants are mainly governed by wind speed. The daily average value of wind speed was in the range 1.3 to 3.3 m/s. 25.89 % of the total observations (672 observations) recorded by the met instrument for the month of February, 2013 was less than 0.5 m/s, which represents calm period.

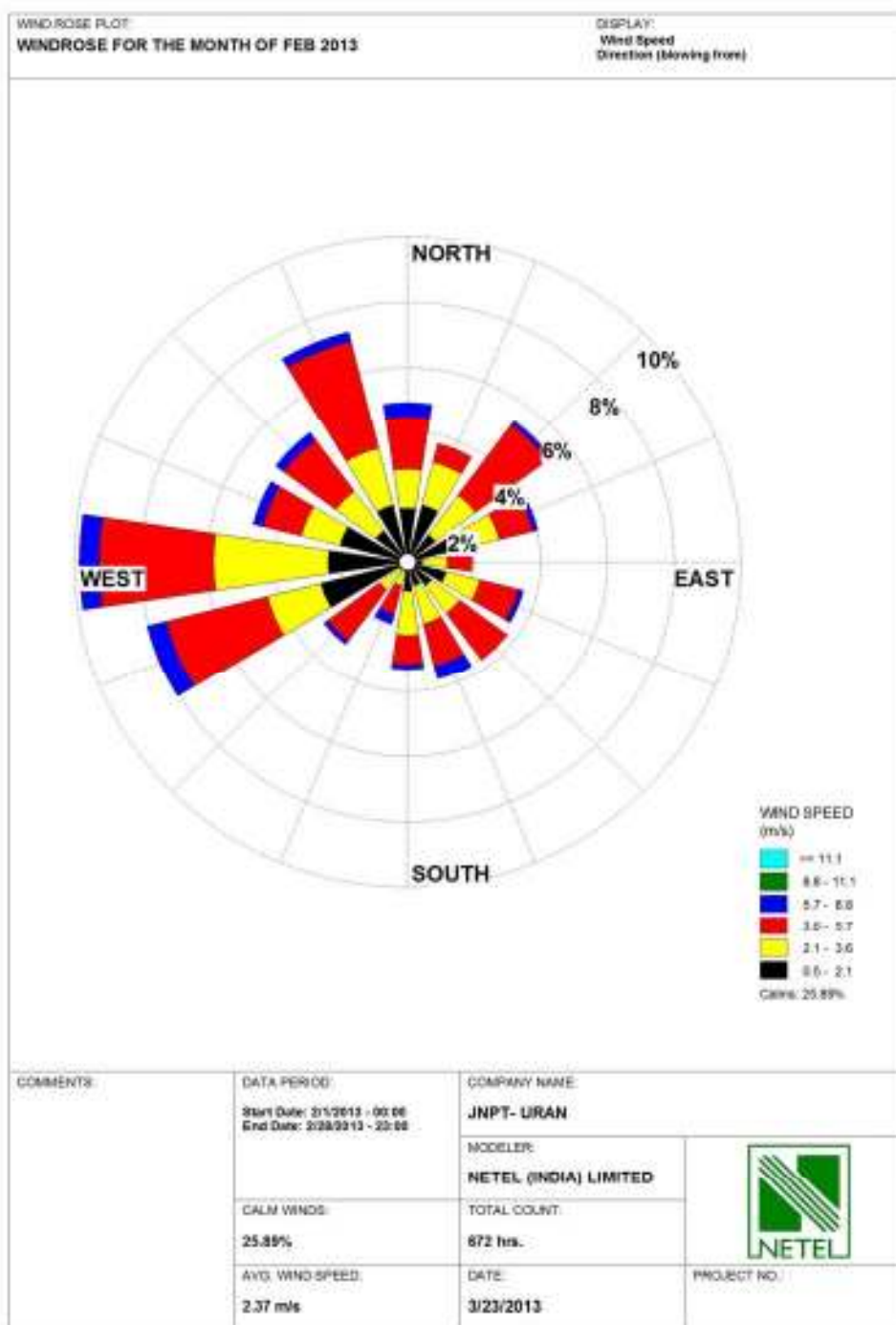
1.8b Wind direction:

The prominent wind direction was from West (W) followed by West South West (WSW) at the JN Port for the month of February, 2013. Wind directions are pictorially represented by drawing a windrose. The spoke represents the direction from which the wind is blowing. The wind rose drawn for the month of February, 2013 is given in Figure 1.

1.8c Temperature:

The maximum daily average temperature 29.4 °C was obtained on 13th February, 2013 and minimum daily average temperature 22.2 °C was obtained on 7th February, 2013. The maximum and minimum hourly average temperature recorded was 43.0 °C at 12:00 hrs on 1st February. The monthly average temperature for February, 2013 was calculated as 25.4 ± 1.6 °C.

Figure 1
Wind Rose for the month of February, 2013





1.8d Relative Humidity:

The monthly average relative humidity was found to be 62.7 ± 7.7 %. Relative humidity is the measure of water vapour in the atmosphere. Maximum daily average relative humidity was obtained as 74.6 % on 4th February, 2013 and minimum daily average relative humidity was obtained as 48.3 % on 13th February, 2013. The minimum value of hourly average relative humidity 26.1 % was observed on 20th February, 2013 at 13:00 hrs whereas, maximum value of 94.2 % recorded on 22nd February, 2013 at 5:00 & 6:00 hrs.

Table A.11

Daily average values of wind speed, temperature, relative humidity and solar radiation for the month of February, 2013

Sr. No.	Date	Average Wind Speed (m/s)	Average Temperature (°C)	Average Relative Humidity (%)	Average Solar Radiation (W/m ²)
1	01/2/13	2.4	24.9	72.0	98.9
2	02/2/13	2.9	24.2	70.3	113.4
3	03/2/13	2.2	24.5	70.5	95.9
4	04/2/13	2.0	24.1	74.6	136.7
5	05/2/13	2.5	24.3	70.8	180.3
6	06/2/13	2.4	22.8	61.2	197.7
7	07/2/13	1.3	22.2	51.9	218.1
8	08/2/13	2.1	23.1	61.9	200.6
9	09/2/13	2.6	25.0	63.0	191.9
10	10/2/13	1.9	24.9	71.2	186.1
11	11/2/13	2.6	27.2	63.9	148.3
12	12/2/13	2.6	28.4	51.4	168.6
13	13/2/13	2.8	29.4	48.3	212.2
14	14/2/13	2.6	27.5	62.6	232.6
15	15/2/13	2.1	26.4	72.6	247.1



Sr. No.	Date	Average Wind Speed (m/s)	Average Temperature (°C)	Average Relative Humidity (%)	Average Solar Radiation (W/m ²)
16	16/2/13	2.7	24.3	67.3	250.0
17	17/2/13	3.0	24.2	66.0	250.0
18	18/2/13	1.6	26.0	59.8	232.6
19	19/2/13	3.2	25.2	53.2	244.2
20	20/2/13	2.3	26.3	51.0	247.1
21	21/2/13	2.2	25.6	63.2	253.0
22	22/2/13	2.3	25.7	69.4	258.8
23	23/2/13	2.2	25.5	68.1	247.1
24	24/2/13	2.8	26.3	53.2	282.0
25	25/2/13	2.1	25.6	59.7	261.7
26	26/2/13	2.6	25.7	60.1	261.7
27	27/2/13	2.9	25.1	66.7	255.9
28	28/2/13	3.3	27.0	52.5	255.9
Average		2.4	25.4	62.7	211.7



Table A.12

Record of daily rainfall in the month of February, 2013

Sr. No	Date	Rainfall in mm
1	01/2/13	0.0
2	02/2/13	0.0
3	03/2/13	0.0
4	04/2/13	0.0
5	05/2/13	0.0
6	06/2/13	0.0
7	07/2/13	0.0
8	08/2/13	0.0
9	09/2/13	0.0
10	10/2/13	0.0
11	11/2/13	0.0
12	12/2/13	0.0
13	13/2/13	0.0
14	14/2/13	0.0
15	15/2/13	0.0
16	16/2/13	0.0
17	17/2/13	0.0
18	18/2/13	0.0
19	19/2/13	0.0
20	20/2/13	0.0
21	21/2/13	0.0
22	22/2/13	0.0
23	23/2/13	0.0
24	24/2/13	0.0
25	25/2/13	0.0
26	26/2/13	0.0
27	27/2/13	0.0
28	28/2/13	0.0
Total rainfall in mm		0.0



1.8e Rainfall:

JN Port received no rainfall during the monitoring period as given in Table A. 12 which gives information about amount of daily rainfall received in the month of February, 2013.

1.8f Solar Radiation:

The maximum hourly average solar radiation was recorded to be 1116.5 W/m^2 at 14:00 hrs on 13th and 14:00 hrs on 14th February, 14:00 hrs on 15th February, 12:00 hrs on 16th February, 12:00 hrs on 17th February, 12:00 hrs on 21st February, 12:00 & 14:00 hrs on 22nd February, 15:00 hrs on 24th February, 12:00 hrs on 25th February, 12:00 & 15:00 hrs on 26th February, 12:00 hrs on 27th February and 12:00 hrs on 28th February 2013. Solar radiation determines the stability of the atmosphere. It is usually measured in W/m^2 . But it was recorded in milli Volts (mV). The monthly average value of solar radiation was $211.7 \pm 53.09 \text{ W/m}^2$. Solar radiation increased from 9.00 AM during morning hours and reached maximum during noon hours and then decreased during evening hours up to 18.00 PM. So, solar radiation data from 9.00 AM to 18:00 PM of a day has been taken for analysis. The daily average values of solar radiation ranged from 95.9 W/m^2 to 282.0 W/m^2 .

1.9 Conclusions

The meteorology of a region plays a key role in dispersion and transport of pollutants emitted by various point, area and line sources, thereby influencing the ground level concentrations of pollutants during different times of a day. Meteorological parameters characterize the dilution capacity of the atmosphere for pollutants. In a coastal region the land-sea interface prominently effects the variation of met parameters. During the month of February, 2013 the prominent wind direction (blowing from) was West (W) in the port area. Average values of Wind Speed, Temperature, Relative Humidity, Solar Radiation and Rainfall recorded were 2.4 m/s , 25.4°C , 62.7% , 211.7 W/m^2 and 0.0 mm respectively. No rainfall was recorded for the month of February, 2013 in the Port Area.



PART-A

Chapter-2: Water Quality Monitoring

2.1 HARBOUR AREA

2.1.1 Introduction

Nine sites are identified for water sampling as per the Environment Management plan. Water samples are collected from harbour region in and around JNP area.

The **Objectives** of Marine water Quality Monitoring are as follows,

- Indicate the state of health of marine waters;
- Assess compliance with the statutory Water Quality Objectives (WQOs);
- Reveal long-term changes in water quality;
- Provide a basis for the planning of pollution control strategies.

Method of Monitoring:

Three samples from the surface, mid depth and bottom are collected and composite from each Harbor water quality monitoring station during spring and neap tidal cycles. The samples were collected after 1st, 3rd and 5th hour of flood and ebb tide and composite. In all 54 samples will be collected from eight fixed and one moving station every month. In addition the Sediment samples will be collected from all these stations to estimate total organic matter, organic carbon and inorganic phosphate. Table W.1 provides the Description of Water Quality Monitoring stations (Creek Region).

Table: W.1
Description of Water Quality Monitoring stations (Harbour Region)

Station Name	Location/Landmark	Date of Water Sampling
W1	Near ONGC	27 th February, 2013
W2	Elephanta Jetty	27 th February, 2013
W3	In-between Vessel channel	28 th February, 2013
W4	Near Butcher Island	28 th February, 2013
W5	Near NSICT	27 th February, 2013
W6	JNPT Shallow Berth	27 th February, 2013
W7	Towards Landing Jetty	28 th February, 2013
W9	Near GTI Warf	28 th February, 2013
W10	Near Mora village	28 th February, 2013



Table W. 3 & W.4 provides the results for each of the water quality parameters sampled at various water quality monitoring stations of Harbour area of JNP from 27th & 28th February, 2013.

2.1.2 Results and Discussion

Following parameters are checked for the samples collected at the nine stations for pH, temperature, salinity, turbidity, TDS, SS, TS, DO, COD, BOD, and NH₄⁺-N, SPC, Coliform count, Phenol and Oil & Grease during the sampling period.

Table: W. 2

Minimum & Maximum concentrations of various parameters for Harbour region

Sr. No	Parameter	Observed Range	CPCB Limits	Method Used	Reference
1	pH	7.4- 8.0	6.5-9.0	pH meter	IS 3025 (Part 11)
2	Temperature	25.8- 29.8 °C	-	Thermometer	APHA 2550-B
3	Salinity	31.8- 37.4 ppt	-	Argentometric Titration	IS 3025 (Part 32)
4	Turbidity	41- 186 NTU	-	Nephelometer	IS 3025 (Part 10)
5	TDS	32320- 38569 mg/L	-	Gravimetry	IS 3025 (Part 16)
6	SS	181- 298 mg/L	-	Gravimetry	IS 3025 (Part 16)
7	TS	32561- 35813 mg/L	-	-	-
8	DO	5.5- 7.0 mg/L	3.0 mg/L or 40% of the higher saturation value	DO meter	-
9	COD	58- 179 mg/L	-	Potassium Dichromate	IS 3025 (Part 58)
10	BOD	<5- 5.1 mg/ L	5 mg/L	DO consumption in 5days at 20 ^{0C}	IS 3025 (Part 44)
11	NH ₄ ⁺ -N	0.17- 0.52 mg/L	-	Colorimetry	IS 3025 (Part 34)
12	SPC	72- 309 / ml	-	Pour plate	IS 1622 1981
13	Coliform	<2- 7 CFU/100 ml	500/100 ml	Membrane Filtration	IS 1622- 1981
14	Phenol	0.07- 0.34 mg/ L	-	Titrimetric	IS 3025 (Part 43)
15	Oil & Grease	5- 12 mg/ L	10 mg/L	Solvent Extraction	IS 3025 (Part 39)



The maximum concentration of oil and grease (12 mg/L) was found during spring tide of W2 station. The minimum concentration (5 mg/L) was found during spring tide of W6 station.

The values of various water quality parameters such as pH, dissolved oxygen, oil and grease, CFU and BOD obtained during the month of February, 2013 are compared with the primary water quality criteria for class IV waters (Harbour waters) given by Central Pollution Control Board (CPCB) in Table S.2. They were found to be within the range for these parameters except Oil & Grease and BOD. The concentration of BOD was below the CPCB standard at all the stations except spring tide of W2 station. The concentration of Oil & Grease was below the CPCB standard at all the stations except during spring tide of W2 station.



Table W. 3
Results of Physico-Chemical Analysis of Water Samples Collected From JNP
Harbor Area during February, 2013

Sample Name	Depth (m)	Temp. (°C)	pH	Salinity (ppt)	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	TS (mg/L)	
Standards	NA	NA	6.5-9.0	NA	NA	NA	NA	NA	
W1									
	SS	16.3	25.9	7.5	32.1	078	38547	266	38813
	SM		26.6	7.6	33.5	093	38569	196	38765
	SB		26.3	7.8	34.1	064	37561	190	37751
	NS	16.2	26.8	7.6	34.5	055	36457	253	36710
	NM		27.1	7.4	33.9	112	35268	248	35516
NB	27.2		7.5	33.6	136	35684	231	35915	
W2									
	SS	7.0	26.0	7.9	32.4	161	35987	211	36198
	SM		26.2	7.8	32.8	180	33415	209	33624
	SB		26.3	7.9	36.5	186	36547	278	36825
	NS	6.8	26.4	8.0	35.4	111	37458	296	37754
	NM		26.4	7.4	32.9	107	37451	298	37749
NB	26.3		7.9	34.5	103	35124	187	35311	
W3									
	SS	10.0	26.6	7.8	36.0	178	37451	188	37639
	SM		26.8	7.5	34.2	181	36894	196	37090
	SB		27.2	7.9	33.4	100	33420	193	33613
	NS	9.8	26.6	7.5	32.4	042	34741	185	34926
	NM		27.2	7.6	31.8	057	37685	201	37886
NB	26.5		7.9	32.5	066	37165	236	37401	
W4									
	SS	10.3	26.0	7.7	33.7	061	38366	287	38653
	SM		26.4	7.9	31.8	096	37635	277	37912
	SB		27.0	7.7	35.4	109	36854	254	37108
	NS	10.7	26.4	7.8	34.9	116	35699	213	35912
	NM		26.1	7.8	34.2	124	37154	209	37363
NB	25.8		7.7	34.6	139	37458	258	37716	
W5									
	SS	8.3	27.2	7.9	35.4	148	38541	269	38810
	SM		27.8	7.5	36.2	177	35005	274	35279
	SB		28.3	7.9	35.4	185	34658	277	34935
	NS	8.5	29.1	7.9	33.5	165	35621	298	35919
	NM		28.9	7.7	34.6	128	35741	296	36037
NB	27.2		7.5	37.4	142	37415	284	37699	

SS - SPRING SURFACE; SM -SPRING MIDDLE; SB - SPRING BOTTOM; NS-NEAP SURFACE
 NM - NEAP MIDDLE; NB - NEAP BOTTOM
 NS#- NEAP SAMPLE, SS #- SURFACE SAMPLE; BDL- BELOW DETECTABLE LIMIT
 (*) indicates the values exceeding the standard



Contd.....

Sample Name		Depth (m)	Temp. (°C)	pH	Salinity (ppth)	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	TS (mg/L)
Standards		NA	NA	6.5-9.0	NA	NA	NA	NA	NA
W6									
	SS	18.5	26.1	7.4	36.1	164	37815	214	38029
	SM		26.2	7.9	34.9	182	34655	253	34908
	SB		26.1	7.9	35.7	136	35101	207	35308
	NS	18.2	26.1	8.0	36.4	122	38501	254	38755
	NM		26.4	7.8	35.6	130	35058	253	35311
NB	26.4		7.6	34.5	142	36048	224	36272	
W7									
	SS	5.8	27.7	7.6	33.6	097	35654	200	35854
	SM		27.7	7.8	34.6	069	34214	182	34396
	SB		28.3	7.7	37.0	045	35841	203	36044
	NS	5.8	29.1	7.8	36.2	041	35963	196	36159
	NM		29.6	7.7	36.8	088	34474	181	34655
NB	29.2		7.6	32.7	091	36741	274	37015	
W9									
	SS	17.3	27.9	7.8	36.2	144	36899	294	37167
	SM		28.3	7.7	36.9	128	32320	245	32561
	SB		29.1	7.8	34.5	139	32670	265	32881
	NS	15.3	29.5	7.8	33.8	122	36950	233	37206
	NM		29.8	7.9	32.8	184	37590	281	37828
NB	29.7		7.9	34.2	180	37966	196	38243	
W10									
	SS	4.5	28.0	7.5	36.2	145	35200	268	35494
	SM		28.0	7.4	34.1	168	35570	241	35815
	SB		28.2	7.9	35.7	122	36640	211	36905
	NS	4.8	27.9	7.8	36.4	139	36270	256	36503
	NM		28.0	7.9	36.3	185	34820	238	35101
NB	28.0		7.9	34.1	153	37530	277	37726	

SS - SPRING SURFACE; SM -SPRING MIDDLE; SB - SPRING BOTTOM; NS – NEAP SURFACE NM - NEAP MIDDLE; NB - NEAP BOTTOM

NS#- NEAP SAMPLE, SS #- SURFACE SAMPLE; BDL- BELOW DETECTABLE LIMIT

(*) indicates the values exceeding the standard



Table W. 4
Results of Bio-chemical Analysis of Water Samples Collected From JNP Harbor
Area during February, 2013

Sample Name		DO (mg/L)	COD (mg/L)	BOD (mg/L)	NH ₄ ⁺ -N (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	SPC (Per ml)	Coliform Count (per 100 ml)
Standards		3.0 or 40% of the saturation value	NA	5	NA	NA	10	NA	500 (MPN)
W1	SS#						9		
	SS	6.6	90	<5	0.27	0.09		213	<2
	SM	7.0	83						
	SB	6.7	118						
	NS#						7		
	NS	6.9	64	<5	0.34	0.1		119	<2
	NM	6.7	96						
	NB	6.7	122						
W2	SS#						12*		
	SS	6.1	67	5.1*	0.39	0.12		209	<2
	SM	6.0	90						
	SB	6.0	58						
	NS#						9		
	NS	5.9	144	<5	0.47	0.25		300	<2
	NM	6.0	122						
	NB	6.0	125						
W3	SS#						7		
	SS	5.5	141	<5	0.42	0.07		309	<2
	SM	5.5	166						
	SB	5.7	118						
	NS#						6		
	NS	5.8	122	<5	0.17	0.2		301	<2
	NM	5.7	93						
	NB	5.6	109						
W4	SS#						9		
	SS	5.5	90	<5	0.4	0.31		297	<2
	SM	5.5	80						
	SB	5.5	61						
	NS#						8		
	NS	5.9	109	<5	0.21	0.32		211	<2
	NM	5.7	80						
	NB	5.7	83						
W5	SS#						10		
	SS	6.7	67	<5	0.18	0.19		93	6
	SM	6.6	118						
	SB	6.8	99						
	NS#						8		
	NS	5.9	93	<5	0.33	0.18		76	<2
	NM	5.8	109						
	NB	6.2	90						

(*) indicates the values exceeding the standard



Contd.....

Sample Name		DO (mg/L)	COD (mg/L)	BOD (mg/L)	NH ₄ ⁺ -N (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	SPC (Per ml)	Coliform Count (per100 ml)
Standards		3.0 or 40% of the saturation value	NA	5	NA	NA	10	NA	500 (MPN)
W6	SS#						5		
	SS	6.0	083	<5	0.38	0.11		202	<2
	SM	5.9	080						
	SB	6.0	099						
	NS#						9		
	NS	6.1	093	<5	0.51	0.08		271	7
	NM	6.4	090						
	NB	6.2	106						
W7	SS#						10		
	SS	6.4	109	<5	0.44	0.09		72	<2
	SM	6.2	102						
	SB	6.0	122						
	NS#						8		
	NS	5.7	134	<5	0.52	0.24		83	<2
	NM	5.7	179						
	NB	5.6	109						
W9	SS#						9		
	SS	6.4	090	<5	0.28	0.16		200	<2
	SM	6.4	080						
	SB	6.0	099						
	NS#						6		
	NS	6.0	077	<5	0.19	0.13		207	<2
	NM	5.7	080						
	NB	5.7	106						
W10	SS#						7		
	SS	6.4	163	<5	0.49	0.34		118	<2
	SM	6.4	147						
	SB	6.3	141						
	NS#						10		
	NS	6.1	131	<5	0.22	0.19		164	<2
	NM	6.0	115						
	NB	6.1	090						

SS - SPRING SURFACE; SM -SPRING MIDDLE; SB - SPRING BOTTOM; NS – NEAP SURFACE NM - NEAP MIDDLE; NB - NEAP BOTTOM
 NS#- NEAP SAMPLE, SS #- SURFACE SAMPLE; BDL- BELOW DETECTABLE LIMIT
 (*) indicates the values exceeding the standard



Table W.5
Results of Sediment Samples Collected From JNP Harbor Area during February, 2013

Sediment Sample		Organic matter		Total carbon content		Inorganic phosphate µg/g
	Time, Hr	mg/g	%	mg/g	%	
Standards		N.A.	N.A.	N.A.	N.A.	N.A.
W1	1 st S	36.2	3.6	21.2	2.1	23.6
	3 rd S	50.3	5.0	29.3	2.9	28.5
	5 th S	48.1	4.8	28.4	2.8	34.9
	1 st N	33.8	3.4	19.8	2.0	41.6
	3 rd N	37.9	3.8	21.8	2.2	45.9
	5 th N	53.3	5.3	30.9	3.1	42.1
W2	1 st S	59.1	5.9	33.7	3.4	40.6
	3 rd S	56.8	5.7	32.6	3.3	37.6
	5 th S	54.7	5.5	32.1	3.2	33.4
	1 st N	29.3	2.9	17.1	1.7	28.5
	3 rd N	28.2	2.8	16.2	1.6	26.3
	5 th N	59.1	5.9	33.7	3.4	49.6
W3	1 st S	31.1	3.1	17.9	1.8	48.1
	3 rd S	23.8	2.4	14.2	1.4	22.4
	5 th S	27.6	2.8	16.2	1.6	26.3
	1 st N	31.1	3.1	18.1	1.8	27.4
	3 rd N	33.2	3.3	19.2	1.9	28.6
	5 th N	28.1	2.8	16.3	1.6	38.5
W4	1 st S	21.8	2.2	13.1	1.3	21.4
	3 rd S	28.9	2.9	16.8	1.7	39.6
	5 th S	29.1	2.9	17.2	1.7	41.5
	1 st N	26.3	2.6	15.2	1.5	44.6
	3 rd N	28.4	2.8	16.3	1.6	48.2
	5 th N	40.1	4.0	22.7	2.3	47.6
W5	1 st S	48.2	4.8	27.9	2.8	33.6
	3 rd S	47.3	4.7	27.1	2.7	38.5
	5 th S	49.6	5.0	28.9	2.9	35.1
	1 st N	40.7	4.1	23.9	2.4	39.3
	3 rd N	52.9	5.3	31.1	3.1	26.6
	5 th N	56.7	5.7	33.2	3.3	25.1
W6	1 st S	48.2	4.8	28.3	2.8	22.6
	3 rd S	43.1	4.3	25.2	2.5	27.4
	5 th S	45.2	4.5	26.3	2.6	24.7
	1 st N	52.1	5.2	30.1	3.0	28.6
	3 rd N	50.2	5.0	29.4	2.9	31.5
	5 th N	41.4	4.1	23.7	2.4	38.4

S - SPRING, N - NEAP, 1ST - FIRST HOUR, 3RD - THIRD HOUR, 5TH - FIFTH HOUR.

(*) indicates the values exceeding the standard



Contd...

Sediment Sample		Organic matter		Total carbon content		Inorganic phosphate $\mu\text{g/g}$
	Time, Hr	mg/g	%	mg/g	%	
Standards		NA	NA	NA	NA	NA
W7	1 st S	44.9	4.5	25.9	2.6	39.6
	3 rd S	35.9	3.6	20.7	2.1	33.5
	5 th S	48.2	4.8	27.9	2.8	29.9
	1 st N	27.9	2.8	15.8	1.6	47
	3 rd N	29.1	2.9	16.7	1.7	45.2
	5 th N	31.1	3.1	18.2	1.8	40.6
W9	1 st S	21.2	2.1	12.2	1.2	31.6
	3 rd S	57.4	5.7	33.2	3.3	38.5
	5 th S	57.8	5.3	31.2	3.1	42.9
	1 st N	51.9	5.2	30.1	3.0	44.7
	3 rd N	40.7	4.1	24.1	2.4	45.6
	5 th N	49.9	5.0	29.3	2.9	35.4
W10	1 st S	50.2	5.0	29.1	2.9	40
	3 rd S	48.1	4.8	28.2	2.8	33.9
	5 th S	20.8	2.1	11.9	1.2	30.1
	1 st N	31.2	3.1	17.8	1.8	38.5
	3 rd N	23.9	2.4	13.7	1.4	37.2
	5 th N	27.8	2.8	15.6	1.6	32.5

S - SPRING, N - NEAP, 1ST - FIRST HOUR, 3RD - THIRD HOUR, 5TH - FIFTH HOUR.

(*) indicates the values exceeding the standard

Table W.5 provides the results for each of the sediment quality parameters sampled at various water quality monitoring stations from JNP harbor area for the month of February, 2013. The organic matter, total carbon content and inorganic phosphate in the sediment samples collected during the month of February, 2013 were found to be in the range of 2.1- 5.9 %, 1.2- 3.4 %, and 21.4- 49.6 $\mu\text{g/g}$.

2.1.3 CONCLUSIONS

Definite correlation between turbidity and suspended solids could not be established. This could be due to presence of fine sediments in suspension also since turbidity depends upon the particle size and the refractive properties of the particles.

Locations of various water quality monitoring stations are given in MAP 2. The standards for marine water quality are given in Table S.2.

Comparison with the standards (primary water quality criteria for class SW-IV waters (for harbour waters), observations and their mitigation measures are mentioned in the Table.W. 6

Table W.6
Conclusions and Mitigation Measures of Results for Water Samples Collected from Harbour During February, 2013

Sr. No.	Parameter	Criteria	Observation (above/below) standard	Reasons	Mitigation measures
1	pH range	6.5 - 9.0	7.4- 8.0	-	-
2	Dissolved Oxygen	3.0 mg/L or 40 % of the saturation value, whichever is higher	5.5- 7.0 mg/L	-	-
3	Colour and Odour	No visible colour or offensive order	No visible colour or distinct odour was observed	-	-
4	Floating objects oil, grease and scum (including the petroleum products)	10 mg/L	5- 12 mg/ L Below at all stations except spring tide of W2 station.	This could be due to indiscriminate discharge of oil contaminated bilge water from launches moving from Gateway of India to Elephanta and JNP Jetty and from motorized fishing boats and vessels moving in the harbor waters of JNP and adjacent areas	Strict management actions to be undertaken to avoid indiscriminate discharge of oil or oil contaminated water
5	Fecal Coliform	500 per 100 ml (MPN)	<2 – 7 CFU /100 ml	-	-
6	Biochemical Oxygen Demand	5 mg/L	<5- 5.1 mg/L Below at all stations except spring tide of W2 station.	Wastewater runoff from nearby areas, or waste dumping from launches and vessels	Avoid indiscriminate drainage of waste or wastewater into sea water





2.2 NHAVA CREEK

2.2.1 INTRODUCTION

Four sites are identified for water sampling as per the Environment Management plan. Water samples are collected from creek region in and around JNP area. Table W.7 provides the Description of Water Quality Monitoring stations (Creek Region).

Method of Monitoring:

Three samples from the surface, mid depth and bottom are collected and composite from each Harbor water quality monitoring station during spring and neap tidal cycles. The samples were collected after 1st, 3rd and 5th hour of flood and ebb tide and composite. In all 54 samples will be collected from eight fixed and one moving station every month. In addition the Sediment samples will be collected from all these stations to estimate total organic matter, organic carbon and inorganic phosphate.

Table: W.7

Description of Water Quality Monitoring stations (Creek Region)

Station Name	Location/Landmark	Date of Water Sampling
W11	At mouth of Nhava Creek	26th February, 2013
W12	Near Nhava Village	26th February, 2013
W13	Opposite North Gate	26th February, 2013
W14	Towards end of the Creek	26th February, 2013

Table W. 9 and W. 10 provides the results for each of the water quality parameters sampled at various water quality monitoring stations in the Nhava creek for the month of February, 2013.

2.2.2 RESULTS AND DISCUSSION

The range of values at nine stations for pH, temperature, salinity, turbidity, TDS, SS, TS, DO, COD, BOD, $\text{NH}_4^+\text{-N}$, SPC, Coliform count, Phenol and Oil & Grease during the period as shown below,



Table: W. 8

Minimum & Maximum concentrations of various parameters for Creek Region

Sr. No.	Parameter	Observed Range	Prescribed Limits	Method Used	Reference
1	pH	7.5- 8.1	6.5-9.0	pH meter	IS 3025 (Part 11)
2	Temperature	27.2- 30.2 °C	-	Thermometer	APHA 2550-B
3	Salinity	33.9- 37.8 ppth	-	Argentometric Titration	IS 3025 (Part 32)
4	Turbidity	101- 231 NTU	-	Nephelometer	IS 3025 (Part 10)
5	TDS	34896- 39454 mg/L	-	Gravimetry	IS 3025 (Part 16)
6	SS	241- 312 mg/L	-	Gravimetry	IS 3025 (Part 16)
7	TS	35196- 39720 mg/L	-	-	-
8	DO	4.6- 5.9 mg/L	3.0 mg/L or 40% of the saturation value, whichever is higher	DO meter	-
9	COD	67- 144 mg/L	-	Potassium Dichromate	IS 3025 (Part 58)
10	BOD	<5- 5.2 mg/L	5 mg/L	DO consumption in 5 days at 20 ^{0C}	IS 3025 (Part 44)
11	NH ₄ ⁺ -N	0.22- 0.44 mg/L	-	Colorimetry	IS 3025 (Part 34)
12	SPC	186- 317 / ml	-	Pour plate	IS 1622 1981
13	Coliform	<2- 9 CFU/ 100 ml	500 per 100 ml	Membrane Filtration	IS 1622 1981
14	Phenol	0.08- 0.29 mg/ L	-	Titrimetric	IS 3025 (Part 43)
15	Oil and Grease	7- 12 mg/L	10 mg/L	Solvent Extraction	IS 3025 (Part 39)

The maximum concentration of oil and grease (12 mg/L) was found at W12 station during spring tide. The minimum concentration of oil and grease (7 mg/L) was found during neap tide of W14 station. The values of various water quality parameters such as pH, dissolved oxygen, oil and grease, CFU and BOD obtained during the month of February, 2013 were compared with the primary water quality criteria for class IV waters (Harbour waters) given by Central Pollution Control Board (CPCB) in the Table S.2. They were found to be within the range for these parameters except BOD and Oil & Grease. The concentration of BOD was below the CPCB standard at all the stations except during neap tide of W11 station. The concentration of oil and grease was below the CPCB standards except spring tide of W12 station.



Table W. 9

Results of Physico-Chemical Analysis of Water Samples Collected From JNP Creek Area during February, 2013

Sample Name		Depth (m)	Temp. (°C)	pH	Salinity (ppt)	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	TS (mg/L)
Standards				6.5-9.0	N.A.	N.A.	N.A.	N.A.	N.A.
W11									
	SS	5.5	28.4	7.9	36.5	113	35748	284	36032
	SM		30.2	7.8	37.4	169	38561	263	38824
	SB		29.5	7.6	34.6	187	38542	274	38816
	NS	5.0	27.2	7.5	33.9	193	39111	299	39410
	NM		27.4	7.9	34.5	200	39014	307	39321
NB	27.6		7.7	35.6	207	35894	301	36195	
W12									
	SS	5.5	29.6	8.1	37.8	231	34896	300	35196
	SM		28.2	7.6	36.4	202	36541	311	36852
	SB		28.0	7.8	35.5	158	37415	241	37656
	NS	5.0	28.1	7.9	33.9	136	37140	286	37426
	NM		28.0	7.7	34.6	124	38965	244	39209
NB	27.9		7.9	34.2	101	38154	287	38441	
W13									
	SS	5.0	28.2	7.9	36.5	114	38151	241	38392
	SM		27.7	7.8	36.4	197	39254	258	39512
	SB		27.3	7.6	36.8	193	37154	256	37410
	NS	4.5	28.1	7.8	35.6	158	36894	269	37163
	NM		27.6	7.5	34.5	174	39454	266	39720
NB	27.4		7.8	36.3	169	38574	261	38835	
W14									
	SS	5.0	27.7	7.9	37.1	222	35741	285	36026
	SM		27.4	7.9	36.4	128	36544	274	36818
	SB		27.5	8.0	35.7	163	37457	296	37753
	NS	4.5	27.3	7.9	34.2	174	38524	312	38836
	NM		27.7	8.0	35.2	198	39045	309	39354
NB	27.9		8.1	35.7	145	38472	310	38782	

SS - SPRING SURFACE; SM -SPRING MIDDLE; SB - SPRING BOTTOM; NS – NEAP SURFACE NM - NEAP MIDDLE; NB - NEAP BOTTOM

NS#- NEAP SAMPLE, SS #- SURFACE SAMPLE; BDL- BELOW DETECTABLE LIMIT

(*) indicates the values exceeding the standard



Table W. 10
Results of Bio-chemical Analysis of Water Samples Collected From JNP Creek Area
during February, 2013

Sample Name	DO (mg/L)	COD (mg/L)	BOD (mg/L)	NH ₄ ⁺ -N (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	SPC (Per ml)	Coliform Count (per 100 ml)
Standards	3.0 or 40% of the saturation value	N.A.	5	N.A.	N.A.	10	N.A.	500 (MPN)
W11	SS#					10		
	SS	5.0	093	<5	0.34	0.17	246	<2
	SM	5.2	080					
	SB	5.1	067					
	NS#					8		
	NS	5.2	112	5.2*	0.22	0.29	186	<2
	NM	5.2	102					
	NB	4.9	080					
W12	SS#					12*		
	SS	4.7	080	<5	0.39	0.16	285	<2
	SM	5.9	067					
	SB	5.2	109					
	NS#					10		
	NS	4.8	115	<5	0.42	0.12	307	<2
	NM	5.1	093					
	NB	5.2	096					
W13	SS#					8		
	SS	4.7	090	<5	0.43	0.08	317	<2
	SM	4.8	131					
	SB	5.0	112					
	NS#					9		
	NS	4.6	144	<5	0.44	0.09	288	<2
	NM	5.1	093					
	NB	5.3	090					
W14	SS#					10		
	SS	4.8	112	<5	0.38	0.28	193	9
	SM	5.0	099					
	SB	5.3	090					
	NS#					7		
	NS	5.1	080	<5	0.34	0.22	212	<2
	NM	4.9	074					
	NB	4.8	099					

SS - SPRING SURFACE; SM -SPRING MIDDLE; SB - SPRING BOTTOM; NS – NEAP SURFACE NM - NEAP MIDDLE; NB - NEAP BOTTOM

NS#- NEAP SAMPLE, SS #- SURFACE SAMPLE; BDL- BELOW DETECTABLE LIMIT

(*) indicates the values exceeding the standard



Table W. 11
Results of Sediment Samples Collected From JNP Creek Area during February, 2013

Sediment Sample		Organic matter		Total carbon content		Inorganic phosphate µg/g
	Time, Hr	mg/g	%	mg/g	%	
Standards		N.A.	N.A.	N.A.	N.A.	N.A.
W11	S	40.2	4.0	23.2	2.3	23.5
	N	46.8	4.7	27.3	2.7	47
W12	S	48.2	4.8	27.9	2.8	39.6
	N	33.3	3.3	18.6	1.9	19.6
W13	S	28.2	2.8	15.7	1.6	27.4
	N	31.1	3.1	18.2	1.8	20.6
W14	S	35.9	3.6	21.3	2.1	52.1
	N	50.1	5.0	29.1	2.9	51.4

S - SPRING, N - NEAP.

(-) SEDIMENT SAMPLES CONTAINED ONLY PEBBLES AND GRAVELS.

Table W.11 provides the detailed results for each of the sediment quality parameters sampled at various water quality monitoring stations in the Nhava creek for the month of February, 2013. The organic matter, total carbon content and inorganic phosphate in the sediment samples collected during the month of February, 2013 were found to be in the range of 2.8- 5.0 %, 1.6- 2.9 % and 19.6- 52.1 µg/g of sediments, respectively.

2.2.3 CONCLUSIONS

Definite correlation between turbidity and suspended solids could not be established. This could be due to presence of fine sediments in suspension also since turbidity depends upon the particle size and the refractive properties of the particles. Salinity varied between stations and between different water column depths.

Comparison with the standards (primary water quality criteria for class SW-IV waters (for harbour waters), observations and their mitigation measures are mentioned in the Table W.12

Table W.12
Conclusions and Mitigation Measures of Results for Water Samples Collected from Nhava Creek During February, 2013

Sr. No.	Parameter	Criteria	Observation (above/below) standard	Reasons	Mitigation measures
1	pH range	6.5 - 9.0	7.5- 8.1	-	-
2	Dissolved Oxygen	3.0 mg/L or 40 % of the saturation value, whichever is higher	4.6- 5.9 mg/L	-	-
3	Colour and Odour	No visible colour or offensive order	No visible colour or distinct odour was observed	-	-
4	Floating objects oil, grease and scum (including the petroleum products)	10 mg/L	7- 12 mg/ L Below at all stations except spring tide of W12 station.	This could be due to indiscriminate discharge of oil contaminated bilge water from motorized fishing boats, moving in the upstream of creek or accidental discharge of oil along with drainage water from vessels or nearby areas	Strict management actions to be undertaken to avoid indiscriminate discharge of oil or oil contaminated water
5	Fecal Coliform	500 per 100 ml (MPN)	<2- 9 CFU /100 ml	-	-
6	Biochemical Oxygen Demand (5 days at 20oC)	5 mg/L	<5- 5.2 mg/L Below at all stations except neap tide of W11 & W14 stations.	Wastewater runoff from nearby areas, or waste dumping from launches and vessels	Avoid indiscriminate drainage of waste or wastewater into sea water



PART-B

Chapter-3: Monitoring Of Marine Ecosystem

3.1 Introduction

Marine ecosystems are very important for the overall health of both marine and terrestrial environments and are largely the study of population numbers and the processes, which brings about fluctuation in these numbers. Each individual in a population interact with other members of that population, with other species and with the environment. Ecosystem comprises of two units viz., structure and function. The structure of any ecosystem includes nutrients, light, living organisms etc. and the function includes flow of energy to different trophic levels, mineral cycles etc.

The marine ecosystem of JNP was studied by collecting surface water samples from various water quality monitoring stations of harbour region and Nhava creek. The details of the study are given below:

3.2. Objectives

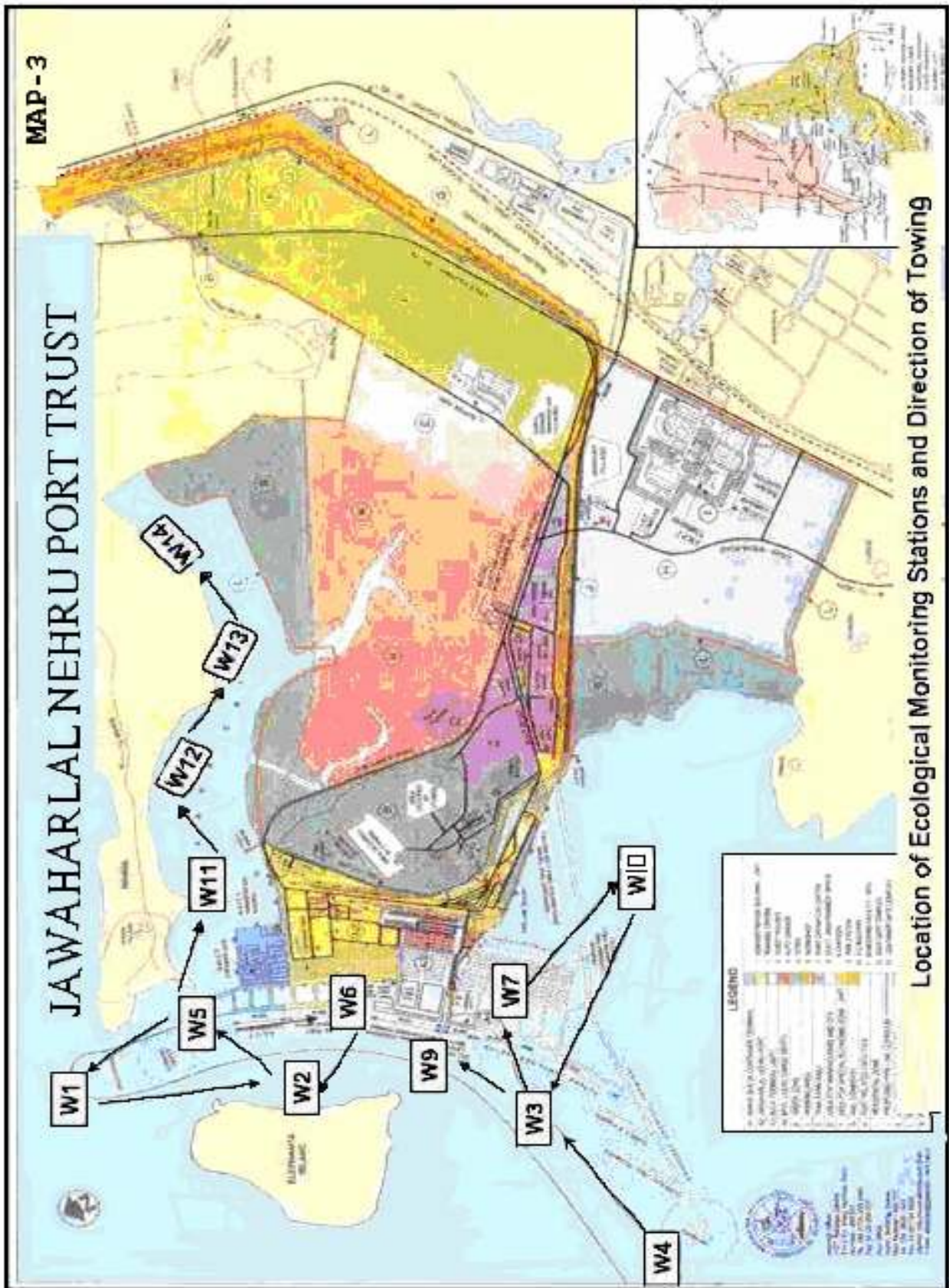
- a) Assessment of primary productivity;
- b) Analysis of phytoplankton and zooplankton diversity, density, relative abundance and biomass;
- c) Assessment of particulate oxidisable organic carbon (POC);
- d) Assessment of Secchi depth (light penetration); and
- e) Assessment of nutrients (NO_3^- , NO_2^- , SiO_2 and PO_4^{3-})
- f) Sediment quality and their biological characteristics.

3.3. Materials and methods

The monitoring of marine environment for the study of biological and ecological parameters was done on 26th February, 2013 in Nhava Creek regions of JNP and 27th and 28th February, 2013 in harbour of JNP and, during flood tide. The surface water samples were collected by a water sampler from nine water quality monitoring stations of JNP harbour area (viz., W1, W2, W3, W4, W5, W6, W7, W9 and W10) and four stations (W11, W12, W13 and W14) in Nhava Creek for the estimation of primary productivity and analysis of phytoplankton, zooplanktons and nutrients. The primary productivity was estimated using light and dark bottle method and assessed for the changes in oxygen content by Winkler's Iodometric titration method after five hours of incubation in sunlight.



For phytoplankton assay, the collected water samples were fixed using Lugol's solution fixative (Standard Methods, APHA, 2005). The zooplankton was collected by transect survey towing the plankton net against tidal current at the towing rate of 1.5 meter/sec up to a certain distance. The direction of towing the plankton net and the thirteen marine water quality monitoring stations are shown in Figure 3. The collected zooplankton samples were then fixed using 5% formaldehyde solution. For quantitative study of phytoplankton, the collected water sample, after fixation, was subjected to sedimentation for three days and carefully decanting the supernatant, the sediment was taken in small volume of water. This was then taken in a Sedgwick-Rafter counting cell and examined under compound microscope to enumerate and identify the phytoplankton. The zooplankton sample was also taken in a counting cell and enumerated under dissecting and compound microscope. For the estimation of chlorophyll-a and pheophytin-a, a certain volume of water sample was filtered through glass fiber filter paper (GF/C-47 mm) and the filter paper was immersed in 5 ml of 90% acetone and grinded in tissue grinder and kept overnight at 4°C in dark for extraction of pigments. The extract of pigments was then measured by spectrophotometer at wavelength of 750 nm and 664 nm before acidification and at 665 nm after acidification by 0.1ml of 0.1N HCl. The particulate oxidisable organic carbon (POC) of water sample was estimated by wet oxidation method with sulphuric acid-potassium dichromate oxidant followed by spectrophotometry at wavelength of 440 nm. The standing crop (Biomass) of phytoplankton was estimated by chlorophyll-a method while biomass of zooplankton was estimated by gravimetric method. The euphotic zone (light penetration) of JNP harbour and creek water was measured by Secchi disc. The NO₃-nitrogen and PO₄³-phosphorus were analyzed by brucine method and stannous-chloride method respectively while NO₂-nitrogen was analyzed by NEDA method and silicate by molybdosilicate method (Standard Methods, APHA, 2005)





3.4. Results and Discussion:

3.4.1. PRIMARY PRODUCTIVITY

The phytoplankton mainly algae of aquatic ecosystem is responsible to fix radiant energy into organic carbon by the process of photosynthesis. The primary productivity depends upon light penetration, light intensity and duration of light.

The gross and net primary productivity of JNP harbour water was estimated in surface water taken from 1-meter depth of euphotic zone in terms of mg oxygen produced as well as mg carbon fixed in per unit volume of water per day. The producers (Phytoplankton) would release the oxygen in the process of photosynthesis, while a part of it would be utilized in the process of community respiration by phytoplankton as well as zooplankton over the period of incubation. The amount of oxygen increased in light bottle accounts for the net production while the depletion in oxygen in dark bottle accounts for the respiratory depletion. The sum of the amount of oxygen utilized in respiration during incubation period and the increased amount of oxygen from light bottle gives the gross production. From the Stoichiometric of photosynthetic reaction, the amount of oxygen liberated is related to the amount of glucose fixed in the process of photosynthesis. The net and gross primary productivity including community respiration rate of nine water quality monitoring stations of JNP harbour and four water quality monitoring stations of Nhava Creek is given in Table E.1. The range of net primary productivity (NPP) of JNP harbour water was found between 150- 375 mgC/m³/day with an average of 217 mgC/m³/day. minimum value (150 mgC/m³/day) was found at W3, W5, W6, W7 and W9 stations and maximum value of (375 mgC/m³/day) was found at W1 station during monitoring period. In Nhava creek the net primary productivity was found to be in the range of 150- 225 mgC/m³/ day with an average of 188 mgC/m³/day. Minimum value (150 mgC/ m³/ day) was found at W13 and W14 stations and maximum value of (225 mgC/ m³/ day) was found at W11 and W12 stations during monitoring period as indicated in Table E.1. The light penetration measured by Secchi disc was found to be 0.5 feet, at all stations during monitoring period.



Table E.1.
Primary Productivity

Sr. No.	Stations	Community Respiration rate (24hrs.) mg O ₂ /m ³ /day	Gross Primary Productivity (10hrs.)		Net Primary Productivity (10hrs.)	
			mgO ₂ /m ³ /day	mgC /m ³ /day	mgO ₂ /m ³ /day	mgC /m ³ /day
Standard		NA	NA	NA	NA	<1500
JNP HARBOUR AREA						
1	W1	480	1200	450	1000	375
2	W2	960	1200	450	800	300
3	W3	960	800	300	400	150
4	W4	1920	1400	525	600	225
5	W5	1440	1000	375	400	150
6	W6	960	800	300	400	150
7	W7	960	800	300	400	150
8	W9	1440	1000	375	400	150
9	W10	480	1000	375	800	300
Average		1067	1022	383	578	217
NHAVA CREEK						
10	W11	960	1000	375	600	225
11	W12	960	1000	375	600	225
12	W13	960	800	300	400	150
13	W14	960	800	300	400	150
Average		960	900	338	500	188



3.4.2. POPULATION DENSITY AND ABUNDANCE OF PHYTOPLANKTON

Phytoplankton, being an autotrophic organism plays an important role to maintain the ecosystem of any aquatic community. They are primary producers and provide the energy to the heterotrophic herbivores. The growth of phytoplankton depends upon nutrients mainly nitrogen and phosphorous and intensity of light. The microscopic observation of water sample revealed phytoplankton of class Bacillariophyceae (Diatoms). The population density of phytoplankton in JNP harbour water and Nhava Creek is given in Table E.2. The average density of phytoplankton in JNP harbour water was found to be 477×10^3 no's/L with minimum (370×10^3 no's/L) at W6 station and maximum (553×10^3 no's/L) at W7 station. In Nhava Creek the average phytoplankton density was found to be 519×10^3 no's/L with minimum (417×10^3 no's/L) at W12 and maximum (600×10^3 no's/L) at W11 station. The concentration of phytoplankton density depends on the grazing activity of zooplankton and nutrients dissolved in water. Relative abundance of phytoplankton in percentage is given in Table E.3.

3.4.3. PHOTOSYNTHETIC PIGMENTS AND ALGAL BIOMASS

The pigment distribution in aquatic ecosystem is useful tool for quantitative assessment of phytoplankton community composition and zooplankton grazing activity. Chlorophyll-a is the main photosynthetic pigment of primary producers and its concentration is widely used to assess the phytoplankton standing crop and growth. It can, therefore, also serve as an indirect measure of nutrient levels and eutrophication of water (class of water). The standard range of chlorophyll-a recorded as $<4 \text{ mg/m}^3$ indicates oligotrophic class of water, $4-10 \text{ mg/m}^3$ indicates mesotrophic and $>10 \text{ mg/m}^3$ indicates eutrophic class of water. Pheophytin-a is an important degradation product of chlorophyll-a.

Chlorophyll-a constitutes approximately 1 to 2% (an average 1.5%) of dry weight of the phytoplankton and is extensively used to estimate the algal biomass. The estimated concentration of chlorophyll-a and pheophytin-a of JNP harbour water and Nhava Creek is given in Table E.4. The range of chlorophyll-a in JNP harbour water was found to be between $1.6 - 3.2 \text{ mg/m}^3$ with an average of 2.4 mg/m^3 . The minimum concentration of chlorophyll-a (1.6 mg/m^3) was found at W7 stations and maximum value (3.2 mg/m^3) was found at W4 station as indicated in Table E4. In Nhava Creek the range of chlorophyll-a was found between $1.9- 3.7 \text{ mg/m}^3$ with an average of 2.4 mg/m^3 . Pheophytin-a is the main degradation product of chlorophyll-a and it was found below detectable limit (BDL) at all



stations (except W1, W3, W6, W7 and W10 stations) in Harbour water and also found BDL at all stations in creek region during monitoring period.

The biomass is the main source of food for the primary consumers and it was evaluated by chlorophyll-a method and its value is given in Table E.5. In JNP harbour water, the range of algal biomass was found between 107- 258 mg/m³. The minimum algal biomass was (107 mg/m³) found at W7 stations and maximum (258 mg/m³) was found at W10 station and average value of phytoplankton standing crop (Biomass) in JNP harbour water was found 159 mg/m³. In Nhava Creek it was found between 125- 250 mg/m³ with an average of 162 mg/m³ during monitoring period. The minimum algal biomass was 125 mg/m³ at W11 and W12 station and maximum (250 mg/m³) was found at W14 station.

Table E. 2.
Population Density of Phytoplankton

Sr.No.	Station	Density (no's / L)
JNP HARBOUR AREA		
1	W1	410 x 10 ³
2	W2	417 x 10 ³
3	W3	523 x 10 ³
4	W4	520 x 10 ³
5	W5	477 x 10 ³
6	W6	370 x 10 ³
7	W7	553 x 10 ³
8	W9	540 x 10 ³
9	W10	483 x 10 ³
Average		477 x 10³
NHAVA CREEK		
10	W11	600 x 10 ³
11	W12	417 x 10 ³
12	W13	540 x 10 ³
13	W14	517 x 10 ³
Average		519 x 10³

Table E. 3.
Abundance of Phytoplankton at Various Stations

Sr. No		Species	PERCENTAGE OF PHYTOPLANKTON														
			JNP HARBOUR AREA										NHAVA CREEK				
			W1	W2	W3	W4	W5	W6	W7	W9	W10	Avg	W11	W12	W13	W14	Avg
1		Cyclotella spp.	3.3	2.4	2.5	1.9	2.8	1.8	1.8	2.1	2.5	2.3	-	2.4	-	-	0.6
2		Gyrosigma spp	-	2.4	1.3	1.9	-	3.6	3.0	2.8	3.1	2.0	1.7	-	3.1	2.6	1.9
3		Navicula spp	2.4	2.4	1.3	-	2.1	2.7	2.4	2.8	1.9	2.0	1.7	3.2	1.9	1.9	2.2
4		Skeletonema spp	79.7	84.7	76.5	83.3	86.7	88.3	85.6	81.4	81.5	83.1	88.9	83.1	79.0	83.2	83.6
5		Nitzschia spp	1.6	1.6	1.9	1.9	2.8	3.6	1.2	1.4	1.2	1.9	1.1	1.6	1.2	1.3	1.3
6		Rhodomonas spp	1.6	-	-	0.6	-	-	-	-	-	0.2	-	-	-	-	-
7		Thalassiosira spp.	11.4	6.4	16.6	10.3	5.6	-	6.0	9.7	9.9	8.4	5.6	6.4	13.6	9.1	8.7
8		Ceratium spp.	-	-	-	-	-	-	-	-	-	-	1.1	1.6	1.2	1.9	1.5
9		Tetrahedron spp	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-	0.4



Table E.4.
Photosynthetic Pigments

Sr.No.	Station	Chlorophyll-a (mg/m ³)	Pheophytin- a (mg/m ³)
JNP HARBOUR AREA			
1	W1	1.9	0.5
2	W2	2.5	BDL
3	W3	2.2	0.7
4	W4	3.2	BDL
5	W5	2.5	BDL
6	W6	1.9	0.7
7	W7	1.6	0.6
8	W9	1.8	BDL
9	W10	3.8	BDL
Average		2.4	0.28
NHAVA CREEK			
10	1.9	BDL	1.9
11	1.9	BDL	1.9
12	2.2	BDL	2.2
13	3.7	BDL	3.7
Average		2.4	BDL

BDL: Below Detectable Limit

Parameter	Standard	Remarks
Chlorophyll-a	< 4	Oligotrophic class of water
	4-10	Mesotrophic class of water
	>10	Eutrophic class of water



Table E.5. Algal Biomass (Chlorophyll-a Method)

Sr.No.	Station	Algal Biomass (mg/m ³)
JNP HARBOUR AREA		
1	W1	125
2	W2	167
3	W3	146
4	W4	215
5	W5	167
6	W6	125
7	W7	107
8	W9	119
9	W10	258
Average		159
NHAVA CREEK		
10	W11	125
11	W12	125
12	W13	146
13	W14	250
Average		162

3.4.4. POPULATION DENSITY AND ABUNDANCE OF ZOOPLANKTON

The most distinct parameter that could be used to analyze the biodiversity and or density or richness of marine community is the population density of zooplankton and its abundance. The population density of zooplankton and species diversity index (Shannon-Wiener's index) in the harbour water of JNP and Nhava Creek are given in Table E.6. Table E.7 gives the relative abundance of each species of zooplankton found at various stations. Since the size and exposure of the exoskeleton varies among the forms, only number would have given a false picture of abundance of zooplankton. Therefore, dry as well as ash free organic weight (biomass) constituted by zooplankton was used for the comparison of abundance of the same in marine ecosystem at various locations.

The zooplankton density collected by towing between various stations in JNP harbor water (as given in Table E.6) was found in the range of 26 - 98 no's/m³. The minimum population density of zooplankton (26 no's/m³) was found at towing between stations W3→W7 and maximum of 98 no's/m³ was found in between stations W5→W6 stations. The average population density of zooplankton in JNP harbour water was 54



no's/m³. In Nhava creek population density of zooplankton was found in the range of 41-77 no's/m³ with an average of 66 no's/m³. The minimum density of zooplankton in creek water was 41 no's/m³ found at towing between stations W5→W11 and maximum of 77 no's/m³ at towing between stations W12→W13 and W13→W14 stations. The typical value of Shannon Wiener's index of species diversity of non-polluted sea water remains above 1 for moderate or more diversity. If the index value is obtained below 1, then it will represent less diversity. The Shannon Wiener's index of species diversity for JNP harbour was found between 0.45 - 0.74 with an average of 0.58 and in Nhava creek it was found between 0.35 – 0.54 with an average of 0.48 shows less diversity. Over all diversity index of zooplankton was found less in jnp harbour region and also less in Nhava creek region.

By the enumeration of zooplankton, the Copepods of crustacean group were found dominant in harbour region, 85.8 % of the total communities of JNP harbour water and 88.9 % were found to be dominant in creek region.

There was another representative (Barnacles) of subclass cirripedia of class crustacea seen to be attached on rocks, pilings, boats and other water retaining structures. These are economically important organisms. Zooplankton biomass crop was determined with reference to weight (dry wt. as well as ash free wt). Table E.8 records the data of the same. In JNP harbour water, the minimum ash free biomass was 0.9 µg/L recorded between towing area of stations W5→W1, stations and maximum was 1.6 µg/L recorded between towing area of W6→W2 and W3→W9 station. The average ash free zooplankton biomass of JNP harbour water was 1.3 µg/L. In Nhava creek the minimum ash free biomass was 0.8 µg /L found between towing area of stations W11→W12 and W13→W14 and maximum 1.9 µg /L was found between towing area of stations W12→W13 with an average of 1.2 µg /L.

The Particulate Oxidizable Carbon (POC) totally depends on the suspended dead remains of organisms like plant twigs, zooplankton or fish droppings, phytoplankton etc. The concentration of particulate oxidizable carbon (POC) is given in Table E.9. The concentration of particulate oxidizable carbon in JNP harbour was found between 2011 - 2278 mg/m³ with an average of 2126 mg/m³. The minimum concentration of POC (2011mg/m³) was found at, W9 station and maximum 2278 mg/m³ at W1 station. In Nhava creek the POC content was found to be between 3122 - 3233 mg/m³ with an average of 3164 mg/m³. POC content in Nhava creek was found minimum as 3122 mg/m³ at W14 station and maximum at 3233 mg/m³ at W12 station. The POC concentration was found very high at all stations in JNP harbour and creek both region in JNP. prescribed standard range (10 - 100 mg/m³) due to suspended and organic dead remains.



Table E.6.
Population Density of Zooplankton

Sr.No.	Towing between stations	Zooplankton Density (no's/ m ³)	Shannon Wiener's Diversity Index
JNP HARBOUR AREA			
1	W1 → W2	84	0.45
2	W2 → W5	92	0.57
3	W5 → W1	30	0.64
4	W5 → W6	98	0.69
5	W6 → W2	28	0.54
6	W4 → W3	38	0.46
7	W3 → W7	26	0.58
8	W7 → W10	38	0.64
9	W10 → W3	56	0.74
10	W3 → W9	49	0.51
Average		54	0.58
NHAVA CREEK			
11	W5 → W11	41	0.50
12	W11 → W12	67	0.35
13	W12 → W13	77	0.51
14	W13 → W14	77	0.54
Average		66	0.48



Table E.7.
Abundance of Zooplankton at Various Towing Stations

PERCENTAGE OF PHYTOPLANKTON																			
Sr. No	Species	JNP HARBOUR AREA												NHAVA CREEK					
		W1 → W2	W2 → W5	W5 → W6	W6 → W2	W5 → W1	W6 → W3	W4 → W3	W3 → W7	W7 → W10	W10 → W3	W9 → W3	Avg	W5 → W11	W11 → W12	W12 → W13	W13 → W14	Avg	
1	Sagitta	1.3	1.8	1.9	1.7	-	2.9	4.3	-	3.0	2.3	2.0	2.0	2.4	3.3	1.4	1.4	2.1	
2	Medusa	1.3	1.2	1.9	2.8	4.0	1.4	6.4	8.7	4.0	2.3	3.6	3.6	4.1	1.7	2.2	1.4	2.4	
3	Mysids	3.3	6.1	5.6	6.2	8.0	4.3	4.3	5.8	8.0	3.4	5.7	5.7	5.5	-	2.9	3.6	3.0	
4	Copepods	90.1	86.7	85.2	82.4	86.0	89.9	85.1	82.6	81.0	88.6	85.3	85.3	87.7	92.5	88.4	87.0	88.9	
5	Fish larva	-	0.6	1.9	-	2.0	1.4	-	-	-	-	0.7	0.7	-	-	-	-	-	
6	Zoea larva	3.9	3.6	3.7	6.8	-	-	-	2.9	4.0	3.4	2.7	2.7	-	2.5	5.1	6.5	3.5	



Table E.8. Zooplankton Biomass

Sr.No	Towing between stations	Biomass	
		Dry wt. (µg/L)	Ash free wt. (µg/L)
JNP HARBOUR AREA			
1	W1 → W2	1.7	1.5
2	W2 → W5	2.2	1.0
3	W5 → W1	3.0	0.9
4	W5 → W6	1.3	1.0
5	W6 → W2	3.1	1.6
6	W4 → W3	3.9	1.4
7	W3 → W7	1.5	1.2
8	W7 → W10	1.6	1.2
9	W10→ W3	1.6	1.2
10	W3 → W9	3.2	1.6
Average		2.3	1.3
NHAVA CREEK			
11	W5 →W11	1.7	1.4
12	W11 →W12	1.9	0.8
13	W12 →W13	2.1	1.9
14	W13 →W14	1.9	0.8
Average		1.9	1.2

Table E.9. Concentration of Particulate Oxidisable Organic Carbon

Sr. No.	Stations	Concentration of POC (mg/m3)
Standards		10 - 100
JNP HARBOUR AREA		
1	W1	2278
2	W2	2222
3	W3	2244
4	W4	2089
5	W5	2133
6	W6	2067
7	W7	2033
8	W9	2011
9	W10	2056
Average		2126
NHAVA CREEK		
10	W11	3133
11	W12	3233
12	W13	3167
13	W14	3122
Average		3164



3.4.5. BENTHIC FAUNA

Benthic fauna are organisms that live in the bottom of a water body (or in the sediment) and they are mostly invertebrates i.e., they have no backbone. They range from microscopic (e.g. micro invertebrates, <10 microns) to macroscopic (i.e., a few tens of centimeters or more in length, e.g. macro invertebrates, >50 cm). Benthic invertebrates live either on the surface of bedforms (e.g. rock, coral or sediment - epibenthos) or within sedimentary deposits (infauna), and comprise several types of feeding groups e.g. deposit-feeders, filter-feeders, grazers and predators. The abundance, biomass and species composition of benthic invertebrates can be used as indicators of changing environmental conditions.

In JNP harbour water, there was no macrobenthos was found during monitoring period as indicated in Table E.10. Overall in JNP harbour region macro fauna was found absent or less due to clayey sediment while in the creek water, some species of gastropods and pelecypods are found. The population density of benthic fauna in JNP harbour was found to be in the range of 1500 - 1800 no's/100 gm with an average of 1667 no's/100 gm given in Table E.10. The minimum value of 1500 no's/m² was found W5 station while the maximum value of 1800 no's/gm at W2 and W3 stations and in nhava creek POC was to be in the range of 1507 - 1706 no's/gm with an average of 1607 no's/100gm. The minimum value of 1507 no's/100 gm was found at W13 and the maximum value of 1706 no/100 gms found at W11 station.

In the month of February, 2013 the benthic faunal (generic) was in the range of one to three types of genera in each station, as given in Table E.10. The most common group of genera identified are, Foraminiferans, Gastropods, Pelecypods etc.

Table E.10
Results of averages of biomass and population density of faunal groups at various stations

Sr. No.	Station	Biomass of macrobenthos wet wt (g/100gm)	Population density of total faunal group (no's/ 100gm)	Total no. faunal group identified	Major group
1	W1	-	1700	1	Foraminiferans
2	W2	-	1800	1	Foraminiferans
3	W3	-	1800	1	Foraminiferans
4	W4	-	1600	1	Foraminiferans
5	W5	-	1500	1	Foraminiferans
6	W6	-	1600	1	Foraminiferans
7	W7	-	1700	1	Foraminiferans
8	W9	-	1700	1	Foraminiferans
9	W10	-	1600	1	Foraminiferans
Average			1667	1	
NHAVA CREEK					
11	W11	6	1706	3	Pelecypods, gastropods, foraminifera
12	W12	8	1608	3	Pelecypods, gastropods, foraminifera
13	W13	7	1507	3	Pelecypods, gastropods, foraminifera
14	W14	5	1605	3	Pelecypods, gastropods, foraminifera
Average			1607	3	



3.4.6. Nutrients

3.4.6.A Anions:

The important micronutrients (viz., nitrate, nitrite, silica and phosphate) have received particular attention for any aquatic ecosystem because they are limiting factors for population of aquatic plants, algae and other vegetation and they are also important in relation to primary productivity. Levels of nitrogen and phosphorus in sea water include not only dissolved nutrients, but also the amount that are bound in plankton and suspended organic particulate matter. The level of nitrogen and phosphorus vary widely throughout the year. Nitrate is the most highly oxidized form of nitrogen commonly present in natural water and produced by the aerobic decomposition of nitrogenous compounds by nitrifying bacteria. The general range of nitrate in seawater has been recorded between 1-500 µg/L.

Phosphorus occurs in natural waters and wastewater almost solely as phosphate. These are classified as orthophosphate, condensed phosphate and organically bound phosphate. They occur in solution, particle or detritus, or in bodies of aquatic organisms. The condensed phosphates are the most abundant form of phosphate in natural water. Phosphates enter in lakes, ponds, rivers, estuaries and ocean from various primary sources such as inorganic fertilizers, wastewater treatment from municipal sources, soaps and detergents and industrial processes.

The nutrients at various stations in JNP harbour water and Nhava Creek are given in Table E.11. In harbour region the Phosphate was found between 86- 90 µg/L with an average of 88 µg/L. The minimum concentration of 86 µg/L of Phosphate was found at W6 and W10 stations and maximum concentration of 90 µg/L was found at W2, W4 and W5 stations. Overall in JNP harbour region the Phosphate value was found within standard range (0.1 - 90 µg/L). The Nitrate was found between 138 - 156 µg/L, with minimum value as 138 µg/L W6 station and maximum as 156 µg/L at W7 and W9 stations. The average concentration of Nitrate was found to be 148 µg/L and overall Nitrate was found within range (1.0 - 500 µg/L) at all stations. The Nitrite was found to be between 120 - 122 µg/L with an average of 121 µg/L. The minimum concentration of nitrite (120 µg/L) was found at W5 station and maximum of 122 µg/L at W9 station. Overall in JNP harbour region the Nitrite value was found under standard range (<125 µg/L). Silica is another important nutrient in seawater. The requirement of silica by diatoms is however, entirely limited to skeletal formation and has particular importance in coastal upwelling region where diatoms form a dominant part of phytoplankton. Silica in the form of silicate in JNP harbour water was found between 1399 – 1503 µg/L with an



average of 1461 $\mu\text{g/L}$. The minimum concentration of silica of 1399 $\mu\text{g/L}$ was found at W2 station and maximum of 1503 $\mu\text{g/L}$ at W5 & W9 stations. The Sulphate was found between 3002 - 3009 mg/L, with minimum value as 3002 mg/L at W7 station and maximum as 3009 mg/L at W1 station. The average concentration of Sulphate was found to be 3006 mg/L.

In Nhava Creek, Phosphate was found between 86 - 88 $\mu\text{g/L}$ with an average 87 $\mu\text{g/L}$ which was under standard range (0.1 - 90 $\mu\text{g/L}$). Nitrate was found between 152 - 161 $\mu\text{g/L}$ with an average 156 $\mu\text{g/L}$. The minimum Nitrate (152 $\mu\text{g/L}$) was found at W11 station and maximum (161 $\mu\text{g/L}$) at W12 station and Nitrite was found 122 $\mu\text{g/L}$ at all stations in Nhava creek region. The silica content in Nhava creek was found between 1434 - 1503 $\mu\text{g/L}$ with an average of 1460 $\mu\text{g/L}$. The minimum silica content of 1434 $\mu\text{g/L}$ was found at station W11 and W13 stations and maximum as 1503 $\mu\text{g/L}$ was found at W14 station. Sulphate was found between 3005 - 3007 mg/L with an average of 3006 mg/L. The minimum Sulphate (3005 mg/L) was found at W12 station and maximum (3007 mg/L) at W11 station. Overall in JNP harbour and creek region the values of all the nutrients were found to be within the recommended ranges, which are given in Table.E.11.

The nutrients at various stations in JNP harbour area and Nhava Creek sediments are given in Table E.12. In harbour region the Phosphate was found between 43.7 – 59.2 $\mu\text{g/g}$ with an average of 51.2 $\mu\text{g/g}$. The minimum concentration of Phosphate (43.7 $\mu\text{g/g}$) was found at W5 and maximum concentration (59.2 $\mu\text{g/g}$) at W9 and W10 stations. The Nitrate was found between 0.69 – 0.80 $\mu\text{g/g}$, with minimum value (0.69 $\mu\text{g/g}$) at W5 station and maximum (0.80 $\mu\text{g/g}$) at W1 station. The average concentration of Nitrate was found to be 0.74 $\mu\text{g/g}$. The Nitrite was found to be between 3.72 – 3.82 $\mu\text{g/g}$ with an average of 3.76 $\mu\text{g/g}$. The minimum concentration of nitrite (3.72 $\mu\text{g/g}$) was found at W2, W6 and W9 stations and maximum (3.82 $\mu\text{g/g}$) at W7 station. Silica in the form of silicate in JNP harbour sediments were found between 0.089 – 0.095 $\mu\text{g/g}$ with an average of 0.092 $\mu\text{g/g}$. The minimum concentration of silica (0.089 $\mu\text{g/g}$) was found at W2, W5 & W9 stations and maximum (0.095 $\mu\text{g/g}$) was found at W4 and W6 stations. The Sulphate was found between 5609 - 5992 $\mu\text{g/g}$, with minimum value of 5609 $\mu\text{g/g}$ at W1 and W2 stations and maximum of 5992 $\mu\text{g/g}$ at W6 and W10 stations. The average concentration of Sulphate was found to be 5836 $\mu\text{g/g}$.

In Nhava Creek, Phosphate was found between 64.4 – 69.5 $\mu\text{g/L}$ with an average 66.9 $\mu\text{g/L}$ which was under standard range (0.1- 90 $\mu\text{g/L}$). Nitrate was found between 0.73 – 0.83 $\mu\text{g/L}$ with an average 0.78 $\mu\text{g/L}$. The minimum Nitrate (0.73 $\mu\text{g/L}$) was found at



W13 station and maximum (0.83 µg/L) at W11 station and Nitrite was found between 3.75 - 3.82 µg/L with an average of 3.79 µg/L. The minimum Nitrite (3.75 µg/L) was found at W11 station and maximum (3.82 µg/L) at W14 station. The silica content in Nhava creek was found between 0.097– 0.103 µg/L with an average of 0.100 µg/L. The minimum silica content of 0.097 µg/L was found at W11 station and maximum as 0.103 µg/L at W13 station. Sulphate was found between 6119 - 6183 mg/L with an average of 6151 mg/L. The minimum Sulphate (6119 mg/L) was found at W11 and W13 stations and maximum (6183 mg/L) at W12 and W14 stations. Overall in JNP harbour and creek region the values of all the nutrients were found to be within the recommended ranges.

3.4.6. B Cations:

JNP harbour and creek water is indeed a complex solution of mineral salts like sodium, potassium, magnesium and calcium compounds and of decayed biologic matter. The concentration of some metals ions is given in Table.E.13. Most of the ocean's salts are derived by the gradual processes of weathering and erosion, the wearing down of mountains, and the dissolving action of rains and streams which transport their mineral washings to the sea. Dissolution of minerals from the rocks and sediments in the ocean floor also contribute to dissolved ions in the sea.

Mollusks (oysters, clams, and mussels) extract calcium from the sea to build their shells and skeletons. Foraminifers (unicellular sea animals) and crustaceans (crabs, shrimp, lobsters, and barnacles) likewise take out large amounts of calcium salts to build their bodies. When these organisms die their shells dissolve or degrade to again contribute to calcium concentration in sea water.

In harbour region water the Calcium was found between 825 - 835 mg/L with an average of 829 mg/L. The minimum concentration (825 mg/L) of Calcium was Found at W7 station and maximum concentration (835 mg/L) at W1 station. Potassium in JNP harbour water was found between 525 - 531 mg/L with an average of 528 mg/L. The minimum concentration of Potassium (525 mg/L) was found at W6 station and maximum (531 mg/L) at W3 station. The Magnesium was found between 844 - 848 mg/L, with minimum value (844 mg/L) at W3 station and maximum (848 mg/L) at W9 and W10 stations. The average concentration of Magnesium was found to be 846 mg/L. The Sodium was found between 12432 - 12531 mg/L with an average of 12445 mg/L. The minimum concentration of sodium (12432 mg/L) was found at W2 station and maximum (12531 mg/L) at W1 station.

In Nhava Creek, Calcium concentration was found between 827- 830 mg/L with an average 829 mg/L. The minimum value of Calcium (827 mg/L) was found at W14 station



and maximum (830 mg/L) at W11 station. The Potassium content in Nhava creek was found between 528 - 530 mg/L with an average of 530 mg/L. The minimum potassium value (528 mg/L) was found at W12 station and maximum (531 mg/L) at W13 station. Magnesium concentration was found between 847 – 849 mg/L with an average of 848 mg/L. The minimum value of Magnesium (847 mg/L) was found at W12 and W14 stations and maximum (849 mg/L) was found at W11 station. Sodium concentration was found between 12435 - 12437 mg/L with an average of 12436 mg/L. The minimum sodium value (12435 mg/L) was found at W11 station and maximum (12437 mg/L) at W12 station.

In harbour region sediments, the Calcium was found between 227- 231 mg/Kg with an average of 229 mg/Kg given in Table E.14. The minimum Concentration of 227 mg/Kg of Calcium was found at W9 station and maximum concentration of 231 mg/Kg at W2 and W6 stations. Potassium in JNP harbour sediment was found between 527- 532 mg/Kg with an average of 529 mg/Kg. The minimum concentration of Potassium of 527 mg/Kg was found at W9 station and maximum of 532 mg/Kg at W2 station. Magnesium was found between 1725 - 1730 mg/Kg, with minimum value as 1725 mg/Kg at W1 and W4 stations and maximum as 1730 mg/Kg was found at W3 station. The average concentration of Magnesium was found to be 1727 mg/Kg. Sodium was found to be between 2957 - 2964 mg/Kg with an average of 2960 mg/Kg. The minimum concentration of sodium (2957 mg/Kg) was found at W4 station and maximum of 2964 mg/Kg at W6 station.

In Nhava Creek sediments, Calcium was found between 233 - 236 mg/Kg with an average 235 mg/Kg given in Table E. 14. The minimum value of calcium (233 mg/Kg) was found at W11 station and maximum (236 mg/Kg) was found at W13 station. The Potassium content in Nhava creek was found between 527 - 529 mg/Kg with an average of 528 mg/Kg. The minimum Potassium content (527 mg/Kg) was found at W12 station and maximum (529 mg/Kg) at W13 station. Magnesium was found between 1727 - 1729 mg/Kg with an average of 1728 mg/Kg. The minimum Magnesium value (1727 mg/Kg) was found at W14 station and maximum (1729 mg/Kg) at W12 station. Sodium was found between 3060 -3062 with an average of 3061 mg/Kg. The minimum sodium value (3060 mg/Kg) was found at W12 station and maximum (3062 mg/Kg) at W13 station.

The depth of light penetration decreased by particles suspended in water, including any algal cells that are growing there. Coastal waters with high sediment content, or water in which an algal bloom is occurring, have less light penetration than clear open ocean water. The light penetration (Euphotic zone) in harbour of JNP and Nhava creek is given



in Table E.16. It was measured by Secchi disc. The visibility of Secchi disc was found to be 0.5 feet in JNP harbor water and in Nhava creek region.

Table E.11. Concentration of Nutrients: Anions in Water

Sr. No.	Stations	$\text{PO}_4^{3-}\text{-P}$ ($\mu\text{g/L}$)	$\text{NO}_3^{-}\text{-N}$ ($\mu\text{g/L}$)	$\text{NO}_2^{-}\text{-N}$ ($\mu\text{g/L}$)	SiO_2^{-} ($\mu\text{g/L}$)	SO_4^{2-} (mg/L)
Standards		0.1 - 90	1.0 - 500	< 125	10-5000	NA
JNP HARBOUR AREA						
1	W1	88	152	121	1434	3009
2	W2	90	143	121	1399	3007
3	W3	88	147	121	1469	3007
4	W4	90	152	121	1434	3008
5	W5	90	143	120	1503	3006
6	W6	86	138	121	1469	3007
7	W7	88	156	121	1469	3002
8	W9	88	156	122	1503	3005
9	W10	86	147	121	1469	3003
Average		88	148	121	1461	3006
NHAVA CREEK						
10	W11	88	152	122	1434	3007
11	W12	86	161	122	1469	3005
12	W13	86	156	122	1434	3006
13	W14	88	156	122	1503	3006
Average		87	156	122	1460	3006

(*) Indicate results higher than standard range



Table E.12. Concentration of Nutrients: Anions in Sediment

Sr. No.	Stations	$\text{PO}_4^{3-}\text{-P}$ ($\mu\text{g/g}$)	$\text{NO}_3^{-}\text{-N}$ ($\mu\text{g/g}$)	$\text{NO}_2^{-}\text{-N}$ ($\mu\text{g/g}$)	SiO_2^{-} ($\mu\text{g/g}$)	SO_4^{2-} ($\mu\text{g/g}$)
Standards		NA	NA	NA	NA	NA
JNP HARBOUR AREA						
1	W1	48.9	0.80	3.79	0.092	5609
2	W2	46.3	0.73	3.72	0.089	5609
3	W3	48.9	0.76	3.75	0.092	5737
4	W4	56.6	0.73	3.79	0.095	5864
5	W5	43.7	0.69	3.75	0.089	5928
6	W6	46.3	0.73	3.72	0.095	5992
7	W7	51.5	0.76	3.82	0.092	5864
8	W9	59.2	0.76	3.72	0.089	5928
9	W10	59.2	0.73	3.79	0.092	5992
Average		51.2	0.74	3.76	0.092	5836
NHAVA CREEK						
10	W11	66.9	0.83	3.75	0.097	6119
11	W12	64.4	0.76	3.79	0.100	6183
12	W13	69.5	0.73	3.79	0.103	6119
13	W14	66.9	0.80	3.82	0.100	6183
Average		66.9	0.78	3.79	0.100	6151

(-) Samples containing only shells and pebbles



Table E.13. Concentration of Nutrients: Cations in water

Sr. No.	Stations	Ca ⁺⁺ (mg/L)	K ⁺ (mg/L)	Mg ⁺⁺ (mg/L)	Na ⁺ (mg/L)
Standards		NA	NA	NA	NA
JNP HARBOUR AREA					
1	W1	835	530	845	12531
2	W2	829	526	846	12432
3	W3	828	531	844	12433
4	W4	830	527	847	12434
5	W5	834	526	845	12435
6	W6	827	525	847	12436
7	W7	825	529	846	12434
8	W9	828	528	848	12435
9	W10	828	527	848	12437
Average		829	528	846	12445
NHAVA CREEK					
10	W11	830	529	849	12435
11	W12	829	528	847	12437
12	W13	829	531	848	12436
13	W14	827	530	847	12436
Average		829	530	848	12436



Table E.14. Concentration of Nutrients: Cations in sediment

Sr. No.	Stations	Ca ⁺⁺ (mg/kg)	K ⁺ (mg/kg)	Mg ⁺⁺ (mg/kg)	Na ⁺ (mg/kg)
Standards		NA	NA	NA	NA
JNP HARBOUR AREA					
1	W1	230	531	1725	2959
2	W2	231	532	1727	2961
3	W3	230	530	1730	2958
4	W4	229	531	1725	2957
5	W5	229	529	1728	2959
6	W6	231	528	1728	2964
7	W7	228	528	1728	2961
8	W9	227	527	1729	2962
9	W10	229	529	1727	2960
Average		229	529	1727	2960
NHAVA CREEK					
10	W11	233	528	1728	3061
11	W12	235	527	1729	3060
12	W13	236	529	1728	3062
13	W14	235	528	1727	3061
Average		235	528	1728	3061



Table E.15. Results of Moisture Content

Sr. No.	Stations	Moisture (%)
JNP HARBOUR AREA		
1	W1	0.38
2	W2	0.36
3	W3	0.36
4	W4	0.37
5	W5	0.37
6	W6	0.35
7	W7	0.36
8	W9	0.38
9	W10	0.37
Average		0.37
NHAVA CREEK		
10	W11	0.38
11	W12	0.37
12	W13	0.38
13	W14	0.38
Average		0.38



Table E.16. Results of Secchi Depth

Sr. No.	Stations	Secchi depth (ft)
JNP HARBOUR AREA		
1	W1	0.5
2	W2	0.5
3	W3	0.5
4	W4	0.5
5	W5	0.5
6	W6	0.5
7	W7	0.5
8	W9	0.5
9	W10	0.5
Average		1.1
NHAVA CREEK		
10	W11	1.0
11	W12	1.0
12	W13	1.0
13	W14	1.0
Average		1.0



3.5 Conclusions

The net primary productivity in month of February, 2013 in JNP harbour and creek region was found 150 to 375 mgC/m³/day. The visibility of Secchi disc (light penetration) in the JNP harbour water and Nhava creek was found to be 0.5 fee during sampling periods. Low visibility could be due to the dredging activity and surface runoff water from nearby areas. The overall average value of chlorophyll-a in JNP harbour and creek water was found to be 2.4 mg/m³ which represent oligotrophic class of water. The phytoplankton species observed belong to the diatoms group. The marine community of JNP harbour represents pelagic invertebrates and some other zooplankton. Copepods were found to be the dominant species in harbour region and Nhava creek region. The average value of Shannon Wiener Index of species diversity was found to be 0.58 in JNP harbour water and 0.48 in creek water. These values represent less species diversity in JNP harbour and in creek region.

In JNP harbour and creek region the benthic production in terms of biomass and population suggested organic pollution induced productivity at different tropic levels. To reduce the organic loading, effluent releases to inner creek or marine zone should be discouraged. For existing effluent discharges detailed site survey for assimilative capacity for receiving water body should be conducted and also if needed based on the study the effluent release sites should be shifted downstream or additional treatment should be provided to the effluent based on model studies.

Comparison with the standards (of some ecological parameters for Arabian Sea and other parts of Indian Ocean given by Raymont, 1980), of observations and mitigation measures are mentioned in Table E.17.

The standard ranges of some ecological parameters for Arabian Sea and other parts of Indian Ocean given by Raymont (1980) are given in Table S. 3.

Table E.17.
Conclusions and Mitigation Measures for Ecological Parameters During February, 2013

Sr. No.	Parameter	Range	Observation (above/below than standard)	Reasons	Mitigation measures
1	Net primary productivity	<1500 mgC/m ³ /day at surface	Low in both harbour and creek	High turbidity due to surface runoff water from nearby areas	-
2	Chlorophyll-a	-	Oligotrophic at all stations. including harbour and creek both regions .	Low phytoplankton density in harbour regions than creek region due to high turbidity.	-
3	Phosphate	0.1- 90 µg/L	Harbour –88.0µg/L Creek -87 µg/L	-	-
4	Nitrate	1.0-500 µg/L	Harbour –148.0µg/L Creek -156.0 µg/L	-	Within range
5	Nitrite	<125 µg/L	Harbour – 121.0 µg/L Creek – 122.0 µg/L	-	Within range
6	Particulate Organic Carbon (POC)	10-100 mg/m ³	Harbour – 2126 mg/m ³ Creek -3164 mg/m ³ High concentration at all stations	This may be due to detritus of dead organisms and droppings of zooplankton.	-
7	Silicate (SiO ₂)	10-5000 µg/L	Harbour –1461 µg/L Creek-1460 µg/L	This is a natural phenomena.	Within range



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Table S.1

CPCB standards of ambient air quality for different areas

Sr. No.	Parameter	CPCB 24-Hours Standard		
		Industrial and Mixed areas	Residential and Rural areas	Sensitive areas
1.	TSP, $\mu\text{g}/\text{m}^3$	500	200	100
2.	PM ₁₀ , $\mu\text{g}/\text{m}^3$	100	100	100
3.	NO _x , $\mu\text{g}/\text{m}^3$	80	80	80
4.	SO ₂ , $\mu\text{g}/\text{m}^3$	80	80	80
5.	NH ₃ , $\mu\text{g}/\text{m}^3$	400	400	400

Table S.2

Primary water quality criteria for class SW-IV waters (For Harbour Waters)

Sr. No	Parameter	Criteria	Rationale/Remarks
1.	pH range	6.5 - 9.0	To minimize the corrosive and scaling effects.
2.	Dissolved Oxygen	3.0 mg/L or 40 % of the saturation value, whichever is higher	Considering bio-degradation of oil and inhibition to oxygen production through photosynthesis.
3.	Colour and Odour	No visible colour or offensive order	None from reactive chemicals which may corrode paints/metallic surfaces.
4.	Floating objects oil, grease and scum (including the petroleum products)	10 mg/L	Floating matter should be free from excessive living organisms which may clog or coat operative parts of marine vessels/equipment.
5.	Fecal Coliform	500/ 100 ml (MPN)	Not exceeding 1000/100 ml in 20 % of the samples in the year and in 3 consecutive samples in the monsoon months.
6.	Biochemical Oxygen Demand (5 days at 20°C)	5 mg/L	To maintain water relatively free from the pollution caused by sewage and other decomposable wastes.

Table S.3

Recommended ranges of the ecological parameters for Arabian sea

Parameter	Range	Remark
Net primary productivity	<1500 mgC/m ³ /day at surface	High productivity indicates the abundance of phytoplankton crop available to primary producers this could lead to poor water quality.
Chlorophyll-a	< 4 mg/m ³ 4-10 mg/m ³ >10 mg/m ³	Oligotrophic class of water Mesotrophic class of water Eutrophic class of water
Phosphate	0.1- 90 µg/L	A nutrient that acts as a fertilizer. High level of this nutrient causes excessive plant and algal growth in aquatic ecosystem
Nitrate	1.0- 500 µg/L	This is also a nutrient produced in natural water by decomposition of nitrogenous organic compounds. High level of nitrate represents the presence of more nitrogenous compounds and resulting in to excessive growth of algae and other aquatic vegetation.
Nitrite	<125 µg/L	Nitrite in water poisons the fish by binding to the hemoglobin in the blood preventing oxygen carrying capacity, in effect suffocating the fish .The gills of fish dying as a result of nitrite poisoning are characteristic brown color.
Particulate Organic Carbon (POC)	10-100 mg/m ³	POC is directly related to primary productivity. High concentration of POC represents the region of high productivity.
Silicate (SiO₂)	10-5000 µg/L	Nucleic acid synthesis and skeletal formation of Diatoms.



PART-C

Chapter-4: Drinking Water Quality Monitoring

4.1 Introduction

Assessment of drinking water quality was carried out for the month of February, 2013 to determine the present status of drinking water quality of JNPT area and to compare it with the prescribed standards. As per requirement samples were collected and analyzed from eighteen stations from outside and inside the port area of JNPT. Ten stations were outside the port area and eight stations were inside the port area. All the water samples were collected from the port area of JNPT on 28th February, 2013. Table D. 1 shows the description of the eighteen water quality- monitoring stations outside and inside the port area of JNPT. These water samples were analyzed for various physical, chemical and biological parameters viz., colour, odour, turbidity, conductivity, pH, total dissolved solids, chlorides, hardness, total iron, sulfate, $\text{NH}_4^+\text{-N}$, $\text{PO}_4^{3-}\text{-P}$ and bacterial count .

Table D.1

Description of Drinking Water Quality Monitoring Stations Outside and Inside the Port Area of JNPT

Sr. No.	Stations	Locations
Outside the Port Area		
1	DW1	Administration building
2	DW2	Secondary school
3	DW3	PUB canteen
4	DW4	Hospital canteen
5	DW5	JNPT Inlet
6	DW9	Sector II
7	DW10	Sector III
8	DW13	CISF canteen
9	DW14	Custom Canteen
10	DW15	Adam guest House
Inside the Port Area		
11	DW6	NSICT Canteen
12	DW7	GTI Canteen
13	DW8	POC canteen
14	DW11	JNPT Workshop
15	DW12	C.T. Canteen
16	DW16	PPD Site Office
17	DW17	GTI -2
18	DW18	GTI CGC



Table D.2 provides the value for each of the parameters sampled at various drinking water quality monitoring stations in the month of February, 2013 and also shows the acceptable standard for various parameters of drinking water as prescribed by Ministry of Urban Development, 1999 (CPHEEO). The results show that all the eighteen samples were colourless and odourless. Conductivity of all the samples was found to be in the range of 52 - 74 $\mu\text{Mhos/cm}$. pH of all eighteen samples was in the range of 7.2 - 7.3 which is within the acceptable limits to the permissible standard of 7.0- 8.5. Concentration of chlorides was 4.0- 7.9 mg/L and was well within the acceptable limit (200 mg/L). TDS of all the eighteen samples was in the range of 61- 92 mg/L and was within the acceptable range (500 mg/L). Hardness of all the eighteen samples was found to be in the range of 21- 58 mg/L as CaCO_3 and was within the acceptable limit (200 mg/L). Concentration of total iron was found to be in the range of 0.02- 0.05 mg/L and was within the acceptable limit (0.1 mg/L). Sulphate content of all the eighteen samples was in the range of 4.0- 5.5 mg/L and was within the acceptable limit of 200 mg/L in drinking water. Concentration of $\text{NH}_4^+\text{-N}$ was in the range of 0.02- 0.04 mg/L. Concentration of $\text{PO}_4^{3-}\text{-P}$ at all the eighteen stations, was found to be in the range of 0.05- 0.11 mg/L. Analysis of the bacteriological parameter showed that all the drinking water samples were safe in terms of bacteriological quality.

The results show that as per ISO: 10500 the water at all the eighteen stations is suitable for drinking purpose.

Table D. 2
Results of Drinking Water Quality Monitoring, 28th February, 2013

Parameters	DW1	DW2	DW3	DW4	DW5	DW6	Standards
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	-
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Unobjectionable
Turbidity (NTU)	0.52	0.59	0.61	0.68	0.62	0.65	1.0
Conductivity [μMhos/cm]	55	61	68	70	74	64	-
pH	7.2	7.2	7.3	7.3	7.3	7.3	7.0 to 8.5
Chlorides (mg/l)	5.2	6.1	6.3	7.1	7.5	7.2	200
TDS (mg/l)	78	91	62	69	92	61	500
Total Hardness (mg/l as CaCO ₃)	37	21	29	34	31	30	200
Iron (mg/l)	0.03	0.04	0.02	0.03	0.04	0.05	0.1
Sulphate (mg/l)	5.1	5.4	4	4.8	4.1	4.9	200
NH ₄ ⁺ -N (mg/l)	0.03	0.03	0.04	0.02	0.02	0.03	-----
PO ₄ ³⁻ -P (mg/l)	0.07	0.08	0.05	0.1	0.09	0.08	-----
CFU (Per 100 ml)	Nil	Nil	Nil	Nil	Nil	Nil	Nil

: Below Detection Limit, *Ref: Manual on Water supply and Treatment- (CPHEEO), Ministry of Urban Development, 1999.

Results of Drinking Water Quality Monitoring, 28th February, 2013

Parameters	DW7	DW8	DW9	DW10	DW11	DW12	*Standards
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	-
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Unobjectionable
Turbidity (NTU)	0.51	0.50	0.57	0.54	0.64	0.61	1
Conductivity [μ Mhos/cm]	59	52	55	71	67	63	-
pH	7.2	7.2	7.3	7.2	7.3	7.2	7.0 to 8.5
Chlorides (mg/l)	6.9	6.4	7.9	4.4	5.7	4	200
TDS (mg/l)	78	81	89	85	90	86	500
Total Hardness (mg/l as CaCO_3)	47	49	58	41	48	45	200
Iron (mg/l)	0.04	0.03	0.04	0.03	0.02	0.04	0.1
Sulphate (mg/l)	4.4	4.7	5.2	5.4	5.5	4.7	200
$\text{NH}_4^+ \text{-N}$ (mg/l)	0.03	0.04	0.02	0.03	0.02	0.03	----
$\text{PO}_4^{3-} \text{-P}$ (mg/l)	0.07	0.06	0.11	0.06	0.08	0.09	-----
CFU (Per 100 ml)	Nil	Nil	Nil	Nil	Nil	Nil	Nil

: Below Detection Limit, *Ref: Manual on Water supply and Treatment- (CPHEO), Ministry of Urban Development, 1999.

Results of Drinking Water Quality Monitoring, 28th February, 2013

Parameters	DW13	DW14	DW15	DW16	DW17	DW18	*Standards
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	-
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Unobjectionable
Turbidity (NTU)	0.58	0.59	0.55	0.56	0.62	0.67	1
Conductivity [μMhos/cm]	55	73	64	69	62	59	-
pH	7.2	7.3	7.2	7.2	7.2	7.2	7.0 to 8.5
Chlorides (mg/l)	5.8	6.3	5.8	6.1	7.2	7.7	200
TDS (mg/l)	80	77	84	88	83	74	500
Total Hardness (mg/l as CaCO ₃)	51	55	22	27	31	34	200
Iron (mg/l)	0.03	0.02	0.02	0.02	0.02	0.02	0.1
Sulphate (mg/l)	4.9	5.3	4	4.7	4.3	5.1	200
NH ₄ ⁺ -N (mg/l)	0.03	0.02	0.04	0.03	0.03	0.02	----
PO ₄ ⁻³ -P (mg/l)	0.05	0.08	0.09	0.07	0.06	0.05	-----
CFU (Per 100 ml)	Nil	Nil	Nil	Nil	Nil	Nil	Nil

: Below Detection Limit, *Ref: Manual on Water supply and Treatment- (CPHEO), Ministry of Urban Development, 1999.