



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 March, 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 March, 2013 respectively. Table A.5 shows results of air pollutant concentration at Elephanta Island during 25th to 26th March, 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	March, 2013	Minimum	March, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		
TSP	175	1 st to 2 nd	145	11 th to 12 th	200
PM ₁₀	82	1 st to 2 nd	56	11 th to 12 th	100
NO _x	20.3	5 th to 6 th	10.7	1 st to 2 nd & 11 th to 12 th	80
SO ₂	4.3	5 th to 6 th	1.1	18 th to 19 th	80
NH ₃	48.3	25 th to 26 th	22.7	21 st to 22 nd	400
CO	1.71 mg/m ³	18 th to 19 th	1.58mg/m ³	5 th to 6 th	2mg/m ³
CO ₂	305 ppm	11 th to 12 th	302 ppm	8 th to 9 th	-

The values for TSP and PM₁₀ were below the prescribed limit during whole sampling period in the month of March, 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	March, 2013	Minimum	March, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	385	14 th to 15 th	264	25 th to 26 th	200
PM₁₀	162	5 th to 6 th	135	25 th to 26 th	100
NO_x	28.5	14 th to 15 th	16.7	25 th to 26 th	80
SO₂	5.7	25 th to 26 th	1.3	21 st to 22 nd	80
NH₃	64.1	8 th to 9 th	26.0	25 th to 26 th	400
CO	1.79	5 th to 6 th	1.61	11 th to 12 th & 25 th to 26 th	2mg/m ³
CO₂	313	8 th to 9 th	305	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 March, 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	March, 2013	Minimum	March, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	190	28 th to 29 th	169	14 th to 15 th	200
PM₁₀	92	28 th to 29 th	70	14 th to 15 th	100
NO_x	25.1	15 th to 16 th	9.8	21 st to 22 nd	80
SO₂	5.3	11 th to 12 th	1.2	25 th to 26 th	80
NH₃	44.2	18 th to 19 th	21.3	14 th to 15 th	400
CO	1.82	25 th to 26 th	1.63	14 th to 15 th	2mg/m ³
CO₂	314	8 th to 9 th	304	18 th to 19 th	-

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



Table A.5 provides the results of the air quality parameters at Elephanta Island station during 25th to 26th March, 2013. The concentration of TSP and PM₁₀ was found to be 80µg/m³ and 56µg/m³ respectively. The concentration range of NO_x, SO₂, NH₃, CO & CO₂ was found to be in the range of 5.6 to 6.4µg/m³, 1.3 to 2.6µg/m³, 20.3µg/m³ to 25.3 µg/m³, 1.64 mg/m³ to 1.69 mg/m³ and 303 ppm to 305 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 March, 2013.

Table A.5

**Results of Air Pollutant Concentration at Elephanta Island During
25th to 26th March, 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	21/03/13	2:00-8:00	80	56	6.0	1.3	21.3	1.64	303
	22/03/13	8:10-6:10			5.6	2.6	20.3	1.67	304
	22/03/13	6:15-2:15			6.4	1.3	25.3	1.69	305

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 March, 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	311± 32	152± 10	21.1± 3.3	4.2± 1.0	43.8± 10.7	1.69± 0.05
POC	178± 7	79± 7	15± 3.4	2.6± 1.0	31.3± 6.1	1.74± 0.06
Residential and Rural Areas						
NAAQ STDS.	200	100	80	80	400	2.0
RC	160±10	68±8	14.6±3.2	2.7±0.9	35.7±6.9	1.65±0.04
Sensitive Areas						
NAAQ STDS.	100	100	80	80	400	2.0
EC	80	56	6.0	1.7	22.3	1.67

Values as mean ± std deviation

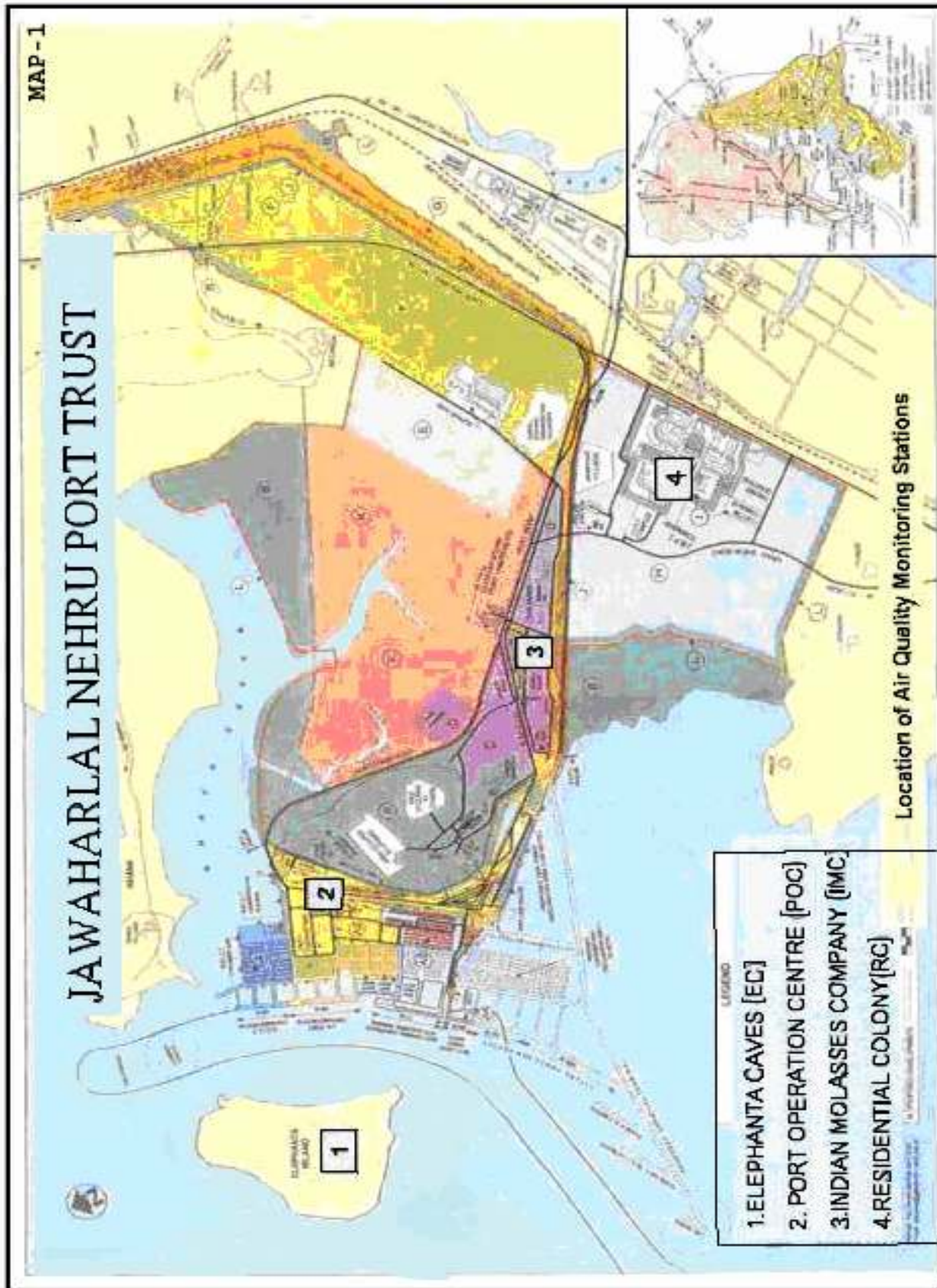




Table A.7
Results of Air Pollutant Concentration at RC Station of JNP Area during the Month of March, 2013

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	01/03/13	03:30-11:30	175	82	18.6	14.8	2.6	3.0	40.8	35.2	1.62	303
		02/03/13	11:30-07:30			15.2		3.8		33.1		1.68	
		02/03/13	07:30-03:30			10.7		2.5		31.6		1.59	
2	RC-II	05/03/13	03:30-11:30	170	79	20.2	18.3	2.6	3.2	42.2	35.9	1.61	304
		06/03/13	11:30-07:30			20.3		4.3		33.1		1.58	
		06/03/13	07:30-03:30			14.4		2.8		32.3		1.70	
3	RC-III	08/03/13	03:30-11:30	164	69	14.2	15.3	2.9	2.2	43.7	39.4	1.65	305
		09/03/13	11:30-07:30			18.3		1.3		38.6		1.62	
		09/03/13	07:30-03:30			13.4		2.6		35.9		1.63	
4	RC-IV	11/03/13	03:30-11:30	145	56	13.2	11.8	2.6	2.6	32.3	32.8	1.68	302
		12/03/13	11:30-07:30			11.3		4.0		36.1		1.69	
		12/03/13	07:30-03:30			10.7		1.3		30.1		1.70	
5	RC-V	14/03/13	03:30-11:30	167	70	14.4	13.0	2.8	2.3	43.4	35.4	1.66	304
		15/03/13	11:30-07:30			12.2		2.8		29.3		1.67	
		15/03/13	07:30-03:30			12.5		1.3		33.5		1.62	
6	RC-VI	18/03/13	03:30-11:30	157	68	20.1	18.5	2.5	1.7	31.6	37.7	1.71	303
		19/03/13	11:30-07:30			19.9		1.1		47.8		1.59	
		19/03/13	07:30-03:30			15.5		1.3		33.8		1.68	
7	RC-VII	21/03/13	03:30-11:30	150	62	12.8	11.8	3.8	3.3	30.9	25.8	1.62	304
		22/03/13	11:30-07:30			10.8		3.5		23.8		1.63	
		22/03/13	07:30-03:30			11.8		2.6		22.7		1.67	
8	RC-VIII	25/03/13	03:30-11:30	155	63	13.2	13.1	2.6	3.1	46.0	43.2	1.60	303
		26/03/13	11:30-07:30			13.2		2.8		48.3		1.69	
		26/03/13	07:30-03:30			12.7		3.8		35.5		1.70	
9	RC-IX	28/03/13	03:30-11:30	160	65	14.6	13.7	3.9	2.7	28.1	33.1	1.64	304
		29/03/13	11:30-07:30			15.1		2.9		40.1		1.69	
		29/03/13	07:30-03:30			11.3		1.4		31.0		1.70	



Table A.8
Results of Air Pollutant Concentration at IMC Station of JNP Area during the Month of March, 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
STANDARD				200 $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$	8 hr 24 hr Avg $\mu\text{g}/\text{m}^3$	8 hr 24 hr Avg $\mu\text{g}/\text{m}^3$	8 hr 24 hr Avg $\mu\text{g}/\text{m}^3$	2.0 mg/m ³	-
1	IMC-I	01/03/13	03:00-11:00			19.3	3.9	59.6	1.65	309
		02/03/13	11:00-07:00	300	156	25.5	4.3	42.7	1.69	
		02/03/13	07:00-03:00			19.3	2.5	45.0	1.70	
2	IMC-II	05/03/13	03:00-11:00			21.4	5.2	42.6	1.77	311
		06/03/13	11:00-07:00	321	162	18.4	4.3	44.7	1.79	
		06/03/13	07:00-03:00			17.7	5.1	34.7	1.71	
3	IMC-III	08/03/13	03:00-11:00			17.5	3.8	62.1	1.69	313
		09/03/13	11:00-07:00	301	155	21.0	5.6	64.1	1.65	
		09/03/13	07:00-03:00			21.6	4.2	43.0	1.62	
4	IMC-IV	11/03/13	03:00-11:00			21.4	5.2	44.4	1.74	306
		12/03/13	11:00-07:00	299	148	19.1	3.8	31.9	1.61	
		12/03/13	07:00-03:00			17.2	5.0	29.2	1.62	
5	IMC-V	14/03/13	03:00-11:00			27.5	3.8	41.4	1.69	308
		15/03/13	11:00-07:00	285	136	25.9	2.8	48.3	1.67	
		15/03/13	07:00-03:00			28.5	5.1	35.9	1.64	
6	IMC-VI	18/03/13	03:00-11:00			21.2	3.8	46.4	1.66	305
		19/03/13	11:00-07:00	304	156	21.3	5.1	58.3	1.72	
		19/03/13	07:00-03:00			24.7	3.9	52.4	1.76	
7	IMC-VII	21/03/13	03:00-11:00			23.4	1.3	49.1	1.77	307
		22/03/13	11:00-07:00	318	160	21.6	3.8	34.5	1.73	
		22/03/13	07:00-03:00			20.5	4.6	29.8	1.70	
8	IMC-VIII	25/03/13	03:00-11:00			18.3	5.7	33.4	1.61	312
		26/03/13	11:00-07:00	264	135	17.2	3.8	26.0	1.63	
		26/03/13	07:00-03:00			16.7	4.2	33.2	1.67	
8	IMC-IX	28/03/13	03:00-11:00			18.8	2.3	44.7	1.69	308
		29/03/13	11:00-07:00	310	159	21.5	5.2	50.7	1.67	
		29/03/13	07:00-03:00			20.1	4.3	55.2	1.62	



Table A.9
Results of Air Pollutant Concentration at POC Station of JNP Area during the Month of March, 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	01/03/13	02:30-10:30			20.7		1.3		35.5		1.67	
		02/03/13	10:30-06:30	175	78	17.0	17.1	2.6	2.0	32.0	33.3	1.68	307
		02/03/13	06:30-02:30			13.6		2.3		32.4		1.70	
2	POC-II	05/03/13	02:30-10:30			17.0		2.9		30.7		1.80	
		06/03/13	10:30-06:30	182	85	25.1	18.4	2.8	3.2	35.9	34.3	1.81	309
		06/03/13	06:30-02:30			13.1		3.8		36.5		1.79	
3	POC-III	08/03/13	02:30-10:30			15.1		2.3		28.7		1.77	
		09/03/13	10:30-06:30	173	76	14.6	15.2	1.3	2.0	30.1	32.6	1.72	314
		09/03/13	06:30-02:30			15.7		2.3		38.9		1.78	
4	POC-IV	11/03/13	02:30-10:30			17.2		2.5		27.3		1.74	
		12/03/13	10:30-06:30	170	72	16.7	16.1	5.3	3.4	26.9	28.8	1.71	311
		12/03/13	06:30-02:30			14.5		2.6		32.3		1.64	
5	POC-V	14/03/13	02:30-10:30			14.6		3.8		22.3		1.68	
		15/03/13	10:30-06:30	169	70	11.9	14.6	2.6	3.0	21.4	21.7	1.63	308
		15/03/13	06:30-02:30			17.3		2.6		21.3		1.63	
6	POC-VI	18/03/13	02:30-10:30			15.2		3.8		44.2		1.67	
		19/03/13	10:30-06:30	175	77	11.0	13.3	2.8	3.1	40.5	39.0	1.72	304
		19/03/13	06:30-02:30			13.6		2.8		32.3		1.80	
7	POC-VII	21/03/13	02:30-10:30			9.8		2.3		35.1		1.74	
		22/03/13	10:30-06:30	180	84	11.4	11.4	2.6	2.9	32.3	33.0	1.79	310
		22/03/13	06:30-02:30			12.9		3.8		31.7		1.75	
8	POC-VIII	25/03/13	02:30-10:30			13.0		1.2		30.7		1.82	
		26/03/13	10:30-06:30	185	88	18.8	14.2	1.3	1.3	22.1	25.8	1.81	305
		26/03/13	06:30-02:30			10.8		1.4		24.6		1.80	
8	POC-IX	28/03/13	02:30-10:30			12.5		3.8		35.9		1.74	
		29/03/13	10:30-06:30	190	92	10.9	11.6	5.1	4.5	34.7	33.6	1.76	313
		29/03/13	06:30-02:30			11.4		2.9		30.1		1.77	



1.4 Conclusions and Mitigations Measures

Table A.6 shows the overall average values of TSP, PM₁₀ and all gaseous pollutants at RC and POC station were found to be below the permissible standard in the month of March, 2013. Whereas at IMC station the values of TSP were found to be higher than the permissible limit during whole month of March, 2013. CPCB standards for ambient air quality for different areas are given in Table A. 6. All pollutants were found within prescribed limits at EC station for March, 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 March, 2013 in JN Port respectively.

1.8a Wind speed:

The monthly average wind speed for March, 2013 was found to be 2.04 m/s. The maximum hourly average wind speed recorded was 5.1 m/s at 15:00 hrs on 29th March, 2013. As compared to the previous month (February, 2013) lower 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 1.1 to 2.8 m/s. 13.17 % of the total observations (745 observations) recorded by the met instrument for the month of March, 2013 was less than 0.5 m/s, which represents calm period.

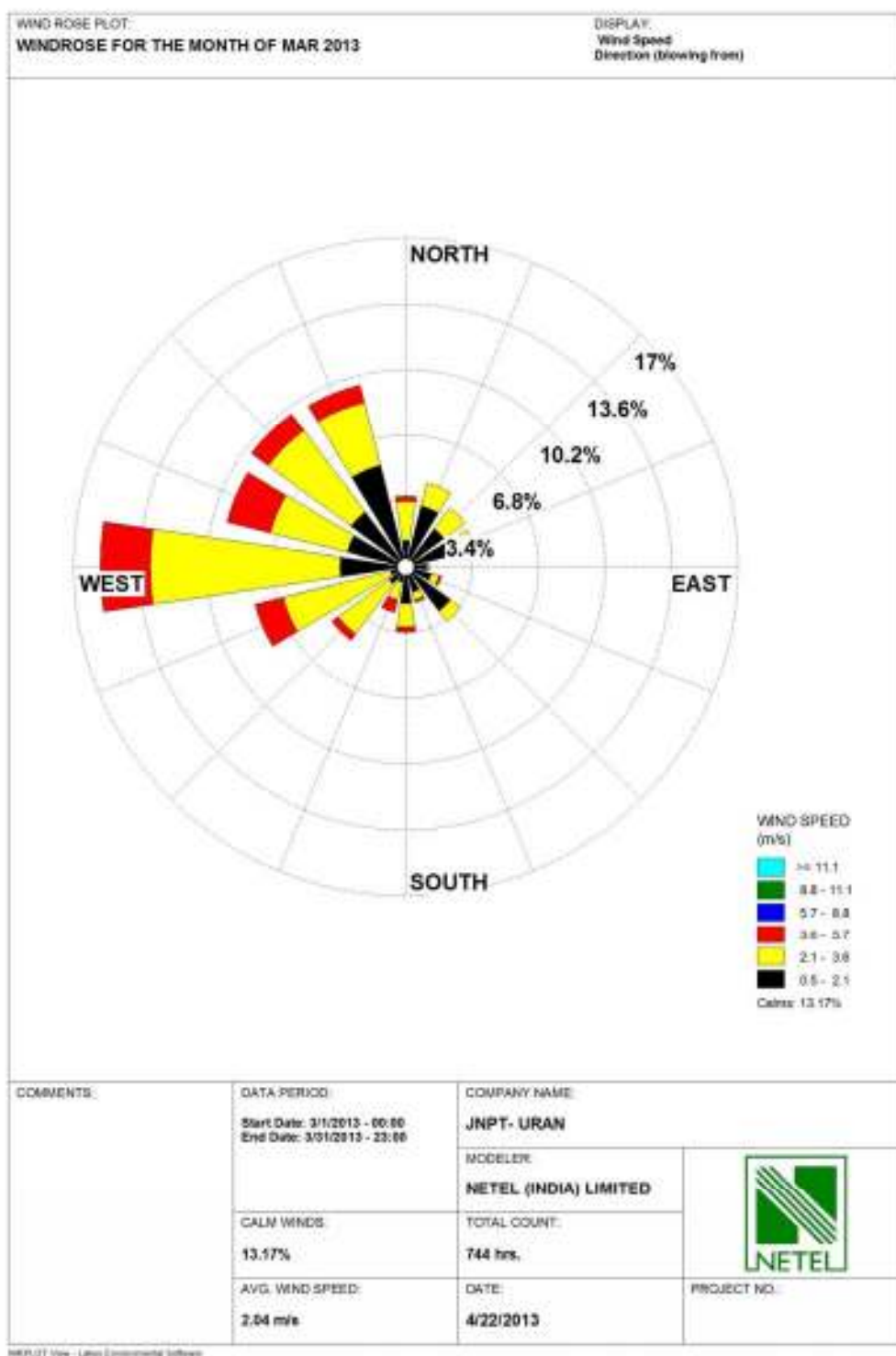
1.8b Wind direction:

The prominent wind direction was from West (W) followed by North West (NW) at the JN Port for the month of March, 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 March, 2013 is given in Figure 1.

1.8c Temperature:

The maximum daily average temperature 30.9 °C was obtained on 7th March, 2013 and minimum daily average temperature 25.6 °C was obtained on 13th March, 2013. The maximum and minimum hourly average temperature recorded was 41.4 °C at 13:00 hrs on 1st March, 2013. The monthly average temperature for March, 2013 was calculated as 28.1 ± 1.4 °C.

Figure 1
Wind Rose for the month of March, 2013





1.8d Relative Humidity:

The monthly average relative humidity was found to be 56.7 ± 13.1 %. Relative humidity is the measure of water vapour in the atmosphere. Maximum daily average relative humidity was obtained as 72.1 % on 17th March, 2013 and minimum daily average relative humidity was obtained as 33.5 % on 4th March, 2013. The minimum value of hourly average relative humidity 15.5 % was observed on 3rd March, 2013 at 14:00 hrs whereas, maximum value of 93.4 % recorded on 19th March, 2013 at 8:00 hrs.

Table A.11

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

Sr. No.	Date	Average Wind Speed (m/s)	Average Temperature (°C)	Average Relative Humidity (%)	Average Solar Radiation (W/m ²)
1	01/3/13	1.5	29.2	45.7	305.3
2	02/3/13	1.8	29.5	41.2	255.9
3	03/3/13	1.1	30.0	39.6	270.4
4	04/3/13	1.4	29.5	33.5	267.5
5	05/3/13	1.7	29.4	35.8	270.4
6	06/3/13	1.8	30.2	36.8	261.7
7	07/3/13	1.7	30.9	38.2	261.7
8	08/3/13	1.7	30.3	38.6	282.0
9	09/3/13	1.7	29.6	45.3	261.7
10	10/3/13	2.1	28.7	47.2	250.0
11	11/3/13	2.0	26.8	69.8	273.3
12	12/3/13	2.2	26.7	67.7	290.8
13	13/3/13	1.9	25.6	67.3	223.9
14	14/3/13	2.3	26.0	68.1	305.3
15	15/3/13	2.4	27.8	63.5	267.5



Sr. No.	Date	Average Wind Speed (m/s)	Average Temperature (°C)	Average Relative Humidity (%)	Average Solar Radiation (W/m ²)
16	16/3/13	2.0	27.4	65.9	270.4
17	17/3/13	2.1	26.7	72.1	273.3
18	18/3/13	1.9	27.3	69.4	284.9
19	19/3/13	2.0	28.1	63.1	267.5
20	20/3/13	2.1	28.3	47.8	264.6
21	21/3/13	2.0	27.7	52.2	270.4
22	22/3/13	2.2	27.1	71.2	293.7
23	23/3/13	2.1	27.2	70.0	273.3
24	24/3/13	2.6	27.2	67.1	253.0
25	25/3/13	2.8	28.4	64.4	223.9
26	26/3/13	2.3	27.1	69.2	194.8
27	27/3/13	2.4	26.8	69.5	273.3
28	28/3/13	2.4	27.0	67.3	247.1
29	29/3/13	2.7	27.5	56.1	264.6
30	30/3/13	2.4	27.9	56.4	270.4
31	31/3/13	2.2	28.5	59.0	267.5
Average		2.04	28.1	56.7	265.8



Table A.12

Record of daily rainfall in the month of March, 2013

Sr. No	Date	Rainfall in mm
1	01/3/13	0.0
2	02/3/13	0.0
3	03/3/13	0.0
4	04/3/13	0.0
5	05/3/13	0.0
6	06/3/13	0.0
7	07/3/13	0.0
8	08/3/13	0.0
9	09/3/13	0.0
10	10/3/13	0.0
11	11/3/13	0.0
12	12/3/13	0.0
13	13/3/13	0.0
14	14/3/13	0.0
15	15/3/13	0.0
16	16/3/13	0.0
17	17/3/13	0.0
18	18/3/13	0.0
19	19/3/13	0.0
20	20/3/13	0.0
21	21/3/13	0.0
22	22/3/13	0.0
23	23/3/13	0.0
24	24/3/13	0.0
25	25/3/13	0.0
26	26/3/13	0.0
27	27/3/13	0.0
28	28/3/13	0.0
29	29/3/13	0.0
30	30/3/13	0.0
31	31/3/13	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 March, 2013.

1.8f Solar Radiation:

The maximum hourly average solar radiation was recorded to be 1325.82 W/m^2 at 13:00 hrs on 1st March, 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 $265.8 \pm 22.33 \text{ W/m}^2$. Solar radiation increased from 8.00 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 8.00 AM to 18:00 PM of a day has been taken for analysis. The daily average values of solar radiation ranged from 194.8 W/m^2 to 305.3 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 March, 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 2.04 m/s, 28.1°C , 56.7 %, 265.8 W/m^2 and 0.0 mm respectively. No rainfall was recorded for the month of March, 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 (Harbour Region).

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

Station Name	Location/Landmark	Date of Water Sampling
W1	Near ONGC	25 th March, 2013
W2	Elephanta Jetty	25 th March, 2013
W3	In-between Vessel channel	26 th March, 2013
W4	Near Butcher Island	26 th March, 2013
W5	Near NSICT	25 th March, 2013
W6	JNPT Shallow Berth	25 th March, 2013
W7	Towards Landing Jetty	26 th March, 2013
W8	Near Mora village	26 th March, 2013
W9	Near GTI Warf	26 th March, 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 25th & 26th March, 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- 8.1	6.5-9.0	pH meter	IS 3025 (Part 11)
2	Temperature	28.3- 31.4 °C	-	Thermometer	APHA 2550-B
3	Salinity	30.1- 38.2 ppt	-	Argentometric Titration	IS 3025 (Part 32)
4	Turbidity	48- 181 NTU	-	Nephelometer	IS 3025 (Part 10)
5	TDS	31856- 38980 mg/L	-	Gravimetry	IS 3025 (Part 16)
6	SS	174- 289 mg/L	-	Gravimetry	IS 3025 (Part 16)
7	TS	32030- 39229 mg/L	-	-	-
8	DO	5.4- 6.3 mg/L	3.0 mg/L or 40% of the higher saturation value	DO meter	-
9	COD	67- 170 mg/L	-	Potassium Dichromate	IS 3025 (Part 58)
10	BOD	<5- 5.3 mg/ L	5 mg/L	DO consumption in 5 days at 20°C	IS 3025 (Part 44)
11	NH ₄ ⁺ -N	0.19- 0.54 mg/L	-	Colorimetry	IS 3025 (Part 34)
12	SPC	68- 321 / ml	-	Pour plate	IS 1622 1981
13	Coliform	<2- 6 CFU/100 ml	500/100 ml	Membrane Filtration	IS 1622- 1981
14	Phenol	0.08- 0.31 mg/ L	-	Titrimetric	IS 3025 (Part 43)
15	Oil & Grease	6- 11 mg/ L	10 mg/L	Solvent Extraction	IS 3025 (Part 39)



The maximum concentration of oil and grease (11 mg/L) was found during spring tide of W2 station. The minimum concentration (5 mg/L) was found during neap tide of W3 & W9 stations.

The values of various water quality parameters such as pH, dissolved oxygen, oil and grease, CFU and BOD obtained during the month of March, 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 March, 2013

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	
W1	SS	13.3	30.9	7.5	30.1	99	32568	181	32749
	SM		31.4	7.6	32.1	113	37894	189	38083
	SB		30.9	7.5	33.9	178	36987	207	37194
	NS	13.2	30.4	7.8	34.5	101	35124	213	35337
	NM		30.2	7.9	35.2	132	34894	247	35141
	NB		29.9	7.5	35.9	174	33968	259	34227
	W2	SS	5.2	30.5	7.6	35.1	049	32894	175
SM		30.3		7.9	36.1	097	31856	174	32030
SB		30.2		7.4	37.4	128	32405	289	32694
NS		5.3	29.9	8.0	37.8	048	33698	198	33896
NM			29.7	7.8	38.1	069	35987	201	36188
NB			29.8	7.5	38.2	103	36124	275	36399
W3		SS	10.7	29.8	7.8	37.0	113	38000	279
	SM	29.8		7.6	37.9	145	36457	281	36738
	SB	29.9		7.6	37.4	168	36457	288	36745
	NS	10.3	29.8	7.8	38.0	147	32784	265	33049
	NM		29.8	7.8	30.9	158	38001	174	38175
	NB		29.8	7.9	37.4	181	33596	231	33827
	W4	SS	10.0	30.0	7.5	36.6	058	34784	214
SM		30.2		7.4	38.0	096	36988	209	37197
SB		30.0		8.1	32.3	109	37457	199	37656
NS		9.2	30.0	8.0	33.6	135	35212	184	35396
NM			30.0	7.9	36.4	165	35021	183	35204
NB			30.1	7.5	34.5	172	36894	277	37171
W5		SS	14.3	30.8	7.8	35.9	082	34784	284
	SM	31.1		7.9	31.2	093	33568	208	33776
	SB	30.8		7.5	37.5	117	36457	194	36651
	NS	12.8	30.8	7.6	36.2	122	37485	197	37682
	NM		30.4	7.8	35.2	153	32598	208	32806
	NB		29.8	7.9	38.0	159	31996	248	32244

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	13.0	30.4	7.6	36.5	079	32874	243	33117
	SM		30.1	7.9	31.4	144	33569	201	33770
	SB		29.9	8.1	31.8	153	37154	234	37388
	NS	12.2	30.5	8.0	32.5	121	35698	211	35909
	NM		30.3	7.8	35.3	134	36894	286	37180
	NB		30.1	7.8	33.6	180	37458	248	37706
W7	SS	7.5	29.3	7.9	33.8	055	35986	281	36267
	SM		29.0	7.5	33.1	098	34784	222	35006
	SB		28.9	7.9	32.5	099	38980	249	39229
	NS	7.2	30.2	8.0	35.6	102	32454	268	32722
	NM		29.9	7.9	36.4	128	33289	197	33486
	NB		29.7	7.5	38.0	134	34124	192	34316
W8	SS	8.2	28.4	7.7	37.4	139	37457	206	37663
	SM		28.4	7.8	37.4	125	35987	217	36204
	SB		28.4	7.6	37.9	166	36985	256	37241
	NS	8.5	30.0	7.5	37.1	087	33567	258	33825
	NM		30.0	7.9	35.3	111	32457	224	32681
	NB		29.9	8.0	36.5	139	34578	274	34852
W9	SS	17.8	28.3	8.0	37.4	140	33259	271	33530
	SM		28.4	8.1	36.4	154	34754	258	35012
	SB		28.5	7.7	33.2	180	35845	265	36110
	NS	17.2	30.2	7.9	31.2	101	37654	243	37897
	NM		29.9	7.8	35.6	132	37841	231	38072
	NB		29.9	7.9	36.1	144	36894	204	37098

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 March, 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	6.0	128	<5	0.26	0.21		97	<2
	SM	6.0	141						
	SB	5.7	131						
	NS#						7		
	NS	5.4	125	<5	0.31	0.29		116	<2
	NM	5.4	147						
	NB	5.4	157						
W2	SS#						11*		
	SS	5.9	170	5.3*	0.44	0.12		321	<2
	SM	5.8	163						
	SB	5.9	157						
	NS#						9		
	NS	5.8	134	<5	0.48	0.11		214	6
	NM	5.7	125						
	NB	5.6	074						
W3	SS#						7		
	SS	5.8	067	<5	0.19	0.31		231	<2
	SM	5.9	125						
	SB	5.6	077						
	NS#						6		
	NS	5.6	083	<5	0.51	0.09		168	<2
	NM	5.8	106						
	NB	5.8	099						
W4	SS#						9		
	SS	5.9	150	<5	0.5	0.13		68	<2
	SM	5.7	115						
	SB	5.5	99						
	NS#						8		
	NS	5.6	090	<5	0.23	0.18		102	<2
	NM	5.9	125						
	NB	5.8	122						
W5	SS#						10		
	SS	6.3	118	<5	0.39	0.08		119	<2
	SM	5.9	070						
	SB	5.9	160						
	NS#						8		
	NS	5.4	163	<5	0.54	0.29		127	<2
	NM	5.5	150						
	NB	5.5	122						

(*) 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#						10		
	SS	5.8	131	<5	0.27	0.3		169	4
	SM	5.9	109						
	SB	5.7	106						
	NS#						9		
	NS	5.9	099	<5	0.46	0.27		177	<2
	NM	5.8	141						
W7	NB	5.6	166						
	SS#						10		
	SS	6.0	080	<5	0.41	0.24		241	<2
	SM	5.6	070						
	SB	5.9	093						
	NS#						8		
	NS	5.8	122	<5	0.52	0.26		308	<2
W8	NM	5.7	138						
	NB	5.5	131						
	SS#						7		
	SS	6.0	157	<5	0.38	0.18		289	3
	SM	5.7	141						
	SB	5.7	125						
	NS#						10		
W9	NS	5.8	128	<5	0.29	0.17		311	<2
	NM	5.7	077						
	NB	5.5	083						
	SS#						9		
	SS	6.0	157	<5	0.4	0.26		307	<2
	SM	5.9	122						
	SB	5.7	109						
W9	NS#						6		
	NS	5.9	086	<5	0.24	0.22		247	<2
	NM	5.7	115						
	NB	5.6	074						

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 March, 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	33.1	3.3	19.3	1.9	22.8
	3 rd S	35.6	3.6	21.1	2.1	31.4
	5 th S	40.2	4.0	22.8	2.3	30.9
	1 st N	28.9	2.9	17.9	1.7	45.8
	3 rd N	23.8	2.4	14.2	1.4	43.1
	5 th N	27.6	2.8	16.1	1.6	39.8
W2	1 st S	31.1	3.1	18.1	1.8	37.5
	3 rd S	33.2	3.3	18.9	1.9	30.6
	5 th S	36.2	3.6	21.2	2.1	35.4
	1 st N	50.2	5.0	29.3	2.9	20.1
	3 rd N	43.2	4.3	25.4	2.5	42.6
	5 th N	41.1	4.1	23.9	2.4	40.9
W3	1 st S	44.6	4.5	25.7	2.6	22.3
	3 rd S	52.8	5.3	30.7	3.1	28.5
	5 th S	45.1	4.5	26.3	2.6	34.6
	1 st N	50.3	5.0	29.1	2.9	23.4
	3 rd N	60.1	6.0	35.1	3.5	22.1
	5 th N	41.2	4.1	23.8	2.4	41.4
W4	1 st S	52.8	5.3	31.1	3.1	37.6
	3 rd S	52.2	5.2	30.2	3.0	31.2
	5 th S	50.1	5.0	29.3	2.9	46.2
	1 st N	58.9	5.9	33.8	3.4	35.2
	3 rd N	22.3	2.2	13.1	1.3	21.6
	5 th N	55.1	5.5	32.2	3.2	44.8
W5	1 st S	23.7	2.4	14.1	1.4	46.1
	3 rd S	28.7	2.9	16.7	1.7	40.8
	5 th S	31.2	3.1	17.9	1.8	38.5
	1 st N	45.3	4.5	25.7	2.6	32.4
	3 rd N	47.8	4.8	28.2	2.8	36.9
	5 th N	58.6	5.9	33.8	3.4	28
W6	1 st S	47.2	4.7	27.3	2.7	26.6
	3 rd S	48.2	4.8	28.1	2.8	41.5
	5 th S	35.6	3.6	21.1	2.1	37.6
	1 st N	34.2	3.4	20.2	2.0	32.5
	3 rd N	45.1	4.5	26.3	2.6	32.2
	5 th N	43.2	4.3	24.7	2.5	35.9

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	28.3	2.8	15.8	1.6	39.3
	3 rd S	42.8	4.3	24.9	2.5	31.7
	5 th S	47.1	4.7	27.3	2.7	42.6
	1 st N	22.3	2.2	12.8	1.3	44.8
	3 rd N	33.4	3.3	19.2	1.9	41.2
	5 th N	27.7	2.8	16.2	1.6	35.6
W8	1 st S	47.8	4.8	28.3	2.8	39.7
	3 rd S	54.9	5.5	32.4	3.2	31.6
	5 th S	58.9	5.9	34.1	3.4	30.6
	1 st N	31.1	3.1	17.8	1.8	33.2
	3 rd N	28.2	2.8	16.2	1.6	42.6
	5 th N	43.3	4.3	25.4	2.5	46.1
W9	1 st S	35.9	3.6	20.7	2.1	25.6
	3 rd S	40.1	4.0	22.9	2.3	28.4
	5 th S	50.3	5.0	29.3	2.9	29.6
	1 st N	47.3	4.7	27.1	2.7	23.5
	3 rd N	33.2	3.3	19.3	1.9	28.6
	5 th N	41.3	4.1	24.1	2.4	42.1

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 March, 2013. The organic matter, total carbon content and inorganic phosphate in the sediment samples collected during the month of March, 2013 were found to be in the range of 2.2- 6.0 %, 1.3- 3.5 %, and 20.1- 46.2 $\mu\text{g/g}$.

2.1.3 CONCLUSIONS

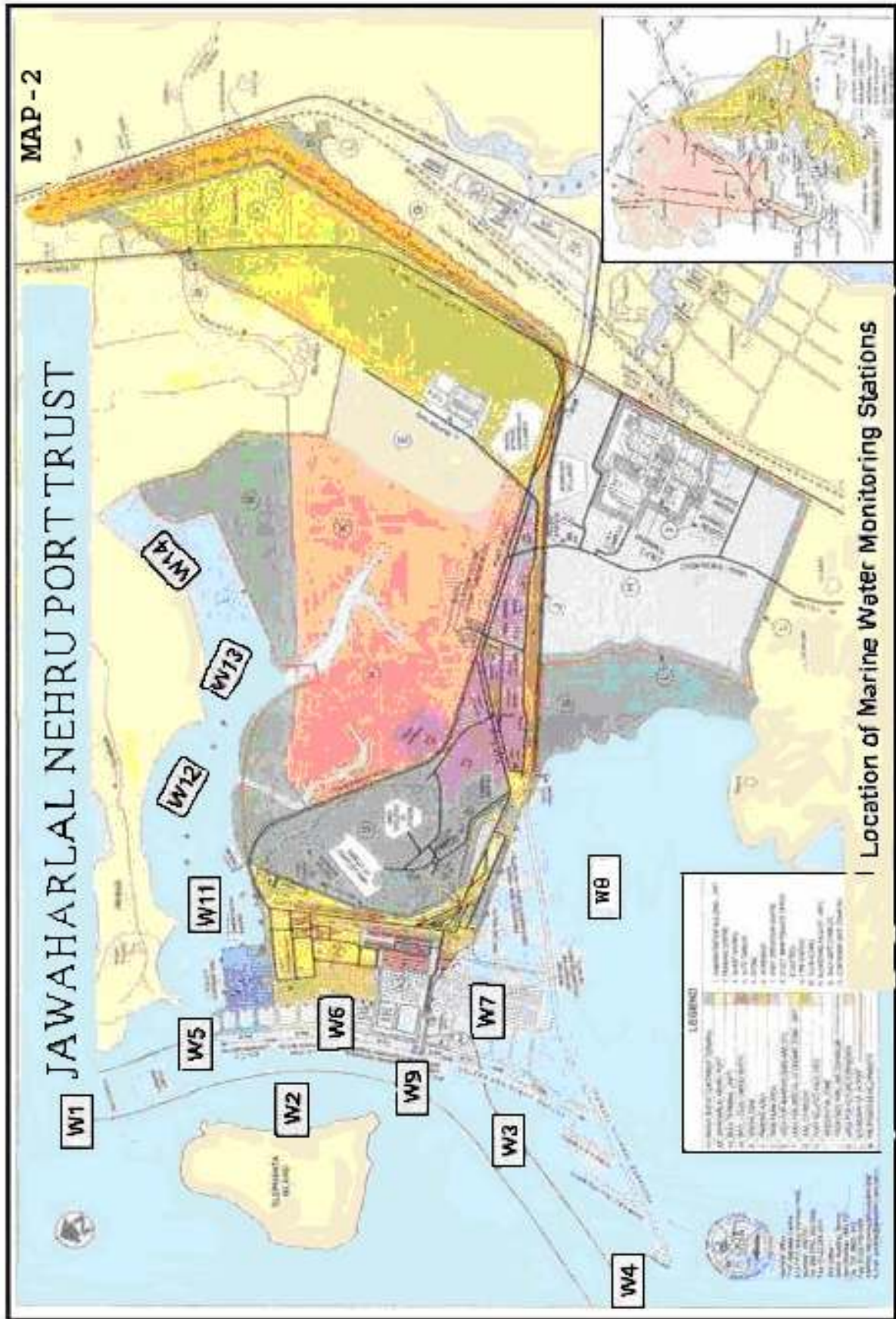
Definite correlation between turbidity and suspended solids could not be established. This could be due to presence of fine sediments in suspension also since turbidity depends upon the particle size and the refractive properties of the particles.

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 March, 2013

Sr. No.	Parameter	Criteria	Observation (above/below) standard	Reasons	Mitigation measures
1	pH range	6.5 - 9.0	7.4- 8.1	-	-
2	Dissolved Oxygen	3.0 mg/L or 40 % of the saturation value, whichever is higher	5.4- 6.3 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	6- 11 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 – 6 CFU /100 ml	-	-
6	Biochemical Oxygen Demand	5 mg/L	<5- 5.3 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	24th March, 2013
W12	Near Nhava Village	24th March, 2013
W13	Opposite North Gate	24th March, 2013
W14	Towards end of the Creek	24th March, 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 March, 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- 8.2	6.5-9.0	pH meter	IS 3025 (Part 11)
2	Temperature	29.2- 31.2 °C	-	Thermometer	APHA 2550-B
3	Salinity	33.4- 38.2 ppt	-	Argentometric Titration	IS 3025 (Part 32)
4	Turbidity	97- 228 NTU	-	Nephelometer	IS 3025 (Part 10)
5	TDS	33569- 39000 mg/L	-	Gravimetry	IS 3025 (Part 16)
6	SS	239- 316 mg/L	-	Gravimetry	IS 3025 (Part 16)
7	TS	33875- 39247 mg/L	-	-	-
8	DO	5.0- 6.4mg/L	3.0 mg/L or 40% of the saturation value, whichever is higher	DO meter	-
9	COD	70- 163 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 ^o C	IS 3025 (Part 44)
11	NH ₄ ⁺ -N	0.22- 0.48 mg/L	-	Colorimetry	IS 3025 (Part 34)
12	SPC	210- 321 / ml	-	Pour plate	IS 1622 1981
13	Coliform	<2- 7 CFU/ 100 ml	500 per 100 ml	Membrane Filtration	IS 1622 1981
14	Phenol	0.08- 0.34 mg/ L	-	Titrimetric	IS 3025 (Part 43)
15	Oil and Grease	7- 11 mg/L	10 mg/L	Solvent Extraction	IS 3025 (Part 39)

The maximum concentration of oil and grease (11 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 March, 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 W12 & W14 stations. 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 March, 2013

Sample Name		Depth (m)	Temp. (°C)	pH	Salinity (ppth)	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	4.5	30.9	8.0	34.7	103	34214	284	34498
	SM		30.8	7.9	36.9	119	34857	296	35153
	SB		30.6	7.8	37.5	142	35297	277	35574
	NS	2.3	31.2	7.6	38.1	152	33569	306	33875
	NM		31.0	7.9	37.5	122	36894	312	37206
NB	30.9		8.1	36.2	163	36124	315	36439	
W12									
	SS	3.0	30.1	8.1	33.4	106	37458	301	37759
	SM		29.5	8.0	33.7	097	38564	268	38832
	SB		29.4	7.7	33.9	174	39000	247	39247
	NS	2.0	30.4	7.8	34.1	099	38451	239	38690
	NM		30.3	8.2	36.5	107	34897	258	35155
NB	30.1		7.9	35.9	133	35987	255	36242	
W13									
	SS	3.5	29.6	7.5	35.2	127	35986	269	36255
	SM		30.1	7.6	35.7	154	36454	298	36752
	SB		29.2	7.8	36.6	186	37457	278	37735
	NS	2.0	30.8	7.9	35.5	114	38451	248	38699
	NM		30.4	7.9	36.8	165	34564	261	34825
NB	30.1		7.8	37.4	199	35120	260	35380	
W14									
	SS	3.0	29.6	7.7	38.2	145	35784	312	36096
	SM		29.4	7.5	35.2	228	38546	300	38846
	SB		29.2	8.1	36.0	220	37984	304	38288
	NS	2.0	30.2	8.0	34.4	109	37458	308	37766
	NM		30.0	7.8	35.8	117	35894	316	36210
NB	29.8		8.1	35.1	216	36451	307	36758	

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 March, 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	6.4	150	<5	0.38	0.09	210	<2
	SM	5.5	106					
	SB	5.3	163					
	NS#					8		
	NS	5.5	122	<5	0.48	0.16	256	5
	NM	5.9	118					
	NB	5.6	083					
W12	SS#					11*		
	SS	5.3	070	<5	0.29	0.27	213	<2
	SM	5.0	074					
	SB	5.1	099					
	NS#					10		
	NS	5.4	106	5.2*	0.41	0.08	275	<2
	NM	5.5	134					
	NB	5.6	150					
W13	SS#					8		
	SS	5.4	115	<5	0.22	0.31	318	<2
	SM	5.2	131					
	SB	5.1	074					
	NS#					9		
	NS	5.8	141	<5	0.47	0.34	312	7
	NM	6.0	115					
	NB	5.9	109					
W14	SS#					10		
	SS	5.8	080	<5	0.32	0.33	321	<2
	SM	5.8	090					
	SB	5.8	106					
	NS#					7		
	NS	5.5	102	5.2*	0.26	0.24	271	<2
	NM	5.7	147					
	NB	5.8	163					

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 March, 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	35.8	3.6	21.2	2.1	38.6
	N	50.2	5.0	28.9	2.9	26.3
W12	S	29.3	2.9	17.2	1.7	19.3
	N	41.1	4.1	24.1	2.4	34.6
W13	S	45.4	4.5	25.9	2.6	51.0
	N	30.9	3.1	18.2	1.8	53.1
W14	S	52.7	5.3	31.1	3.1	52.6
	N	48.2	4.8	28.4	2.8	32.1

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 March, 2013. The organic matter, total carbon content and inorganic phosphate in the sediment samples collected during the month of March, 2013 were found to be in the range of 2.9- 5.3 %, 1.7- 3.1 % and 19.3- 53.1 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 March, 2013

Sr. No.	Parameter	Criteria	Observation (above/below) standard	Reasons	Mitigation measures
1	pH range	6.5 - 9.0	7.5- 8.2	-	-
2	Dissolved Oxygen	3.0 mg/L or 40 % of the saturation value, whichever is higher	5.0- 6.4 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- 11 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- 7 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 W12 & 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.

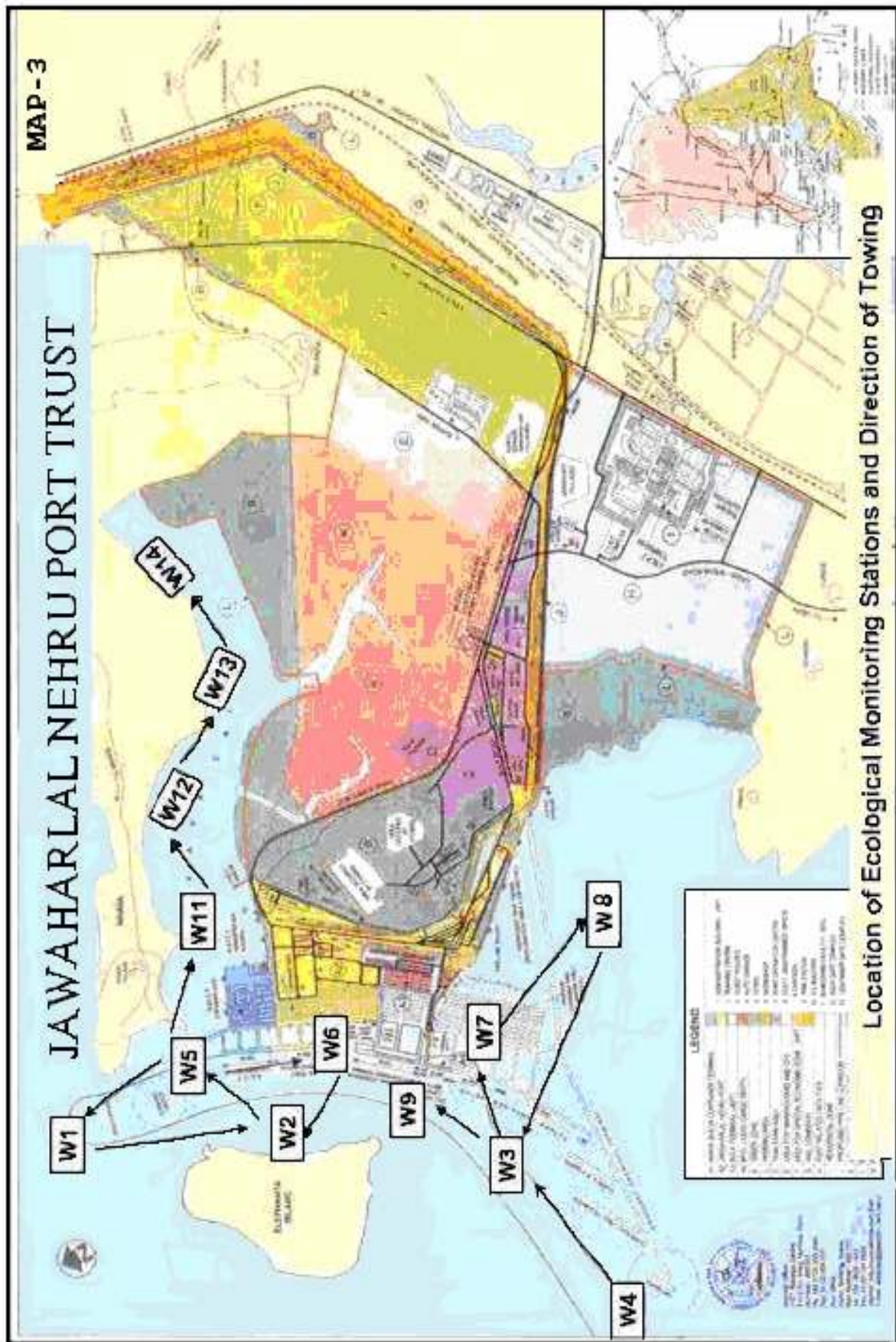
3.3. Materials and methods

The monitoring of marine environment for the study of biological and ecological parameters was done on 24th March-2013 in Nhava Creek regions of JNP and 25th and 26th March-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, W8 and W9) 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 (StandardMethods,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 225-375 mgC/m³/day with an average of 275 mgC/m³/day. minimum value (225 mgC/m³/day) was found at W2,W6,W8 and W9 stations and maximum value of (375 mgC/m³/day) was found at W4 station during monitoring period. In Nhava creek the net primary productivity was found to be in the range of 225- 450 mgC/m³/ day with an average of 319 mgC/m³/day. Minimum value (225 mgC/ m³/ day) was found at W11 and W14 stations and maximum value of (450 mgC/ m³/ day) was found at W13 stations during monitoring period as indicated in Table E.1. The light penetration measured by Secchi disc was found to be 0.5-1.5 feet, at JNP Harbour and Creek regions 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	960	1200	450	800	300
2	W2	480	800	300	600	225
3	W3	960	1200	450	800	300
4	W4	480	1200	450	1000	375
5	W5	480	1000	375	800	300
6	W6	960	1000	375	600	225
7	W7	480	1000	375	800	300
8	W8	1440	1200	450	600	225
9	W9	1440	1200	450	600	225
Average		853	1089	408	733	275
NHAVA CREEK						
10	W11	960	1000	375	600	225
11	W12	480	1200	450	1000	375
12	W13	960	1600	600	1200	450
13	W14	960	1000	375	600	225
Average		840	1200	450	850	319



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 419×10^3 no's/L with minimum (327×10^3 no's/L) at W2 station and maximum (530×10^3 no's/L) at W8 station. In Nhava Creek the average phytoplankton density was found to be 476×10^3 no's/L with minimum (433×10^3 no's/L) at W12 and maximum (533×10^3 no's/L) at W13 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, $4\text{-}10 \text{ mg/m}^3$ 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 $1.0\text{--}3.2 \text{ mg/m}^3$ with an average of 2.0 mg/m^3 . The minimum concentration of chlorophyll-a (1.0 mg/m^3) was found at W6 station and maximum value (3.2 mg/m^3) was found at W8 station as indicated in Table E4. In Nhava Creek the range of chlorophyll-a was found between $1.9\text{--}2.4 \text{ mg/m}^3$ with an average of 2.1 mg/m^3 . Pheophytin-a is the main degradation product of chlorophyll-a and in harbour region it was found below



detectable limit (BDL) to 2.0 mg/m³ with an average of 0.9 mg/m³ and in creek region it was found between 1.2-1.7 mg/m³ with an average of 1.4 mg/m³ during monitoring period..

The algal 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 64- 215 mg/m³. The minimum algal biomass was (64 mg/m³) found at W6 station and maximum (215 mg/m³) was found at W8 station and average value of phytoplankton standing crop (Biomass) in JNP harbour water was found 136 mg/m³. In Nhava Creek it was found between 129- 162 mg/m³ with an average of 144 mg/m³ during monitoring period. The minimum algal biomass was 129mg/m³ at W11 and maximum (162 mg/m³) was found at W13 station.

Table E. 2.
Population Density of Phytoplankton

Sr.No.	Station	Density (no's / L)
JNP HARBOUR AREA		
1	W1	330 x 10 ³
2	W2	327 x10 ³
3	W3	420 x 10 ³
4	W4	400 x 10 ³
5	W5	380 x10 ³
6	W6	403 x10 ³
7	W7	520 x 10 ³
8	W8	530 x 10 ³
9	W9	463 x 10 ³
Average		419 x 10³
NHAVA CREEK		
10	W11	453 x 10 ³
11	W12	433 x 10 ³
12	W13	533 x 10 ³
13	W14	483 x 10 ³
Average		476 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	W8	W9	Avg	W11	W12	W13	W14	Avg
1	Cyclotella spp.	2.0	2.0	0.8	1.7	2.6	2.5	1.9	1.3	1.4	1.8	W11	W12	W13	W14	Avg
2	Gyrosigma spp	1.0	2.0	2.4	0.8	-	1.7	1.9	1.9	1.4	1.5	-	3.1	1.9	2.1	1.8
3	Navicula spp	2.0	1.0	2.4	0.8	3.5	1.7	1.9	2.5	2.2	2.0	0.7	2.3	1.9	2.1	1.8
4	Skeletonema spp	82.8	81.5	83.3	91.7	83.3	84.4	1.9	84.9	86.4	75.6	1.5	2.3	1.9	1.4	1.8
5	Nitzschia spp	3.0	1.0	0.8	1.7	2.6	2.5	87.2	1.9	2.2	11.4	91.2	86.2	83.8	87.0	87.1
6	Rhodomonas spp	1.0	-	0.8	-	0.9	0.8	-	-	0.7	0.5	2.2	2.3	2.5	2.1	2.3
7	Thalassiosira spp.	8.1	8.2	9.5	3.3	5.3	6.6	5.1	7.5	5.8	6.6	-	0.8	0.6	-	0.4
8	Ceratium spp.	-	-	-	-	1.8	-	-	-	-	0.2	4.4	3.1	7.5	5.5	5.1
9	Tetrahedron spp	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-



Table E.4.
Photosynthetic Pigments

Sr.No.	Station	Chlorophyll-a (mg/m ³)	Pheophytin- a (mg/m ³)
JNP HARBOUR AREA			
1	W1	1.8	0.7
2	W2	1.6	1.5
3	W3	2.7	BDL
4	W4	2.7	0.2
5	W5	1.5	1.2
6	W6	1.0	2.0
7	W7	2.2	0.9
8	W8	3.2	BDL
9	W9	1.5	1.5
Average		2.0	0.9
NHAVA CREEK			
10	W11	1.9	1.7
11	W12	2.1	1.3
12	W13	2.4	1.2
13	W14	2.1	1.3
Average		2.1	1.4

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	122
2	W2	107
3	W3	182
4	W4	182
5	W5	101
6	W6	64
7	W7	150
8	W8	215
9	W9	101
Average		136
NHAVA CREEK		
10	W11	129
11	W12	142
12	W13	162
13	W14	142
Average		144

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 42- 87 no's/m³. The minimum population density of zooplankton (42 no's/m³) was found at towing between stations W3→W9 and maximum of 87 no's/m³ was found in between stations W6→W2 stations. The average population density of zooplankton in JNP harbour water was 65 no's/m³. In



Nhava creek population density of zooplankton was found in the range of 53- 88 no's/m³ with an average of 76 no's/m³. The minimum density of zooplankton in creek water was 53 no's/m³ found at towing between stations W5→W11 and maximum of 88 no's/m³ at towing between stations W13→W14. 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 0.40- 0.59 with an average of 0.51 and in Nhava creek it was found between 0.34 – 0.59 with an average of 0.46 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, 87.9% of the total communities of JNP harbour water and 88.3 % 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 0.7 µg/L recorded between towing area of stations W4→W3, W3→W7 and W7→W8 stations and maximum was 1.5 µg/L recorded between towing area of W3→W9 station. The average ash free zooplankton biomass of JNP harbour water was 1.2 µg/L. In Nhava creek the minimum ash free biomass was 0.7 µg /L found between towing area of stations W11→W12 and maximum 1.3 µg /L was found between towing area of stations W5→W11 with an average of 1.0 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 1311- 2067 mg/m³ with an average of 1679 mg/m³. The minimum concentration of POC (1311mg/m³) was found at, W4 and W8 stations and maximum 2067 mg/m³ at W6 station. In Nhava creek the POC content was found to be between 1533- 1656 mg/m³ with an average of 1606 mg/m³. POC content in Nhava creek was found minimum as 1533 mg/m³ at W13 station and maximum at 1656 mg/m³ at W14 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	76	0.46
2	W2 → W5	79	0.44
3	W5 → W1	61	0.55
4	W5 → W6	85	0.56
5	W6 → W2	87	0.40
6	W4 → W3	61	0.48
7	W3 → W7	53	0.50
8	W7 → W8	51	0.57
9	W8 → W3	57	0.55
10	W3 → W9	42	0.59
Average		65	0.51
NHAVA CREEK			
11	W5 → W11	53	0.49
12	W11 → W12	78	0.34
13	W12 → W13	83	0.43
14	W13 → W14	88	0.59
Average		76	0.46



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

Sr. No	Species	PERCENTAGE OF PHYTOPLANKTON															
		JNP HARBOUR AREA										NHAVA CREEK					
		W1 → W2	W2 → W5	W5 → W1	W5 → W6	W6 → W2	W4 → W3	W3 → W7	W7 → W8	W8 → W3	W9 → W3	Avg	W5 → W11	W11 → W12	W12 → W13	W13 → W14	Avg
1	Sagitta	1.5	0.7	1.8	1.3	0.6	-	1.0	1.1	2.0	1.3	1.1	-	0.7	-	0.6	0.3
2	Medusa	2.2	2.1	2.8	1.3	1.9	1.8	2.1	1.1	2.9	3.9	2.2	1.1	1.4	0.7	1.9	1.3
3	Mysids	4.4	3.5	3.7	5.2	3.2	6.4	5.2	7.7	4.9	6.6	5.1	3.2	2.9	5.4	5.7	4.3
4	Copepods	89.8	90.2	87.1	86.3	90.4	88.1	88.5	85.7	87.2	85.5	87.9	88.4	90.0	89.9	84.9	88.3
5	Fish larva	-	-	-	-	-	-	-	-	-	-	-	1.1	-	0.7	-	0.5
6	Zoea larva	2.2	3.5	4.6	5.9	3.8	3.7	3.1	4.4	2.9	2.6	3.7	6.3	5.0	3.4	6.9	5.4



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	1.6	1.2
2	W2 → W5	1.7	1.1
3	W5 → W1	1.6	1.4
4	W5 → W6	1.3	1.0
5	W6 → W2	1.8	1.3
6	W4 → W3	1.5	0.7
7	W3 → W7	1.6	0.7
8	W7 → W8	1.4	0.7
9	W8→ W3	1.5	1.2
10	W3 → W9	2.0	1.5
Average		1.6	1.1
NHAVA CREEK			
11	W5 →W11	1.8	1.3
12	W11 →W12	1.8	0.7
13	W12 →W13	1.6	0.8
14	W13 →W14	1.7	1.2
Average		1.7	1.0

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	1811
2	W2	1878
3	W3	1744
4	W4	1311
5	W5	1756
6	W6	2067
7	W7	1367
8	W8	1311
9	W9	1867
Average		1679
NHAVA CREEK		
10	W11	1644
11	W12	1589
12	W13	1533
13	W14	1656
Average		1606



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 1600- 2000 no's/100 gm with an average of 1744 no's/100 gm given in Table E.10. The minimum value of 1600 no's/m² was found W2,W5 and W9 stations while the maximum value of 2000 no's/gm at W1 station and in nhava creek poc was to be in the range of 1607- 1805 no's/gm with an average of 1705 no's/100gm. The minimum value of 1607 no's/100 gm was found at W12 and the maximum value of 1805 no/100 gms found at W13 station.

In the month of march- 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	-	2000	1	Foraminiferans
2	W2	-	1600	1	Foraminiferans
3	W3	-	1800	1	Foraminiferans
4	W4	-	1700	1	Foraminiferans
5	W5	-	1600	1	Foraminiferans
6	W6	-	1800	1	Foraminiferans
7	W7	-	1900	1	Foraminiferans
8	W8	-	1700	1	Foraminiferans
9	W9	-	1600	1	Foraminiferans
Average			1744	1	
NHAVA CREEK					
11	W11	4	1704	3	Pelecypods, gastropods, foraminifera
12	W12	7	1607	3	Pelecypods, gastropods, foraminifera
13	W13	5	1805	3	Pelecypods, gastropods, foraminifera
14	W14	3	1703	3	Pelecypods, gastropods, foraminifera
Average			1705	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 64- 77 µg/L with an average of 71 µg/L. The minimum concentration of 64 µg/L of Phosphate was found at W7 station and maximum concentration of 77 µg/L was found at W8 station. Overall in JNP harbour region the Phosphate value was found within standard range (0.1- 90 µg/L). The Nitrate was found between 165 - 183 µg/L, with minimum value as 165 µg/L W5 and W9 stations and maximum as 183 µg/L at W3 station.. The average concentration of Nitrate was found to be 173 µg/L and overall Nitrate was found within range (1.0- 500 µg/L) at all stations. The Nitrite was found to be between 115- 116 µg/L with an average of 115 µg/L. The minimum concentration of nitrite (115 µg/L) was found at W1,W2,W4,W5 and W9 stations and maximum of 116 µg/L at W3 ,W6 W7 and W8 stations. 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 1119– 1329 µg/L with an average of 1224 µg/L.



The minimum concentration of silica of 1119 $\mu\text{g/L}$ was found at W6 and W8 stations. The Sulphate was found between 2755 - 2910 mg/L , with minimum value as 2755 mg/L at W4 station and maximum as 2910 mg/L at W7 station. The average concentration of Sulphate was found to be 2832 mg/L .

In Nhava Creek, Phosphate was found between 66- 75 $\mu\text{g/L}$ with an average 70 $\mu\text{g/L}$ which was under standard range (0.1- 90 $\mu\text{g/L}$). Nitrate was found between 174- 183 $\mu\text{g/L}$ with an average 178 $\mu\text{g/L}$. The minimum Nitrate (174 $\mu\text{g/L}$) was found at W13 and W14 stations and maximum (183 $\mu\text{g/L}$) at W11 station and Nitrite was found 116 $\mu\text{g/L}$ at all stations in Nhava creek region except. W11 station The silica content in Nhava creek was found between 1189- 1434 $\mu\text{g/L}$ with an average of 1312 $\mu\text{g/L}$. The minimum silica content of 1189 $\mu\text{g/L}$ was found at station W12 station and maximum as 1434 $\mu\text{g/L}$ was found at W13 station. Sulphate was found between 2910- 2925 mg/L with an average of 2916 mg/L . The minimum Sulphate (2910 mg/L) was found at W13 station and maximum (2925 mg/L) at W12 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 33.4– 59.2 $\mu\text{g/g}$ with an average of 44.0 $\mu\text{g/g}$. The minimum concentration of Phosphate (33.4 $\mu\text{g/g}$) was found at W4 station and maximum concentration (59.2 $\mu\text{g/g}$) at W2 8 station. The Nitrate was found between 0.41– 0.62 $\mu\text{g/g}$, with minimum value (0.41 $\mu\text{g/g}$) at W4 station and maximum (0.62 $\mu\text{g/g}$) at W7 and W8 stations. The average concentration of Nitrate was found to be 0.54 $\mu\text{g/g}$. The Nitrite was found to be between 3.29– 3.54 $\mu\text{g/g}$ with an average of 3.41 $\mu\text{g/g}$. The minimum concentration of nitrite (3.29 $\mu\text{g/g}$) was found at W8 station and maximum (3.54 $\mu\text{g/g}$) at W2 station. Silica in the form of silicate in JNP harbour sediments were found between 0.081– 0.103 $\mu\text{g/g}$ with an average of 0.093 $\mu\text{g/g}$. The minimum concentration of silica (0.081 $\mu\text{g/g}$) was found at W4 station and maximum (0.103 $\mu\text{g/g}$) was found at W2 station. The Sulphate was found between 4271- 5673 $\mu\text{g/g}$, with minimum value of 4271 $\mu\text{g/g}$ at W3 station and maximum of 5673 $\mu\text{g/g}$ at W6 station. The average concentration of Sulphate was found to be 5071 $\mu\text{g/g}$.

In Nhava Creek, Phosphate was found between 43.7 – 59.2 $\mu\text{g/L}$ with an average 52.1 $\mu\text{g/L}$ which was under standard range (0.1- 90 $\mu\text{g/L}$). Nitrate was found between 0.59– 0.66 $\mu\text{g/L}$ with an average 0.62 $\mu\text{g/L}$. The minimum Nitrate (0.59 $\mu\text{g/L}$) was found at W13 and W14 stations and maximum (0.66 $\mu\text{g/L}$) at W11 station and Nitrite was found



between 3.54-3.68 $\mu\text{g/L}$ with an average of 3.62 $\mu\text{g/L}$. The minimum Nitrite (3.54 $\mu\text{g/L}$) was found at W14 station and maximum (3.68 $\mu\text{g/L}$) at W11 station. The silica content in Nhava creek was found between 0.099– 0.101 $\mu\text{g/L}$ with an average of 0.100 $\mu\text{g/L}$. The minimum silica content of 0.099 $\mu\text{g/L}$ was found at W11 station and maximum as 0.101 $\mu\text{g/L}$ at W13 station. Sulphate was found between 5035- 5482 mg/L with an average of 5259 mg/L. The minimum Sulphate (5035 mg/L) was found at W13 station and maximum (5482 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.

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 805- 817 mg/L with an average of 813 mg/L. The minimum concentration (805 mg/L) of Calcium was found at W6 station and maximum concentration (817 mg/L) at W7 station. Potassium in JNP harbour water was found between 506- 518 mg/L with an average of 512 mg/L. The minimum concentration of Potassium (506 mg/L) was found at W8 station and maximum (518 mg/L) at W5 station. The Magnesium was found between 820- 832 mg/L, with minimum value (820mg/L) at W6 station and maximum (832 mg/L) at W9 station. The average concentration of Magnesium was found to be 825 mg/L. The Sodium was found between 12420- 12520 mg/L with an average of 12434 mg/L. The minimum concentration of sodium (12420 mg/L) was found at W7 station and maximum (12520 mg/L) at W1 station.

In Nhava Creek, Calcium concentration was found between 817- 822 mg/L with an average 820 mg/L. The minimum value of Calcium (817 mg/L) was found at W12 station and maximum (822 mg/L) at W14 station. The Potassium content in Nhava creek was



found between 530- 536 mg/L with an average of 533 mg/L. The minimum potassium value (530 mg/L) was found at W11 station and maximum (536 mg/L) at W12 station. Magnesium concentration was found between 819– 828 mg/L with an average of 824 mg/L. The minimum value of Magnesium (819 mg/L) was found at W14 station and maximum (828 mg/L) was found at W11 station. Sodium concentration was found between 12417- 12421 mg/L with an average of 12419 mg/L. The minimum sodium value (12417 mg/L) was found at W12 station and maximum (12421 mg/L) at W14 station.

In harbour region sediments, the Calcium was found between 210- 225 mg/Kg with an average of 217 mg/Kg given in Table E.14. The minimum Concentration of 210 mg/Kg of Calcium was found at W6 station and maximum concentration of 225 mg/Kg at W1 station. Potassium in JNP harbour sediment was found between 516- 524 mg/Kg with an average of 519 mg/Kg. The minimum concentration of Potassium of 516 mg/Kg was found at W4 station and maximum of 524 mg/Kg at W3 station. Magnesium was found between 1706- 1719 mg/Kg, with minimum value as 1706 mg/Kg at W2 station and maximum as 1719 mg/Kg was found at W5 and W9 stations. The average concentration of Magnesium was found to be 1714 mg/Kg. Sodium was found to be between 2918- 3022 mg/Kg with an average of 3004 mg/Kg. The minimum concentration of sodium (2918 mg/Kg) was found at W6 station and maximum of 3022 mg/Kg at W9 station.

In Nhava Creek sediments, Calcium was found between 220- 223 mg/Kg with an average 222 mg/Kg given in Table E. 14. The minimum value of calcium (220 mg/Kg) was found at W11 station and maximum (223 mg/Kg) was found at W12 station. The Potassium content in Nhava creek was found between 512- 518 mg/Kg with an average of 515 mg/Kg. The minimum Potassium content (512 mg/Kg) was found at W11 station and maximum (518 mg/Kg) at W14 station. Magnesium was found between 1717- 1723 mg/Kg with an average of 1720 mg/Kg. The minimum Magnesium value (1717 mg/Kg) was found at W11 station and maximum (1723 mg/Kg) at W13 station. Sodium was found between 3019-3025 with an average of 3022 mg/Kg. The minimum sodium value (3019 mg/Kg) was found at W13 station and maximum (3025 mg/Kg) at W11 station.

The depth of light penetration decreased by particles suspended in water, including algal cells. 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 average visibility of Secchi disc was found 1.0 feet in JNP harbor water and in Nhava creek region.

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

Sr. No.	Stations	PO ₄ ⁻³ -P (µg/L)	NO ₃ ⁻ -N (µg/L)	NO ₂ ⁻ -N (µg/L)	SiO ₂ ⁻ (µg/L)	SO ₄ ²⁻ (mg/L)
Standards		0.1 - 90	1.0 - 500	< 125	10-5000	NA
JNP HARBOUR AREA						
1	W1	71	174	115	1294	2850
2	W2	68	179	115	1259	2900
3	W3	73	183	116	1154	2780
4	W4	75	170	115	1189	2755
5	W5	71	165	115	1259	2841
6	W6	66	174	116	1119	2856
7	W7	64	170	116	1294	2910
8	W8	77	174	116	1119	2788
9	W9	70	165	115	1329	2812
Average		71	173	115	1224	2832
NHAVA CREEK						
10	W11	68	183	117	1259	2912
11	W12	71	179	116	1189	2925
12	W13	66	174	116	1434	2910
13	W14	75	174	116	1364	2915
Average		70	178	116	1312	2916

(*) 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	43.7	0.52	3.43	0.097	4972
2	W2	59.2	0.48	3.54	0.103	4780
3	W3	48.9	0.45	3.33	0.095	4271
4	W4	33.4	0.41	3.40	0.081	5227
5	W5	36.0	0.59	3.47	0.100	5545
6	W6	56.6	0.55	3.43	0.095	5673
7	W7	38.6	0.62	3.33	0.086	4844
8	W8	36.0	0.62	3.29	0.084	5290
9	W9	43.7	0.59	3.43	0.097	5035
Average		44.0	0.54	3.41	0.093	5071
NHAVA CREEK						
10	W11	56.6	0.66	3.68	0.099	5482
11	W12	48.9	0.62	3.61	0.100	5227
12	W13	43.7	0.59	3.64	0.101	5035
13	W14	59.2	0.59	3.54	0.100	5290
Average		52.1	0.62	3.62	0.100	5259

(-) 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	812	510	822	12520
2	W2	815	515	826	12421
3	W3	810	513	825	12424
4	W4	816	512	823	12426
5	W5	814	518	826	12423
6	W6	805	514	820	12421
7	W7	817	509	821	12420
8	W8	813	506	828	12427
9	W9	811	511	832	12422
Average		813	512	825	12434
NHAVA CREEK					
10	W11	821	530	828	12418
11	W12	817	536	824	12417
12	W13	820	533	823	12419
13	W14	822	534	819	12421
Average		820	533	824	12419



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	225	518	1710	3012
2	W2	221	519	1706	3014
3	W3	218	524	1718	3009
4	W4	213	516	1713	3017
5	W5	217	523	1719	3016
6	W6	210	521	1708	2918
7	W7	218	518	1715	3010
8	W8	216	517	1716	3015
9	W9	217	519	1719	3022
Average		217	519	1714	3004
NHAVA CREEK					
10	W11	220	512	1717	3025
11	W12	223	515	1721	3021
12	W13	222	516	1723	3019
13	W14	222	518	1720	3022
Average		222	515	1720	3022



Table E.15. Results of Moisture Content

Sr. No.	Stations	Moisture (%)
JNP HARBOUR AREA		
1	W1	0.36
2	W2	0.35
3	W3	0.34
4	W4	0.36
5	W5	0.36
6	W6	0.36
7	W7	0.36
8	W8	0.37
9	W9	0.36
Average		0.36
NHAVA CREEK		
10	W11	0.36
11	W12	0.36
12	W13	0.37
13	W14	0.36
Average		0.36



Table E.16. Results of Secchi Depth

Sr. No.	Stations	Secchi depth (ft)
JNP HARBOUR AREA		
1	W1	1.5
2	W2	0.5
3	W3	1.0
4	W4	1.5
5	W5	1.0
6	W6	0.5
7	W7	1.0
8	W8	1.0
9	W9	1.0
Average		1.0
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 March-2013 in JNP harbour and creek region was found 225 to 375 mgC/m³/day. The visibility of Secchi disc (light penetration) in the JNP harbour water and Nhava creek was found to be 0.5-1.5 feet during sampling periods due to dredging activities towards creek regions. 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 2.0 mg/m³ which represents 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 0.51 in JNP harbour water and 0.46 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 trophic 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 March, 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 –71.0µg/L Creek -70.0 µg/L	-	-
4	Nitrate	1.0-500 µg/L	Harbour –173.0µg/L Creek -178.0 µg/L	-	Within range
5	Nitrite	<125 µg/L	Harbour – 115.0 µg/L Creek – 116.0 µg/L	-	Within range
6	Particulate Organic Carbon (POC)	10-100 mg/m ³	Harbour – 1679 mg/m ³ Creek -1606 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 –1224 µg/L Creek-1312 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 March, 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 24th March, 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 March, 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 51 - 78 μ Mhos/cm. pH of all eighteen samples was in the range of 7.1 - 7.3 which is within the acceptable limits to the permissible standard of 7.0- 8.5. Concentration of chlorides was 3.8- 8.1 mg/L and was well within the acceptable limit (200 mg/L). TDS of all the eighteen samples was in the range of 63- 91 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 23- 59 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 0.03- 0.06 mg/L and was within the acceptable limit (0.1 mg/L). Sulphate content of all the eighteen samples was in the range of 3.7- 5.2 mg/L and was within the acceptable limit of 200 mg/L in drinking water. Concentration of NH_4^+ -N was in the range of 0.01- 0.05 mg/L. Concentration of PO_4^{3-} -P at all the eighteen stations, was found to be in the range of 0.04- 0.09 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, 24th March, 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)	0.51	0.58	0.60	0.48	0.53	0.49	1.0
Conductivity [μMhos/cm]	55	67	71	78	52	69	-
pH	7.2	7.3	7.1	7.2	7.3	7.1	7.0 to 8.5
Chlorides (mg/l)	3.9	5.2	5.6	6.8	4	8.1	200
TDS (mg/l)	65	91	74	79	70	85	500
Total Hardness (mg/l as CaCO ₃)	23	44	51	58	39	33	200
Iron (mg/l)	0.04	0.06	0.04	0.05	0.04	0.05	0.1
Sulphate (mg/l)	4.1	4.4	5.1	5.2	4.9	3.8	200
NH ₄ ⁺ -N (mg/l)	0.02	0.04	0.03	0.04	0.05	0.04	-----
PO ₄ ³⁻ -P (mg/l)	0.06	0.05	0.05	0.04	0.05	0.07	-----
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, 24th March, 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)	0.52	0.64	0.61	0.52	0.57	0.51	1
Conductivity [μMhos/cm]	74	57	64	51	69	71	-
pH	7.3	7.2	7.3	7.2	7.3	7.1	7.0 to 8.5
Chlorides (mg/l)	4.7	5.8	5.2	6.9	3.8	8	200
TDS (mg/l)	72	83	88	63	90	84	500
Total Hardness (mg/l as CaCO ₃)	37	59	40	31	58	28	200
Iron (mg/l)	0.03	0.04	0.05	0.06	0.04	0.05	0.1
Sulphate (mg/l)	4	4.3	4.7	4.9	3.8	3.7	200
NH ₄ ⁺ -N (mg/l)	0.04	0.05	0.03	0.01	0.02	0.03	----
PO ₄ ⁻³ -P (mg/l)	0.06	0.07	0.05	0.06	0.07	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.

Results of Drinking Water Quality Monitoring, 24th March, 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)	0.50	0.57	0.53	0.59	0.63	0.61	1
Conductivity [μMhos/cm]	74	66	61	60	72	76	-
pH	7.2	7.27	7.2	7.2	7.2	7.3	7.0 to 8.5
Chlorides (mg/l)	6.1	6.6	7.4	7.7	5.3	5.9	200
TDS (mg/l)	75	79	83	80	81	77	500
Total Hardness (mg/l as CaCO ₃)	24	36	47	41	59	55	200
Iron (mg/l)	0.05	0.04	0.05	0.04	0.04	0.04	0.1
Sulphate (mg/l)	4.2	4.9	4.5	4.7	3.9	5	200
NH ₄ ⁺ -N (mg/l)	0.04	0.02	0.03	0.04	0.03	0.02	----
PO ₄ ⁻³ -P (mg/l)	0.05	0.07	0.06	0.06	0.09	0.04	-----
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.