



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 January, 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 January, 2013 respectively. Table A.5 shows results of air pollutant concentration at Elephanta Island during 28th to 29th January, 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	January, 2013	Minimum	January, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	155	28 th to 29 th	106	03 rd to 04 th	200
PM₁₀	74	28 th to 29 th	56	03 rd to 04 th	100
NO_x	9.8	21 st to 22 nd	4.4	14 th to 15 th	80
SO₂	4.3	17 th to 18 th	1.2	03 rd to 04 th & 21 st to 22 nd	80
NH₃	33.4	21 st to 22 nd	2.8	03 rd to 04 th	400
CO	1.72	10 th to 11 th	1.61	21 st to 22 nd	2mg/m ³
CO₂	305	14 th to 15 th & 17 th to 18 th	302	7 th to 8 th	-

The values for TSP and PM₁₀ were below the prescribed limit during whole sampling period in the month of January, 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	January, 2013	Minimum	January, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		
TSP	200	03 rd to 04 th	175	17 th to 18 th	200
PM₁₀	100	28 th to 29 th	80	17 th to 18 th	100
NO_x	18.5	21 st to 22 nd	8.0	14 th to 15 th	80
SO₂	8.6	10 th to 11 th	1.3	24 th to 25 th	80
NH₃	65.9	24 th to 25 th	19.4	21 st to 22 nd	400
CO	1.81	7 th to 8 th	1.62	3 rd to 4 th	2mg/m ³
CO₂	315	14 th to 15 th	305	10 th to 11 th	-

The values for TSP and PM₁₀ were below the prescribed limit during whole sampling period in the month of January, 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	January, 2013	Minimum	January, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		
TSP	189	28 th to 29 th	154	17 th to 18 th	200
PM₁₀	89	28 th to 29 th	66	17 th to 18 th	100
NO_x	10.9	14 th to 15 th	5.0	17 th to 18 th	80
SO₂	5.7	21 st to 22 nd	1.2	10 th to 11 th & 24 th to 25 th	80
NH₃	61.3	28 th to 29 th	11.3	7 th to 8 th	400
CO	1.86	7 th to 8 th	1.64	14 th to 15 th	2mg/m ³
CO₂	314	17 th to 18 th	304	7 th to 8 th	-

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



Table A.5 provides the results of the air quality parameters at Elephanta Island station during 28th to 29th January, 2013. The concentration of TSP and PM₁₀ was found to be 62 µg/m³ and 31µg/m³ respectively. The concentration range of NO_x, SO₂, NH₃, CO & CO₂ was found to be in the range of 1.8 to 3.7 µg/m³, 1.3 to 2.6 µg/m³, 19.9 to 42.2 µg/m³, 1.63 mg/m³ to 1.70 mg/m³ and 302 ppm to 304 ppm respectively. The concentration of TSP, PM₁₀ and all gaseous pollutants were found to be below than the prescribed CPCB standard at EC station for the month of January, 2013.

Table A.5

Results of Air Pollutant Concentration at Elephanta Island During 28th to 29th January, 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	28/01/13	2:00-8:00	62	31	3.0	1.3	19.9	1.63	302
	29/01/13	8:10-6:10			1.8	2.6	28.5	1.67	303
	29/01/13	6:15-2:15			3.7	1.3	42.2	1.7	304

EC-ELEPHANTA CAVES

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

Table A.6

Monthly Average Values of Air Pollutant Concentration at Various Stations of JNP Area during the Month of January, 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	188±9	92±8	10.9±2.2	4.0±1.7	37.1±12.2	1.71±0.06
POC	172±11	74±7	7.6±1.4	2.6±1.2	33.6±11.2	1.76±0.07
Residential and Rural Areas						
NAAQ STDS.	200	100	80	80	400	2.0
RC	138±14	65±6	7.4±1.4	2.0±0.9	16.9±6.5	1.67±0.04
Sensitive Areas						
NAAQ STDS.	100	100	80	80	400	2.0
EC	62	31	2.8	1.7	30.2	1.67

Values as mean ± std deviation

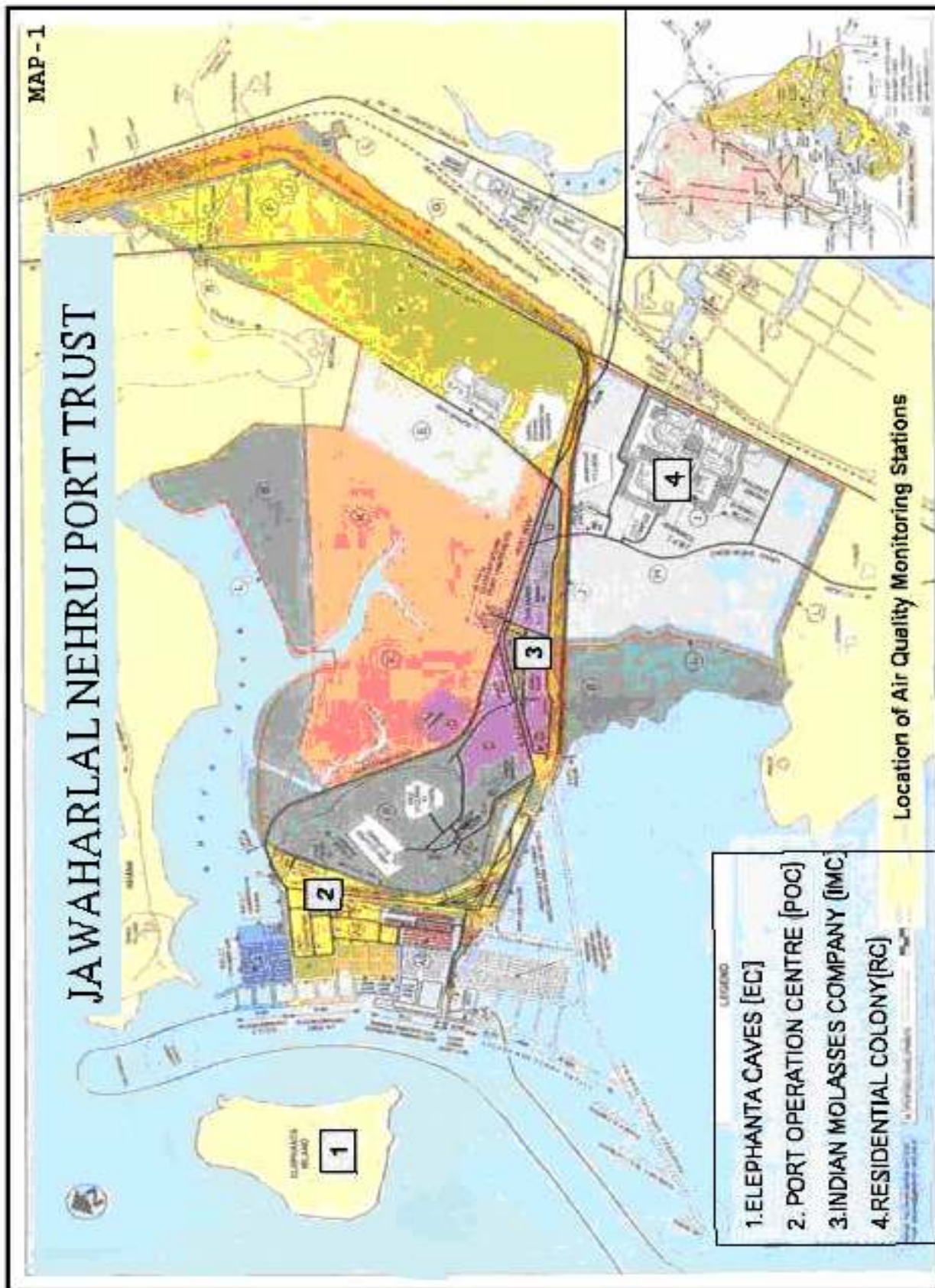




Table A.7
Results of Air Pollutant Concentration at RC Station of JNP Area during the Month of January, 2013

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	03/01/13	03:30-11:30	106	56	7.8	7.2	1.2	1.7	10.4	7.7	1.63	303
		04/01/13	11:30-07:30			5.3		1.3		2.8		1.69	
		04/01/13	07:30-03:30			8.6		2.5		9.8		1.67	
2	RC-II	07/01/13	03:30-11:30	142	66	9.1	6.9	1.3	1.9	19.9	19.2	1.63	302
		08/01/13	11:30-07:30			5.7		1.4		17.7		1.69	
		08/01/13	07:30-03:30			6.0		2.9		20.1		1.64	
3	RC-III	10/01/13	03:30-11:30	136	63	8.5	7.7	2.9	1.8	13.9	16.3	1.72	304
		11/01/13	11:30-07:30			7.9		1.3		15.8		1.70	
		11/01/13	07:30-03:30			6.6		1.3		19.1		1.71	
4	RC-IV	14/01/13	03:30-11:30	140	65	5.7	5.1	1.3	1.7	12.5	16.1	1.62	305
		15/01/13	11:30-07:30			5.3		2.6		16.0		1.71	
		15/01/13	07:30-03:30			4.4		1.3		19.9		1.70	
5	RC-V	17/01/13	03:30-11:30	140	70	7.1	7.6	4.3	2.8	13.7	11.3	1.65	305
		18/01/13	11:30-07:30			8.5		1.4		10.3		1.69	
		18/01/13	07:30-03:30			7.3		2.6		10.0		1.64	
6	RC-VI	21/01/13	03:30-11:30	138	57	8.1	8.2	2.6	2.5	13.8	21.5	1.61	303
		22/01/13	11:30-07:30			9.8		1.2		17.4		1.69	
		22/01/13	07:30-03:30			6.8		3.9		33.4		1.67	
7	RC-VII	24/01/13	03:30-11:30	146	69	7.2	8.3	1.3	2.1	22.8	23.9	1.69	304
		25/01/13	11:30-07:30			8.5		2.3		27.6		1.68	
		25/01/13	07:30-03:30			9.1		2.6		21.3		1.64	
8	RC-VIII	28/01/13	03:30-11:30	155	74	8.0	7.8	1.3	1.3	17.9	18.8	1.62	303
		29/01/13	11:30-07:30			7.5		1.4		13.7		1.63	
		29/01/13	07:30-03:30			8.1		1.3		24.8		1.71	



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

SR. NO	STATION	DATE	TIME (Hrs)	TSP ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)	NO _x $\mu\text{g}/\text{m}^3$ 8 hr 24 hr Avg	SO ₂ $\mu\text{g}/\text{m}^3$ 8 hr 24 hr Avg	NH ₃ $\mu\text{g}/\text{m}^3$ 8 hr 24 hr Avg	CO mg/m ³	CO ₂ ppm
STANDARD	→			200 $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$	80 $\mu\text{g}/\text{m}^3$	80 $\mu\text{g}/\text{m}^3$	400 $\mu\text{g}/\text{m}^3$	2.0 mg/m ³	-
1	IMC-I	03/01/13	03:00-11:00			10.0	5.1	21.1	1.72	306
		04/01/13	11:00-07:00	200	99	9.0	2.8	26.2	1.62	
		04/01/13	07:00-03:00			13.0	2.6	30.4	1.69	
2	IMC-II	07/01/13	03:00-11:00			10.9	3.9	52.0	1.81	308
		08/01/13	11:00-07:00	189	89	9.9	2.9	34.2	1.78	
		08/01/13	07:00-03:00			12.3	2.6	46.9	1.72	
3	IMC-III	10/01/13	03:00-11:00			11.1	3.9	25.1	1.74	305
		11/01/13	11:00-07:00	180	96	9.7	8.6	37.6	1.65	
		11/01/13	07:00-03:00			8.5	5.7	36.0	1.63	
4	IMC-IV	14/01/13	03:00-11:00			13.9	3.9	27.9	1.74	315
		15/01/13	11:00-07:00	198	99	8.0	3.8	34.7	1.78	
		15/01/13	07:00-03:00			9.9	5.2	22.6	1.68	
5	IMC-V	17/01/13	03:00-11:00			10.3	3.8	51.0	1.66	311
		18/01/13	11:00-07:00	175	80	12.0	2.9	43.2	1.80	
		18/01/13	07:00-03:00			12.0	2.6	31.7	1.74	
6	IMC-VI	21/01/13	03:00-11:00			9.1	2.6	47.2	1.63	309
		22/01/13	11:00-07:00	180	82	9.0	5.1	21.4	1.75	
		22/01/13	07:00-03:00			18.5	3.9	19.4	1.78	
7	IMC-VII	24/01/13	03:00-11:00			12.4	1.3	44.6	1.66	314
		25/01/13	11:00-07:00	189	92	10.8	2.6	55.2	1.64	
		25/01/13	07:00-03:00			10.7	2.4	65.9	1.75	
8	IMC-VIII	28/01/13	03:00-11:00			9.7	5.7	30.1	1.71	310
		29/01/13	11:00-07:00	190	100	11.2	6.4	45.1	1.70	
		29/01/13	07:00-03:00			9.7	5.7	39.7	1.67	



Table A.9
Results of Air Pollutant Concentration at POC Station of JNP Area during the Month of January, 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	03/01/13	02:30-10:30			9.1		4.0		24.3		1.67	
		04/01/13	10:30-06:30	175	79	7.9	8.0	2.6	2.9	39.0	32.0	1.71	306
		04/01/13	06:30-02:30			6.9		2.3		32.8		1.79	
2	POC-II	07/01/13	02:30-10:30			8.3		2.9		37.0		1.86	
		08/01/13	10:30-06:30	166	69	7.1	7.7	1.4	2.3	11.3	34.5	1.83	304
		08/01/13	06:30-02:30			7.7		2.6		25.1		1.84	
3	POC-III	10/01/13	02:30-10:30			7.4		1.2		40.3		1.65	
		11/01/13	10:30-06:30	179	72	8.0	7.3	4.0	2.5	37.0	34.1	1.74	310
		11/01/13	06:30-02:30			6.5		2.3		25.1		1.77	
4	POC-IV	14/01/13	02:30-10:30			10.9		1.3		26.1		1.83	
		15/01/13	10:30-06:30	180	77	9.8	9.3	1.3	1.7	43.2	36.9	1.64	312
		15/01/13	06:30-02:30			7.2		2.6		41.4		1.75	
5	POC-V	17/01/13	02:30-10:30			5.0		2.6		25.1		1.79	
		18/01/13	10:30-06:30	154	66	8.8	7.2	2.6	2.6	20.3	29.6	1.84	314
		18/01/13	06:30-02:30			7.9		2.6		43.4		1.84	
6	POC-VI	21/01/13	02:30-10:30			5.3		3.9		42.6		1.71	
		22/01/13	10:30-06:30	164	69	6.0	5.7	5.7	4.6	35.9	35.7	1.79	309
		22/01/13	06:30-02:30			6.0		4.3		28.5		1.72	
7	POC-VII	24/01/13	02:30-10:30			8.9		1.2		43.2		1.77	
		25/01/13	10:30-06:30	170	73	7.7	8.1	1.3	1.3	19.9	27.5	1.81	313
		25/01/13	06:30-02:30			7.7		1.3		19.5		1.69	
8	POC-VIII	28/01/13	02:30-10:30			8.7		2.3		44.6		1.68	
		29/01/13	10:30-06:30	189	89	7.9	7.7	1.3	2.6	61.3	48.1	1.70	305
		29/01/13	06:30-02:30			6.6		4.3		38.5		1.74	



1.4 Conclusions and Mitigations Measures

Table A.6 shows the overall average values of TSP, PM₁₀ and all gaseous pollutants at all three sampling stations. Due to thermal inversion (Winter season) , concentration of all the pollutants increased as compare to previous month .

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 January, 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 January, 2013 in JN Port respectively.

1.8a Wind speed:

The monthly average wind speed for January, 2013 was found to be 1.5 m/s. The maximum hourly average wind speed recorded was 6.6 m/s at 5:00 hrs on 21st January, 2013. As compared to the previous month (December, 2012) 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 0.7 to 2.3 m/s. 23.52 % of the total observations (743 observations) recorded by the met instrument for the month of January, 2013 was less than 0.5 m/s, which represents calm period.

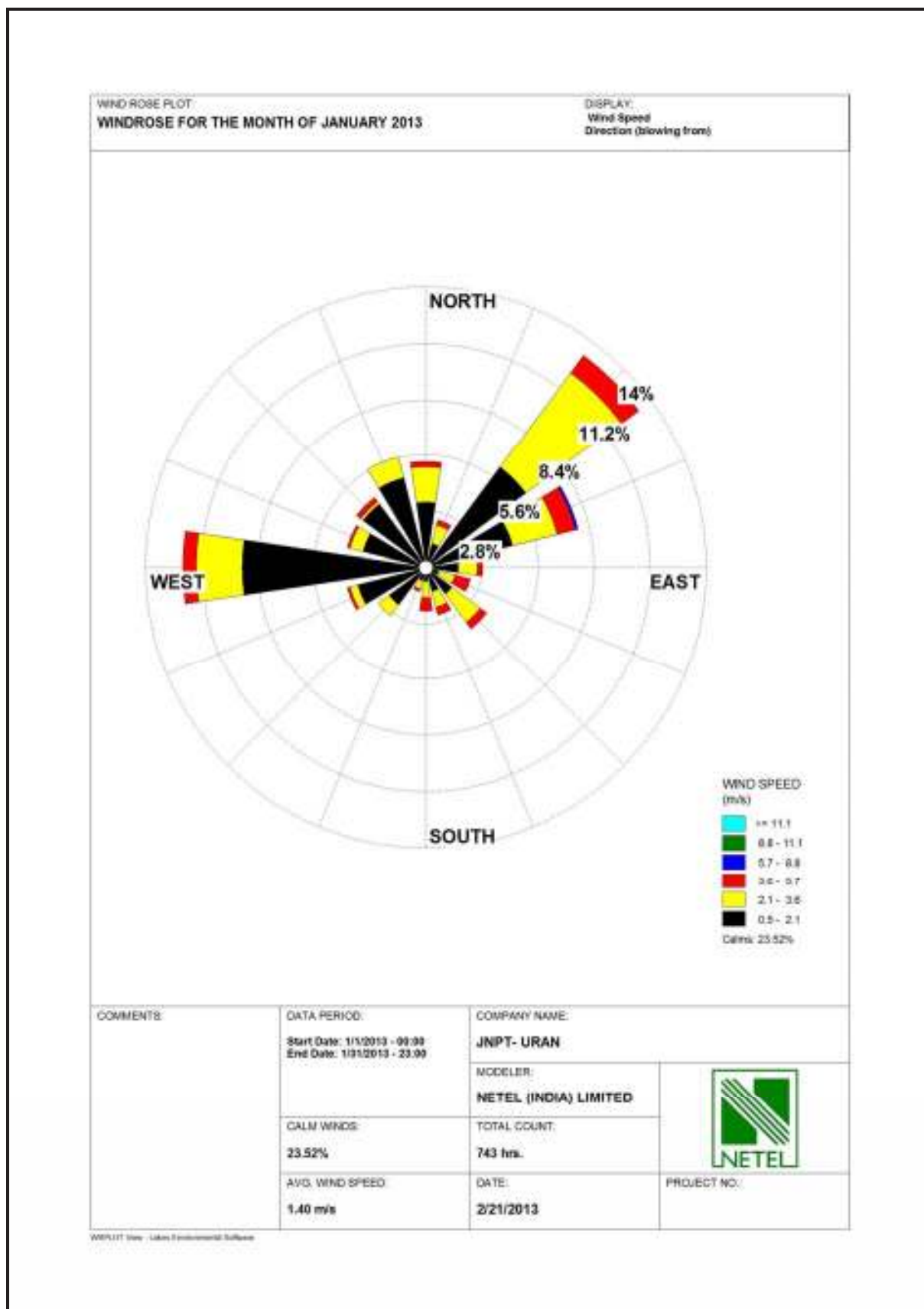
1.8b Wind direction:

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

1.8c Temperature:

The maximum daily average temperature 25.6 °C was obtained on 14th January, 2013 and minimum daily average temperature 20.5 °C was obtained on 6th January, 2013. The maximum and minimum hourly average temperature recorded was 34.4 °C at 15:00 hrs on 12th January, 2013 and 14.2 °C at 07:00 hrs on 6th and 7th January, 2013. The monthly average temperature for January, 2013 was calculated as 23.4 ± 1.26 °C.

Figure 1
Wind Rose for the month of January, 2013





1.8d Relative Humidity:

The monthly average relative humidity was found to be 60.5 ± 6.3 %. Relative humidity is the measure of water vapour in the atmosphere. Maximum daily average relative humidity was obtained as 71.1 % on 25th January, 2013 and minimum daily average relative humidity was obtained as 49.5 % on 6th January, 2013. The minimum value of hourly average relative humidity 27.3 % was observed on 1st, 13th & 19th January, 2013 at 14:00 hrs whereas, maximum value of 93.2 % recorded on 25th January, 2013 at 5:00 hrs.

Table A.11

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

Sr. No.	Date	Average Wind Speed (m/s)	Average Temperature (°C)	Average Relative Humidity (%)	Average Solar Radiation (W/m ²)
1	01/1/13	1.5	24.5	61.2	133.7
2	02/1/13	1.3	24.1	66.5	110.5
3	03/1/13	1.5	26.2	66.1	113.4
4	04/1/13	1.5	27.6	58.0	107.6
5	05/1/13	1.7	28.4	52.2	136.7
6	06/1/13	1.7	29.1	56.7	98.9
7	07/1/13	1.2	28.7	65.8	75.6
8	08/1/13	1.2	28.1	67.0	116.3
9	09/1/13	1.3	27.8	62.7	116.3
10	10/1/13	1.3	25.9	66.9	139.6
11	11/1/13	1.9	24.6	74.3	90.1
12	12/1/13	2.2	24.4	66.7	133.7
13	13/1/13	1.9	23.3	65.4	130.8
14	14/1/13	1.6	23.6	72.7	244.2
15	15/1/13	1.2	24.2	71.9	241.3



Sr. No.	Date	Average Wind Speed (m/s)	Average Temperature (°C)	Average Relative Humidity (%)	Average Solar Radiation (W/m ²)
16	16/1/13	1.5	25.2	65.6	206.4
17	17/1/13	1.7	26.5	58.4	194.8
18	18/1/13	1.7	26.9	55.6	244.2
19	19/1/13	1.7	26.1	52.2	226.8
20	20/1/13	1.7	26.1	51.9	229.7
21	21/1/13	1.4	25.6	54.3	229.7
22	22/1/13	1.7	26.1	51.9	229.7
23	23/1/13	1.4	25.6	54.3	229.7
24	24/1/13	1.6	26.5	57.4	247.1
25	25/1/13	1.7	25.7	58.7	200.6
26	26/1/13	1.9	25.3	65.5	130.8
27	27/1/13	1.6	23.6	72.7	244.2
28	28/1/13	1.2	24.2	71.9	241.3
29	29/1/13	1.5	25.2	65.6	206.4
30	30/1/13	1.7	26.5	58.4	194.8
31	31/1/13	1.7	26.9	55.6	244.2
Average		1.45	23.4	60.5	191.1



Table A.12

Record of daily rainfall in the month of January, 2013

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

1.8f Solar Radiation:

The maximum hourly average solar radiation was recorded to be 976.92 W/m^2 at 13:00 hrs on 1st, 4th, 6th, 7th, 13th and 19th January, 2013 and 14:00 hrs on 7th January, 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 $191.1 \pm 22.7 \text{ W/m}^2$. Solar radiation increased from 9.00 AM during morning hours and reached maximum during noon hours and then decreased during evening hours up to 18.00 PM. So, solar radiation data from 9.00 AM to 18:00 PM of a day has been taken for analysis. The daily average values of solar radiation ranged from 125.1 W/m^2 to 226.8 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 January, 2013 the prominent wind direction (blowing from) was North East (NE) in the port area. Average values of Wind Speed, Temperature, Relative Humidity, Solar Radiation and Rainfall recorded were 1.45 m/s , 23.4°C , 60.5% , 191.1 W/m^2 and 0.0 mm respectively. No rainfall was recorded for the month of January, 2013 in the Port Area.



PART-A

Chapter-2: Water Quality Monitoring

2.1 HARBOUR AREA

2.1.1 Introduction

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

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

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

Method of Monitoring:

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

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

Station Name	Location/Landmark	Date of Water Sampling
W1	Near ONGC	29 th January, 2013
W2	Elephanta Jetty	29 th January, 2013
W3	In-between Vessel channel	30 th January, 2013
W4	Near Butcher Island	30 th January, 2013
W5	Near NSICT	29 th January, 2013
W6	JNPT Shallow Berth	29 th January, 2013
W7	Towards Landing Jetty	30 th January, 2013
W8	Near Mora village	30 th January, 2013
W9	Near GTI Warf	30 th January, 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 29th & 30th January, 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	7.5- 8.0	6.5-9.0	pH meter	IS 3025 (Part 11)
2	Temperature	24.5- 28.8 °C	-	Thermometer	APHA 2550-B
3	Salinity	34.7- 41.3 ppt	-	Argentometric Titration	IS 3025 (Part 32)
4	Turbidity	34- 196 NTU	-	Nephelometer	IS 3025 (Part 10)
5	TDS	34421- 42163 mg/L	-	Gravimetry	IS 3025 (Part 16)
6	SS	189- 312 mg/L	-	Gravimetry	IS 3025 (Part 16)
7	TS	34720- 42417 mg/L	-	-	-
8	DO	5.5- 6.2 mg/L	3.0 mg/L or 40% of the higher saturation value	DO meter	-
9	COD	81- 163 mg/L	-	Potassium Dichromate	IS 3025 (Part 58)
10	BOD	<5 mg/ L	5 mg/L	DO consumption in 5 days at 20°C	IS 3025 (Part 44)
11	NH ₄ ⁺ -N	0.14- 0.47 mg/L	-	Colorimetry	IS 3025 (Part 34)
12	SPC	87- 312 / ml	-	Pour plate	IS 1622 1981
13	Coliform	<2- 4 CFU/100 ml	500/100 ml	Membrane Filtration	IS 1622- 1981
14	Phenol	0.04- 0.31 mg/ L	-	Titrimetric	IS 3025 (Part 43)
15	Oil & Grease	4- 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 W3 station. The minimum concentration (4 mg/L) was found during spring tide of W4 station.

The values of various water quality parameters such as pH, dissolved oxygen, oil and grease, CFU and BOD obtained during the month of January, 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. The concentration of BOD was below the CPCB standard at all the stations. The concentration of Oil & Grease was below the CPCB standard at all the stations except during spring tide of W3 station.



Table W. 3
Results of Physico-Chemical Analysis of Water Samples Collected From JNP
Harbor Area during January, 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	15.2	24.5	7.8	35.2	056	36542	202	36744
	SM		25.7	7.9	36.8	113	39524	236	39760
	SB		26.2	7.6	40.7	109	40124	197	40321
	NS	14.2	26.4	7.8	41.1	127	41358	307	41665
	NM		25.6	7.7	40.2	132	41008	311	41319
	NB		25.1	7.8	39.2	114	42163	206	42369
	W2	SS	6.3	28	7.5	34.7	096	42015	246
SM		27.9		7.9	38.5	188	34857	285	35142
SB		26.6		8.0	38.2	192	34963	277	35240
NS		6.2	26.8	7.9	38.9	040	35921	296	36217
NM			26.4	7.7	39.8	057	38221	247	38468
NB			26.3	7.8	39.1	088	36451	246	36697
W3		SS	9.7	24.8	7.9	40.6	093	36217	189
	SM	25.1		7.8	41.3	104	39365	191	39556
	SB	25.2		7.8	40.3	116	39745	195	39940
	NS	9.8	26.9	7.7	37.2	165	34758	300	35058
	NM		27.2	7.6	39.1	189	40656	268	40924
	NB		27	7.5	35.6	172	40112	267	40379
	W4	SS	8.7	24.8	7.9	36.4	162	40855	289
SM		25.2		7.6	39.2	196	34421	299	34720
SB		25.2		7.8	37.5	039	41322	247	41569
NS		9.0	25.9	7.7	40.2	057	41895	214	42109
NM			26.2	7.9	40.8	052	41021	211	41232
NB			26.3	7.5	41.2	069	39124	269	39393
W5		SS	14.2	28.3	7.6	41.3	118	40859	312
	SM	25.6		7.8	35.2	102	40852	196	41048
	SB	28.4		7.9	39.5	138	38265	247	38512
	NS	13.5	25.8	7.8	38.7	142	37854	216	38070
	NM		28.3	7.9	39.4	136	38256	268	38524
	NB		25.5	7.8	38.7	155	38935	307	39242

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	14.0	28.4	7.8	38.3	124	39365	256	39621
	SM		28.5	8.0	37.1	133	40565	274	40839
	SB		28.5	7.9	38.1	169	41321	268	41589
	NS	13.3	27.7	7.9	36.1	161	41893	244	42137
	NM		26.5	7.8	35.2	152	40562	288	40850
	NB		26.1	7.7	35.9	135	40798	269	41067
W7									
	SS	16.0	27.3	7.6	34.9	034	40741	284	41025
	SM		27.8	7.6	39.6	102	41328	274	41602
	SB		28.1	7.8	40.2	096	42113	304	42417
	NS	15.2	28.5	7.7	40.7	114	37489	301	37790
	NM		27.8	7.9	41.1	098	38458	211	38669
	NB		28.0	7.8	39.5	142	37121	206	37327
W8									
	SS	5.8	28.0	8.0	38.2	136	38216	201	38417
	SM		28.0	7.7	38.3	125	38659	193	38852
	SB		28.4	7.8	37.4	145	39365	265	39630
	NS	5.8	28.8	7.8	35.4	178	38451	235	38686
	NM		27.8	7.9	38.9	152	40841	214	41055
	NB		27.8	7.8	38.5	146	40836	253	41089
W9									
	SS	19.0	27.3	7.7	40.8	169	39231	255	39486
	SM		27.9	7.9	37.8	126	38457	268	38725
	SB		28.5	7.9	39.4	104	39151	284	39435
	NS	17.5	28.4	8.0	38.2	111	38154	286	38440
	NM		28.5	7.7	38.6	136	39231	288	39519
	NB		27.5	8.0	39.4	121	40656	247	40903

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 January, 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#						06		
	SS	5.8	093	<5	0.17	0.09		132	<2
	SM	5.6	116						
	SB	5.7	135						
	NS#						08		
	NS	5.9	147	<5	0.21	0.13		148	<2
	NM	5.6	122						
	NB	5.6	154						
W2	SS#						09		
	SS	6.0	126	<5	0.29	0.2		204	<2
	SM	5.9	107						
	SB	5.9	081						
	NS#						10		
	NS	5.8	086	<5	0.31	0.23		213	<2
	NM	5.8	097						
	NB	5.8	148						
W3	SS#						11*		
	SS	5.9	161	<5	0.26	0.31		87	<2
	SM	6.1	144						
	SB	5.8	134						
	NS#						08		
	NS	6.0	127	<5	0.14	0.24		178	<2
	NM	5.7	100						
	NB	5.9	125						
W4	SS#						04		
	SS	6.1	142	<5	0.38	0.04		296	<2
	SM	6.2	124						
	SB	6.2	163						
	NS#						06		
	NS	6.2	130	<5	0.33	0.06		309	<2
	NM	5.9	122						
	NB	5.9	160						
W5	SS#						08		
	SS	5.8	149	<5	0.41	0.09		274	<2
	SM	5.9	142						
	SB	5.8	146						
	NS#						07		
	NS	5.9	150	<5	0.45	0.16		288	<2
	NM	5.8	111						
	NB	5.7	125						

(*) 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#						09		
	SS	5.9	124	<5	0.15	0.19		107	<2
	SM	6.0	149						
	SB	5.7	156						
	NS#						10		
	NS	5.6	155	<5	0.47	0.26		312	<2
	NM	5.8	104						
	NB	5.7	084						
W7	SS#						08		
	SS	5.5	093	<5	0.19	0.22		211	4
	SM	5.6	107						
	SB	5.6	111						
	NS#						07		
	NS	5.7	132	<5	0.22	0.27		301	<2
	NM	5.6	128						
	NB	5.6	124						
W8	SS#						10		
	SS	6.2	144	<5	0.37	0.17		91	<2
	SM	5.5	142						
	SB	5.5	124						
	NS#						06		
	NS	5.5	136	<5	0.4	0.16		119	<2
	NM	5.6	130						
	NB	5.6	138						
W9	SS#						09		
	SS	5.5	109	<5	0.28	0.08		213	<2
	SM	5.6	085						
	SB	5.7	135						
	NS#						10		
	NS	5.7	126	<5	0.18	0.19		265	<2
	NM	5.7	124						
	NB	5.6	120						

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 January, 2013

Sediment Sample		Organic matter		Total carbon content		Inorganic phosphate µg/g
	Time, Hr	mg/g	%	mg/g	%	
Standards		N.A.	N.A.	N.A.	N.A.	N.A.
W1	1 st S	36.1	3.6	20.9	2.1	28.7
	3 rd S	50.2	5.0	28.7	2.9	29.3
	5 th S	51.9	5.2	29.9	3.0	26.4
	1 st N	52.6	5.3	31.2	3.1	23.9
	3 rd N	23.7	2.4	14.4	1.4	30.4
	5 th N	21.2	2.1	12.1	1.2	31.4
W2	1 st S	24.3	2.4	13.8	1.4	42.8
	3 rd S	22.4	2.2	13.1	1.3	23.7
	5 th S	30.7	3.1	17.9	1.8	49.4
	1 st N	25.6	2.6	14.6	1.5	50.4
	3 rd N	29.8	2.9	17.4	1.7	51.1
	5 th N	35.7	3.6	21.2	2.1	49.6
W3	1 st S	47.2	4.7	27.2	2.7	44.8
	3 rd S	50.3	5.0	29.3	2.9	47.5
	5 th S	45.1	4.5	25.7	2.6	38.9
	1 st N	37.9	3.8	21.9	2.2	28.8
	3 rd N	42.7	4.3	24.8	2.5	29.4
	5 th N	50.1	5.0	28.7	2.9	34.1
W4	1 st S	54.8	5.5	32.1	3.2	31.9
	3 rd S	29.3	2.9	17.2	1.7	30.4
	5 th S	31.1	3.1	17.8	1.8	24.8
	1 st N	47.2	4.7	27.2	2.7	28.2
	3 rd N	32.8	3.3	19.4	1.9	27.6
	5 th N	21.9	2.2	12.8	1.3	30.4
W5	1 st S	33.1	3.3	18.9	1.9	37.1
	3 rd S	26.3	2.6	15.2	1.5	40.9
	5 th S	28.1	2.8	16.3	1.6	41.9
	1 st N	40.9	4.1	24.1	2.4	41.6
	3 rd N	43.2	4.3	24.9	2.5	49.6
	5 th N	34.1	3.4	20.1	2.0	50.2
W6	1 st S	36.2	3.6	21.2	2.1	51.0
	3 rd S	50.2	5.0	29.2	2.9	49.2
	5 th S	41.2	4.1	24.1	2.4	50.4
	1 st N	40.8	4.1	23.6	2.4	47.1
	3 rd N	51.9	5.2	29.8	3.0	28.4
	5 th N	52.1	5.2	30.1	3.0	27.6

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	54.8	5.5	32.2	3.2	23.9
	3 rd S	49.6	5.0	29.1	2.9	30.1
	5 th S	35.7	3.6	21.3	2.1	34.1
	1 st N	40.8	4.1	23.8	2.4	30.9
	3 rd N	45.2	4.5	26.1	2.6	32.5
	5 th N	36.1	3.6	20.7	2.1	33.8
W8	1 st S	47.1	4.7	26.7	2.7	33.4
	3 rd S	49.7	5.0	28.9	2.9	39.7
	5 th S	52.9	5.3	30.9	3.1	39.1
	1 st N	52.1	5.2	30.1	3.0	40.5
	3 rd N	21.8	2.2	13.1	1.3	40.7
	5 th N	31.2	3.1	18.2	1.8	40.6
W9	1 st S	23.7	2.4	13.8	1.4	40.6
	3 rd S	28.1	2.8	16.2	1.6	47.9
	5 th S	31.2	3.1	18.3	1.8	48.1
	1 st N	52.7	5.3	30.8	3.1	49.6
	3 rd N	55.1	5.5	32.9	3.2	46.5
	5 th N	47.3	4.7	27.1	2.7	39.8

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 January, 2013. The organic matter, total carbon content and inorganic phosphate in the sediment samples collected during the month of January, 2013 were found to be in the range of 2.1- 5.5 %, 1.2- 3.2 %, and 23.7- 51.1 $\mu\text{g/g}$.

2.1.3 CONCLUSIONS

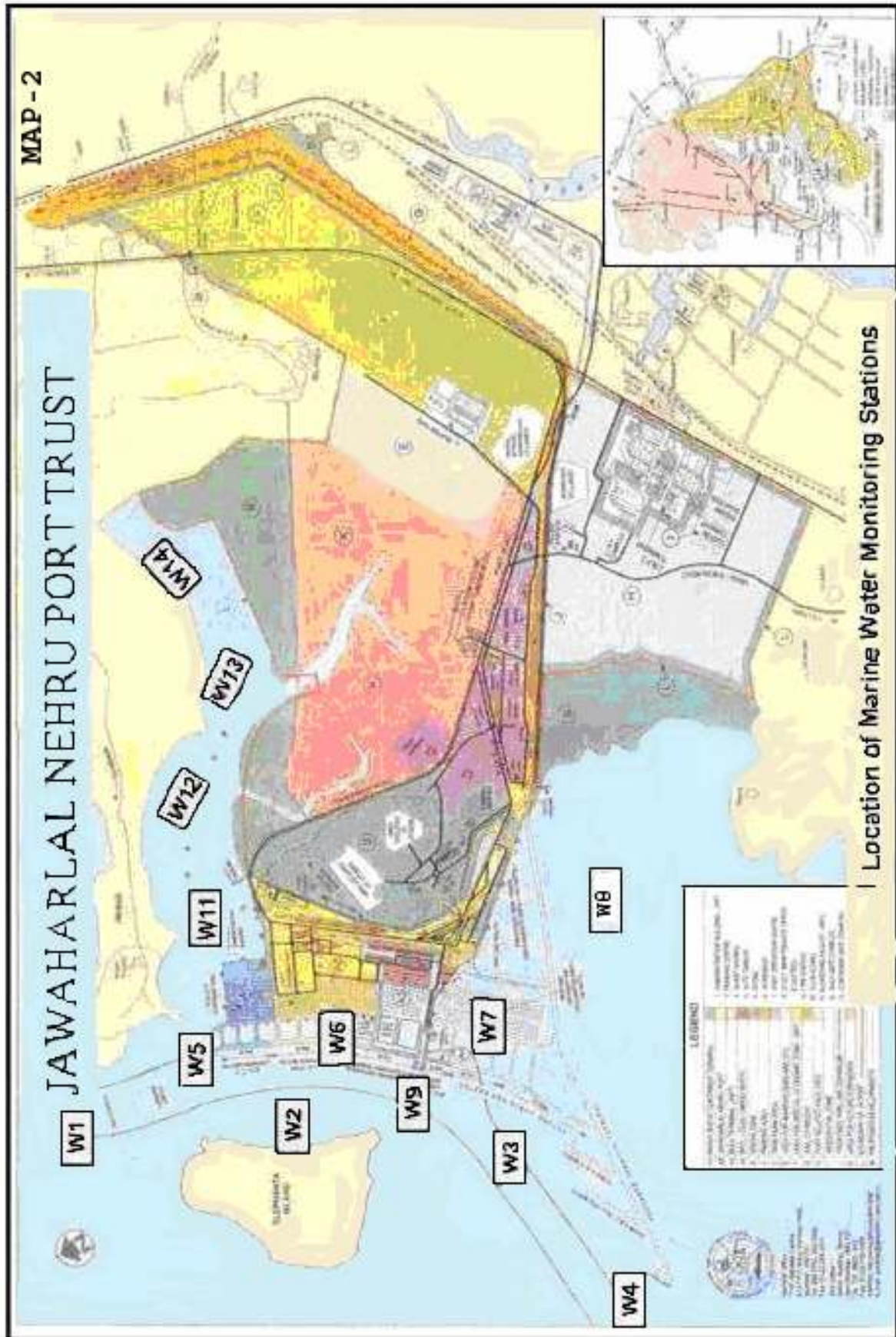
Definite correlation between turbidity and suspended solids could not be established. This could be due to presence of fine sediments in suspension also since turbidity depends upon the particle size and the refractive properties of the particles.

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 January, 2013

Sr. No.	Parameter	Criteria	Observation (above/below) standard	Reasons	Mitigation measures
1	pH range	6.5 - 9.0	7.5- 8.0	-	-
2	Dissolved Oxygen	3.0 mg/L or 40 % of the saturation value, whichever is higher	5.5- 6.2 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	4- 11 mg/ L Below at all stations except neap tide of W3 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 – 4 CFU /100 ml	-	-
6	Biochemical Oxygen Demand	5 mg/L	<5 mg/L Below at all stations	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	28 th January, 2013
W12	Near Nhava Village	28 th January, 2013
W13	Opposite North Gate	28 th January, 2013
W14	Towards end of the Creek	28 th January, 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 January, 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	24.9- 26.5 °C	-	Thermometer	APHA 2550-B
3	Salinity	37.4- 41.6 ppt	-	Argentometric Titration	IS 3025 (Part 32)
4	Turbidity	94- 222 NTU	-	Nephelometer	IS 3025 (Part 10)
5	TDS	36251- 44646 mg/L	-	Gravimetry	IS 3025 (Part 16)
6	SS	234- 309 mg/L	-	Gravimetry	IS 3025 (Part 16)
7	TS	36518- 44952 mg/L	-	-	-
8	DO	5.3- 6.0 mg/L	3.0 mg/L or 40% of the saturation value, whichever is higher	DO meter	-
9	COD	91- 147 mg/L	-	Potassium Dichromate	IS 3025 (Part 58)
10	BOD	<5- 5.6 mg/L	5 mg/L	DO consumption in 5 days at 20°C	IS 3025 (Part 44)
11	NH ₄ ⁺ -N	0.21- 0.39 mg/L	-	Colorimetry	IS 3025 (Part 34)
12	SPC	201- 314 / ml	-	Pour plate	IS 1622 1981
13	Coliform	<2- 5 CFU/ 100 ml	500 per 100 ml	Membrane Filtration	IS 1622 1981
14	Phenol	0.08- 0.22 mg/ L	-	Titrimetric	IS 3025 (Part 43)
15	Oil and Grease	6- 12 mg/L	10 mg/L	Solvent Extraction	IS 3025 (Part 39)

The maximum concentration of oil and grease (12 mg/L) was found at W14 station during spring tide. The minimum concentration of oil and grease (6 mg/L) was found during neap tide of W11 station. The values of various water quality parameters such as pH, dissolved oxygen, oil and grease, CFU and BOD obtained during the month of January, 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 spring tide of W12 and W14 stations. The concentration of oil and grease was below the CPCB standards except spring tide of W14 station.



Table W. 9

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

Sample Name	Depth (m)	Temp. (°C)	pH	Salinity (ppt)	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	TS (mg/L)
Standards			6.5-9.0	N.A.	N.A.	N.A.	N.A.	N.A.
W11	SS	4.5	25.2	7.8	38.7	116	39565	39814
	SM		25.3	7.9	40.6	124	37415	37662
	SB		24.9	7.7	40.1	139	40295	40559
	NS	5	25.8	8	38.9	222	42356	42641
	NM		26.1	8.1	39.4	142	44289	44584
	NB		26.2	7.7	39.1	169	44021	44266
W12	SS	5.5	25.7	7.5	39.8	207	43598	43883
	SM		25.1	7.9	40.4	189	43741	44004
	SB		25	8.2	40.9	193	42854	43163
	NS	5.5	25.6	7.7	40.2	101	41359	41666
	NM		25.4	7.8	37.4	116	39644	39879
	NB		26	7.9	41.3	136	38256	38525
W13	SS	3.5	26	7.6	41.0	124	36251	36518
	SM		26.5	7.8	41.5	178	36988	37229
	SB		25.1	7.5	40.7	94	37415	37677
	NS	4	26.2	8.2	38.1	207	38214	38501
	NM		25.9	7.8	37.5	221	39125	39359
	NB		25.8	7.9	37.9	146	41326	41603
W14	SS	4.5	25.7	7.5	40.2	158	44656	44952
	SM		25.4	8.2	40.9	196	43955	44240
	SB		25.3	7.9	41.4	175	42894	43170
	NS	4	26.1	7.7	38.4	169	43947	44228
	NM		25.9	7.8	41.6	136	44356	44657
	NB		25.8	7.9	39.4	185	42859	43159

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 January, 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#					8		
	SS	5.7	103	<5	0.29	0.17	234	<2
	SM	5.3	124					
	SB	5.7	136					
	NS#					6		
	NS	5.5	127	<5	0.22	0.11	255	<2
	NM	5.7	122					
	NB	5.5	147					
W12	SS#					10		
	SS	5.6	145	5.6*	0.31	0.08	201	<2
	SM	6.0	140					
	SB	5.8	91					
	NS#					7		
	NS	5.4	112	<5	0.21	0.16	214	<2
	NM	5.6	109					
	NB	5.6	133					
W13	SS#					9		
	SS	5.6	137	<5	0.37	0.14	309	5
	SM	6.0	141					
	SB	5.8	140					
	NS#					8		
	NS	5.4	124	<5	0.33	0.1	314	<2
	NM	5.8	138					
	NB	5.5	124					
W14	SS#					12*		
	SS	5.6	128	5.2*	0.39	0.22	287	<2
	SM	5.6	109					
	SB	5.8	98					
	NS#					9		
	NS	5.8	93	<5	0.24	0.09	263	<2
	NM	5.8	113					
	NB	6.0	124					

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 January, 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	47.8	4.8	27.8	2.8	33.2
	N	28.9	2.9	17.9	1.7	27.6
W12	S	33.3	3.3	19.1	1.9	21.3
	N	24.2	2.4	14.2	1.4	29.6
W13	S	36.4	3.6	21.2	2.1	42.5
	N	46.8	4.7	27.3	2.7	49.3
W14	S	40.1	4.0	22.7	2.3	50.4
	N	38.2	3.8	21.9	2.2	51.6

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 January, 2013. The organic matter, total carbon content and inorganic phosphate in the sediment samples collected during the month of January, 2013 were found to be in the range of 2.4- 4.8 %, 1.4- 2.8 % and 21.3- 51.6 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 January, 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	5.3- 6.0 mg/L	-	-
3	Colour and Odour	No visible colour or offensive order	No visible colour or distinct odour was observed	-	-
4	Floating objects oil, grease and scum (including the petroleum products)	10 mg/L	6- 12 mg/ L Below at all stations.	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- 5 CFU /100 ml	-	-
6	Biochemical Oxygen Demand (5 days at 20oC)	5 mg/L	<5- 5.6 mg/L Below at all stations except spring 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 28th January, 2013 in Nhava Creek regions of JNP and 29th and 30th January, 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 150- 300 mgC/m³/day with an average of 208 mgC/m³/day. minimum value (150 mgC/m³/day) was found at W3, W7, W8 and W9 stations and maximum value of (300 mgC/m³/day) was found at W1 and W2 stations during monitoring period. In Nhava creek the net primary productivity was also found to be in the range of 75- 225 mgC/m³/ day with an average of 150 mgC/m³/day. Minimum value (75 mgC/ m³/ day) was found at W13 station and maximum value of (225 mgC/ m³/ day) was found at W12 station during monitoring period as indicated in Table E.1. The light penetration measured by Secchi disc was found to be 1.0- 1.5 feet, 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	960	1200	450	800	300
3	W3	960	800	300	400	150
4	W4	1440	1200	450	600	225
5	W5	480	800	300	600	225
6	W6	960	1000	375	600	225
7	W7	960	800	300	400	150
8	W8	1920	1200	450	400	150
9	W9	1440	1000	375	400	150
Average		1120	1022	383	556	208
NHAVA CREEK						
10	W11	1440	1000	375	400	150
11	W12	1440	1200	450	600	225
12	W13	1440	800	300	200	75
13	W14	1440	1000	375	400	150
Average		1440	1000	375	400	150



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 351×10^3 no's/L with minimum (293×10^3 no's/L) at W1 and W4 stations and maximum (403×10^3 no's/L) at W9 station. In Nhava Creek the average phytoplankton density was found to be 461×10^3 no's/L with minimum (413×10^3 no's/L) at W11 and maximum (493×10^3 no's/L) at W12 station. The concentration of phytoplankton density depends on the grazing activity of zooplankton and nutrients dissolved in water. Relative abundance of phytoplankton in percentage is given in Table E.3.

3.4.3. PHOTOSYNTHETIC PIGMENTS AND ALGAL BIOMASS

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

Chlorophyll-a constitutes approximately 1 to 2% (an average 1.5%) of dry weight of the phytoplankton and is extensively used to estimate the algal biomass. The estimated concentration of chlorophyll-a and pheophytin-a of JNP harbour water and Nhava Creek is given in Table E.4. The range of chlorophyll-a in JNP harbour water was found to be between $1.6-3.7 \text{ mg/m}^3$ with an average of 2.7 mg/m^3 . The minimum concentration of chlorophyll-a (1.6 mg/m^3) was found at W5 station and maximum value (3.7 mg/m^3) was found at W1 station as indicated in Table E4. In Nhava Creek the range of chlorophyll-a was found between $2.8-3.4 \text{ mg/m}^3$ with an average of 3.0 mg/m^3 . Pheophytin-a is the main degradation product of chlorophyll-a and it was found below detectable limit (BDL)



at all stations (except W5 and W8 stations) in Harbour water and also found BDL in creek regions except W14 station 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 107- 250 mg/m³. The minimum algal biomass was (107 mg/m³) found at W5 station and maximum (250 mg/m³) was found at W1 station and average value of phytoplankton standing crop (Biomass) in JNP harbour water was found 183 mg/m³. In Nhava Creek it was found between 188- 230 mg/m³ with an average of 203 mg/m³ during monitoring period. The minimum algal biomass was 188 mg/m³ at W14 station and maximum (230 mg/m³) was found at W12 station.

Table E. 2.
Population Density of Phytoplankton

Sr.No.	Station	Density (no's / L)
JNP HARBOUR AREA		
1	W1	293 x 10 ³
2	W2	390 x10 ³
3	W3	320 x 10 ³
4	W4	293 x 10 ³
5	W5	357 x10 ³
6	W6	333 x10 ³
7	W7	370 x 10 ³
8	W8	400 x 10 ³
9	W9	403 x 10 ³
Average		351 x 10³
NHAVA CREEK		
10	W11	413 x 10 ³
11	W12	493 x 10 ³
12	W13	450 x 10 ³
13	W14	487 x 10 ³
Average		461 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.	1.1	2.6	2.1	-	2.8	4.0	3.6	2.5	2.5	2.4	2.4	1.4	3.0	2.7	2.4
2		Gyrosigma spp	-	-	-	-	-	2.0	-	-2.5	3.3	0.9	3.2	2.0	3.0	2.7	2.7
3		Navicula spp	2.3	3.4	2.1	3.4	1.9	1.0	2.7	1.7	1.7	2.2	1.6	1.4	2.2	1.4	1.7
4		Skeletonema spp	81.9	80.3	72.9	77.4	80.3	78.1	79.3	73.3	72.8	77.4	79.1	81.1	84.4	76.7	80.3
5		Nitzschia spp	3.4	0.9	4.2	3.4	1.9	3.0	1.8	3.3	3.3	2.8	2.4	2.0	1.5	1.4	1.7
6		Rhodomonas spp	-	0.9	-	-	-	-	-	-	-	0.1	-	-	-	-	-
7		Thalassiosira spp.	11.4	12.0	18.8	15.6	13.1	12.0	12.6	16.7	16.5	14.3	11.3	12.2	5.9	15.1	11.1
8		Ceratium spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	3.7	BDL
2	W2	2.5	BDL
3	W3	3.1	BDL
4	W4	2.4	BDL
5	W5	1.6	0.5
6	W6	2.5	BDL
7	W7	3.4	BDL
8	W8	2.1	0.3
9	W9	3.2	BDL
Average		2.7	BDL
NHAVA CREEK			
10	W11	2.9	BDL
11	W12	3.4	BDL
12	W13	2.9	BDL
13	W14	2.8	0.2
Average		3.0	BDL

BDL: Below Detectable Limit

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



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

Sr.No.	Station	Algal Biomass (mg/m ³)
JNP HARBOUR AREA		
1	W1	250
2	W2	167
3	W3	209
4	W4	161
5	W5	107
6	W6	167
7	W7	230
8	W8	143
9	W9	215
Average		183
NHAVA CREEK		
10	W11	197
11	W12	230
12	W13	197
13	W14	188
Average		203

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 73- 133 no's/m³. The minimum population density of zooplankton (73 no's/m³) was found at towing between stations W2→W5 and maximum of 133 no's/m³ was found in between stations W4→W3. The average population density of zooplankton in JNP harbour water was 98 no's/m³. In



Nhava creek population density of zooplankton was found in the range of 75- 103 no's/m³ with an average of 85 no's/m³. The minimum density of zooplankton in creek water was 75 no's/m³ found at towing between stations W12→W13 and maximum of 103 no's/m³ at towing between stations W5→W11. 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 0.51- 0.73 with an average of 0.62 and in Nhava creek it was found between 0.53– 0.61 with an average of 0.58 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, 84.3 % of the total communities of JNP harbour water and 83.8 % were found to be dominant in creek region.

There was another representative (Barnacles) of subclass cirripedia of class crustacea seen to be attached on rocks, pilings, boats and other water retaining structures. These are economically important organisms. Zooplankton biomass crop was determined with reference to weight (dry wt. as well as ash free wt). Table E.8 records the data of the same. In JNP harbour water, the minimum ash free biomass was 0.9 µg/L recorded between towing area of stations W4→W3, W3→W7 and W7→W8 stations and maximum was 1.8 µg/L recorded between towing area of W3→W9 station. The average ash free zooplankton biomass of JNP harbour water was 1.3 µg/L. In Nhava creek the minimum ash free biomass was 0.8 µg /L found between towing area of stations W11→W12 and maximum 1.6 µg /L was found between towing area of stations W12→W13 with an average of 1.2 µg /L.

The Particulate Oxidizable Carbon (POC) totally depends on the suspended dead remains of organisms like plant twigs, zooplankton or fish droppings, phytoplankton etc. The concentration of particulate oxidizable carbon (POC) is given in Table E.9. The concentration of particulate oxidizable carbon in JNP harbour was found between 978- 1100 mg/m³ with an average of 1023 mg/m³. The minimum concentration of POC (978 mg/m³) was found at, W8 station and maximum 1100 mg/m³ at W1 station. In Nhava creek the POC content was found to be between 967- 1000 mg/m³ with an average of 984 mg/m³. POC content in Nhava creek was found minimum as 967 mg/m³ at W12 station and maximum at 1000 mg/m³ at W13 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	0.64
2	W2 → W5	73	0.61
3	W5 → W1	105	0.51
4	W5 → W6	81	0.57
5	W6 → W2	101	0.61
6	W4 → W3	133	0.73
7	W3 → W7	104	0.61
8	W7 → W8	94	0.65
9	W8 → W3	97	0.61
10	W3 → W9	112	0.63
Average		98	0.62
NHAVA CREEK			
11	W5 → W11	103	0.53
12	W11 → W12	84	0.60
13	W12 → W13	75	0.56
14	W13 → W14	78	0.61
Average		85	0.58

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

PERCENTAGE OF PHYTOPLANKTON																				
Sr. No		Species	JNP HARBOUR AREA											NHAVA CREEK						
			W1 → W2	W2 → W5	W5 → W1	W5 → W6	W6 → W2	W6 → W3	W4 → W3	W3 → W7	W7 → W8	W8 → W3	W9 → W3	Avg	W5 → W11	W11 → W12	W12 → W13	W13 → W14	Avg	
1		Sagitta	0.7	-	0.5	1.4	0.6	1.3	-	0.6	0.6	0.5	0.6	0.6	0.5	0.5	-	0.7	-	0.3
2		Medusa	1.5	2.3	1.1	2.1	2.2	4.2	1.1	1.2	1.1	1.0	1.8	0.5	0.7	-	-	-	-	0.3
3		Mysids	7.4	8.3	6.3	6.2	7.5	6.3	6.9	7.1	5.7	6.5	6.82	4.8	7.2	5.9	9.9	8.5	4.8	
4		Copepods	83.8	83.3	87.3	86.3	85.1	81.6	83.5	83.4	84.6	83.6	84.3	87.1	82.2	84.4	81.6	81.6	83.8	
5		Fish larva	0.7	-	-	-	0.6	0.8	0.5	1.2	0.6	0.5	0.5	0.5	0.7	-	-	-	0.3	
6		Zoea larva	5.9	6.1	4.8	4.1	4.4	5.9	8.0	6.5	7.4	8.0	6.1	6.5	9.2	8.9	8.5	8.5	8.3	



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	1.8	1.5
2	W2 → W5	2.0	1.7
3	W5 → W1	2.0	1.2
4	W5 → W6	2.1	1.3
5	W6 → W2	1.8	1.2
6	W4 → W3	1.8	0.9
7	W3 → W7	1.7	0.9
8	W7 → W8	1.6	0.9
9	W8→ W3	1.6	1.5
10	W3 → W9	2.3	1.8
Average		1.9	1.3
NHAVA CREEK			
11	W5 →W11	2.0	1.4
12	W11 →W12	1.9	0.8
13	W12 →W13	1.9	1.6
14	W13 →W14	2.0	0.9
Average		2.0	1.2

Table E.9. Concentration of Particulate Oxidisable Organic Carbon

Sr. No.	Stations	Concentration of POC (mg/m ³)
Standards		10 - 100
JNP HARBOUR AREA		
1	W1	1100
2	W2	1044
3	W3	1056
4	W4	1033
5	W5	1000
6	W6	1011
7	W7	989
8	W8	978
9	W9	1000
Average		1023
NHAVA CREEK		
10	W11	978
11	W12	967
12	W13	1000
13	W14	989
Average		984



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 1100- 1700 no's/100 gm with an average of 1422 no's/100 gm given in Table E.10. The minimum value of 1100 no's/m² was found W6 station while the maximum value of 1700 no's/gm at W9 station and in Nhava creek poc was to be in the range of 1700- 1912 no's/gm with an average of 1831 no's/100gm. The minimum value of 1700 no's/100 gm was found at W14 and the maximum value of 1912 no/100 gms found at W12 station.

In the month of January, 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	-	1600	1	Foraminiferans
2	W2	-	1500	1	Foraminiferans
3	W3	-	1400	1	Foraminiferans
4	W4	-	1600	1	Foraminiferans
5	W5	-	1300	1	Foraminiferans
6	W6	-	1100	1	Foraminiferans
7	W7	-	1400	1	Foraminiferans
8	W8	-	1200	1	Foraminiferans
9	W9	-	1700	1	Foraminiferans
Average			1422	1	
NHAVA CREEK					
11	W11	8	1808	3	Pelecypods, gastropods, foraminifera
12	W12	12	1912	3	Pelecypods, gastropods, foraminifera
13	W13	5	1905	3	Pelecypods, gastropods, foraminifera
14	W14	-	1700	3	Pelecypods, gastropods, foraminifera
Average			1831	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 79- 84 µg/L with an average of 81 µg/L. The minimum concentration of 79 µg/L of Phosphate was found at W5 and W8 stations and maximum concentration of 84 µg/L at W2 station. Overall in JNP harbour region the Phosphate value was found within standard range (0.1- 90 µg/L). The Nitrate was found between 121- 134 µg/L. The minimum value as 121 µg/L at W4 and W5 stations and maximum as 134 µg/L at W3 and W9 stations. The average concentration of Nitrate was found to be 127 µg/L and overall Nitrate was found within range (1.0- 500 µg/L) at all stations. The Nitrite was found to be between 123- 125 µg/L with an average of 124 µg/L. The minimum concentration of nitrite (123 µg/L) was found at W2, W4 and W7 stations and maximum of 125 µg/L at W5 and W8 stations in JNP area. 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 1538– 1678 µg/L with an average of 1589 µg/L.



The minimum concentration of silica of 1538 µg/L was found at W4 and W8 stations JNP harbour region and the maximum concentration of silica of 1678 µg/L was found at W2 station. The Sulphate was found between 3014- 3019 mg/L, the minimum value as 3014 mg/L at W7 station and maximum as 3019 mg/L at W1 station. The average concentration of Sulphate was found to be 3016 mg/L.

In Nhava Creek, Phosphate was found between 81- 84 µg/L with an average 82 µg/L which was under standard range (0.1- 90 µg/L). Nitrate was found between 121- 129 µg/L with an average 127 µg/L. The minimum Nitrate (121 µg/L) was found at W13 station and maximum (129 µg/L) at W11, W12 and W14 stations with an average of 121 µg/L. Nitrite was found between 121- 123 µg/L. The minimum Nitrite (121 µg/L) was found at W11, W12 and W13 stations and maximum (123 µg/L) at W14 station. The silica content in Nhava creek was found between 1538- 1608 µg/L with an average of 1582 µg/L. The minimum silica content of 1538 µg/L was found at station W14 station and maximum as 1608 µg/L was found at W11 and W13 stations. Sulphate was found between 3010- 3012 mg/L with an average of 3011 mg/L. The minimum Sulphate (3010 mg/L) was found at W13 station and maximum (3012 mg/L) at W12 and W14 stations. Overall in JNP harbour and creek region the values of all the nutrients were found to be within the recommended ranges, which are given in Table 3.

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 54.0– 59.2 µg/g with an average of 56.9 µg/g. The minimum concentration of Phosphate (54.0 µg/g) was found at W2 and maximum concentration (59.2 µg/g) at W4 and W7 stations. The Nitrate was found between 0.73– 0.90 µg/g, with minimum value (0.73 µg/g) at, W4 & W8 stations and maximum (0.90 µg/g) at W1 station. The average concentration of Nitrate was found to be 0.80 µg/g. The Nitrite was found to be between 3.96– 4.03 µg/g with an average of 4.00 µg/g. The minimum concentration of nitrite (3.96 µg/g) was found at W2 and W5 stations and maximum (4.03 µg/g) at W6 and W8 stations. Silica in the form of silicate in JNP harbour sediments were found between 0.095– 0.100 µg/g with an average of 0.097 µg/g. The minimum concentration of silica (0.095 µg/g) was found at W2, W3 & W7 stations and maximum (0.100 µg/g) was found at W5 station. The Sulphate was found between 5418- 5928 µg/g, with minimum value of 5418 µg/g at W1 station and maximum of 5928 µg/g at W4, W6 and W9 stations. The average concentration of Sulphate was found to be 5800 µg/g.

In Nhava Creek, Phosphate was found between 56.6– 59.2 µg/L with an average 57.3 µg/L which was under standard range (0.1- 90 µg/L). Nitrate was found between 0.80–



0.87 µg/L with an average 0.83 µg/L. The minimum Nitrate (0.80 µg/L) was found at W11 station and maximum (0.87 µg/L) at W14 station. Nitrite was found between 4.00- 4.07 µg/L with an average of 4.03 µg/L. The minimum Nitrite (4.00 µg/L) was found at W11 station and maximum (4.07 µg/L) at W13 station. The silica content in Nhava creek was found between 0.097– 0.103 µg/L with an average of 0.100 µg/L. The minimum silica content of 0.097 µg/L was found at W14 station and maximum as 0.103 µg/L at W11 station. Sulphate was found between 5928- 6055 mg/L with an average of 6008 mg/L. The minimum Sulphate (5928 mg/L) was found at W13 station and maximum (6055 mg/L) at W11 and W14 stations. Overall in JNP harbour and creek region the values of all the nutrients were found to be within the recommended ranges.

3.4.6. B Cations:

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

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

In harbour region water the Calcium was found between 824- 827 mg/L with an average of 826 mg/L. The minimum concentration (824 mg/L) of Calcium was Found at W5 station and maximum concentration (827 mg/L) at W1, W8 and W9 stations. Potassium in JNP harbour water was found between 533- 536 mg/L with an average of 535 mg/L. The minimum concentration of Potassium (533 mg/L) was found at W3 station and maximum (536 mg/L) at W7 station. The Magnesium was found between 840- 845 mg/L, with minimum value (840 mg/L) at W2 station and maximum (845 mg/L) at W9 station. The average concentration of Magnesium was found to be 842 mg/L. The Sodium was found between 12434- 12536 mg/L with an average of 12446 mg/L. The minimum concentration of sodium (12434 mg/L) was found at W6 and W8 stations and maximum (12536 mg/L) at W1 station.



In Nhava Creek, Calcium concentration was found between 826- 828 mg/L with an average 827 mg/L. The minimum value of Calcium (826 mg/L) was found at W11 station and maximum (828 mg/L) at W12 station. The Potassium content in Nhava creek was found between 530- 532 mg/L with an average of 531 mg/L. The minimum potassium value (530 mg/L) was found at W11 station and maximum (532 mg/L) at W12 and W14 stations. Magnesium concentration was found between 841– 843 mg/L with an average of 842 mg/L. The minimum value of Magnesium (841 mg/L) was found at W11 station and maximum (843 mg/L) was found at W13 station. Sodium concentration was found between 12433- 12436 mg/L with an average of 12435 mg/L. The minimum sodium value (12433 mg/L) was found at W11 station and maximum (12436 mg/L) at W13 station.

In harbour region sediments, the Calcium was found between 224- 227 mg/Kg with an average of 226 mg/Kg given in Table E.14. The minimum Concentration of 224 mg/Kg of Calcium was found at W5 and W9 stations and maximum concentration of 227 mg/Kg at W2 and W7 stations. Potassium in JNP harbour sediment was found between 520- 526 mg/Kg with an average of 523 mg/Kg. The minimum concentration of Potassium of 520 mg/Kg was found at W9 station and maximum of 526 mg/Kg at W1 station. Magnesium was found between 1722- 1728 mg/Kg, with minimum value as 1722 mg/Kg at W1 station and maximum as 1728 mg/Kg was found at W3 station. The average concentration of Magnesium was found to be 1726 mg/Kg. Sodium was found to be between 2955- 2969 mg/Kg with an average of 2958 mg/Kg. The minimum concentration of sodium (2955 mg/Kg) was found at W1 station and maximum of 2969 mg/Kg at W6 station.

In Nhava Creek sediments, Calcium was found between 224- 226 mg/Kg with an average 225 mg/Kg given in Table E. 14. The minimum value of calcium (224 mg/Kg) was found at W12 and W13 stations and maximum (226 mg/Kg) was found at W14 station. The Potassium content in Nhava creek was found between 520- 522 mg/Kg with an average of 521 mg/Kg. The minimum Potassium content (520 mg/Kg) was found at W14 station and maximum (522 mg/Kg) at W12 station. Magnesium was found between 1724- 1726 mg/Kg with an average of 1725 mg/Kg. The minimum Magnesium value (1724 mg/Kg) was found at W12 station and maximum (1726 mg/Kg) at W13 station. Sodium was found between 3054- 3056 with an average of 3055 mg/Kg. The minimum sodium value (3054 mg/Kg) was found at W13 station and maximum (3056 mg/Kg) at W11 and W12 stations.

The depth of light penetration decreased by particles suspended in water, including any algal cells that are growing there. Coastal waters with high sediment content, or water in which an algal bloom is occurring, have less light penetration than clear open ocean



water. The light penetration (Euphotic zone) in harbour of JNP and Nhava creek is given in Table E.16. It was measured by Secchi disc. The visibility of Secchi disc was found to be 1.1 feet in JNP harbor water and 1.0 feet 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	81	129	124	1643	3019
2	W2	84	125	123	1678	3015
3	W3	82	134	124	1573	3017
4	W4	82	121	123	1538	3016
5	W5	79	121	125	1608	3018
6	W6	82	125	124	1573	3017
7	W7	81	124	123	1573	3014
8	W8	79	129	125	1538	3015
9	W9	81	134	124	1573	3016
Average		81	127	124	1589	3016
NHAVA CREEK						
10	W11	82	129	121	1608	3011
11	W12	84	129	121	1573	3012
12	W13	82	121	121	1608	3010
13	W14	81	129	123	1538	3012
Average		82	127	122	1582	3011

(*) 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	56.6	0.90	4.00	0.097	5418
2	W2	54.0	0.76	3.96	0.095	5673
3	W3	56.6	0.87	4.00	0.095	5800
4	W4	59.2	0.73	4.00	0.097	5928
5	W5	56.6	0.76	3.96	0.100	5864
6	W6	56.6	0.80	4.03	0.097	5928
7	W7	59.2	0.80	4.00	0.095	5800
8	W8	56.6	0.73	4.03	0.097	5864
9	W9	56.6	0.83	4.00	0.097	5928
Average		56.9	0.80	4.00	0.097	5800
NHAVA CREEK						
10	W11	56.6	0.80	4.00	0.103	6055
11	W12	56.6	0.83	4.03	0.100	5992
12	W13	59.2	0.83	4.07	0.100	5928
13	W14	56.6	0.87	4.03	0.097	6055
Average		57.3	0.83	4.03	0.100	6008

(-) 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	827	535	842	12536
2	W2	825	535	840	12436
3	W3	826	533	841	12437
4	W4	826	534	844	12435
5	W5	824	534	841	12436
6	W6	825	535	842	12434
7	W7	826	536	843	12435
8	W8	827	534	844	12434
9	W9	827	535	845	12435
Average		826	535	842	12446
NHAVA CREEK					
10	W11	826	530	841	12433
11	W12	828	532	842	12434
12	W13	827	531	843	12436
13	W14	827	532	842	12435
Average		827	531	842	12435



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	226	526	1722	2955
2	W2	227	525	1726	2957
3	W3	226	524	1728	2957
4	W4	225	524	1727	2956
5	W5	224	523	1726	2956
6	W6	226	522	1727	2969
7	W7	227	522	1726	2957
8	W8	225	523	1727	2958
9	W9	224	520	1725	2957
Average		226	523	1726	2958
NHAVA CREEK					
10	W11	225	521	1725	3056
11	W12	224	522	1724	3056
12	W13	224	521	1726	3054
13	W14	226	520	1725	3055
Average		225	521	1725	3055



Table E.15. Results of Moisture Content

Sr. No.	Stations	Moisture (%)
JNP HARBOUR AREA		
1	W1	0.36
2	W2	0.35
3	W3	0.36
4	W4	0.37
5	W5	0.36
6	W6	0.36
7	W7	0.35
8	W8	0.37
9	W9	0.36
Average		0.36
NHAVA CREEK		
10	W11	0.37
11	W12	0.38
12	W13	0.37
13	W14	0.36
Average		0.37



Table E.16. Results of Secchi Depth

Sr. No.	Stations	Secchi depth (ft)
JNP HARBOUR AREA		
1	W1	1.0
2	W2	0.5
3	W3	1.5
4	W4	1.5
5	W5	1.0
6	W6	0.5
7	W7	1.0
8	W8	1.5
9	W9	1.0
Average		1.1
NHAVA CREEK		
10	W11	1.0
11	W12	1.0
12	W13	1.0
13	W14	1.0
Average		1.0



3.5 Conclusions

The net primary productivity in month of January, 2013 in JNP harbour and creek region was found 150 to 300 mgC/m³/day and 75 to 225 mgC/m³/day respectively. The visibility of Secchi disc (light penetration) in the JNP harbour water and Nhava creek was found to be between 1.1 feet and 1.0 feet respectively. 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 2.7 mg/m³ and 3.0 mg/m³ respectively which represent oligotrophic class of water. The phytoplankton species observed belong to the diatoms group. The marine community of JNP harbour represents pelagic invertebrates and some other zooplankton. Copepods were found to be the dominant species in harbour region and Nhava creek region. The average value of Shannon Wiener Index of species diversity was found to be 0.62 in JNP harbour water and 0.58 in creek water. These values represent less species diversity in JNP harbour and moderate species diversity 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 January, 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	Within range	-	-
4	Nitrate	1.0-500 µg/L	Harbour –127.0µg/L Creek -127.0 µg/L	-	Within range
5	Nitrite	<125 µg/L	Harbour – 124.0 µg/L Creek – 122.0 µg/L	-	Within range
6	Particulate Organic Carbon (POC)	10-100 mg/m ³	Harbour – 1023 mg/m ³ Creek -984 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 –1589 µg/L Creek-1582 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 January, 2013 to determine the present status of drinking water quality of JNPT area and to compare it with the prescribed standards. As per requirement samples were collected and analyzed from eighteen stations from outside and inside the port area of JNPT. Ten stations were outside the port area and eight stations were inside the port area. All the water samples were collected from the port area of JNPT on 28th January, 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 January, 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 55 - 79 $\mu\text{Mhos/cm}$. 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 4.2- 8.2 mg/L and was well within the acceptable limit (200 mg/L). TDS of all the eighteen samples was in the range of 64- 87 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 24- 60 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 4.1- 5.7 mg/L and was within the acceptable limit of 200 mg/L in drinking water. Concentration of $\text{NH}_4^+\text{-N}$ was in the range of 0.02- 0.03 mg/L. Concentration of $\text{PO}_4^{3-}\text{-P}$ at all the eighteen stations, was found to be in the range of 0.06- 0.13 mg/L. Analysis of the bacteriological parameter showed that all the drinking water samples were safe in terms of bacteriological quality.

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

Table D. 2
Results of Drinking Water Quality Monitoring, 28th January, 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)	0.53	0.58	0.62	0.59	0.69	0.70	1.0
Conductivity [μMhos/cm]	79	65	68	74	79	63	-
pH	7.1	7.2	7.1	7.3	7.2	7.1	7.0 to 8.5
Chlorides (mg/l)	4.2	4.8	4.7	5.1	6.2	7.8	200
TDS (mg/l)	69	74	72	64	79	82	500
Total Hardness (mg/l as CaCO ₃)	32	39	40	58	55	24	200
Iron (mg/l)	0.04	0.05	0.04	0.03	0.06	0.04	0.1
Sulphate (mg/l)	4.1	5.2	4.3	4.7	4.9	5.1	200
NH ₄ ⁺ -N (mg/l)	0.02	0.02	0.03	0.02	0.03	0.02	-----
PO ₄ ³⁻ -P (mg/l)	0.09	0.08	0.13	0.11	0.1	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, 28th January, 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)	0.63	0.65	0.69	0.61	0.71	0.70	1
Conductivity [μMhos/cm]	65	67	62	61	60	72	-
pH	7.1	7.2	7.3	7.1	7.2	7.2	7.0 to 8.5
Chlorides (mg/l)	8.1	4.9	5.6	5.5	5.1	4.6	200
TDS (mg/l)	84	68	70	75	66	71	500
Total Hardness (mg/l as CaCO ₃)	52	53	60	56	59	27	200
Iron (mg/l)	0.05	0.06	0.04	0.05	0.03	0.04	0.1
Sulphate (mg/l)	5	4.3	4.9	4.7	4.3	5.7	200
NH ₄ ⁺ -N (mg/l)	0.02	0.02	0.03	0.03	0.03	0.03	----
PO ₄ ⁻³ -P (mg/l)	0.08	0.06	0.12	0.11	0.1	0.08	-----
CFU (Per 100 ml)	Nil	Nil	Nil	Nil	Nil	Nil	Nil

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

Results of Drinking Water Quality Monitoring, 28th January, 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)	0.69	0.69	0.66	0.71	0.65	0.67	1
Conductivity [μMhos/cm]	55	63	74	71	70	72	-
pH	7.2	7.2	7.1	7.2	7.1	7.2	7.0 to 8.5
Chlorides (mg/l)	6.8	6.2	7.8	7.1	7.6	8.2	200
TDS (mg/l)	76	82	69	87	79	71	500
Total Hardness (mg/l as CaCO ₃)	60	54	51	49	42	43	200
Iron (mg/l)	0.05	0.04	0.04	0.05	0.05	0.04	0.1
Sulphate (mg/l)	4.7	4.9	5.1	5	5.1	4.6	200
NH ₄ ⁺ -N (mg/l)	0.03	0.02	0.03	0.03	0.02	0.03	----
PO ₄ ⁻³ -P (mg/l)	0.09	0.13	0.07	0.09	0.08	0.09	-----
CFU (Per 100 ml)	Nil	Nil	Nil	Nil	Nil	Nil	Nil

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