



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 April, 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 April, 2013 respectively. Table A.5 shows results of air pollutant concentration at Elephanta Island during 25th to 26th April, 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	April, 2013	Minimum	April, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	193	2 nd to 3 rd	169	18 th to 19 th	200
PM₁₀	96	2 nd to 3 rd	69	18 th to 19 th	100
NO_x	27.8	25 th to 26 th	15.9	8 th to 9 th	80
SO₂	4.8	15 th to 16 th	1.3	2 nd to 3 rd , 5 th to 6 th , 18 th to 19 th & 28 th to 29 th	80
NH₃	100.7	5 th to 6 th	30.3	18 th to 19 th	400
CO	1.68	22 nd to 23 rd	1.51	8 th to 9 th	2mg/m ³
CO₂	306	15 th to 16 th	303	5 th to 6 th	-

The values for TSP and PM₁₀ were below the prescribed limit during whole sampling period in the month of April, 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	April, 2013	Minimum	April, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	344	25 th to 26 th	246	2 nd to 3 rd	200
PM₁₀	172	25 th to 26 th	146	2 nd to 3 rd	100
NO_x	44.2	19 th to 20 th	24.9	9 th to 10 th	80
SO₂	5.7	16 th to 17 th	2.6	26 th to 27 th	80
NH₃	106.2	16 th to 17 th	41.0	23 rd to 24 th	400
CO	1.80	2 nd to 3 rd	1.59	9 th to 10 th	2mg/m ³
CO₂	311	5 th to 6 th	304	16 th to 17 th	-

The values for TSP and PM₁₀ were above the prescribed limit during sampling period most of the time in the month of April, 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	April, 2013	Minimum	April, 2013	CPCB Prescribed Limits
	$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
TSP	221	5 th to 6 th	169	25 th to 26 th	200
PM₁₀	106	5 th to 6 th	78	25 th to 26 th	100
NO_x	31.6	25 th to 26 th	12.0	18 th to 19 th	80
SO₂	7.7	18 th to 19 th	2.6	2 nd to 3 rd , 8 th to 9 th , 11 th to 12 th & 28 th to 29 th	80
NH₃	86.5	5 th to 6 th	27.3	22 nd to 23 rd	400
CO	1.81	22 nd to 23 rd	1.61	5 th to 6 th	2mg/m ³
CO₂	313	18 th to 19 th	303	2 nd to 3 rd	-

The values for TSP were below the prescribed limit except 1st and 2nd monitoring cycle during the whole month of April, 2013. The values for PM₁₀ were below the prescribed limit except 2nd monitoring cycle during the whole month of April, 2013.



Table A.5 provides the results of the air quality parameters at Elephanta Island station during 25th to 26th April, 2013. The concentration of TSP and PM₁₀ was found to be 88 µg/m³ and 60 µg/m³ respectively. The concentration range of NO_x, SO₂, NH₃, CO & CO₂ was found to be in the range of 10.8 to 11.9 µg/m³, 1.3 to 4.3 µg/m³, 30.3 µg/m³ to 47.4 µg/m³, 1.66 mg/m³ to 1.71 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 April, 2013.

Table A.5
Results of Air Pollutant Concentration at Elephanta Island During
25th to 26th April, 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	25/04/13	2:00-8:00	88	60	11.8	1.3	30.3	1.66	302
	26/04/13	8:10-6:10			11.9	2.8	32.8	1.68	304
	26/04/13	6:15-2:15			10.8	4.3	47.4	1.71	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 April, 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	291±27	159±7	32.7±4.0	4.0±1.0	73.8±14.9	1.70±0.06
POC	191±16	92±9	20.4±3.6	4.1±1.9	48.9±12.3	1.71±0.06
Residential and Rural Areas						
NAAQ STDS.	200	100	80	80	400	2.0
RC	179±8	78±10	21.5±2.8	2.8±1.0	58.4±18.8	1.59±0.05
Sensitive Areas						
NAAQ STDS.	100	100	80	80	400	2.0
EC	88	60	11.5	2.8	36.8	1.68

Values as mean ± std deviation





Table A.7
Results of Air Pollutant Concentration at RC Station of JNP Area during the Month of April, 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	02/04/13	03:30-11:30	193	96	23.2	20.6	2.8	2.2	96.5	91.0	1.55	304
		03/04/13	11:30-07:30			21.4		2.6		96.6		1.61	
		03/04/13	07:30-03:30			17.2		1.3		79.8		1.67	
2	RC-II	05/04/13	03:30-11:30	175	74	25.3	22.9	1.3	2.1	77.8	83.1	1.59	303
		06/04/13	11:30-07:30			22.1		2.6		70.7		1.52	
		06/04/13	07:30-03:30			21.3		2.6		100.7		1.53	
3	RC-III	08/04/13	03:30-11:30	182	81	15.9	17.9	2.6	2.2	43.9	50.5	1.60	305
		09/04/13	11:30-07:30			21.3		2.8		63.4		1.65	
		09/04/13	07:30-03:30			16.5		2.8		44.2		1.51	
4	RC-IV	11/04/13	03:30-11:30	174	73	20.4	19.2	2.6	3.0	34.7	47.8	1.55	304
		12/04/13	11:30-07:30			19.3		3.9		57.7		1.59	
		12/04/13	07:30-03:30			18.0		2.6		51.0		1.57	
5	RC-V	15/04/13	03:30-11:30	172	70	21.8	22.2	4.8	4.1	50.2	53.7	1.58	306
		16/04/13	11:30-07:30			22.7		2.8		64.8		1.53	
		16/04/13	07:30-03:30			22.1		4.7		46.1		1.62	
6	RC-VI	18/04/13	03:30-11:30	169	69	25.7	23.4	2.8	2.3	35.9	34.1	1.66	304
		19/04/13	11:30-07:30			23.0		1.3		36.2		1.67	
		19/04/13	07:30-03:30			21.5		2.8		30.3		1.64	
7	RC-VII	22/04/13	03:30-11:30	189	90	24.6	23.8	4.3	3.8	49.6	55.0	1.68	305
		23/04/13	11:30-07:30			22.9		2.9		65.8		1.53	
		23/04/13	07:30-03:30			23.9		4.3		49.6		1.59	
8	RC-VIII	25/04/13	03:30-11:30	178	83	27.8	23.8	2.6	3.0	48.3	55.0	1.55	305
		26/04/13	11:30-07:30			20.1		2.6		57.9		1.57	
		26/04/13	07:30-03:30			23.5		3.8		58.9		1.56	
9	RC-IX	28/04/13	03:30-11:30	175	70	20.3	19.6	2.6	2.1	52.1	55.6	1.67	304
		29/04/13	11:30-07:30			19.1		2.6		55.2		1.60	
		29/04/13	07:30-03:30			19.5		1.3		59.6		1.52	



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

SR. NO	STATION	DATE	TIME (Hrs)	TSP ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)	NO _x $\mu\text{g}/\text{m}^3$		SO ₂ $\mu\text{g}/\text{m}^3$		NH ₃ $\mu\text{g}/\text{m}^3$		CO mg/m ³	CO ₂ ppm
						8 hr	24 hr Avg	8 hr	24 hr Avg	8 hr	24 hr Avg		
STANDARD	→			200 $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$		80 $\mu\text{g}/\text{m}^3$		80 $\mu\text{g}/\text{m}^3$		400 $\mu\text{g}/\text{m}^3$	2.0 mg/m ³	-
1	IMC-I	02/04/13	03:00-11:00			35.1		3.9		57.7		1.80	309
		03/04/13	11:00-07:00	246	146	33.1	35.4	5.1	4.3	81.9	69.3	1.62	
		03/04/13	07:00-03:00			38.1		3.9		68.4		1.69	
2	IMC-II	05/04/13	03:00-11:00			28.7		3.9		70.2		1.70	311
		06/04/13	11:00-07:00	267	157	32.8	30.4	4.3	4.4	60.8	71.8	1.77	
		06/04/13	07:00-03:00			29.9		5.1		84.4		1.79	
3	IMC-III	09/04/13	03:00-11:00			28.4		2.8		75.8		1.75	305
		10/04/13	11:00-07:00	289	158	32.2	28.5	2.8	3.1	70.7	73.7	1.63	
		10/04/13	07:00-03:00			24.9		3.5		74.5		1.59	
4	IMC-IV	12/04/13	03:00-11:00			28.7		4.3		76.6		1.66	309
		13/04/13	11:00-07:00	300	162	30.3	30.6	3.8	4.4	62.1	73.5	1.62	
		13/04/13	07:00-03:00			32.6		5.1		81.9		1.67	
5	IMC-V	16/04/13	03:00-11:00			32.2		5.7		91.0		1.63	304
		17/04/13	11:00-07:00	278	156	33.7	34.0	5.7	5.2	96.5	97.9	1.66	
		17/04/13	07:00-03:00			36.2		4.3		106.2		1.68	
6	IMC-VI	19/04/13	03:00-11:00			33.7		2.6		57.1		1.67	310
		20/04/13	11:00-07:00	298	161	40.4	39.4	3.8	3.0	68.9	62.4	1.71	
		20/04/13	07:00-03:00			44.2		2.6		61.3		1.78	
7	IMC-VII	23/04/13	03:00-11:00			35.9		4.8		55.7		1.77	308
		24/04/13	11:00-07:00	305	164	30.4	33.0	3.8	3.9	41.0	54.5	1.72	
		24/04/13	07:00-03:00			32.6		3.2		66.9		1.76	
8	IMC-VIII	26/04/13	03:00-11:00			31.9		2.9		92.0		1.75	307
		27/04/13	11:00-07:00	344	172	34.2	32.9	5.7	4.1	81.4	90.9	1.79	
		27/04/13	07:00-03:00			32.7		3.8		99.3		1.71	
8	IMC-IX	28/04/13	03:00-11:00			31.8		3.9		69.7		1.61	306
		29/04/13	11:00-07:00	290	156	30.9	29.8	3.9	3.4	67.7	68.1	1.66	
		29/04/13	07:00-03:00			26.8		2.5		72.9		1.74	



Table A.9
Results of Air Pollutant Concentration at POC Station of JNP Area during the Month of April, 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	02/04/13	02:30-10:30			23.3		2.6		38.2		1.66	
		03/04/13	10:30-06:30	203	98	25.3	23.1	2.6	3.0	56.8	42.0	1.65	303
		03/04/13	06:30-02:30			20.7		3.8		31.1		1.71	
2	POC-II	05/04/13	02:30-10:30			19.1		2.9		86.5		1.80	
		06/04/13	10:30-06:30	221	106	18.9	19.0	3.9	3.2	43.4	59.4	1.78	309
		06/04/13	06:30-02:30			19.1		2.8		48.3		1.61	
3	POC-III	08/04/13	02:30-10:30			19.0		3.3		53.2		1.71	
		09/04/13	10:30-06:30	189	97	20.2	19.4	2.6	3.4	57.7	52.1	1.69	308
		09/04/13	06:30-02:30			19.1		4.4		45.5		1.66	
4	POC-IV	11/04/13	02:30-10:30			19.9		2.6		76.6		1.62	
		12/04/13	10:30-06:30	175	90	20.6	20.9	2.6	4.0	52.1	58.8	1.74	311
		12/04/13	06:30-02:30			22.3		6.7		47.8		1.79	
5	POC-V	15/04/13	02:30-10:30			19.6		5.6		35.5		1.72	
		16/04/13	10:30-06:30	180	89	23.9	21.6	7.6	6.8	47.0	44.6	1.63	310
		16/04/13	06:30-02:30			21.2		7.1		51.2		1.79	
6	POC-VI	18/04/13	02:30-10:30			12.0		7.7		52.4		1.70	
		19/04/13	10:30-06:30	198	96	15.9	15.7	2.7	4.4	45.9	48.2	1.64	313
		19/04/13	06:30-02:30			19.1		2.8		46.4		1.66	
7	POC-VII	22/04/13	02:30-10:30			21.3		4.2		47.7		1.78	
		23/04/13	10:30-06:30	200	89	19.1	20.5	3.6	3.5	27.3	45.4	1.80	304
		23/04/13	06:30-02:30			21.1		2.8		54.0		1.81	
8	POC-VIII	25/04/13	02:30-10:30			23.9		5.8		52.4		1.71	
		26/04/13	10:30-06:30	169	78	31.6	26.3	6.4	6.4	45.0	42.9	1.75	306
		26/04/13	06:30-02:30			23.4		7.1		47.4		1.79	
8	POC-IX	28/04/13	02:30-10:30			19.4		2.6		36.2		1.72	
		29/04/13	10:30-06:30	187	82	16.1	17.3	2.2	2.5	36.8	47.6	1.69	309
		29/04/13	06:30-02:30			16.5		2.6		58.3		1.62	



1.4 Conclusions and Mitigations Measures

Table A.6 shows the overall average values of TSP, PM₁₀ and all gaseous pollutants at RC and POC station were found to be below the permissible standard (except at POC it showed slightly higher values during 1st and 2nd monitoring cycles) in the month of April, 2013. Whereas at IMC station the values of TSP and PM₁₀ were found to be higher than the permissible limit during whole month of April, 2013. CPCB standards for ambient air quality for different areas are given in Table A. 6. All pollutants were found within prescribed limits at EC station for April 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 April, 2013 in JN Port respectively.

1.8a Wind speed:

The monthly average wind speed for April, 2013 was found to be 2.45 m/s. The maximum hourly average wind speed recorded was 6.1 m/s at 16:00 hrs on 06th April, 2013. As compared to the previous month (March, 2013) slightly higher values of hourly average wind speed were recorded during night as well as during daytime. Transport and dispersion of air pollutants are mainly governed by wind speed. The daily average value of wind speed was in the range 1.8 to 3.0 m/s. 6.67 % of the total observations (720 observations) recorded by the met instrument for the month of April, 2013 was less than 0.5 m/s, which represents calm period.

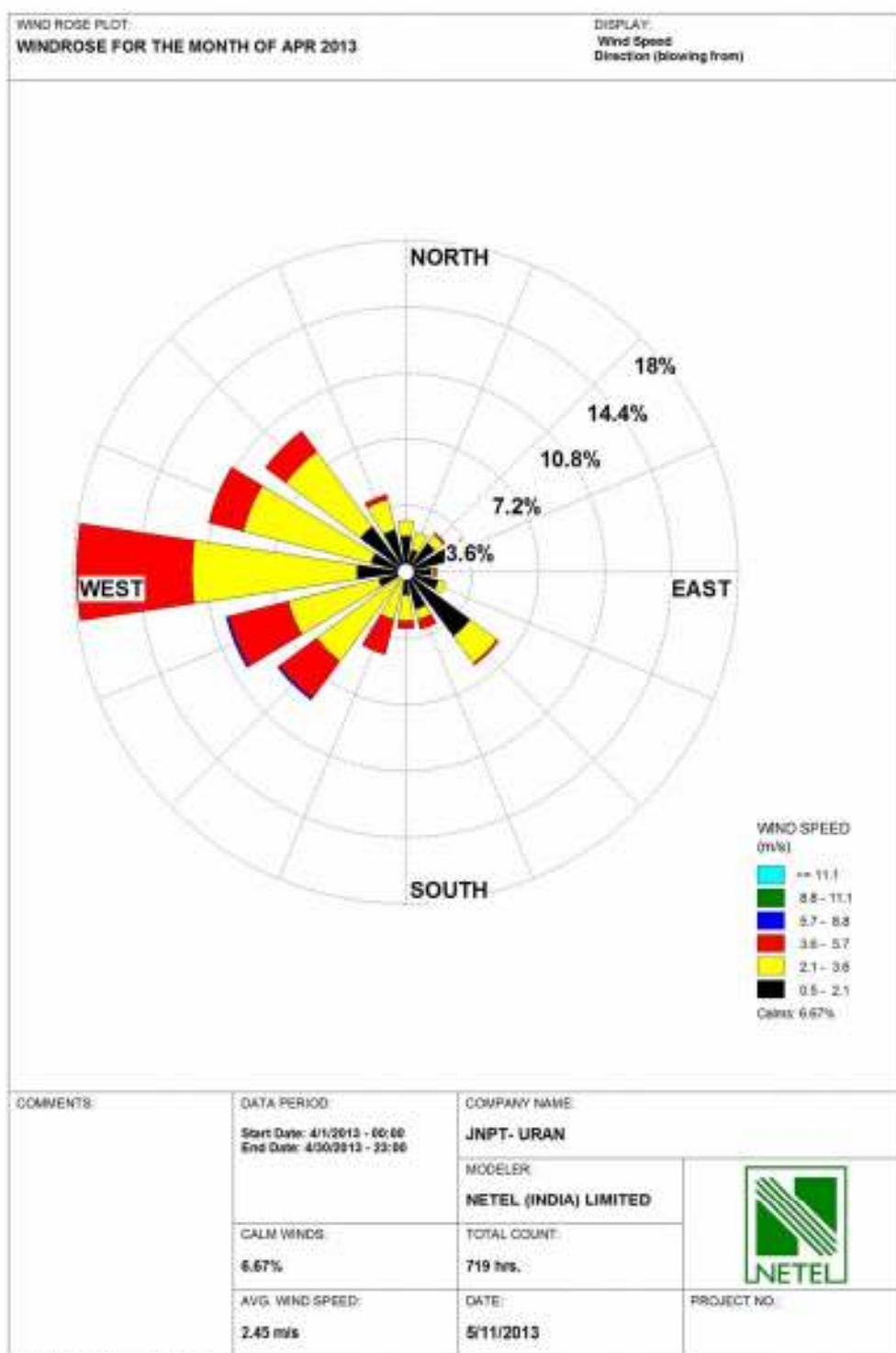
1.8b Wind direction:

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

1.8c Temperature:

The maximum daily average temperature 32.6 °C was obtained on 27th April, 2013 and minimum daily average temperature 26.4 °C was obtained on 16th April, 2013. The maximum hourly average temperature recorded was 37.1 °C at 17:00 & 18:00 hrs on 27th April, 2013. The minimum hourly average temperature recorded was 22°C at 7:00 hrs on 1st April, 2013. The monthly average temperature for April, 2013 was calculated as 28.6 ± 1.6 °C.

Figure 1
Wind Rose for the month of April, 2013





1.8d Relative Humidity:

The monthly average relative humidity was found to be 67.6 ± 5.5 %. Relative humidity is the measure of water vapour in the atmosphere. Maximum daily average relative humidity was obtained as 77.3 % on 6th April, 2013 and minimum daily average relative humidity was obtained as 50.1 % on 27th April, 2013. The minimum value of hourly average relative humidity 32.4 % was observed on 11th April, 2013 at 16:00 hrs whereas, maximum value of 94.3 % recorded on 7th April, 2013 at 6:00 & 7:00 hrs.

Table A.11

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

Sr. No.	Date	Average Wind Speed (m/s)	Average Temperature (°C)	Average Relative Humidity (%)	Average Solar Radiation (W/m ²)
1	01/4/13	2.2	27.4	69.1	264.6
2	02/4/13	1.8	26.6	65.3	250.0
3	03/4/13	2.5	26.8	60.7	273.3
4	04/4/13	2.6	27.3	65.4	273.3
5	05/4/13	2.3	28.2	68.0	276.2
6	06/4/13	2.2	27.2	77.3	276.2
7	07/4/13	2.3	27.8	72.1	267.5
8	08/4/13	2.4	28.5	60.2	276.2
9	09/4/13	2.4	27.9	66.8	255.9
10	10/4/13	2.6	28.4	64.1	284.9
11	11/4/13	2.3	28.2	63.1	270.4
12	12/4/13	2.5	28.1	70.0	311.1
13	13/4/13	2.9	28.7	71.7	276.2
14	14/4/13	2.3	28.2	74.0	282.0
15	15/4/13	2.3	28.2	67.5	244.2



Sr. No.	Date	Average Wind Speed (m/s)	Average Temperature (°C)	Average Relative Humidity (%)	Average Solar Radiation (W/m ²)
16	16/4/13	2.7	26.4	70.0	273.3
17	17/4/13	2.4	26.5	71.2	258.8
18	18/4/13	3.0	27.2	69.4	232.6
19	19/4/13	2.6	28.1	70.9	253.0
20	20/4/13	2.8	27.9	71.5	255.9
21	21/4/13	2.7	28.1	72.2	253.0
22	22/4/13	2.4	28.9	71.2	267.5
23	23/4/13	2.3	29.1	71.6	253.0
24	24/4/13	2.7	30.0	70.8	311.1
25	25/4/13	2.0	31.7	62.7	287.8
26	26/4/13	2.6	31.7	58.8	299.5
27	27/4/13	2.2	32.6	50.1	299.5
28	28/4/13	2.5	30.5	64.1	293.7
29	29/4/13	2.5	30.0	67.9	308.2
30	30/4/13	2.6	30.5	70.9	279.1
Average		2.45	28.6	67.6	273.6



Table A.12

Record of daily rainfall in the month of April, 2013

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

1.8f Solar Radiation:

The maximum hourly average solar radiation was recorded to be 1116.48 W/m^2 at 12:00 hrs on 2nd, 9th, 13th, 14th, 22nd, 27th and 29th April, 2013, at 13:00 hrs on 13th April 2013, at 14:00 hrs on 7th, 13th, 14th, 24th and 25th April 2013 and at 15:00 hrs on 28th April 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 $273.6 \pm 20.00 \text{ W/m}^2$. Solar radiation increased from 8.00 AM during morning hours and reached maximum during noon hours and then decreased during evening hours up to 18.00 PM. So, solar radiation data from 8.00 AM to 18:00 PM of a day has been taken for analysis. The daily average values of solar radiation ranged from 232.6 W/m^2 to 311.1 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 April, 2013 the prominent wind direction (blowing from) was West (W) in the port area. Average values of Wind Speed, Temperature, Relative Humidity, Solar Radiation and Rainfall recorded were 2.45 m/s , 28.6°C , 67.6% , 273.6 W/m^2 and 0.0 mm respectively. No rainfall was recorded for the month of April, 2013 in the Port Area.



PART-A

Chapter-2: Water Quality Monitoring

2.1 HARBOUR AREA

2.1.1 Introduction

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

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

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

Method of Monitoring:

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

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

Station Name	Location/Landmark	Date of Water Sampling
W1	Near ONGC	25 th April, 2013
W2	Elephanta Jetty	25 th April, 2013
W3	In-between Vessel channel	26 th April, 2013
W4	Near Butcher Island	26 th April, 2013
W5	Near NSICT	25 th April, 2013
W6	JNPT Shallow Berth	25 th April, 2013
W7	Towards Landing Jetty	26 th April, 2013
W9	Near GTI Warf	26 th April, 2013
W10	Near Mora village	26 th April, 2013



Table W. 3 & W.4 provides the results for each of the water quality parameters sampled at various water quality monitoring stations of Harbour area of JNP from 25th & 26th April, 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	7.3- 8.2	6.5-9.0	pH meter	IS 3025 (Part 11)
2	Temperature	27.0- 32.8 °C	-	Thermometer	APHA 2550-B
3	Salinity	30.1- 38.4 ppt	-	Argentometric Titration	IS 3025 (Part 32)
4	Turbidity	41- 169 NTU	-	Nephelometer	IS 3025 (Part 10)
5	TDS	30859- 37845 mg/L	-	Gravimetry	IS 3025 (Part 16)
6	SS	182- 274 mg/L	-	Gravimetry	IS 3025 (Part 16)
7	TS	31049- 38102 mg/L	-	-	-
8	DO	5.4- 6.8 mg/L	3.0 mg/L or 40% of the higher saturation value	DO meter	-
9	COD	71- 184 mg/L	-	Potassium Dichromate	IS 3025 (Part 58)
10	BOD	<5- 5.5 mg/ L	5 mg/L	DO consumption on in 5days at 20°C	IS 3025 (Part 44)
11	NH ₄ ⁺ -N	0.21- 0.58 mg/L	-	Colorimetry	IS 3025 (Part 34)
12	SPC	71- 311 / ml	-	Pour plate	IS 1622 1981
13	Coliform	<2- 5 CFU/100 ml	500/100 ml	Membrane Filtration	IS 1622- 1981
14	Phenol	0.08- 0.29 mg/ L	-	Titrimetric	IS 3025 (Part 43)
15	Oil & Grease	7- 11 mg/ L	10 mg/L	Solvent Extraction	IS 3025 (Part 39)



The maximum concentration of oil and grease (11 mg/L) was found during neap tide of W1 station. The minimum concentration (5 mg/L) was found during neap tide of W2 and spring tide of W5 & W9 stations.

The values of various water quality parameters such as pH, dissolved oxygen, oil and grease, CFU and BOD obtained during the month of April, 2013 are compared with the primary water quality criteria for class IV waters (Harbour waters) given by Central Pollution Control Board (CPCB) in Table S.2. They were found to be within the range for these parameters except Oil & Grease and BOD. The concentration of BOD was below the CPCB standard at all the stations except spring tide of W7 station. The concentration of Oil & Grease was below the CPCB standard at all the stations except during neap tide of W1 station.



Table W. 3
Results of Physico- Chemical Analysis of Water Samples Collected From JNP
Harbor Area during April, 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	11.7	31.3	7.8	30.7	058	31258	188	31446
	SM		31.2	7.9	38.1	069	33645	201	33846
	SB		31.1	8.0	37.8	106	32401	206	32607
	NS	10.3	30.8	7.7	38.2	123	33004	213	33217
	NM		30.8	7.8	31.5	133	35274	243	35517
	NB		30.9	7.4	36.6	101	36569	182	36751
	W2	SS	6.2	28.1	7.9	33.4	147	36054	266
SM		27.8		7.6	38.1	155	32698	270	32968
SB		27.7		7.5	34.4	169	31474	272	31746
NS		6.2	28.5	7.8	30.8	099	31025	263	31288
NM			28.2	7.4	32.2	111	36157	261	36418
NB			28.0	7.9	34.7	128	32699	224	32923
W3		SS	12.7	32.0	7.8	37.8	135	37009	222
	SM	32.0		7.7	33.7	168	37569	197	37766
	SB	31.9		7.6	38.4	149	30941	183	31124
	NS	12.2	32.8	7.8	31.0	144	31569	186	31755
	NM		32.6	7.5	30.9	139	33965	195	34160
	NB		32.2	7.6	35.2	152	36457	192	36649
	W4	SS	11.3	32.6	8.0	36.4	140	35145	197
SM		32.4		7.7	38.2	051	33127	193	33320
SB		32.2		7.8	31.9	057	34784	206	34990
NS		11.2	32.0	7.9	37.7	041	30990	274	31264
NM			31.4	7.8	35.6	096	30859	190	31049
NB			31.9	7.7	36.6	103	35144	226	35370
W5		SS	9.8	31.2	7.8	36.6	147	37845	257
	SM	31.5		7.8	31.2	106	35121	254	35375
	SB	31.5		7.9	33.2	117	35004	246	35250
	NS	9.5	31.5	7.9	35.8	134	36112	233	36345
	NM		31.6	7.8	37.8	162	37481	253	37734
	NB		31.6	7.6	32.0	157	31474	263	31737

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	15.0	27.5	7.8	38.0	149	31964	269	32233
	SM		27.1	7.7	38.2	144	33528	271	33799
	SB		27.0	7.6	33.9	160	36454	273	36727
	NS	15.2	28.7	7.7	35.6	123	34889	184	35073
	NM		28.5	7.4	35.2	138	35965	187	36152
	NB		28.3	7.5	36.6	144	34561	195	34756
W7									
	SS	8.3	30.9	7.3	32.8	127	36325	192	36517
	SM		30.7	7.5	30.9	136	31569	190	31759
	SB		30.6	7.9	35.8	160	31600	253	31853
	NS	7.2	30.6	7.8	36.8	158	35697	264	35961
	NM		30.5	7.7	35.2	088	34562	223	34785
	NB		30.3	7.5	37.4	053	34515	241	34756
W9									
	SS	18.5	31.1	7.6	32.6	074	33569	247	33816
	SM		30.8	7.8	34.4	077	32852	253	33105
	SB		30.7	7.7	30.6	086	31569	255	31824
	NS	18.2	30.8	8.2	31.1	087	31693	271	31964
	NM		30.6	7.9	30.1	095	36451	244	36695
	NB		30.5	8.1	33.7	090	36568	260	36828
W10									
	SS	8.7	31.0	8.2	37.4	142	35269	244	35513
	SM		30.8	8.1	31.2	153	34875	243	35118
	SB		30.6	8	30.9	122	33054	232	33286
	NS	7.8	30.9	7.9	31.7	121	32564	233	32797
	NM		30.6	7.8	32.2	163	34578	222	34800
NB	30.5		8.1	30.9	150	31459	204	31663	

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 April, 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#						10		
	SS	6.7	089	<5	0.29	0.09		89	<2
	SM	6.8	121						
	SB	6.6	134						
	NS#						11*		
	NS	6.4	152	<5	0.31	0.13		124	<2
	NM	6.3	166						
	NB	6.2	170						
W2	SS#						9		
	SS	5.7	174	<5	0.22	0.14		162	<2
	SM	5.7	181						
	SB	5.7	180						
	NS#						7		
	NS	5.8	076	<5	0.41	0.19		311	<2
	NM	5.7	077						
	NB	5.7	074						
W3	SS#						10		
	SS	5.8	084	<5	0.21	0.21		241	5
	SM	5.8	083						
	SB	5.5	109						
	NS#						9		
	NS	5.9	125	<5	0.5	0.2		221	<2
	NM	5.7	133						
	NB	5.6	124						
W4	SS#						10		
	SS	5.9	128	<5	0.51	0.28		109	<2
	SM	5.8	071						
	SB	5.6	074						
	NS#						8		
	NS	5.8	085	<5	0.56	0.26		82	<2
	NM	5.7	086						
	NB	5.4	104						
W5	SS#						7		
	SS	6.7	119	<5	0.44	0.25		73	<2
	SM	6.4	127						
	SB	6.4	176						
	NS#						10		
	NS	6.4	144	<5	0.51	0.29		104	3
	NM	6.2	149						
	NB	6.1	112						

(*) 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#						9		
	SS	5.6	152	<5	0.48	0.28		109	<2
	SM	5.7	153						
	SB	5.8	147						
	NS#						10		
	NS	5.9	140	<5	0.43	0.08		71	<2
	NM	5.8	152						
W7	NB	5.8	155						
	SS#						8		
	SS	5.9	176	5.5*	0.58	0.13		310	4
	SM	5.9	105						
	SB	5.9	109						
	NS#						10		<2
	NS	5.6	116	<5	0.37	0.17		257	
W9	NM	5.6	122						
	NB	5.6	131						
	SS#						7		
	SS	5.9	180	<5	0.39	0.19		246	4
	SM	5.8	174						
	SB	5.8	178						
	NS#						9		
W10	NS	5.7	144	<5	0.33	0.09		251	<2
	NM	5.7	165						
	NB	5.7	152						
	SS#						10		
	SS	5.9	122	<5	0.26	0.16		268	<2
	SM	5.9	123						
	SB	5.7	139						
W10	NS#						9		
	NS	5.6	156	<5	0.46	0.22		289	<2
	NM	5.6	184						
	NB	5.6	152						

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 April, 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	24.3	2.4	14.2	1.4	32.2
	3 rd S	31.1	3.1	18.2	1.8	33.6
	5 th S	35.8	3.6	21.1	2.1	41.2
	1 st N	44.9	4.5	25.9	2.6	45.2
	3 rd N	38.1	3.8	21.7	2.2	44.8
	5 th N	53.2	5.3	31.2	3.1	40.9
W2	1 st S	57.1	5.7	33.1	3.3	22.5
	3 rd S	62.3	6.2	36.3	3.6	23.9
	5 th S	48.3	4.8	28.3	2.8	27.8
	1 st N	22.1	2.2	13.1	1.3	29.1
	3 rd N	40.8	4.1	24.1	2.4	31.4
	5 th N	21.6	2.2	12.9	1.3	41.9
W3	1 st S	30.9	3.1	17.8	1.8	44.7
	3 rd S	35.7	3.6	20.9	2.1	35.6
	5 th S	48.2	4.8	27.8	2.8	36.4
	1 st N	47.1	4.7	27.3	2.7	38.4
	3 rd N	44.8	4.5	26.1	2.6	38.6
	5 th N	50.1	5.0	29.4	2.9	47.1
W4	1 st S	64.3	6.4	37.4	3.7	26.6
	3 rd S	53.3	5.3	30.9	3.1	24.2
	5 th S	47.1	4.7	27.4	2.7	31.1
	1 st N	62.2	6.2	35.9	3.6	30.5
	3 rd N	59.2	5.9	33.6	3.4	40.2
	5 th N	54.8	5.5	32.2	3.2	41.2
W5	1 st S	23.7	2.4	14.1	1.4	44.6
	3 rd S	27.8	2.8	16.1	1.6	21.2
	5 th S	31.2	3.1	18.2	1.8	28.4
	1 st N	62.1	6.2	36.2	3.6	25.6
	3 rd N	41.4	4.1	24.2	2.4	24.7
	5 th N	47.8	4.8	28.3	2.8	34.4
W6	1 st S	43.2	4.3	25.1	2.5	33.3
	3 rd S	45.1	4.5	26.3	2.6	38.9
	5 th S	47.4	4.7	27.2	2.7	42.9
	1 st N	53.2	5.3	30.7	3.1	41.7
	3 rd N	55.1	5.5	31.8	3.2	40.9
	5 th N	56.8	5.7	33.1	3.3	32.6

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	49.7	5.0	29.4	2.9	33.9
	3 rd S	35.6	3.6	21.1	2.1	36.5
	5 th S	34.1	3.4	20.3	2.0	34.7
	1 st N	59.2	5.9	34.1	3.4	37.6
	3 rd N	45.2	4.5	26.2	2.6	21.9
	5 th N	53.3	5.3	31.2	3.1	23.3
W9	1 st S	57.1	5.7	33.1	3.3	27.4
	3 rd S	52.2	5.2	29.9	3.0	24.6
	5 th S	57.1	5.7	32.8	3.3	24.0
	1 st N	62.1	6.2	36.4	3.6	28.9
	3 rd N	45.3	4.5	26.1	2.6	31.0
	5 th N	41.1	4.1	24.2	2.4	31.8
W10	1 st S	38.3	3.8	22.4	2.2	36.5
	3 rd S	50.2	5.0	28.9	2.9	38.9
	5 th S	47.3	4.7	26.7	2.7	39.4
	1 st N	33.2	3.3	19.3	1.9	40.5
	3 rd N	28.2	2.8	16.2	1.6	41.8
	5 th N	28.9	2.9	17.1	1.7	46.8

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 April, 2013. The organic matter, total carbon content and inorganic phosphate in the sediment samples collected during the month of April, 2013 were found to be in the range of 2.2- 6.4 %, 1.3- 3.7 %, and 21.2- 47.1 $\mu\text{g/g}$.

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 April, 2013

Sr. No.	Parameter	Criteria	Observation (above/below) standard	Reasons	Mitigation measures
1	pH range	6.5 - 9.0	7.3- 8.2	-	-
2	Dissolved Oxygen	3.0 mg/L or 40 % of the saturation value, whichever is higher	5.4- 6.8 mg/L	-	-
3	Colour and Odour	No visible colour or offensive order	No visible colour or distinct odour was observed	-	-
4	Floating objects oil, grease and scum (including the petroleum products)	10 mg/L	7- 11 mg/ L Below at all stations except neap tide of W1 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 – 5 CFU /100 ml	-	-
6	Biochemical Oxygen Demand	5 mg/L	<5- 5.5 mg/L Below at all stations except spring tide of W7 station.	Wastewater runoff from nearby areas, or waste dumping from launches and vessels.	Avoid indiscriminate drainage of waste or wastewater into sea water.





2.2 NHAVA CREEK

2.2.1 INTRODUCTION

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

Method of Monitoring:

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

Table: W.7

Description of Water Quality Monitoring stations (Creek Region)

Station Name	Location/Landmark	Date of Water Sampling
W11	At mouth of Nhava Creek	24th April, 2013
W12	Near Nhava Village	24th April, 2013
W13	Opposite North Gate	24th April, 2013
W14	Towards end of the Creek	24th April, 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 April, 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	7.4- 8.2	6.5-9.0	pH meter	IS 3025 (Part 11)
2	Temperature	30.5- 33.5 °C	-	Thermometer	APHA 2550-B
3	Salinity	31.0- 39.1 ppt	-	Argentometric Titration	IS 3025 (Part 32)
4	Turbidity	101- 233 NTU	-	Nephelometer	IS 3025 (Part 10)
5	TDS	31451- 38639 mg/L	-	Gravimetry	IS 3025 (Part 16)
6	SS	241- 322 mg/L	-	Gravimetry	IS 3025 (Part 16)
7	TS	31740- 38896 mg/L	-	-	-
8	DO	5.4- 6.0 mg/L	3.0 mg/L or 40% of the saturation value, whichever is higher	DO meter	-
9	COD	78- 173 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	0.24- 0.51 mg/L	-	Colorimetry	IS 3025 (Part 34)
12	SPC	198- 328 / ml	-	Pour plate	IS 1622 1981
13	Coliform	<2- 6 CFU/ 100 ml	500 per 100 ml	Membrane Filtration	IS 1622 1981
14	Phenol	0.08- 0.31 mg/ L	-	Titrimetric	IS 3025 (Part 43)
15	Oil and Grease	8- 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 W13 station during spring tide. The minimum concentration of oil and grease (8 mg/L) was found during spring and neap tide of W12 station and neap tide of W13 & W14 stations. The values of various water quality parameters such as pH, dissolved oxygen, oil and grease, CFU and BOD obtained during the month of April, 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 & neap tide of W14 station. The concentration of oil and grease was below the CPCB standards except spring tide of W13 station.



Table W. 9

Results of Physico-Chemical Analysis of Water Samples Collected From JNP Creek Area during April, 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	4.0	30.8	7.9	31.8	153	32564	320	32884
	SM		30.7	7.8	35.2	147	37465	322	37787
	SB		30.5	8.1	38.7	213	32654	274	32928
	NS	3.0	33.2	7.9	33.2	233	33345	249	33594
	NM		33.1	7.8	39.1	111	37541	241	37782
	NB		33.0	7.7	36.2	134	35658	251	35909
W12									
	SS	3.5	31.5	7.8	34.6	125	34152	268	34420
	SM		31.6	8.2	36.6	134	33669	275	33944
	SB		31.3	8.1	37.1	142	31451	289	31740
	NS	3.0	33.5	7.6	32.2	104	32569	299	32868
	NM		33.2	7.8	37.1	109	32695	285	32980
	NB		33.3	7.4	34.4	101	31561	283	31844
W13									
	SS	3.5	31.1	7.6	31.0	113	33004	280	33284
	SM		31.8	7.5	36.6	214	34568	267	34835
	SB		31.4	7.8	38.5	232	33784	299	34083
	NS	2.5	32.8	7.9	34.5	209	37895	309	38204
	NM		32.1	7.8	31.9	213	34124	301	34425
	NB		31.9	8.1	35.2	196	33501	305	33806
W14									
	SS	4.0	32.5	8.0	33.8	174	34064	311	34375
	SM		32.4	7.9	36.5	113	37451	314	37765
	SB		32.5	8.0	37.4	142	36121	321	36442
	NS	3.0	31.8	8.1	32.3	165	38639	257	38896
	NM		31.9	8.2	35.5	147	34545	262	34807
	NB		31.7	7.9	33.9	185	33656	248	33904

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 April, 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#					9		
	SS	5.8	096	<5	0.34	0.09	209	<2
	SM	5.8	106					
	SB	5.6	173					
	NS#					10		
	NS	6.0	135	<5	0.48	0.27	301	<2
	NM	6.0	122					
	NB	5.7	128					
W12	SS#					8		
	SS	5.9	169	5.6*	0.51	0.22	198	<2
	SM	6.0	171					
	SB	5.7	156					
	NS#					8		
	NS	5.7	078	<5	0.38	0.08	217	<2
	NM	5.6	096					
	NB	5.6	108					
W13	SS#					12*		
	SS	5.8	142	<5	0.31	0.29	234	<2
	SM	5.6	168					
	SB	5.6	165					
	NS#					8		
	NS	5.8	135	<5	0.24	0.3	328	6
	NM	5.8	125					
	NB	5.5	128					
W14	SS#					9		
	SS	5.8	169	<5	0.29	0.31	324	3
	SM	5.7	161					
	SB	5.4	090					
	NS#					8		
	NS	5.9	108	5.6*	0.32	0.28	311	<2
	NM	5.8	154					
	NB	5.5	151					

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 April, 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	28.2	2.8	16.2	1.6	25.6
	N	31.3	3.1	17.8	1.8	34.7
W12	S	35.6	3.6	21.2	2.1	39.6
	N	52.1	5.2	30.3	3.0	19.9
W13	S	45.3	4.5	25.4	2.6	42.7
	N	46.9	4.7	27.1	2.7	49.6
W14	S	50.2	5.0	28.6	2.9	44.7
	N	41.1	4.1	23.9	2.4	54.1

S - SPRING, N - NEAP.

(-) SEDIMENT SAMPLES CONTAINED ONLY PEBBLES AND GRAVELS.

Table W.11 provides the detailed results for each of the sediment quality parameters sampled at various water quality monitoring stations in the Nhava creek for the month of April, 2013. The organic matter, total carbon content and inorganic phosphate in the sediment samples collected during the month of April, 2013 were found to be in the range of 2.8- 5.2 %, 1.6- 3.0 % and 19.9- 54.1 µg/g of sediments, respectively.

2.2.3 CONCLUSIONS

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

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

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

Sr. No.	Parameter	Criteria	Observation (above/below) standard	Reasons	Mitigation measures
1	pH range	6.5 - 9.0	7.4- 8.2	-	-
2	Dissolved Oxygen	3.0 mg/L or 40 % of the saturation value, whichever is higher	5.4- 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	8- 12 mg/ L Below at all stations except spring tide of W13 station.	This could be due to indiscriminate discharge of oil contaminated bilge water from motorized fishing boats, moving in the upstream of creek or accidental discharge of oil along with drainage water from vessels or nearby areas.	Strict management actions to be undertaken to avoid indiscriminate discharge of oil or oil contaminated water.
5	Fecal Coliform	500 per 100 ml (MPN)	<2- 6 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 & neap tide of W14 station.	Wastewater runoff from nearby areas, or waste dumping from launches and vessels.	Avoid indiscriminate drainage of waste or wastewater into sea water.



PART-B

Chapter-3: Monitoring Of Marine Ecosystem

3.1 Introduction

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

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

3.2. Objectives

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

3.3. Materials and methods

The monitoring of marine environment for the study of biological and ecological parameters was done on 24th April, 2013 in Nhava Creek regions of JNP and 25th and 26th April, 2013 in harbour of JNP and, during flood tide. The surface water samples were collected by a water sampler from nine water quality monitoring stations of JNP harbour area (viz., W1, W2, W3, W4, W5, W6, W7, W9 and W10) and four stations (W11, W12, W13 and W14) in Nhava Creek for the estimation of primary productivity and analysis of phytoplankton, zooplanktons and nutrients. The primary productivity was estimated using light and dark bottle method and assessed for the changes in oxygen content by Winkler's Iodometric titration method after five hours of incubation in sunlight. For phytoplankton



assay, the collected water samples were fixed using Lugol's solution fixative (Standard Methods, APHA, 2005). The zooplankton was collected by transect survey towing the plankton net against tidal current at the towing rate of 1.5 meter/sec up to a certain distance. The direction of towing the plankton net and the thirteen marine water quality monitoring stations are shown in Figure 3. The collected zooplankton samples were then fixed using 5% formaldehyde solution. For quantitative study of phytoplankton, the collected water sample, after fixation, was subjected to sedimentation for three days and carefully decanting the supernatant, the sediment was taken in small volume of water. This was then taken in a Sedgwick-Rafter counting cell and examined under compound microscope to enumerate and identify the phytoplankton. The zooplankton sample was also taken in a counting cell and enumerated under dissecting and compound microscope. For the estimation of chlorophyll-a and pheophytin-a, a certain volume of water sample was filtered through glass fiber filter paper (GF/C-47 mm) and the filter paper was immersed in 5 ml of 90% acetone and grinded in tissue grinder and kept overnight at 4°C in dark for extraction of pigments. The extract of pigments was then measured by spectrophotometer at wavelength of 750 nm and 664 nm before acidification and at 665 nm after acidification by 0.1ml of 0.1N HCl.

The particulate oxidisable organic carbon (POC) of water sample was estimated by wet oxidation method with sulphuric acid-potassium dichromate oxidant followed by spectrophotometry at wavelength of 440 nm. The standing crop (Biomass) of phytoplankton was estimated by chlorophyll-a method while biomass of zooplankton was estimated by gravimetric method. The euphotic zone (light penetration) of JNP harbour and creek water was measured by Secchi disc. The NO_3 -nitrogen and PO_4^{3-} -phosphorus were analyzed by brucine method and stannous-chloride method respectively while NO_2 -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 -375 mgC/m³/day with an average of 292 mgC/m³/day. minimum value (150 mgC/m³/day) was found at W5 stations and maximum value of (375 mgC/m³/day) was found at W1, W2,W7 and W10 station during monitoring period. In Nhava creek the net primary productivity was found 225 mgC/m³/ day at all stations during monitoring period as indicated in Table E.1. The light penetration measured by Secchi disc was found to be 0.5 – 1.0 ft, 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	1440	1600	600	1000	375
2	W2	960	1400	525	1000	375
3	W3	960	1000	375	600	225
4	W4	960	1000	375	600	225
5	W5	960	800	300	400	150
6	W6	960	1200	450	800	300
7	W7	480	1200	450	1000	375
8	W9	960	1000	375	600	225
9	W10	480	1200	450	1000	375
Average		907	1156	433	778	292
NHAVA CREEK						
10	W11	960	1000	375	600	225
11	W12	960	1000	375	600	225
12	W13	960	1000	375	600	225
13	W14	960	1000	375	600	225
Average		960	1000	375	600	225



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 126×10^3 no's/L with minimum (83×10^3 no's/L) at W1 station and maximum (167×10^3 no's/L) at W10 station. In Nhava Creek the average phytoplankton density was found to be 177×10^3 no's/L with minimum (110×10^3 no's/L) at W11 and maximum (233×10^3 no's/L) at W14 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 $0.3-1.6 \text{ mg/m}^3$ with an average of 1.2 mg/m^3 . The minimum concentration of chlorophyll-a (0.3 mg/m^3) was found at W6 station and maximum value (1.6 mg/m^3) was found at W1, W3 and W10 stations as indicated in Table E4. In Nhava Creek the range of chlorophyll-a was found between $1.3-2.2 \text{ mg/m}^3$ with an average of 1.7 mg/m^3 . Pheophytin-a is the main degradation product of chlorophyll-a and it was found between



1.0 – 2.7 mg/m³ in Harbour water and 0.2– 1.4 in Nhava creek water 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 20 -107 mg/m³. The minimum algal biomass was (20 mg/m³) found at W6 station and maximum (107 mg/m³) was found at W1, W3 and W10 stations and average value of phytoplankton standing crop (Biomass) in JNP harbour water was found 81 mg/m³. In Nhava Creek it was found between 86- 146 mg/m³ with an average of 115 mg/m³ during monitoring period. The minimum algal biomass was 86 mg/m³ at W11 and maximum (146 mg/m³) was found at W13 station.

Table E. 2.
Population Density of Phytoplankton

Sr.No.	Station	Density (no's / L)
JNP HARBOUR AREA		
1	W1	83 x 10 ³
2	W2	120 x 10 ³
3	W3	130 x 10 ³
4	W4	113 x 10 ³
5	W5	147 x 10 ³
6	W6	123 x 10 ³
7	W7	133 x 10 ³
8	W9	117 x 10 ³
9	W10	167 x 10 ³
Average		126 x 10³
NHAVA CREEK		
10	W11	110 x 10 ³
11	W12	147 x 10 ³
12	W13	217 x 10 ³
13	W14	233 x 10 ³
Average		177 x 10³

Table E. 3.
Abundance of Phytoplankton at Various Stations

Sr. No	Species	PERCENTAGE OF PHYTOPLANKTON														
		JNP HARBOUR AREA										NHAVA CREEK				
		W1	W2	W3	W4	W5	W6	W7	W9	W10	Avg	W11	W12	W13	W14	Avg
1	Cyclotella spp	8.0	19.4	15.4	20.6	9.1	10.8	10.0	5.7	12.0	12.3	12.1	9.1	9.2	8.6	9.8
2	Navicula spp	28.0	11.1	7.7	20.6	13.6	8.1	10.0	17.1	12.0	14.2	12.1	6.8	10.8	11.4	10.3
3	Skeletonema spp	32.0	44.4	56.4	41.3	50.0	43.3	40.0	34.3	40.0	42.4	48.5	45.5	49.2	51.4	48.7
4	Nitzcshia spp	24.0	16.7	12.8	8.8	9.1	18.9	20.0	25.7	22.0	17.6	18.2	25.0	20.0	18.6	20.5
5	Coscinodiscus spp	8.0	8.3	7.7	8.8	4.5	5.4	7.5	5.7	6.0	6.9	-	4.5	1.5	5.7	2.9
6	Gyrosigma spp.	-	-	-	-	13.6	13.5	12.5	11.4	8.0	6.6	9.1	9.1	9.2	4.3	7.9



Table E.4.
Photosynthetic Pigments

Sr.No.	Station	Chlorophyll-a (mg/m ³)	Pheophytin- a (mg/m ³)
JNP HARBOUR AREA			
1	W1	1.6	1.1
2	W2	0.9	1.6
3	W3	1.6	1.3
4	W4	1.2	1.4
5	W5	1.0	2.0
6	W6	0.3	2.7
7	W7	1.5	1.0
8	W9	1.2	1.4
9	W10	1.6	1.3
Average		1.2	1.5
NHAVA CREEK			
10	W11	1.3	1.4
11	W12	1.5	1.0
12	W13	2.2	0.2
13	W14	1.9	0.5
Average		1.7	0.8

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	107
2	W2	61
3	W3	107
4	W4	83
5	W5	64
6	W6	20
7	W7	101
8	W9	83
9	W10	107
Average		
NHAVA CREEK		
10	W11	86
11	W12	101
12	W13	146
13	W14	125
Average		115

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 147-446 no's/m³. The minimum population density of zooplankton (147 no's/m³) was found at towing between stations W2→W5 station and maximum of 446 no's/m³ was found in between stations W1→W2. The average population density of zooplankton in JNP harbour water was 219



no's/m³. In Nhava creek population density of zooplankton was found in the range of 152 -159 no's/m³ with an average of 156 no's/m³. The minimum density of zooplankton in creek water was 152 no's/m³ found at towing between stations W12→W13 and maximum of 159 no's/m³ at towing between stations W13→W14. The typical value of Shannon Wiener's index of species diversity of non-polluted sea water remains above 1 for moderate or more diversity. If the index value is obtained below 1, then it will represent less diversity. The Shannon Wiener's index of species diversity for JNP harbour was found between 0.20- 0.32 with an average of 0.25 and in Nhava creek it was found between 0.13 – 0.27 with an average of 0.22 shows moderate diversity. Over all diversity index of zooplankton in harbor region and Nhava creek region was found less it may due to the dredging activities into port region.

By the enumeration of zooplankton, the Copepods of crustacean group were found dominant in harbour region, 95.2 % of the total communities of JNP harbour water and 95.7 % 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 2.3 µg/L recorded between towing area of stations W2→W6 and maximum was 13.6 µg/L recorded between towing area of W1→W2 stations. The average ash free zooplankton biomass of JNP harbour water was 4.8 µg/L. In Nhava creek the minimum ash free biomass was 3.2 µg/L found between towing area of stations W11→W12 and maximum 6.5 µg/L was found between towing area of stations W13→W14 with an average of 4.6 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 1000 – 1178 mg/m³ with an average of 1074 mg/m³. The minimum concentration of POC (1000 mg/m³) was found at W2 and W4 stations and maximum (1178 mg/m³) at W3 station. In Nhava creek the POC content was found to be between 956-1000 mg/m³ with an average of 981 mg/m³. The POC content in Nhava creek was found minimum as 956 mg/m³ at W11 station and maximum at 1000 mg/m³ at W12 station. The POC concentration was found very high at all stations in JNP harbour and creek both region in JNP harbour and at



all stations in creek region compared to prescribed standard range (10-100 mg/m³) due to suspended and organic dead remains and dredging activity.

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	446	0.32
2	W2 → W5	147	0.32
3	W5 → W1	200	0.24
4	W5 → W6	209	0.20
5	W6 → W2	203	0.23
6	W4 → W3	218	0.26
7	W3 → W7	224	0.22
8	W7 → W10	220	0.22
9	W10 → W3	174	0.25
10	W3 → W9	152	0.22
Average		219	0.25
NHAVA CREEK			
11	W5 → W11	156	0.27
12	W11 → W12	158	0.26
13	W12 → W13	152	0.13
14	W13 → W14	159	0.22
Average		156	0.22



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

Sr. No	Species	PERCENTAGE OF PHYTOPLANKTON															
		JNP HARBOUR AREA										NHAVA CREEK					
		W1 → W2	W2 → W5	W5 → W1	W5 → W6	W6 → W2	W4 → W3	W3 → W7	W7 → W10	W10 → W3	W9 → W3	Avg	W5 → W11	W11 → W12	W12 → W13	W13 → W14	Avg
1	Sagitta	1.4	1.1	0.3	-	-	0.5	0.5	0.5	0.6	0.7	0.6	0.4	-	-	-	0.1
2	Medusa	2.7	2.7	1.9	1.9	2.7	2.6	1.7	1.8	2.2	1.1	2.1	1.4	4.2	1.1	2.1	2.2
3	Mysids	93.6	93.6	95.6	96.3	95.4	94.9	96.0	96.0	95.2	95.6	95.2	94.6	94.4	97.8	95.8	95.7
4	Copepods	1.7	1.1	1.1	0.8	1.1	1.5	0.7	0.8	1.0	1.8	1.2	2.5	0.7	0.4	1.4	1.3
5	Fish larva	0.4	1.5	1.5	1.1	0.8	0.5	1.0	1.0	1.0	0.7	1.0	1.1	0.7	0.4	0.7	0.7
6	Zoea larva	0.1	-	-	-	-	-	-	-	-	-	0.0	-	-	0.4	-	0.1



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	20.4	13.6
2	W2 → W5	5.8	3.2
3	W5 → W1	7.8	3.9
4	W5 → W6	5.3	4.3
5	W6 → W2	6.0	2.3
6	W4 → W3	7.1	3.3
7	W3 → W7	6.8	2.8
8	W7 → W10	7.6	3.1
9	W10→ W3	7.8	6.1
10	W3 → W9	6.9	5.1
Average		8.2	4.8
NHAVA CREEK			
11	W5 →W11	7.0	4.8
12	W11 →W12	6.8	3.2
13	W12 →W13	7.2	3.9
14	W13 →W14	7.3	6.5
Average		7.1	4.6

Table E.9. Concentration of Particulate Oxidisable Organic Carbon

Sr. No.	Stations	Concentration of POC (mg/m3)
Standards		10 - 100
JNP HARBOUR AREA		
1	W1	1011
2	W2	1000
3	W3	1178
4	W4	1000
5	W5	1078
6	W6	1111
7	W7	1100
8	W9	1067
9	W10	1122
Average		1074
NHAVA CREEK		
10	W11	956
11	W12	1000
12	W13	989
13	W14	978
Average		981



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 1000 - 1500 no's/100gm with an average of 1278 no's/100 gm given in Table E.10. The minimum value of 1000 no's/m² was found at W1 station while the maximum value of 1500 no's/gm at W5 station. In Nhava creek region it was found to be in the range of 1502 -1700 no's/gm with an average of 1578 no's/100gm. The minimum value of 1502 no's/100 gm was found at W13 and the maximum value of 1700 no's/ gm was found at W14 station.

In the month of April, 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	-	1000	1	Foraminiferans
2	W2	-	1300	1	Foraminiferans
3	W3	-	1100	1	Foraminiferans
4	W4	-	1400	1	Foraminiferans
5	W5	-	1500	1	Foraminiferans
6	W6	-	1300	1	Foraminiferans
7	W7	-	1400	1	Foraminiferans
8	W9	-	1300	1	Foraminiferans
9	W10	-	1200	1	Foraminiferans
Average			1278		1278
NHAVA CREEK					
11	W11	3	1603	3	Pelecypods, gastropods, foraminifera
12	W12	5	1505	3	Pelecypods, gastropods, foraminifera
13	W13	2	1502	3	Pelecypods, gastropods, foraminifera
14	W14	0	1700	3	Pelecypods, gastropods, foraminifera
Average			1578	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 75- 86 µg/L with an average of 81 µg/L. The minimum concentration of 75 µg/L of Phosphate was found at W2 station and maximum concentration of 86 µg/L at W3 station. Overall in JNP harbour region the Phosphate value was found under the standard range (0.1-90 µg/L) . The Nitrate was found between 183-219 µg/L, with minimum value as 183 µg/L at W5 and maximum as 219 µg/L at W3 station. The average concentration of Nitrate was found to be 197 µg/L and overall Nitrate was found within range (1.0-500 µg/L) at all stations. The Nitrite was found to be between 105-115 µg/L with an average of 112 µg/L. The minimum concentration of nitrite (105 µg/L) was found at W5 station and maximum of 115 µg/L at W7 station. Overall in JNP harbour region the Nitrite value was found under standard range (<125 µg/L). Silica is another important nutrient in seawater. The requirement of silica by diatoms is however, entirely limited to skeletal formation and has particular importance in coastal upwelling region where diatoms form a dominant part of phytoplankton. Silica in the form of silicate in JNP harbour water was found between 1399 – 1538 µg/L with an average of 1457 µg/L. The minimum concentration of silica of 1399



µg/L was found at W1 and W6 stations and maximum was found 1538 µg/L at W4 station. The Sulphate was found between 1976 - 2358 mg/L, with minimum value as 1976 mg/L at W1 station and maximum as 2358 mg/L at W7 station. The average concentration of Sulphate was found to be 2210 mg/L.

In Nhava Creek, Phosphate was found between 66-75 µg/L with an average 70 µg/L which was under standard range (0.1-90 µg/L). Nitrate was found between 183 - 201 µg/L with an average 191 µg/L. The minimum Nitrate (183 µg/L) was found at W13 station and maximum (201 µg/L) at W11 station and Nitrite was found between 106- 114 µg/L with an average of 109 µg/L. The minimum Nitrite (106 µg/L) was found at W13 station and maximum (114 µg/L) at W14 station. The silica content in Nhava creek was found between 1469 µg/L- 1573 µg/L with an average of 1504 µg/L. The minimum silica content of 1469 µg/L was found at stations W13 and W14 and maximum as 1573 µg/L at W11 station. Sulphate was found between 2358- 2486 mg/L with an average of 2406 mg/L. The minimum Sulphate (2358 mg/L) was found at W12 and W14 station and maximum (2486mg/L) at W13 station. Overall in JNP harbour and creek region the values of all the nutrients were found to be within the recommended ranges, which are given in Table 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 28.2– 43.7 µg/g with an average of 36.0 µg/g. The minimum concentration of Phosphate (28.2µg/g) was found at W5 and maximum concentration (43.7 µg/g) at W6 stations. The Nitrate was found between 0.38 – 0.52 µg/g, with minimum value (0.38 µg/g) at W2 and W6 stations and maximum (0.52 µg/g) at W10 station. The average concentration of Nitrate was found to be 0.43 µg/g. The Nitrite was found to be between 3.19– 3.43 µg/g with an average of 3.30 µg/g. The minimum concentration of nitrite (3.19 µg/g) was found at W1 and W6 stations and maximum (3.43 µg/g) at W4 station. Silica in the form of silicate in JNP harbour sediments were found between 0.086 – 0.097 µg/g with an average of 0.092 µg/g. The minimum concentration of silica (0.086 µg/g) was found at W10 station and maximum (0.097 µg/g) was found at W3 station. The Sulphate was found between 4079- 4398 µg/g, with minimum value of 4079 µg/g at W7 and W9 stations and maximum of 4398 µg/g at W1 station. The average concentration of Sulphate was found to be 4235 µg/g.

In Nhava Creek, Phosphate was found between 51.5- 56.6 µg/L with an average 53.4 µg/L which was under standard range (0.1-90 µg/L). Nitrate was found between 0.52 – 0.59 µg/L with an average 0.55 µg/L. The minimum Nitrate (0.52 µg/L) was found at W12 station and maximum (0.59 µg/L) at W13 station and Nitrite was found



between 3.54- 3.61 $\mu\text{g/L}$ with an average of 3.57 $\mu\text{g/L}$. The minimum Nitrite (3.54 $\mu\text{g/L}$) was found at W12 station and maximum (3.61 $\mu\text{g/L}$) at W14 station. The silica content in Nhava creek was found between 0.105 – 0.111 $\mu\text{g/L}$ with an average of 0.107 $\mu\text{g/L}$. The minimum silica content of 0.105 $\mu\text{g/L}$ was found at W11 and W13 stations and maximum as 0.111 $\mu\text{g/L}$ at W14 station. Sulphate was found between 5099- 5418 mg/L with an average of 5227 mg/L. The minimum Sulphate (5099 mg/L) was found at W14 station and maximum (5418 mg/L) at W12 station. Overall in JNP harbour and creek region the values of all the nutrients were found to be within the recommended ranges.

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 845- 854 mg/L with an average of 848 mg/L. The minimum concentration (845 mg/L) of Calcium was Found at W10 station and maximum concentration (854 mg/L) at W5 station. Potassium in JNP harbour water was found between 511 - 547 mg/L with an average of 540 mg/L. The minimum concentration of Potassium (511 mg/L) was found at W10 station and maximum (547 mg/L) at W2 station. The Magnesium was found between 842- 848 mg/L, with minimum value (842 mg/L) at W1 station and maximum (848 mg/L) at W3 station. The average concentration of Magnesium was found to be 845 mg/L. The Sodium was found between 12454 - 12558 mg/L with an average of 12467 mg/L. The minimum concentration of sodium (21454 mg/L) was found at W6 station and maximum (12558 mg/L) at W1 station.

In Nhava Creek, Calcium concentration was found between 840 - 848 mg/L with an average 845 mg/L. The minimum value of Calcium (840 mg/L) was found at W13 station



and maximum (848 mg/L) at W11 station. The Potassium content in Nhava creek was found between 540-542 mg/L with an average of 541 mg/L. The minimum potassium value (540 mg/L) was found at W14 station and maximum (542 mg/L) at W12 and W13 Stations. Magnesium concentration was found between 844 – 848 mg/L with an average of 846 mg/L. The minimum value of Magnesium (844 mg/L) was found at W12 station and maximum (848 mg/L) was found at W11 station. Sodium concentration was found between 12455-12458 mg/L with an average of 12457 mg/L. The minimum sodium value (12455mg/L) was found at W12 station and maximum (12458 mg/L) at W11 and W14 stations.

In harbour region sediments, the Calcium was found between 243- 249 mg/Kg with an average of 245 mg/Kg given in Table E.14. The minimum Concentration of 243 mg/Kg of Calcium was found at W2 and W9 stations and maximum concentration of 249 mg/Kg at W3 station. Potassium in JNP harbour sediment was found between 534- 538 mg/Kg with an average of 536 mg/Kg. The minimum concentration of Potassium of 534 mg/Kg was found at W4 station and maximum of 538 mg/Kg at W2,W6 and W10 stations. Magnesium was found between 1725- 1729 mg/Kg, with minimum value as 1725 mg/Kg at W7 station and maximum as 1729 mg/Kg at W2 and W10 stations. The average concentration of Magnesium was found to be 1727 mg/Kg. Sodium was found to be between 2946 - 3048 mg/Kg with an average of 3035 mg/Kg. The minimum concentration of sodium (2946 mg/Kg) was found at W6 station and maximum of 3048 mg/Kg at W5 station.

In Nhava Creek sediments, Calcium was found between 232- 236 mg/Kg with an average 235 mg/Kg given in Table E. 14. The minimum value of calcium (232 mg/Kg) was found at W13 and maximum (236 mg/Kg) was found at W11 station. The Potassium content in Nhava creek was found between 537- 542 mg/Kg with an average of 539 mg/Kg. The minimum Potassium content (537 mg/Kg) was found at station W13 station and maximum (542 mg/Kg) at W11 station. Magnesium was found between 1724 - 1727 mg/Kg with an average of 1725 mg/Kg. The minimum Magnesium value (1724 mg/Kg) was found at W12 and W13 stations and maximum (1727 mg/Kg) at W14 station. Sodium was found between 3024- 3045 mg/Kg with an average of 3038 mg/Kg. The minimum sodium value (3024 mg/Kg) was found at W12 station and maximum (3045 mg/Kg) at W11 station.

The depth of light penetration decreased by particles suspended in water, including any algal cells that are growing there. Coastal waters with high sediment content, or water



in which an algal bloom is occurring, have less light penetration than clear open ocean water. The light penetration (Euphotic zone) in harbour of JNP and Nhava creek is given in Table E.16. It was measured by Secchi disc. The average visibility of Secchi disc was found to be 0.7 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	82	214	114	1399	1976
2	W2	75	188	113	1469	2231
3	W3	86	219	114	1434	2231
4	W4	84	205	110	1538	2167
5	W5	77	183	105	1469	2295
6	W6	82	192	108	1399	2167
7	W7	79	196	115	1469	2358
8	W9	81	192	114	1434	2295
9	W10	84	188	111	1503	2167
Average		81	197	112	1457	2210
NHAVA CREEK						
10	W11	68	201	107	1573	2422
11	W12	71	188	108	1503	2358
12	W13	66	183	106	1469	2486
13	W14	75	192	114	1469	2358
Average		70	191	109	1504	2406

(*) 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	33.4	0.41	3.19	0.092	4398
2	W2	36.0	0.38	3.33	0.089	4143
3	W3	30.8	0.45	3.29	0.097	4334
4	W4	36.0	0.41	3.43	0.095	4334
5	W5	28.2	0.41	3.36	0.092	4271
6	W6	43.7	0.38	3.19	0.089	4143
7	W7	38.6	0.48	3.29	0.092	4079
8	W9	41.1	0.45	3.36	0.095	4079
9	W10	36.0	0.52	3.22	0.086	4334
Average		36.0	0.43	3.30	0.092	4235
NHAVA CREEK						
10	W11	51.5	0.55	3.57	0.105	5163
11	W12	56.6	0.52	3.54	0.108	5418
12	W13	54.0	0.59	3.57	0.105	5227
13	W14	51.5	0.55	3.61	0.111	5099
Average		53.4	0.55	3.57	0.107	5227

(-) 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	849	545	842	12558
2	W2	846	547	843	12455
3	W3	850	546	848	12457
4	W4	848	542	845	12460
5	W5	854	543	847	12456
6	W6	847	544	846	12454
7	W7	846	539	847	12455
8	W9	846	545	846	12456
9	W10	845	511	845	12456
Average		848	540	845	12467
NHAVA CREEK					
10	W11	848	541	848	12458
11	W12	847	542	844	12455
12	W13	840	542	846	12457
13	W14	843	540	845	12458
Average		845	541	846	12457



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	245	535	1728	3044
2	W2	243	538	1729	3043
3	W3	249	535	1728	3045
4	W4	247	534	1726	3047
5	W5	246	537	1727	3048
6	W6	245	538	1726	2946
7	W7	244	537	1725	3047
8	W9	243	536	1726	3046
9	W10	246	538	1729	3047
Average		245	536	1727	3035
NHAVA CREEK					
10	W11	236	542	1726	3045
11	W12	235	539	1724	3024
12	W13	232	537	1724	3039
13	W14	235	538	1727	3042
Average		235	539	1725	3038



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	0.34
5	W5	0.36
6	W6	0.35
7	W7	0.37
8	W9	0.36
9	W10	0.35
Average		0.36
NHAVA CREEK		
10	W11	0.37
11	W12	0.36
12	W13	0.36
13	W14	0.35
Average		0.36



Table E.16. Results of Secchi Depth

Sr. No.	Stations	Secchi depth (ft)
JNP HARBOUR AREA		
1	W1	0.5
2	W2	0.5
3	W3	1.0
4	W4	1.0
5	W5	0.5
6	W6	0.5
7	W7	0.5
8	W9	0.5
9	W10	1.0
Average		0.7
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 April, 2013 in JNP harbour and creek region was found 150 to 375 mgC/m³/day. The visibility of Secchi disc (light penetration) in the JNP harbour water and Nhava creek was found to be between 0.5 – 1.0 feet. Low visibility could be due to the dredging activity in JNP area and surface runoff water from nearby areas. The overall average value of chlorophyll-a in JNP harbour water was found 1.2 mg/m³ and in creek water was found to be 1.7 mg/m³ 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 0.25 in JNP harbour water and 0.22 in creek water. These values represent less species diversity in JNP harbour and in creek region.

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

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

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

Table E.17.
Conclusions and Mitigation Measures for Ecological Parameters During April, 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	-	Harbour 1.2 mg/m ³ Creek 1.7 mg/m ³	Low phytoplankton density in harbour regions than creek region due to high turbidity.	-
3	Phosphate	0.1- 90 µg/L	Harbour – 81.0 µg/L Creek – 70.0 µg/L	-	-
4	Nitrate	1.0-500 µg/L	Harbour – 197.0 µg/L Creek -191.0 µg/L	-	Within range
5	Nitrite	<125 µg/L	Harbour – 112.0 µg/L Creek – 109.0 µg/L	-	Within range
6	Particulate Organic Carbon (POC)	10-100 mg/m ³	Harbour – 1074 mg/m ³ Creek -981 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 – 1457 µg/L Creek - 1504 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 April, 2013 to determine the present status of drinking water quality of JNPT area and to compare it with the prescribed standards. As per requirement samples were collected and analyzed from eighteen stations from outside and inside the port area of JNPT. Ten stations were outside the port area and eight stations were inside the port area. All the water samples were collected from the port area of JNPT on 24th April, 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 April, 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 49- 71 $\mu\text{Mhos/cm}$. pH of all eighteen samples was in the range of 7.1 - 7.4 which is within the acceptable limits to the permissible standard of 7.0- 8.5. Concentration of chlorides was 3.7- 7.9 mg/L and was well within the acceptable limit (200 mg/L). TDS of all the eighteen samples was in the range of 58- 86 mg/L and was within the acceptable range (500 mg/L). Hardness of all the eighteen samples was found to be in the range of 21- 52 mg/L as CaCO_3 and was within the acceptable limit (200 mg/L). Concentration of total iron was found to be in the range of 0.02- 0.05 mg/L and was within the acceptable limit (0.1 mg/L). Sulphate content of all the eighteen samples was in the range of 3.4- 5.3 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 0.01- 0.04 mg/L. Concentration of $\text{PO}_4^{3-}\text{-P}$ at all the eighteen stations, was found to be in the range of 0.04- 0.08 mg/L. Analysis of the bacteriological parameter showed that all the drinking water samples were safe in terms of bacteriological quality.

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

Table D. 2
Results of Drinking Water Quality Monitoring, 24th April, 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)	0.48	0.51	0.50	0.53	0.54	0.48	1.0
Conductivity [μMhos/cm]	55	65	62	49	58	66	-
pH	7.2	7.3	7.2	7.3	7.2	7.3	7.0 to 8.5
Chlorides (mg/l)	3.8	4.7	3.7	4.1	6.8	6.1	200
TDS (mg/l)	58	65	74	86	70	61	500
Total Hardness (mg/l as CaCO ₃)	45	37	46	21	47	52	200
Iron (mg/l)	0.04	0.04	0.04	0.03	0.04	0.05	0.1
Sulphate (mg/l)	3.8	4.1	5.3	5.1	3.8	4	200
NH ₄ ⁺ -N (mg/l)	0.02	0.03	0.04	0.03	0.04	0.04	-----
PO ₄ ³⁻ -P (mg/l)	0.04	0.05	0.08	0.07	0.06	0.07	-----
CFU (Per 100 ml)	Nil	Nil	Nil	Nil	Nil	Nil	Nil

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

Results of Drinking Water Quality Monitoring, 24th April, 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)	0.47	0.44	0.56	0.59	0.45	0.55	1
Conductivity [μMhos/cm]	61	71	57	50	70	62	-
pH	7.4	7.1	7.2	7.3	7.3	7.2	7.0 to 8.5
Chlorides (mg/l)	6.9	7.1	7.8	7.7	7.9	3.7	200
TDS (mg/l)	78	60	80	83	74	59	500
Total Hardness (mg/l as CaCO ₃)	33	38	48	44	50	36	200
Iron (mg/l)	0.03	0.02	0.041	0.04	0.03	0.05	0.1
Sulphate (mg/l)	5	5.2	4.7	4.3	4.4	3.9	200
NH ₄ ⁺ -N (mg/l)	0.02	0.03	0.01	0.03	0.03	0.02	----
PO ₄ ⁻³ -P (mg/l)	0.05	0.04	0.05	0.06	0.07	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, 24th April, 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)	0.49	0.51	0.59	0.46	0.55	0.57	1
Conductivity [μMhos/cm]	60	67	54	65	56	52	-
pH	7.4	7.3	7.2	7.2	7.3	7.2	7.0 to 8.5
Chlorides (mg/l)	5	6.6	3.9	4.4	4.8	7.5	200
TDS (mg/l)	67	77	82	70	61	68	500
Total Hardness (mg/l as CaCO ₃)	39	45	27	24	44	48	200
Iron (mg/l)	0.04	0.03	0.02	0.03	0.04	0.04	0.1
Sulphate (mg/l)	3.4	3.6	4.6	4	3.8	3.5	200
NH ₄ ⁺ -N (mg/l)	0.03	0.03	0.03	0.04	0.03	0.02	----
PO ₄ ⁻³ -P (mg/l)	0.08	0.05	0.03	0.04	0.04	0.05	-----
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.