TANGEDCO

TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LTD

COMPREHENSIVE MARINE ENVIRONMENTAL IMPACT ASSESSMENT STUDY FOR OUTFALL OF THE PROPOSED ENNORE SEZ AND NCTPS STAGE III THERMAL POWER PROJECTS IN THE NCTPS COMPLEX

CENTRE FOR ENVIRONMENT

WAPCOS LIMITED

(A GOVERNMENT OF INDIA UNDERTAKING)

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EXECUTIVE SUMMARY

1. INTRODUCTION

In order to offset the demand supply gap in power position of the state of Tamilnadu, Tamilnadu Generation and Distribution Corporation Ltd (TANGEDCO) has proposed to establish the following two power projects in and around North Chennai Thermal Power Station area (NCTPS).

- 2x800 MW Ennore SEZ TPP by reclaiming a portion of existing Ash Dyke of NCTPS in Vayalur Village, Ponneri Taluk, Thiruvallur District.
- 1X800 MW NCTPS Stage III TPP in the vacant land within the existing NCTPS Complex, Ennur Village, Ponneri Taluk, Thiruvallur District.

For the above projects, it has been proposed to draw Cooling water from the forebay of NCTPS Stage II intake channel located within NCTPS complex.

The Cooling water system is a closed cycle system for both projects consists of Natural Draft Cooling Towers. The coolant water from both the cooling towers has been proposed to be discharged in the existing pre cooling channel of NCTPS complex

2. NEED OF THE STUDY

<u>Ennore SEZ Project (2 x 800 MW)</u>

The Expert Appraisal Committee (EAC) on CRZ, Infrastructure & Miscellaneous Projects of MoEF, has considered the project in the meeting held on 5.3.2012 for issuing clearance under CRZ notification. The committee recommended to TANGEDCO to carry out the Marine EIA study with special emphasis on the impact of temperature and salinity on Marine Environment due to outfall discharge.

NCTPS Stage-III (1 X 800 MW)

During the 46th meeting of EAC held on 10.4.2012, the subject project was discussed for issue of ToR. The committee recommended to TANGEDCO to submit comprehensive Marine EIA report along with Terrestrial EIA report.

To carry out the said studies, TANGEDCO has appointed Indian Institute of Technology (IIT), Madras for undertaking the study of thermal dispersion characteristics of the Ennore creek for the purpose of assessing the marine Environmental impact due to the cooling water discharge for all the power stations discharging into the existing pre-cooling water channel of the North Chennai Thermal Power Station. To carry out Marine EIA study IIT, Madras have appointed WAPCOS Limited, A Government of India Undertaking under the Ministry of Water Resources and Accreditated EIA consulting organization of NABET-QCI in Ports and Harbour sector.

3. PROJECT DESCRIPTION

The existing and proposed power plants in NCTPS complex and its adjacent area are as follows:

- **North Chennai Thermal Power station stage I (3x210 MW)**

  The North Chennai Thermal power station stage I (3x210 MW) was commissioned during 1995.The cooling water of 90,000 m3/hr is being drawn from the Ennore Port through a open channel as the cooling water system is a once through system. The coolant water is being discharged through a pre cooling channel in the mouth of Ennore Creek.

- **North Chennai Thermal power project Stage II (2x600 MW):**

  The North Chennai TPP stage II (2x600 MW) has been commissioned recently. The cooling water of 2,00,000 m3/hr is being drawn from Ennore Port through open channel as the cooling system is open cycle. The coolant water is being discharged in the existing pre cooling channel of NCTPS.

- **Vallur Thermal power project (3x500 MW)**

  Out of the three units, two units of the Vallur Thermal power plant have been commissioned recently. The 3rd unit is under construction. 20,000 m3/hr of cooling water is required for the 3 units. The water is being drawn from the existing forebay of NCTPS stage I. The cooling water system is a closed cycle one. The coolant water is being/will be discharged into the existing Pre cooling channel of NCTPS.

- **Ennore SEZ TPP (2x800 MW)**

  The total water requirement for the proposed 2x800 MW project has been estimated as 13,790 m^3/hr. The above quantity of water has been proposed to be drawn from the existing forebay of NCTPS Stage – II intake channel. The plant is having closed cycle cooling system. The coolant water will be discharged through the existing pre cooling channel of NCTPS.

- **North Chennai Thermal power project stage III (1x800 MW)**

  The total water requirement has been estimated as 6,900 m^3/hr. The cooling water is proposed to be drawn from the forebay of NCTPS Stage-II intake channel. The system is closed cycle cooling water system. The coolant water will be discharged through the existing pre cooling channel.

4. ENVIRONMENTAL BASELINE DATA

The Environmental Baseline Status of the proposed project area highlights the following:

- The marine water quality and sediment analysis indicates that there is no coastal pollution in the project area

- The heavy metals analysed in the marine water and sediment samples indicate that all the parameters are well within the WHO standard.
- No rare, endangered or threatened Marine Floral and Faunal species is reported in and around project area
- The marine ecological survey of the project area indicates that the availability of primary Nutrient like Nitrogen and Phosphorus in moderate level and hence the project area has moderate productivity.
- The various parameters monitored as part of marine ecological survey indicates that the project area is as good as any other normal coastal environment.

5. ASSESSMENT OF IMPACTS

Impact of Temperature changes

Based on the Modeling study carried out by IIT, Madras, it is observed that the outfall temperature increase is only about 3.3^{0}C above ambient temperature which is below the stipulated limit of 5^{0}C. This temperature further reduces to about 0.4^{0}C, ie., almost reaches ambient temperature at a distance of 2 km from the outfall. Hence there shall be negligible / insignificant impact on the marine organism.

Impact of salinity changes

The pre-cooling channel receives a total discharge of 3,20,000 m^3/hr. The brine is present only in the blow down discharges of 3 plants (Vallur, Ennore SEZ and NCTPS-III).The average salinity differential of these discharges is 10.39 g/l. However, when all the discharges get mixed, the outfall discharge will have insignificant salinity differential of only 1.53g/l. In comparison, the present outfall will have already highly diluted discharge which will not have any impact on marine environment.

6. ENVIRONMENTAL MANAGEMENT PLAN

In the proposed project, the outfall temperature shall be increased only by 3.3 ^{o}C from the ambient temperature, which is well below the standard prescribed by the statutory authority. Hence, no specific management measures is suggested. However, it is recommended that TANGEDCO should implement all the good practices for outfall management to further enhance the protection of the Marine Environment.

7. ENVIRONMENTAL MONITORING PROGRAMME

Monitoring is an essential component for sustainability of any developmental project and is an integral part of any environmental assessment process. For maintenance of quality of the marine ecology of the study area designated monitoring sites for periodic monitoring with respect to water quality, sediment quality and flora and fauna have been recommended.

8. CONCLUSION

The conclusions of the study are as follows:

- The outfall discharge temperature will be only about 3.3^{o}C higher than ambient conditions . This temperature further reduces to about 0.4^{0}C, ie., almost reaches ambient temperature at a distance of 2 km from the outfall.
- The present creek dilutes and disperses the outfall water temperature well as there is good tidal exchange between ennore creek and sea.
- The average salinity differential of the discharges blowdown from closed cycle discharges of 3 plants of NCTPP III,Vallur TPP and Ennore SEZ TPP is 10.39 g/l..Hence, the present outfall which will have highly diluted discharge will have marginal / insignificant impacts.
- The marine water quality in and around the proposed outfall area is that of any normal coastal environment .

- The project area has biological features charecteristics of any normal coastal area in the occurence, abuandance and bio diversity of biological community of phytoplankton, zooplankton, benthos and fishes. The area is devoid of mangrove vegetation,Seaweeds and corel reefs. No rare, endangered, threatend marine speices were recorded .
- Inview of the above,it is concluded that the outfall of the proposed Ennore SEZ and NCTPS stage III Thermal Power projects in the NCTPS Complex would not change the quality of existing natural coastal environment.

CHAPTER - 1

INTRODUCTION

1.1 Background

The North Chennai Thermal power station complex (NCTPP) Stage I has at present 3 units of 210 MW in operation. The cooling water system is “Once through sea water cooling system” and the quantum of 90,000 m^3/hr is discharge into the pre cooling channel which finally discharge into the Bay of Bengal.

As part of reducing the power demand supply gap in the state of Tamil Nadu, TANGEDCO has established two projects and proposed to establish two more projects in NCTPP Complex. The brief details are as follows:

- **NCTPP Stage –II – 2 x 600 MW -** The cooling water system is “Once through sea water cooling system” operation, where the quantum of 2,00,000m^3/hr is discharge into the pre cooling channel.
- **Vallur Thermal Power Project – 3 x 500MW -** The cooling water system is “Closed cycle System”, where the quantum of 20,000^{m3}/hr is proposed to be discharge into the pre cooling channel.
- **Ennore SEZ Thermal Power Project – 2 x 800 MW -** The cooling water system is “Closed cycle System”, where the quantum of 15,000m^3/hr is proposed to be discharge into the pre cooling channel.
- **NCTPP Stage –III – 1 x 800 MW –** The cooling water system is “Closed cycle System”, where the quantum of 8,000^{m3}/hr is proposed to discharge into the pre cooling channel.

The location of various projects in the NCTPS complex along with the location of Intake and Outfall are shown in **Figure-1.**

Figure- 1 : Location of the pre-cooling channel and discharge points of 5 power projects

1.2 NEED OF THE STUDY

Ennore SEZ Project (2 x 800 MW)

TANGEDCO had submitted the proposed project for obtaining CRZ clearance to Tamil Nadu Coastal Zone Management Authority (TNCZMA). The project was recommended by the TNCZMA for CRZ clearances from MoEF vide letter dated 27.07.2011. The Expert Appraisal Committee (EAC) on CRZ, Infrastructure & Miscellaneous Projects of MoEF, has considered the project in the meeting held on 5.3.2012 for issuing clearance under CRZ notification for the foreshore facilities of the captioned project viz, cooling water, Intake and Outfall structures and coal conveying arrangement from Ennore Port which are permitted activity as per clause (3) sub clause (iii) and clause (4), sub clause I (f) of CRZ regulation.The committee of CRZ, Infrastructure & Miscellaneous Projects of MoEF after detailed deliberation recommended to carry out the following studies ,so as to reconsider the project:

- Examine and submit the impact on Marine ecology especially due to temperature and salinity
- Temperature and Salinity of cooling bleed and mitigation plan to comply the discharge norms
- To submit the details of the Intake and Outfall pumps, Pipe lines on the CRZ map of 1:4000 scale prepared by an authorized agency.
- Proper coordinates shall be given on the CRZ map for field verification as and when required. The CRZ map shall be covering 7 km around the Project site indicating the CRZ classifications including notified ecological sensitive areas shall be submitted.

NCTPS Stage-III (1 X 800 MW)

During the 46th meeting of EAC held on 10.4.2012, the EAC has discussed the project for issue of ToR for NCTPS stage III TPP (1 x 800 MW) and directed to submit comprehensive Marine EIA report along with Terrestrial EIA report for NCTPS Stage III TPP (800 MW).

To carry out the above studies, TANGEDCO has appointed Indian Institute of Technology (IIT), Madras for conducting Mathematical Model study of Thermal / Salinity dispersion of the cooling water discharge and impact of the coolant water of the following projects:

i. NCTPS – Stage I
ii. NCTPS – Stage II
iii. NTECL Vallur project
iv. NCTPS – Stage III
v. Ennore SEZ – TPP

IIT, Madras has carried out the Mathematical Modeling studies of the NCTPS complex. To carry out Marine EIA study IIT, Madras have appointed WAPCOS Limited, A Government of India Undertaking under the Ministry of Water Resources and Accreditated EIA consulting organization of NABET-QCI.

1.3 OUTLINE OF THE REPORT

The contents of the Marine EIA report are as follows:

Chapter- 1: This chapter explains the background, and need for the study for the proposed Ennore SEZ Thermal Power Plant and NCTPS Stage III

Chapter- 2: This chapter describes the various projects in operation and proposed project in the NCTPS Complex.

Chapter- 3: This chapter describes the Baseline environmental conditions with reference to Marine Environment. The baseline study involved both field work and review of existing documents.

Chapter- 4: This chapter describes the anticipated impacts due to the proposed activity and Mitigation plans to minimize the adverse impacts.

Chapter- 5: This chapter describes the post Environmental Monitoring Programme to be implemented.

Chapter- 6: This chapter summarizes the conclusion of the study.

CHAPTER -2

PROJECT DESCRIPTION

2.1 North Chennai Thermal power station (NCTPS) Complex

The existing and proposed power plants in NCTPS complex and its adjacent area are described below:

- **North Chennai Thermal Power station stage I (3x210 MW)**

The North Chennai Thermal power station stage I (3x210 MW) was commissioned during 1995. The NCTPS complex has an area of about 1100 acres. The NCTPS Stage I Power plant has been established over an area of 180 acres. The cooling water of 90,000 m3/hr is being drawn from the Ennore Port through a open channel as the cooling water system is a once through system and the raw water is obtained from Chennai Metro Water Supply and Sewerage Board (CMWSSB). Coal for the plant is received through Ennore Port adjacent to the Plant through External Coal conveyor. The coolant water is being discharged through a pre cooling channel in the mouth of Ennore Creek.

- **North Chennai Thermal power project Stage II (2x600 MW):**

The North Chennai TPP stage II (2x600 MW) is being commissioned. The power plant has been established within NCTPS complex over an area of 180 acres. The cooling water of 2, 00,000 m3/hr is being drawn from Ennore Port through open channel as the cooling system is open cycle and Raw water is being obtained from CMWSSB. Coal for the plant received through Ennore Port. The coolant water has been proposed for discharge in the existing pre cooling channel of NCTPS.Both the units have already been synchronized.

- **Vallur Thermal power project (3x500 MW)**

  Two units of the Vallur Thermal power plant have already been commissioned. The power plant has been established adjacent to the existing NCTPS over a area of 1000 acres. The cooling water of 20,000 m3/hr is being drawn from the existing forebay of NCTPS stage I. The cooling water system is a closed cycle one. Raw water is obtained through a desalination plant within the power plant. Coal is received through Ennore Port. The coolant water of 15,000 m3/hr is being discharged into the existing Pre cooling channel of NCTPS.

- **Ennore SEZ TPP (2x800 MW)**

  It is proposed to develop the project in 500 acres of reclaimed land from the existing Ash dyke area (Appx. 1100 acres) of NCTPS. Land is under the possession of TANGEDCO. The total water requirement for the proposed 2x800 MW project has been estimated as 13,790 m^3/hr. The above quantity of water has been proposed to be drawn from the existing forebay of NCTPS intake channel. From the total water requirement, 12,230 m3/hr to be used for cooling water. The plant is having closed cycle cooling system. The balance quantity of 1,560 m3/hr is processed through a desalination plant to obtain required raw water. Apart from Desalination plant, supply of 4 MGD (630 m3/hr) water commitment received from CMWSSB. The coolant water will be discharged through the outfall channel of NCTPS through existing pre cooling channel.

- **North Chennai Thermal power project stage III (1x800 MW)**

  It is proposed to develop the said project in the TANGEDCO land of about 190 acres in the existing NCTPS complex and Land is under the possession of TANGEDCO. The total water requirement has been estimated as 6,900 m^3/hr. As the cooling water system is closed cycle cooling water system, the water requirement is 6120 m3/hr. The balance quantity of 780 m3/hr is used for raw water which will be obtained through desalination plant.

The location of the above five Power projects are shown below:

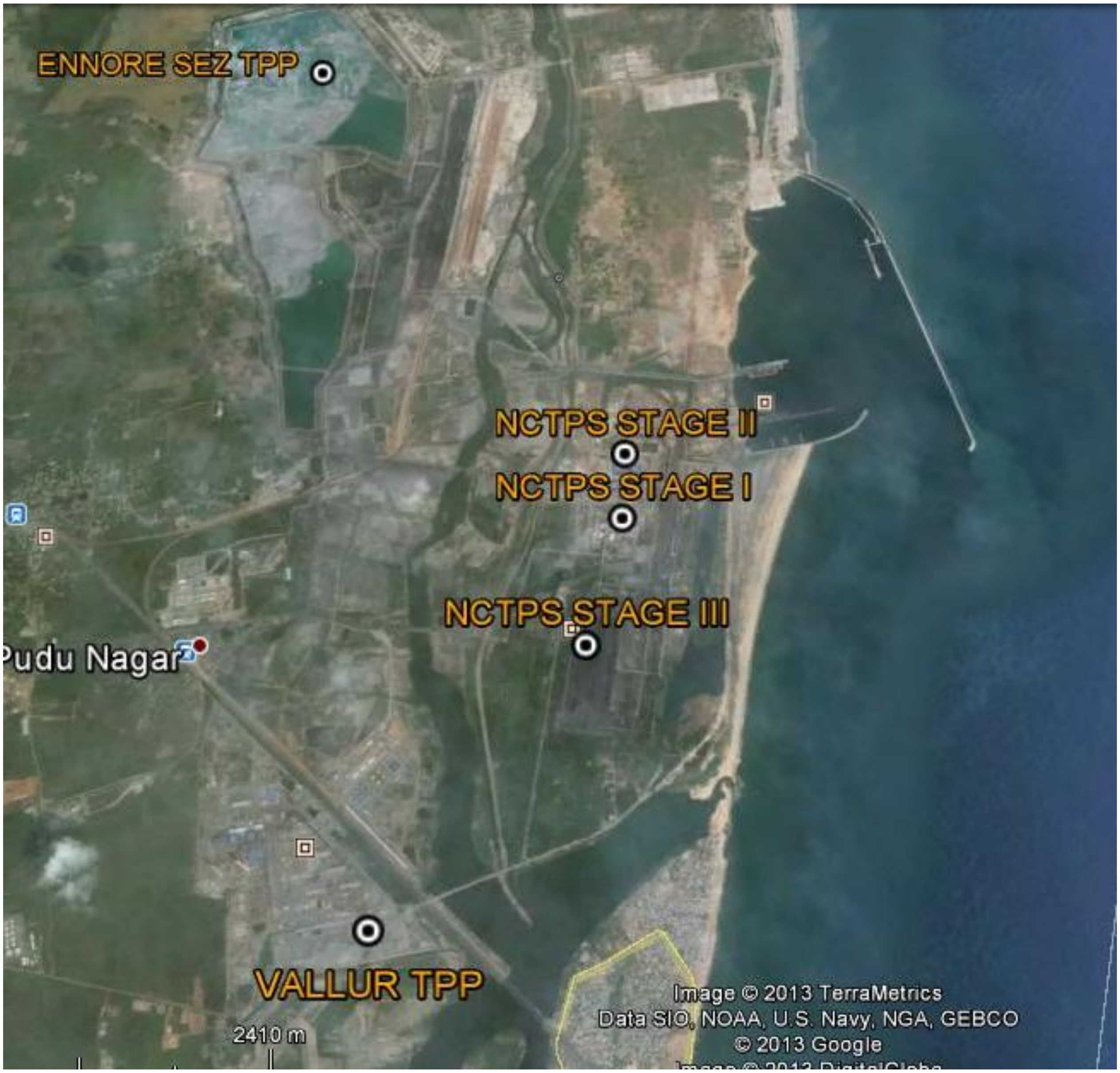


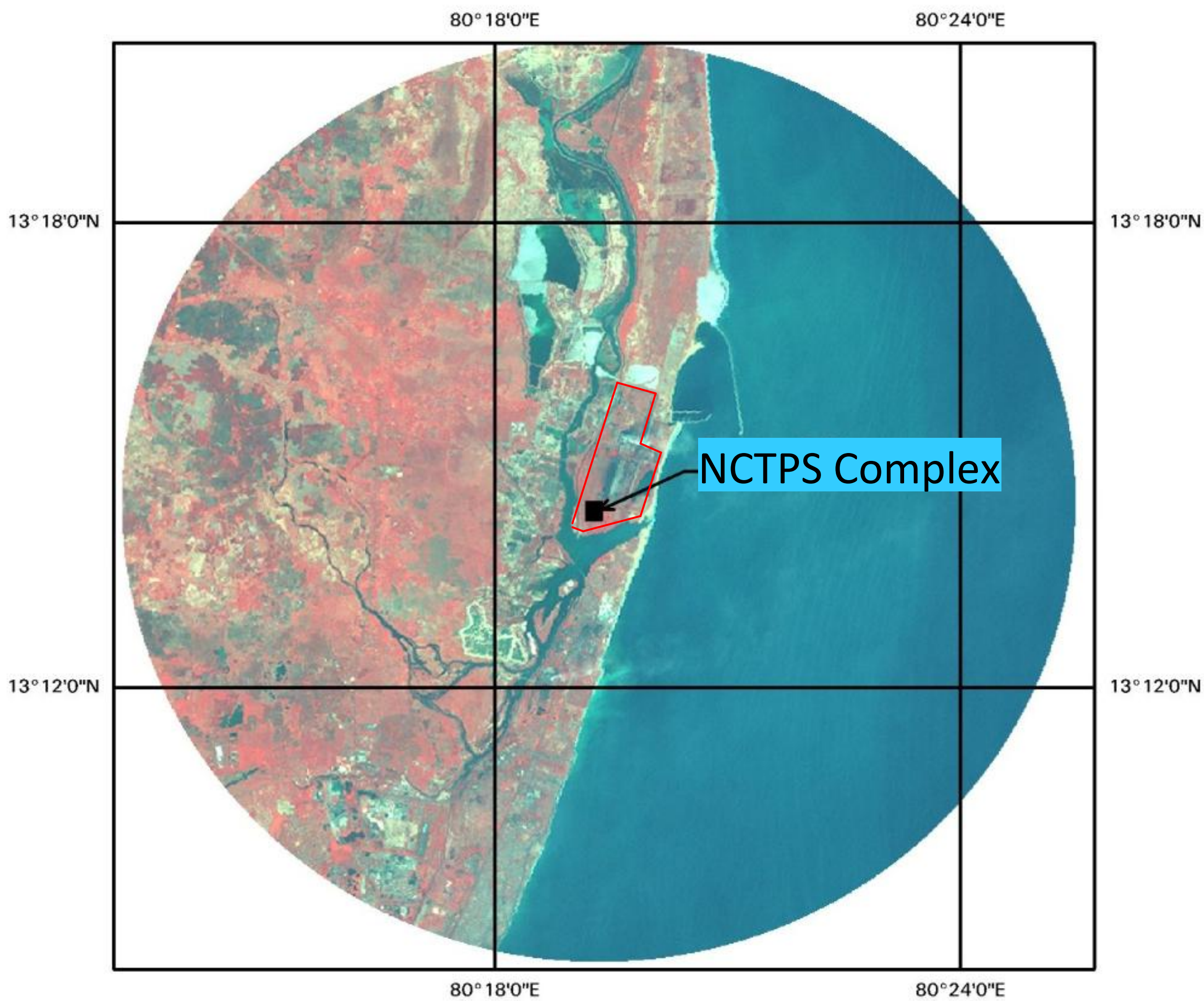
Fig 2. Google Map showing locations of the Power Projects in NCTPS Complex

CHAPTER - 3

ENVIRONMENTAL BASELINE STATUS

3.1 INTRODUCTION

The assessment of baseline environmental setting is an essential component of any EIA study Field survey was conducted in June 2013, September 2013 and January 2014 for primary data generation on various aspects of marine water quality and ecology. The satellite imagery of the study area is shown below:



SATELLITE IMAGERY (FCC) OF THE STUDY AREA

3.2 METEOROLOGY

Climate

The project area has a moderate climate with high humidity. Extreme climatic conditions are not prevalent in the project area. Both the monsoons, i.e. south-west and north-east monsoons influence the rainfall pattern in the project area. In summer months, heat is considerably mitigated in the by the sea breeze. The project area is characterized by an oppressive summer and good seasonal rain fall. Based on average distribution of climatic features the climate of the area can be divided into four distinct seasons, namely summer season (March to May), south-west monsoon season (June to August), north-east monsoon season (September to November) and winter season (December to February), with the associated rains being confined to December.

Temperature

In project area district, large-scale variations in temperature in various seasons are not observed. Generally May and June are the hottest months of the year with mean daily maximum temperature of 37.6^{o}C. The month of December and January are the coolest months of the year with a mean daily minimum temperature of 20-21^{o}C.

Wind

In the project area the predominant wind direction is mostly from W and SW, direction during the rainy season from June to September at 8.30 hrs and 17.30 hrs. In the post-monsoon months and upto the month of December, the pre-dominant wind direction is from SW and NW at 8.30 hrs and from SE and NE at 17.30 hrs. However, during this period, decrease in wind speed is observed. During the months from January to March, winds from NW and NE direction predominate at 8.30hrs and from N and W at 17.30 hrs. During monsoon months, predominant direction is from S and SW.

Rainfall

The average annual rainfall in the district is around 1326 mm. Majority of the rainfall is received under the influence of north-east monsoons, months of September, October and November. On an average, the project area has about 59 rainy days per year.

Humidity

Humidity is generally high throughout the year in the project area. During north-east monsoon months i.e. October to December, humidity ranges from 81 to 84%. The average humidity observed over the year is about 70%.

The average meteorological conditions in the project area are given in Table-3.1.

TABLE- 3.1
Average meteorological conditions in the project area

Month	Temperature (^oC)		Rainfall (mm)	No. of rainy days	Relative Humidity (%)		Wind Speed (kmph)
	Max.	Min			At 8.30	At 17.30	
January	28.6	20.4	23.5	1.6	83	65	8.3
February	30.6	21.3	2.1	0.3	80	63	8.3
March	33.1	23.3	3.7	0.3	76	63	9.7
April	35.2	26.1	13.5	0.9	72	66	11.7
May	37.6	27.7	45.7	1.7	64	62	13.4
June	37.0	27.2	61.5	4.6	60	57	14.6
July	35.0	26.0	118.5	7.4	68	60	12.8
August	34.2	25.4	157.0	9.0	72	65	11.9
September	33.8	25.3	121.8	7.1	74	68	10.3
October	31.7	24.3	283.2	10.2	81	75	7.7

Month	Temperature (^oC)		Rainfall (mm)	No. of rainy days	Relative Humidity (%)		Wind Speed (kmph)
	Max.	Min			At 8.30	At 17.30	
November	29.3	22.6	339.2	10.4	84	74	8.9
December	28.1	21.2	156.2	5.6	83	70	9.0
Total			**1325.9**	**59.1**			
Average	**32.85**	**24.23**			**74.75**	**65.67**	**9.74**

Source: IMD

3.3 MARINE ECOLOGY (MARCH, 2013)

WAPCOS appointed Centre for Advanced Study in Marine Biology, Annamalai University, which is the nodal agency of MoEF in Marine Biology to carry out the Marine Ecological survey at NCTPS coastal areas The survey was carried out during March 2013. Marine samples were collected from 14 stations including intake and outfall of NCTPS – Stage I & Stage -II. These stations were located in the following latitude and longitude in which it is proposed to lay the intake (13°25'93.0"N & 80°33'36.0"E) and outfall (13°23'36.0"N & 80°32'70.0"E) systems.

The lists of stations covered as a part of Marine EIA Study are given below:

- Station -1 is located near IInd Stage intake inside the Ennore port.
- Station -2 is located near to Ist Stage intake inside the Ennore port.
- Station -3 is located on Ist Stage intake (Cooling Water Pump House)
- Station -4, 5 and 6 are located on intake channel with 100 m distance to each.
- Station -7 is IInd stage outlet which is a concrete channel with 5 m depth running above the intake channel.
- Station -8 is also on the outlet channel (Pre cooling Channel), but not a concrete channel.
- Stations -9 and 10 are located parallel to out fall positions inside the NCTPS

- Stations -11and 12 are located in outlet with 50 m distance (Outlet positions).
- Stations -13 and 14 are located in Ennore creek mouth, which is parallel to the station -11 and 12..

The sediment samples were not collected at stations found in cement built channels and were collected only at station 3 to 6 (Ennore creek) and 12 (Pre cooling Channel). The sampling locations are shown in Fig 3.

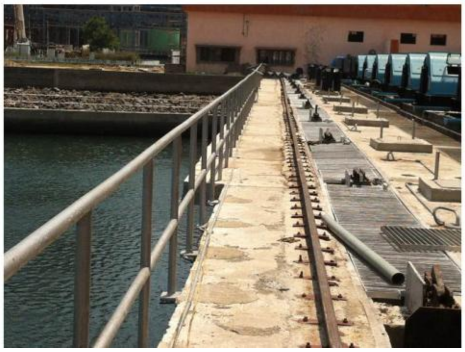
The co-ordinates of sampling stations are given in Table-3.2 below:

Table - 3.2

Sampling locations and its geographical coordinates

S. No.	St. Code	Latitude	Longitude
1.	S-1	13°25’93” N	80°33’36” E
2.	S-2	13°25’68” N	80°33’46” E
3.	S-3	13°23’11” N	80°33’30” E
4.	S-4	13°25’93” N	80°33’36” E
5.	S-5	13°25’93” N	80°33’36” E
6.	S-6	13°25’21” N	80°32’49” E
7.	S-7	13°15’27” N	80°19’59” E
8.	S-8	13°24’14” N	80°33’32” E
9.	S-9	13°23’44” N	80°32’77” E
10.	S-10	13°23’44” N	80°32’77” E
11.	S-11	13°23’36” N	80°32’70” E
12.	S-12	13°23’37” N	80°32’68” E
13.	S-13	13°23’46” N	80°32’82” E
14.	S-14	13°23’46” N	80°32’82” E

Station 3 (IstStage Intake)



Station 4, 5 and 6 (Inlet channel with 100 meter distance each)

Station 7 (II[nd] Stage outlet located on inlet channel)

Station 8 (Pre cooling Channel -Outlet channel)

Station 9 and 10 (100 m distance inside on outlet channel)

Station 11 and 12 (Outlet)

Station 13 and 14 (with 100 m distance towards Ennore Creek mouth)

Fig. 3: Marine Water, Sediment and Ecological sampling locations

MARINE WATER SAMPLING

Water and Sediment Sampling

Water samples were collected using Universal water sampler below the surface and transferred to the precleaned polypropylene and glass containers. Sediment samples were collected using a Peterson Grab, transferred to clean polythene bags and transported to the laboratory. The samples were air-dried. The plant root and other debris were removed and stored for further analysis.

Water Analysis

Preservation and Laboratory Analysis

After collection, all samples were immediately cooled to 4°C and then brought to the laboratory in an insulated thermocool box. In the laboratory, water samples were filtered through Whatman GF/C filter paper and analyzed for organic matter and all other nutrients. Unfiltered samples were used for the estimation of total nitrogen and total phosphorus. All the analyses were carried out as per internationally used standard procedures for samples of aquatic origin.

Temperature, Salinity and pH

The physical parameters like pH, temperature and salinity were measured i*n-situ* in field condition. The subsurface temperature was measured with a mercury thermometer having $\pm$ 0.02°C accuracy and the pH of water was measured by a calibrated pH pen (pH ep-3 model). With the use of a hand refractometer (Erma Company, Japan), the salinity of samples was measured. Water samples collected for dissolved oxygen estimation were transferred carefully to BOD bottles. The DO was immediately fixed and these were brought to the laboratory for further analysis.

Dissolved Oxygen (DO)

The modified Winkler's method described by Strickland and Parsons (1972) was adopted for the estimation of dissolved oxygen fixed at the collection site. The values were expressed in mg/l.

Nitrate and Nitrite

The nitrate and nitrite content of samples were analysed by following the method described by Strickland and Parsons (1972). The nitrite was estimated from highly coloured azo dye formed by the addition of N (1-Napthyl) ethylene diamine dihydro-chloride and sulfanilamide into the solution was then measured at 543 nm in a spectrophotometer. Same procedure was followed for the estimation of nitrate. For this, nitrate was reduced to nitrite by passing the sample through copper coated cadmium column. The calculated values were expressed in μmol of Nitrogen/l

Inorganic Phosphate (IP)

The single solution mixed reagent procedure developed by Murphy and Riley (1962) was followed for the estimation of dissolved inorganic phosphate levels in water samples. This involves the conversion of phosphate into phosphomolybdic acid which was then reduced to molybdinum blue color complexes and then the intensity of colour was measured at 882 nm in a spectrophotometer. The calculated value was expressed in µmol of Phosphorus/l.

Total Phosphorus (TP)

The Total Phosphate in samples was estimated by employing the method described by Menzel and Corwin (1964). This procedure involves the conversion of organically bound phosphate into inorganic phosphate by wet oxidation of samples with potassium persulphate in an autoclave for 30 min at 15 lbs pressure. The converted inorganic phosphate was then estimated by using the method described by Murphy and Riley (1962). The subtraction of original dissolved inorganic phosphate from total phosphate yielded the organic phosphate in the water sample. The calculated value was expressed in µmol of Phosphorus/l.

Reactive Silicate

The reactive silicate content of water was estimated by following the method of Strickland and Parsons (1972). In this method the intensity of blue color formed by silico-molybdate complex was measured in a spectrophotometer at 810 nm and the calculated values were expressed in µmol of Silica/l

Sediment Analysis

For the analysis of textural composition and pH, the air-dried sediment samples were used as such. For all other analyses of organic matter and trace metals, sediment samples were ground to fine powder and dried in an oven at 110°C to constant weight for an hour.

Total Organic Carbon (TOC)

The estimation of total organic carbon in sediment was performed by adopting the method of El Wakeel and Riley (1956). The procedure involves chromic acid digestion and subsequent titration with ferrous ammonium sulphate solution in the presence of 1, 10 phenonthroline indicator. The values calculated are expressed in mg C/g of sediment.

b) Bacteriological Parameters

Surface water samples were collected in 100 ml sterile screw capped bottles for bacteriological assessment. Enough air space was left in the bottles to allow thorough mixing. Precautionary measures were taken to avoid contamination through handling. Sediment samples were collected by employing an alcohol rinsed air-dried small Peterson's grab. The central portion of the collected sediment was aseptically transferred into sterile polyethylene bags using sterile spatula. All the samples were brought to the laboratory in portable icebox as soon as possible after collection and bacteriological analyses were done in the laboratory at CAS immediately after arrival, with necessary dilution.

c) Total Viable Counts (TVC)

TVC was enumerated by adopting the spread plate method using Zobell's Marine Agar medium (EA123, Hi-Media, Mumbai). The samples (water and sediment) were diluted using the sterile sea water and 0.1 ml of the diluted sample was pippeted into the petriplates containing Zobell's Marine Agar and it was spread using a 'L' shaped glass spreader. The plates after inaculation were incubated in an inverted position at a temperature of 28+2°C for 24 to 48 hours. The colonies were counted and the population density expressed as colony forming unit (CFU) per ml or g of the sample. The bacterial colonies were picked up from the pertidishes and re-streaked in appropriate nutrient agar plates thrice before a pure culture was established in agar slants.

d) Total Coliforms

Macconkey agar with 0.15% bile salt, crystal violet and NaCl has been recommended in accordance with USP/Nfxi (1) for the detection, isolation and enumeration of coliforms and intestinal pathogens in water, dairy products, pharmaceutical preparations, etc. The agar weighing 51.5 g in 1000 ml distilled water was heated upto the boiling point to dissolve the medium completely and sterilized by autoclaving at 15 lbs pressure (121°C) for 15 min. suitably diluted samples were inoculated in the petriplates containing medium and were incubated for 48 h. After incubation, the colonies of *E. coli* appeared with pink color.

M-FC agar is employed for detection and enumeration Fecal Coliforms by the membrane filter technique at higher temperature (44.5°C). The agar weighing 52 g was suspended in 1000 ml of distilled water and heated upto the boiling point to dissolve the medium completely, 10 ml of Rosolic acid (dissolved in 0.2 N NaOH) was added, heated with frequent agitation and boiled for 1 min. Then the medium was cooled to 50°C. Finally, the medium was poured into small 60 mm plates. Samples filtered by Millipore apparatus using 0.45µm Whatsman filter papers were impregnated in the petriplates. After 48 h of incubation, the colonies of *E. coli* appeared with blue color.

Streptococcus faecalis

M-Enterococcus agar is recommended as a selective medium for membrane filtration procedure or as a direct plating medium for the isolation and enumeration of Enterococci in food, water and other sources. The agar medium weighing 41.5 g was suspended in 1000 ml distilled water and mixed thoroughly. Then it was heated with frequent agitation until the agar was dissolved and then, the medium was cooled to 50°C with the addition of 0.5 ml of polysorbate 80 and 2 ml of 10% aqueous solution of sodium carbonate. The finally the medium was poured into small 60 mm plates. Samples filtered by Millipore apparatus using 0.45µm Whatsman filter papers were impregnated in the petriplates. After 48 h of incubation the colonies of *S. faecalis* appeared with maroon color.

e) Primary Productivity (PP)

The primary productivity in the study area was estimated following the dark and light bottle method (Strickland and Parsons, 1972). The dissolved oxygen concentration during the experiment was determined by following modified Winkler's method.

Chlorophyll `a'

The samples were filtered through Whatman GF/C filter papers and the chlorophyll was extracted into 90% acetone. The resulting colored acetone extract was measured in a spectrophotometer at different wavelengths and the same acetone extracts were acidified and measured for the phaeo-pigments. The methodology is described in detail in APHA manual (1989).

f) Phytoplanktons

Phytoplankton samples were collected from the surface waters of the study areas by towing a plankton net (mouth diameter 0.35 m) made of bolting silk [No.25 mesh size 48 µm) for half an hour. These samples were preserved in 5% neutralized formalin and used for qualitative analysis. For the quantitative analysis of phytoplankton, the settling method described by Sukhanovo (1978) was adopted. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope.

Phytoplankton was identified using the standard works of Hustedt (1930-1966), Venkataraman (1939), Cupp (1943), Subramanian (1946), Prescott (1954), Desikachary (1959 and 1987), Hendey (1964), Steidinger and Williams (1970) and Taylor (1976) and Anand *et al.* (1986)

g) Zooplanktons

Zooplankton samples were collected from the surface waters of the study areas by horizontal towing of a plankton net with mouth diameter of 0.35 m, made of bolting silk (No. mesh size 33 mm) for half an hour. These samples were preserved in 5% neutralized formalin and used for quantitative analysis. The zooplankton was identified using the classical works of Dakin and Colefax (1940), Davis (1955), Kasthurirangan (1963) and Wickstead (1965) and Damodara Naidu (1981). For the quantitative analysis of zooplankton, a known quantity of water (100 l) was filtered through a bag net (0.33 mm mesh size) and filtrate was made up to 1 l in a wide mouthed enumerated using Utermohl's inverted plankton microscope. The plankton density is expressed as number of organisms/m^3.

h) Benthic Community

For studying the benthic organisms, sediment samples were collected using a Petersen grab. The wet sediment was sieved with varying mesh sizes for segregating the organisms. The sieved organisms were stains with Rose Bengal and sorted to different groups. The number of organisms in each grab sample was expressed in number per meter square. According to size, benthic animals are divided into three groups. (i) macrobenthos (ii) meiobenthos and (iii) microbenthos (Mare, 1942). Macrobenthos are organisms which are retained in the sieve having mesh size between 0.5 and 1 mm. For Meiobenthos, the lowest size attributed is 63 µm and the upper limit depends upon the mesh size of the sieve used for separating macrobenthos from meiobenthos.

FINDINGS OF MARINE WATER QUALITY ANALYSIS

Physico-Chemical Parameters

The analysis of various physic-chemical parameters is given in Table-3.3

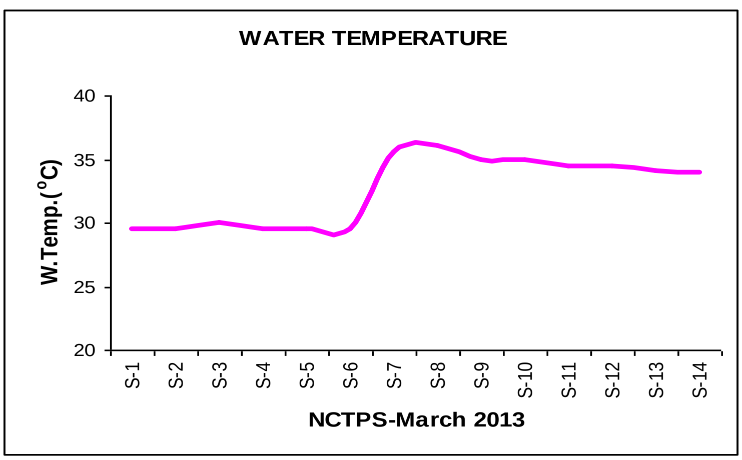
TABLE– 3.3
Physico - Chemical Properties at various marine water sampling stations

Sl. No.	St. Code	Temp. (°C)	Salinity (‰)	pH	TSS (mg/l)	Turbidity (NTU)	DO (mg/l)	BOD (mg/l)
1.	S-1	29.5	32.0	8.1	54.8	06	5.624	0.75
2.	S-2	29.5	33.0	8.1	114.8	15	6.076	0.82

3.	S-3	30.0	31.0	8.2	122.6	08	5.624	1.52
4.	S-4	29.5	31.0	8.1	143.0	17	5.753	1.51
5.	S-5	29.5	32.0	8.2	129.8	12	6.399	0.64
6.	S-6	29.5	32.0	8.1	62.0	05	6.108	0.68
7.	S-7	35.5	31.0	8.1	134.4	13	6.108	1.28
8.	S-8	36.0	33.0	8.2	128.2	11	6.125	0.71
9.	S-9	35.0	32.0	8.1	160.6	24	5.236	0.96
10.	S-10	35.0	33.0	8.2	131.6	15	5.898	0.48
11.	S-11	34.5	33.0	8.1	162.6	17	6.496	0.73
12.	S-12	34.5	32.0	8.1	140.0	13	6.254	0.69
13.	S-13	34.1	32.0	8.1	111.2	09	6.189	0.16
14.	S-14	33.9	33.0	8.2	158.4	21	6.367	0.58

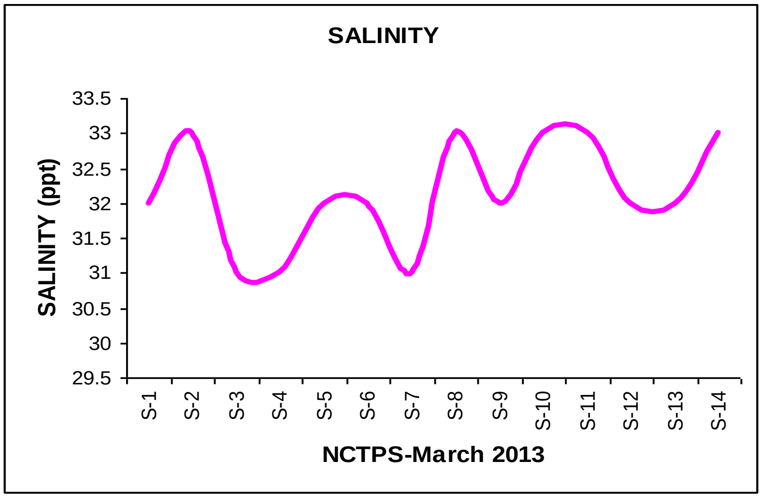
Water Temperature

The water temperature ranged from 29.5 to 36.0°C with maximum at S-8 and minimum at S-3 & S-2 respectively (Table-3.3).



Salinity

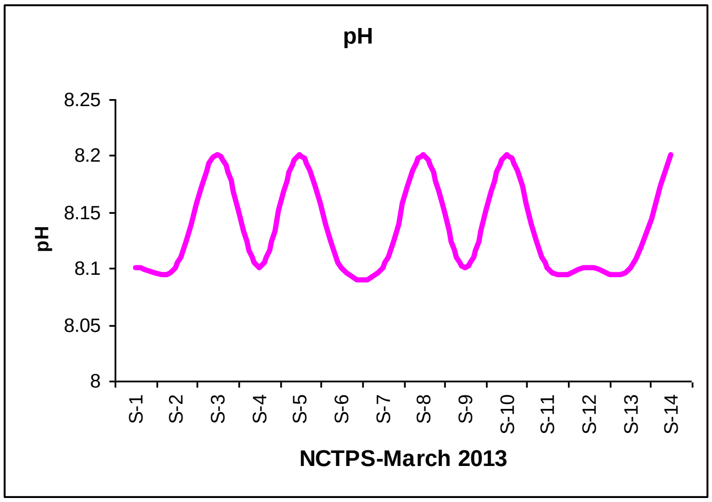
The water salinity varied from 31.0 to 33.0 ‰ with maximum at S-11, S-14, S-10, S-3 & S-2 and minimum at S-7, S-4 & S-3 respectively (Refer Table 3.3).



pH

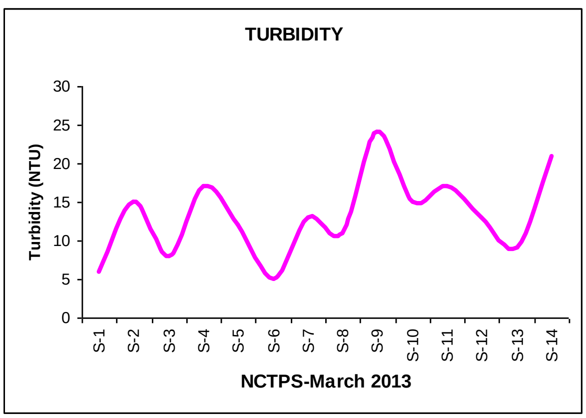
The higher percentage of silt is observed in the station S-13 (>90%). Similarly, a higher sand content (44.75%) and clay content (17.24 %) was recorded at station S-10 during this survey. The higher percentage of silt and clay content is also due to the mixing of fresh water from the Kosistalair River, Pulicat channel and the Buckingham Canal in the coastal area. Overall, the sand, silt and clay content indicate a silty sand type of sediment in the study area.

The water pH varied from 8.1 to 8.2 with maximum in S-14, 10, 5,3 & 8 and minimum in S-11, 12, 13, 9, 7, 4 & 6 respectively. The details are given in Table-3.3



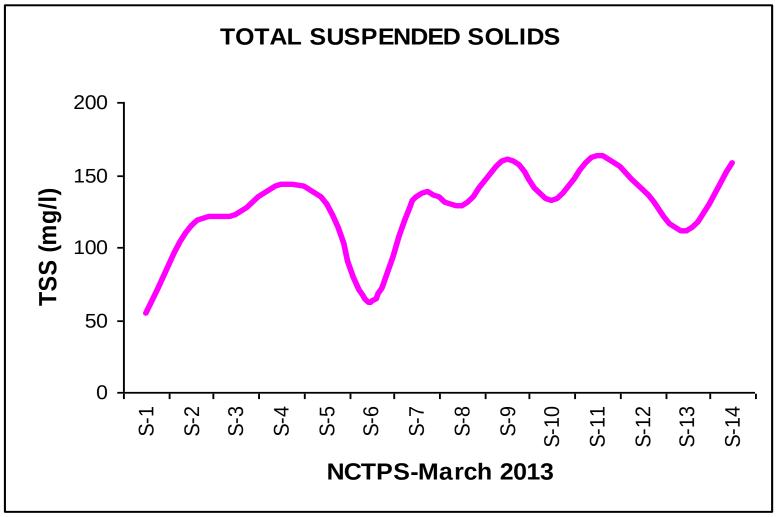
Turbidity

The turbidity values ranged from 5 to 24 NTU with maximum at TPS-9 and minimum at TPS-6. The turbidity values at various sampling stations is given in Table-3.3



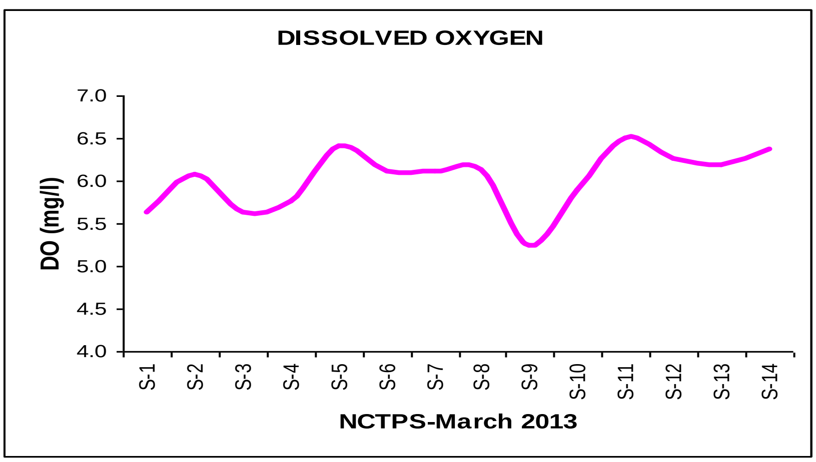
Total Suspended Solids

The TSS values ranged from 54.8 to 162.6 mg/l. The total suspended solids values showed minimum (54.8 mg/l) in S-1 and maximum (162.6 mg/l) in S-11 (Refer Table 3.3).



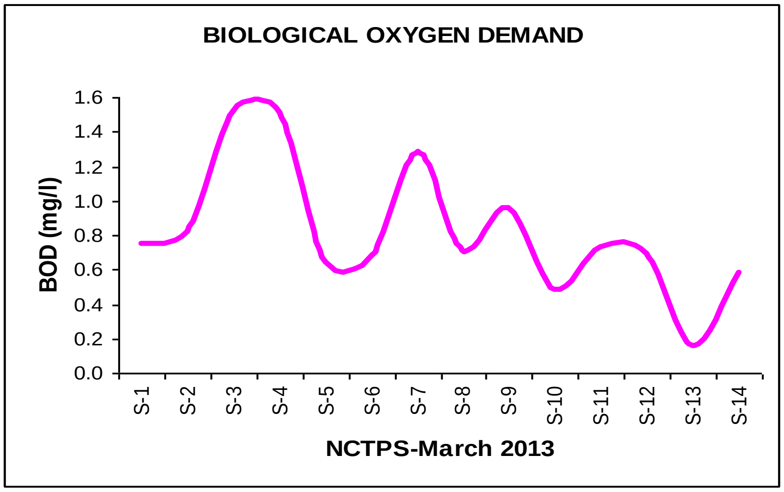
Dissolved Oxygen

Dissolved oxygen level in the water varied from 5.236 mg/l at S-9 to 6.496 mg/l aximum at S-11 (Refer Table 3.3). The DO level indicate that there are no major sources of pollution in the area. These DO values indicate a normal condition and shows moderate level of productivity in this region.



Biological Oxygen Demand

The BOD values ranged between 0.16 and 1.52 mg/l. The Biological oxygen demand showed maximum (1.52 mg/l) at S-3 and minimum (0.16 mg/l) in S-13 (Refer Table 3.3).



TABLE– 3. 4.

Nutrients in Various Marine Water Sampling Locations

S. No.	Station Code	Parameter (μmol/l)						
		NO_2	NO_3	NH_4	TN	IP	TP	SiO_4
1.	S-1	0.326	0.578	0.195	11.196	0.138	2.125	0.103
2.	S-2	0.383	0.440	0.141	10.101	0.831	2.079	0.628
3.	S-3	0.440	0.552	0.158	11.160	0.600	2.065	0.873
4.	S-4	0.574	0.850	0.241	10.241	0.646	1.749	0.431
5.	S-5	0.364	0.453	0.174	11.114	0.299	1.832	1.035
6.	S-6	0.402	0.683	0.216	12.490	0.554	2.020	0.837
7.	S-7	0.421	0.738	0.108	10.617	0.415	1.604	0.375
8.	S-8	0.345	0.429	0.108	10.590	0.923	2.112	0.267
9.	S-9	0.709	0.846	0.324	9.781	0.248	1.929	0.421
10.	S-10	0.498	0.574	0.249	12.295	0.323	1.986	0.253
11.	S-11	0.594	1.260	0.307	10.412	0.785	1.176	0.267

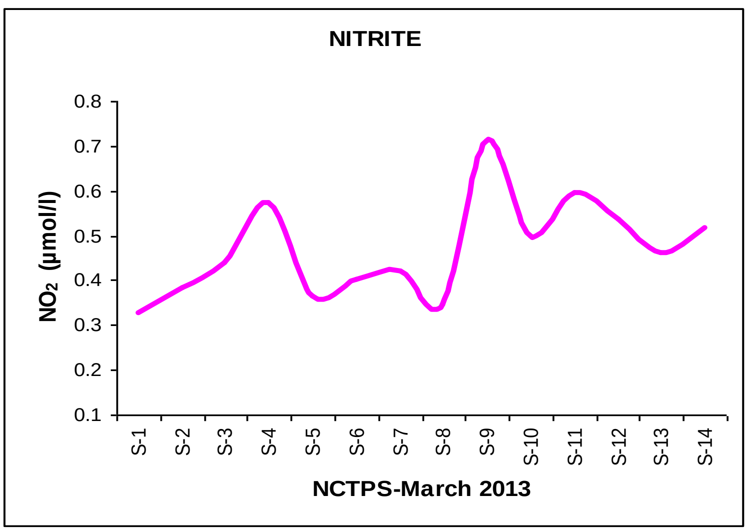
S. No.	Station Code	Parameter (µmol/l)						
		NO_2	NO_3	NH_4	TN	IP	TP	SiO_4
12.	S-12	0.536	0.739	0.232	11.270	0.185	1.924	0.770
13.	S-13	0.460	0.747	0.160	11.479	0.646	2.032	0.268
14.	S-14	0.517	0.740	0.168	10.399	0.462	1.917	0.427

Nutrients

Nutrients determine the potential fertility of an ecosystem and hence it is important to know their distribution and behaviour in different geographical locations and seasons. The productivity of an area is in turn, dependent on the availability of primary nutrients like nitrogen and phosphorus. The concentration of nutrients in various sampling stations is listed in Table-3.4.

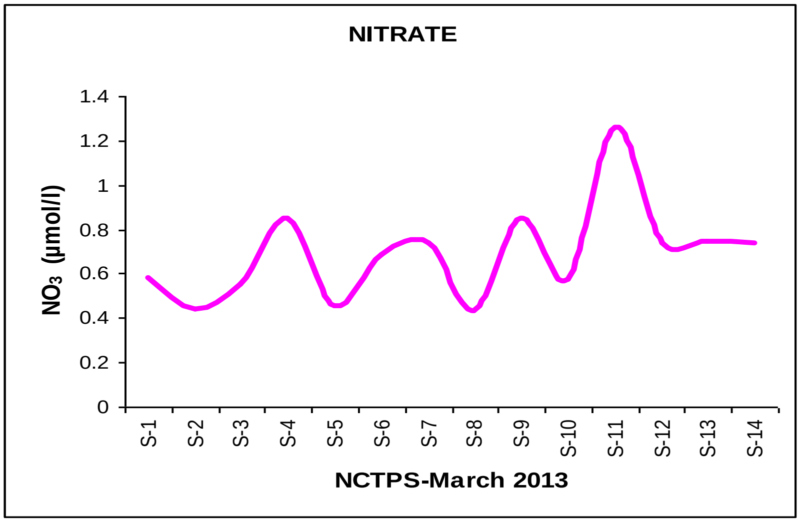
Nitrite

The nitrite varied from 0.326 to 0.709 µmol/l. The minimum and maximum was recorded at S-1 and S-9. (Refer Table 3.4)



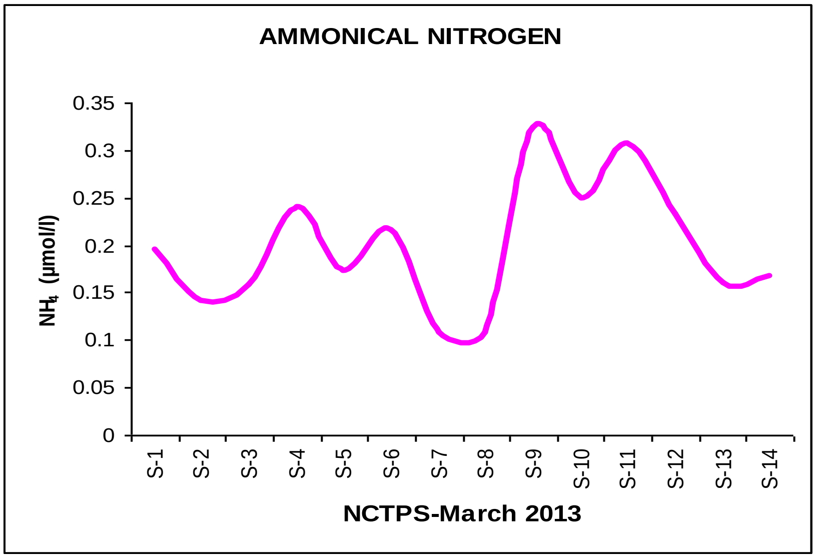
Nitrate

Nitrate content varied from 0.429 to 1.26 µmol/l (Table 3.4) with maximum at S-11 and minimum at S-8. The details are given in Table-3.4



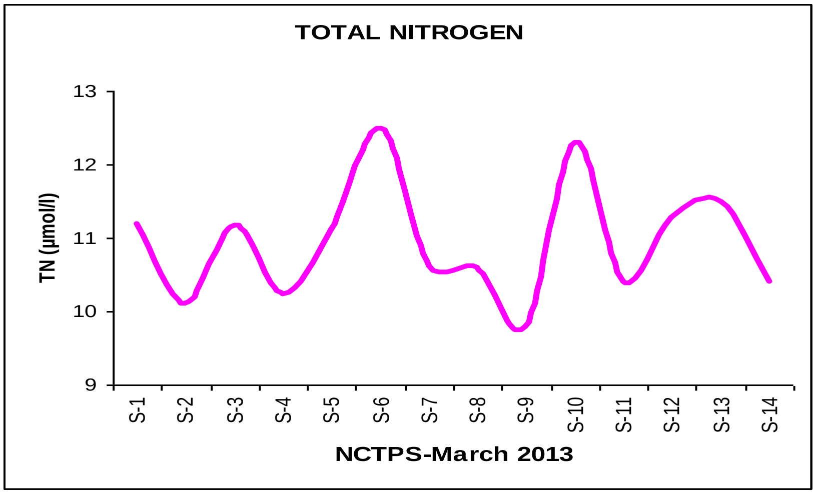
Ammonical Nitrogen

The ammonia concentration fluctuated from 0.108 to 0.324 µmol/l. The ammonia level in the water showed maximum (0.324 µmol/l) at S-9 and the minimum (0.108 µmol/l) at S-7 & S-8 respectively (Refer Table 3.4).



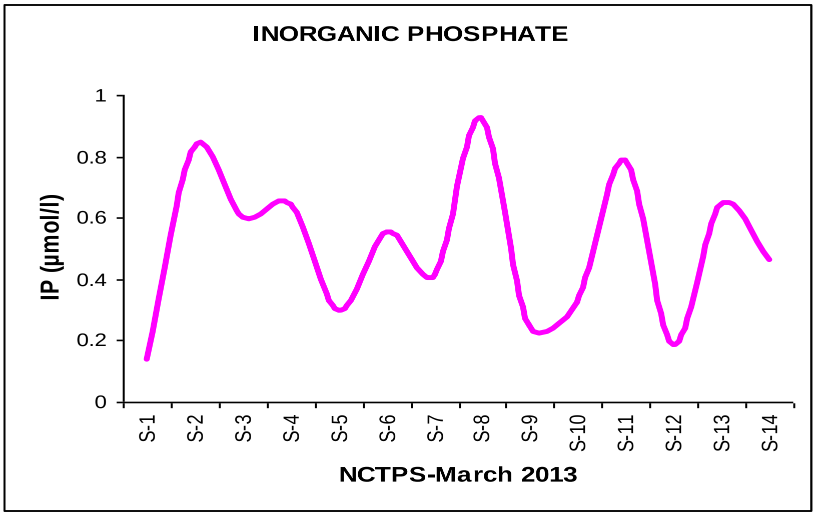
Total Nitrogen

Total nitrogen values were recorded maximum at S-6 (12.49 µmol/l) and minimum at S-9 (9.781 µmol/l) (Refer Table 3.4)



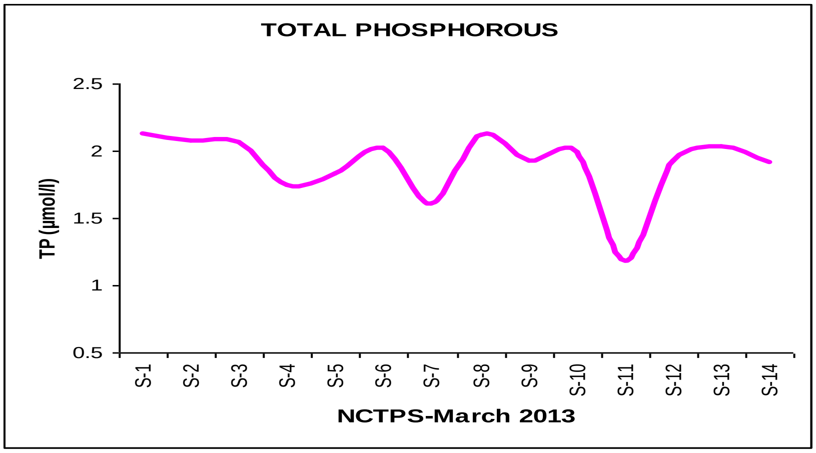
Inorganic Phosphate

Inorganic phosphate level was maximum at S-8 (0.923 µmol/l) and minimum value was recorded at S-1 (0.138 µmol/l) (Refer Table 3.4). Inorganic phosphate level at various sampling station is given in Table-3.4



Total Phosphorus

The total phosphorus values ranged from 1.176 to 2.125 µmol/l. The maximum was recorded at S-1 (2.125 µmol/l) and the minimum was recorded at TPS-11 (1.176 µmol/l) (Table-3.4).



Reactive Silicate

The silicate values varied between 0.103 and 1.035 µmol/l. The maximum (1.035 µmol/l) and minimum (0.103 µmol/l) values were recorded at S-5 and S-1 (Refer Table 3.4).

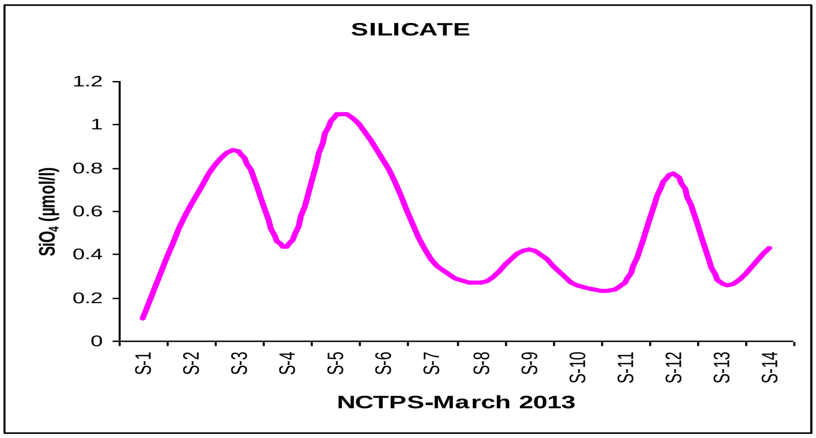


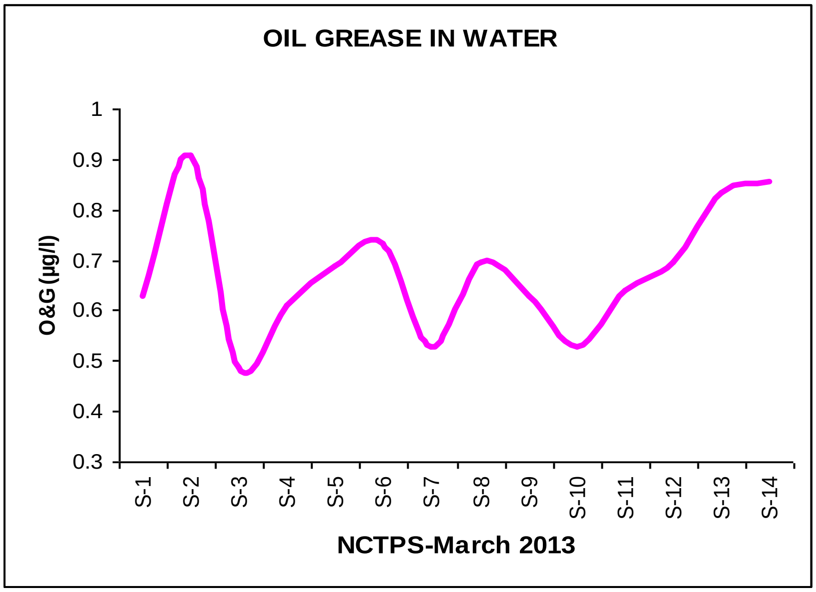
TABLE -3.5

Oil & Grease in Various Marine Water & Sediment Samples

S. No.	Station Code	Water (µg/l)	Sediment (µg/g)
			Unable to collect sediment samples due to concrete channel
1.	S-1	0.628	
2.	S-2	0.908	
3.	S-3	0.488	**Unable to collect sediment samples due to concrete channel**
4.	S-4	0.608	
5.	S-5	0.688	
6.	S-6	0.733	
7.	S-7	0.528	
8.	S-8	0.693	0.128
9.	S-9	0.628	0.092
10.	S-10	0.528	0.095
11.	S-11	0.638	**Unable to collect sediment samples due to concrete channel**
12.	S-12	0.693	
13.	S-13	0.833	0.165
14.	S-14	0.853	0.068

OIL & GREASE

In NCTPS areas, the Oil & Grease in water fluctuated between 0.488 and 0.908 µg/l. The minimum concentration was recorded at S-3 and the maximum was recorded at S-2 during March'13. The oil and grease level at various water and sediment sampling stations is given in Table-3.5



In sediment, the Oil & Grease varied from 0.068 to 0.165 µg/g. The minimum was recorded at S-14 during March'13 and the maximum concentration of PHC was recorded at S-13 during March'13 (Refer Table 3.5). These values indicate anthropogenic release of petroleum in the system. A part of PHC may also originate from the Harbour activities transported by tidal ingress.

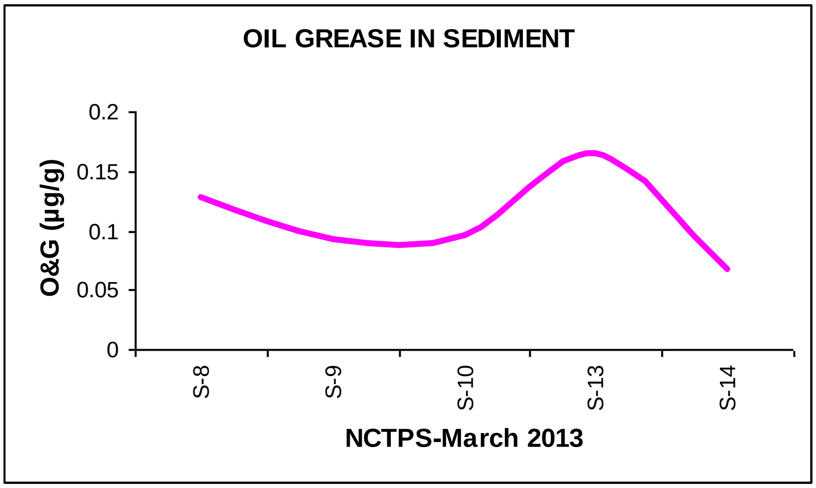


TABLE – 3.6

Heavy Metal concentration at various marine Sampling Stations

Sl. No.	Parameters	Parameters (µg/l)					
		Cd	Cu	Fe	Pb	Zn	Hg
1..	S-1	1.355	2.864	33.852	4.344	26.476	0.024
2.	S-2	1.039	2.549	35.152	3.444	21.021	0.008
3.	S- 3	2.972	4.296	53.413	3.032	21.993	0.006
4.	S-4	0.485	2.911	32.244	1.944	28.586	0.006
5.	S-5	1.055	4.343	25.182	3.159	17.462	0.003
6.	S-6	2.117	3.918	41.349	4.407	27.149	0.078
7.	S-7	0.554	2.093	52.288	1.896	22.277	0.006
8.	S-8	3.211	4.138	45.912	2.306	20.769	0.022
9.	S-9	0.516	2.439	53.13	3.032	35.671	0.012

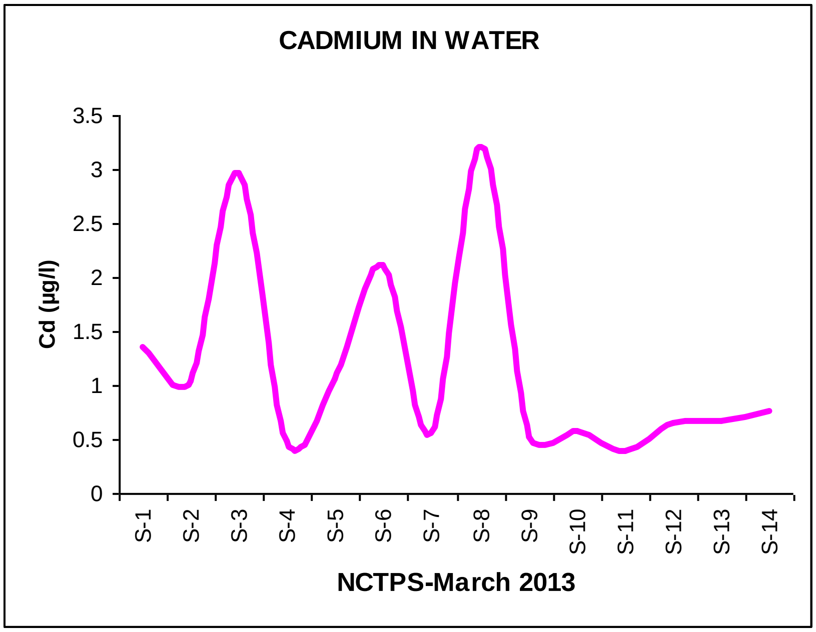
Sl. No.	Parameters	Parameters (µg/l)					
		Cd	Cu	Fe	Pb	Zn	Hg
10.	S-10	0.570	3.352	40.482	2.464	21.021	0.048
11.	S-11	0.392	3.336	35.841	3.507	20.147	0.015
12.	S-12	0.647	4.689	22.356	3.791	22.651	0.010
13.	S-13	0.662	4.988	36.606	4.313	28.625	0.021
14.	S-14	0.755	4.422	52.315	2.006	24.687	0.017

Heavy Metals in Water

The concentrations of trace metals such as cadmium, lead, mercury, copper and zinc are very low but even at such low concentrations they can be bio accumulated by certain organisms and biomagnified up the food chain. The details of various of heavy metals at various sampling stations is given in Table-3.6 and the maximum permissible level is given in Annexure.

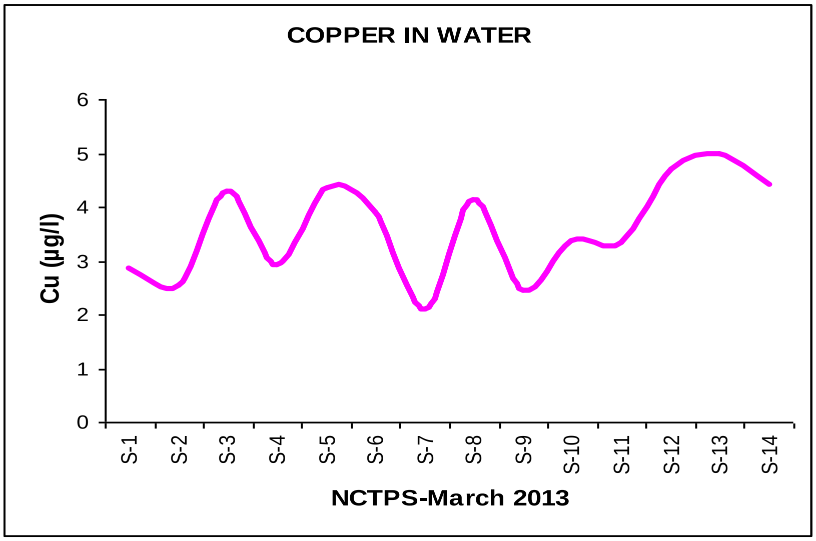
Cadmium

The cadmium level varied from 0.392 to 3.211 µg/l. The maximum cadmium was recorded at TPS-12 and the minimum of 0.392 µg/l was recorded TPS-1 (Refer Table-3.6).



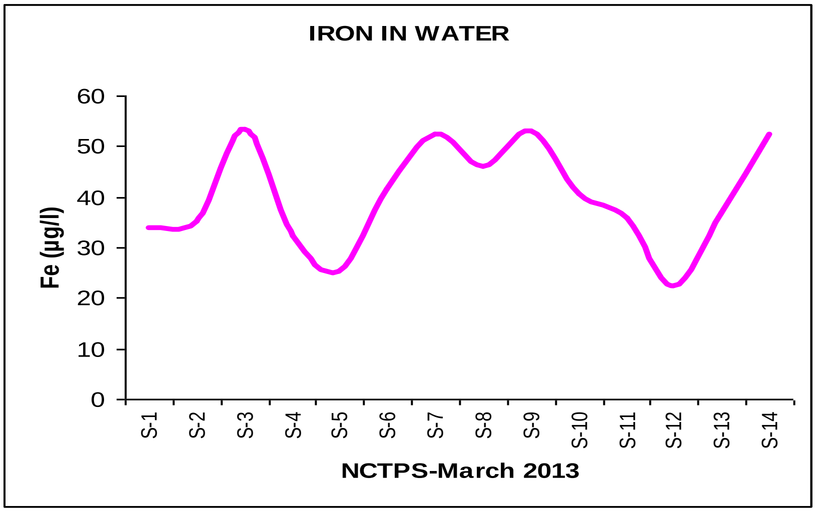
Copper

The copper level in the study area varied from 2.093 to 4.988 µg/l. The maximum copper was recorded at S-13 and the minimum of 2.093 µg/l was recorded S-7. The details are given in Table-3.6



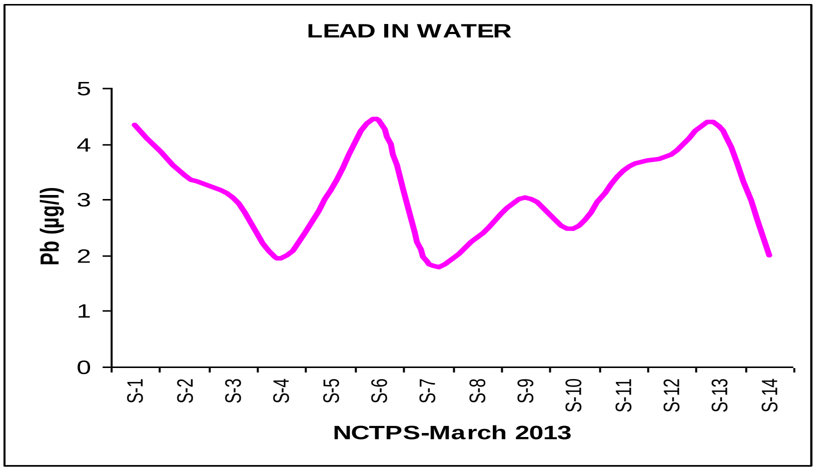
Iron

The iron level varied between 22.356 and 53.41 µg/l. The maximum iron was recorded at TPS-3 and the minimum iron was recorded at S-12. The details are given in Table-3.6



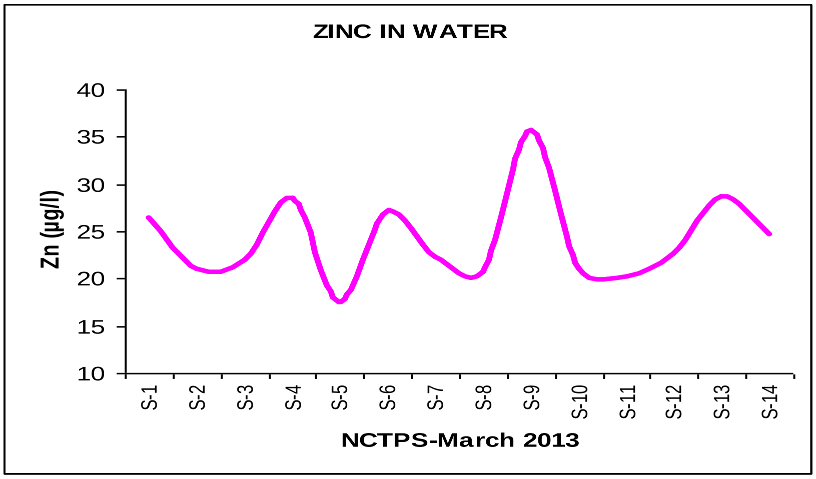
Lead

The lead level in the study area fluctuated between 1.896 and 4.407 µg/l. The maximum of 4.407 µg/l was observed at S-6 during March'13 and the minimum of 1.896 µg/l was recorded at S-7 (Refer Table-3.6).



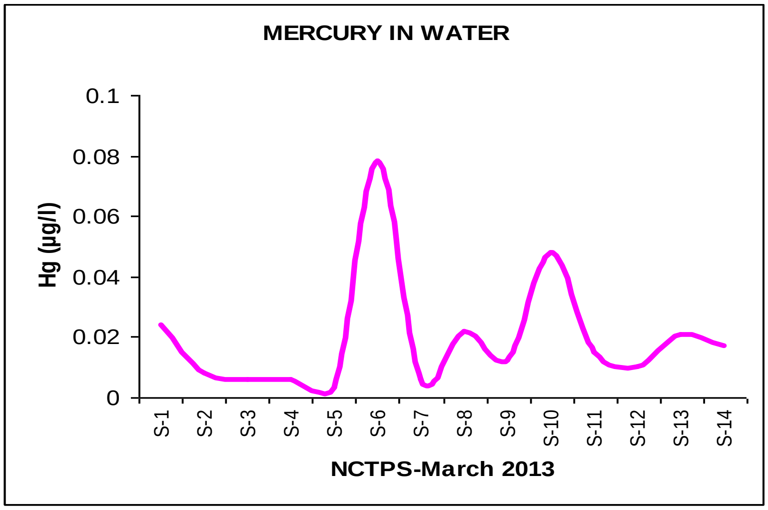
Zinc

The zinc level in the study areas varied between 17.462 and 35.671 µg/l. The maximum zinc was recorded at S-9 and the minimum of 17.462 was recorded at S-5 during March'13 (Refer Table-3.6).



Mercury

The mercury level in the study areas varied from 0.003 to 0.078 µg/l. The maximum mercury was recorded at S-6 and the minimum mercury was recorded at S-9 (Refer Table-3.6).



Microbiology in water samples

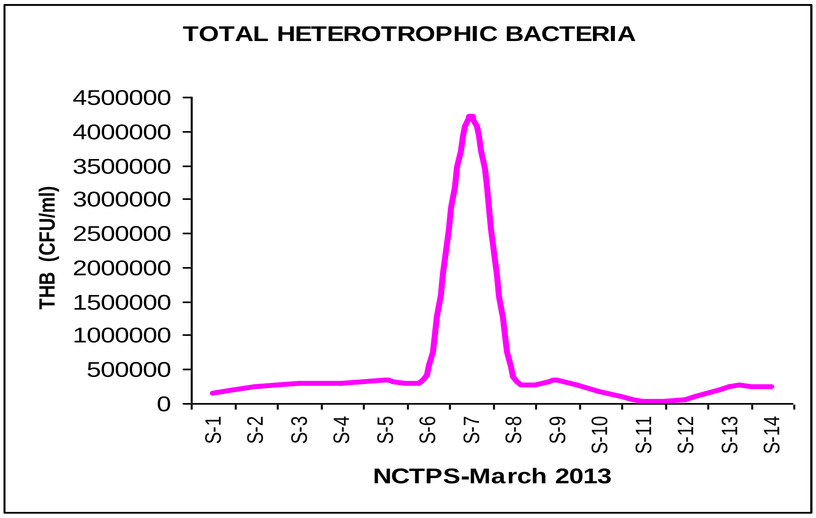
Water Sample

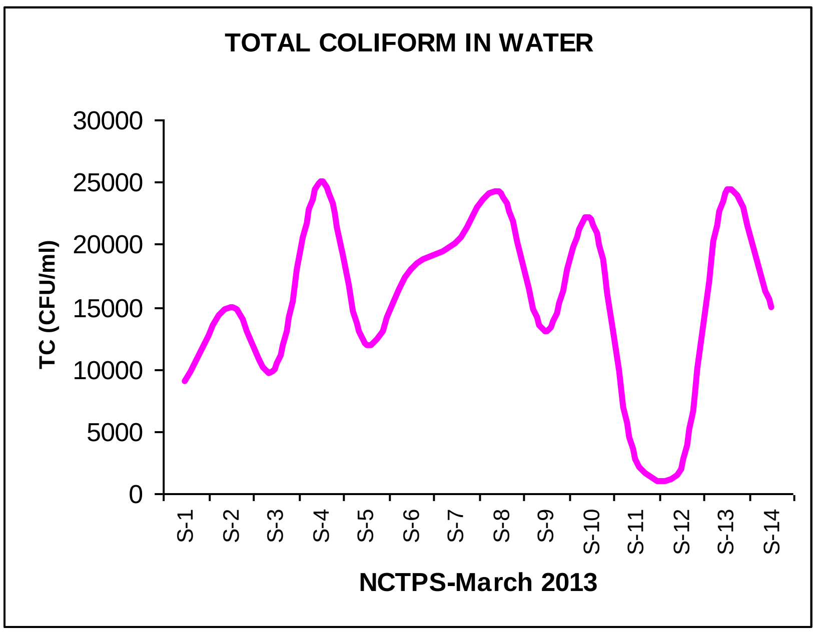
The level of various micro-biological parameters at different water sampling locations is given in Table-3.7. The Total Heterotrophic Bacteria (THB) varied from $28x10^3$ to $42x10^5$ with maximum at S-7& 6 and minimum at S-11 of water samples collected in North Chennai Thermal Power Station areas. The Total Coliform varied from $19x10^2$ to $25x10^4$ with maximum at S-4 and minimum at S-12. The *Escherichia coli* Bacteria in water sample varied from $28x10^1$ to $34x10^3$ CFU/ml with maximum at S-4 and minimum at S-12 during the sample collection. Faecal coliform varied between 25 to $17x10^3$ with maximum at S-1 and minimum at S-2. The *Streptococcus faecalis* varied from 20 to $26x10^3$. The minimum and maximum values observed at S-2 and S-1 during March'13 (Refer Table 3.7).

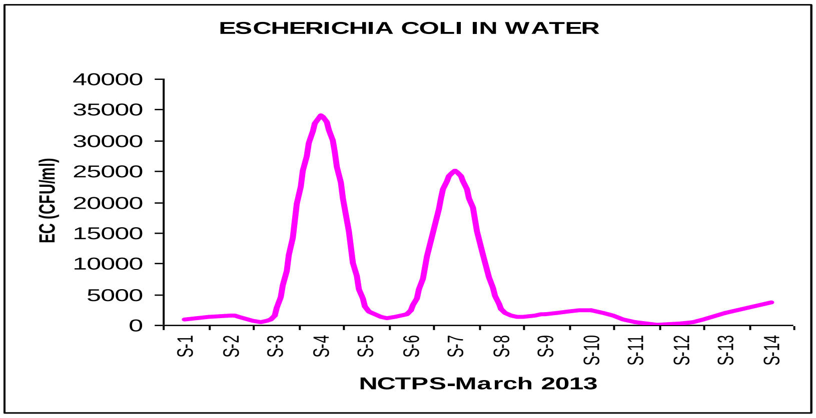
TABLE – 3.7

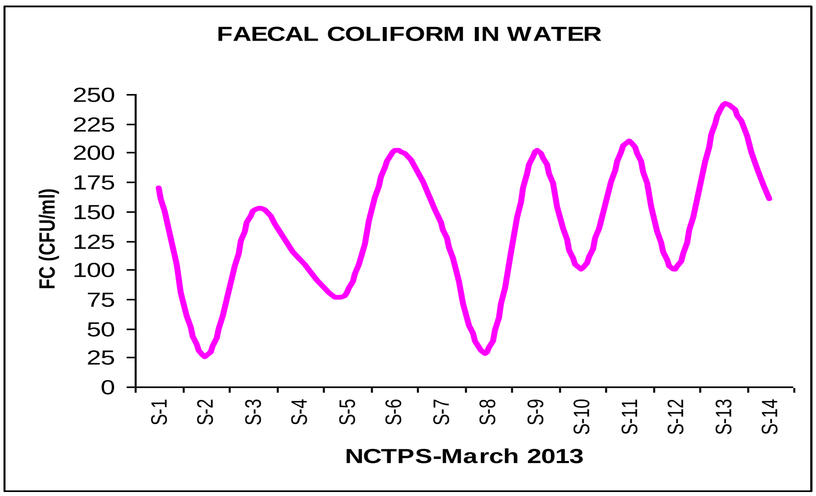
Microbial Populations in Various Water Sampling Location

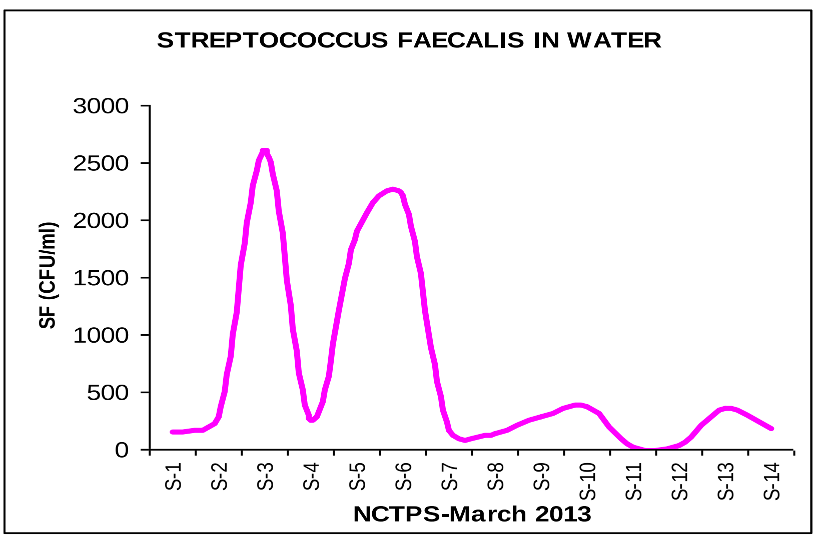
Sl. No.	St. Code	THB	TC	EC	FC	SF
1.	S-1	14×10^4	09×10^3	09×10^2	17×10^1	15×10^1
2.	S-2	24×10^4	15×10^3	14×10^2	25	28×10^1
3.	S-3	28×10^4	10×10^3	16×10^2	15×10^1	26×10^2
4.	S-4	28×10^4	25×10^3	34×10^3	11×10^1	25×10^1
5.	S-5	34×10^4	12×10^3	30×10^2	08×10^1	19×10^2
6.	S-6	42×10^4	18×10^3	23×10^2	20×10^1	22×10^2
7.	S-7	42×10^5	20×10^3	25×10^3	14×10^1	16×10^1
8.	S-8	39×10^4	24×10^3	25×10^2	30	13×10^1
9.	S-9	33×10^4	13×10^3	17×10^2	20×10^1	28×10^1
10.	S-10	18×10^4	22×10^3	24×10^2	10×10^1	37×10^1
11.	S-11	28×10^3	28×10^2	33×10^1	21×10^1	20
12.	S-12	37×10^3	19×10^2	28×10^1	10×10^1	24
13.	S-13	25×10^4	24×10^3	20×10^2	24×10^1	36×10^1
14.	S-14	25×10^4	15×10^3	37×10^2	16×10^1	18×10^1


TOTAL HETEROTROPHIC BACTERIA
THB (CFU/ml)
4500000
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
S-1 S-2 S-3 S-4 S-5 S-6 S-7 S-8 S-9 S-10 S-11 S-12 S-13 S-14
NCTPS-March 2013


TOTAL COLIFORM IN WATER
TC (CFU/ml)
30000
25000
20000
15000
10000
5000
0
S-1 S-2 S-3 S-4 S-5 S-6 S-7 S-8 S-9 S-10 S-11 S-12 S-13 S-14
NCTPS-March 2013


ESCHERICHIA COLI IN WATER
EC (CFU/ml)
40000
35000
30000
25000
20000
15000
10000
5000
0
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
S-9
S-10
S-11
S-12
S-13
S-14
NCTPS-March 2013


FAECAL COLIFORM IN WATER
FC (CFU/ml)
250
225
200
175
150
125
100
75
50
25
0
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
S-9
S-10
S-11
S-12
S-13
S-14
NCTPS-March 2013


STREPTOCOCCUS FAECALIS IN WATER
SF (CFU/ml)
3000
2500
2000
1500
1000
500
0
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
S-9
S-10
S-11
S-12
S-13
S-14
NCTPS-March 2013

Sediment Characteristics

pH, Texture and Total Organic Carbon

The concentration of Soil texture, Total Organic Carbon & pH in various sediment samples is given in Table-3.8

TABLE– 3.8

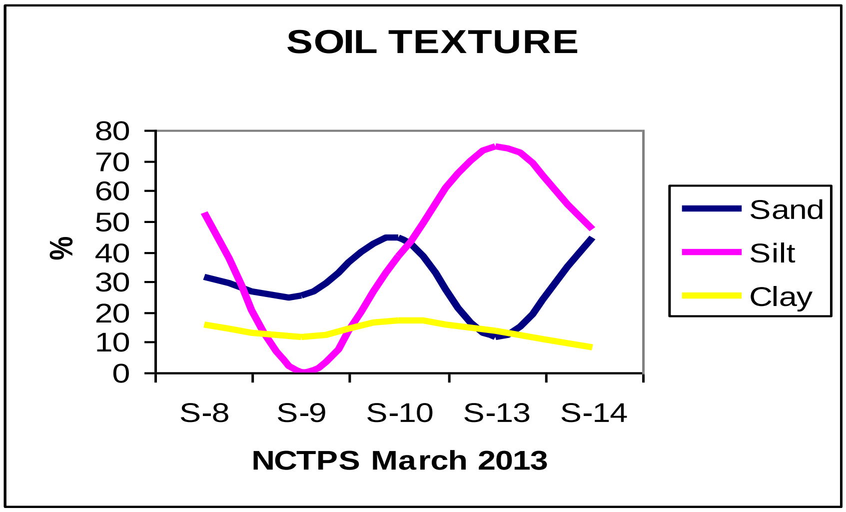
Soil Texture, Total Organic Carbon & Ph of Sediments at Various Sampling Locations

S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (mgC/g)	pH
1.	S-1	**Unable to collect sediment samples due to concrete channel**				
2.	S-2					
3.	S-3					
4.	S-4					
5.	S-5					
6.	S-6					
7.	S-7					
8.	S-8	31.47	52.82	15.71	5.037	7.86
9.	S-9	25.50	63.03	11.46	2.553	8.09
10.	S-10	44.18	38.58	17.24	3.588	7.92
11.	S-11	**Unable to collect sediment samples due to concrete channel**				
12.	S-12					
13.	S-13	11.53	74.83	13.64	2.139	8.21
14.	S-14	44.75	47.28	7.97	2.346	8.19

Soil Texture

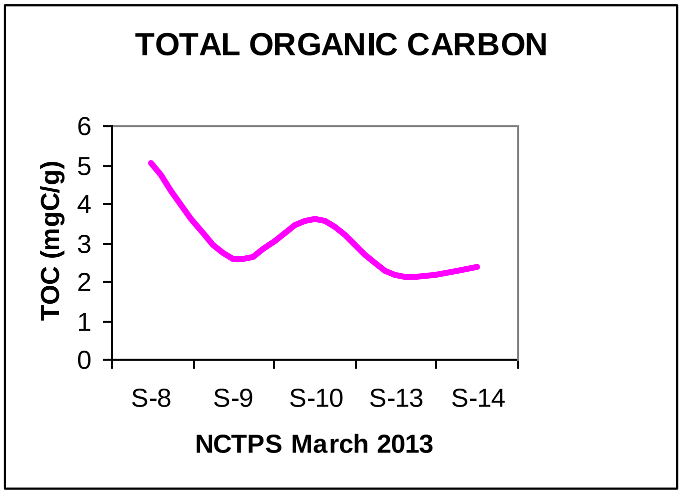
The soil texture was analysed, in which, sand content varied from 11.53 % to 44.75 % the maximum was recorded at S-14 and the minimum sand content was recorded in the station S-13 and the silt content found be maximum at S-13 (74.83%) and minimum at S-10 (38.58 %) and the clay was found to be maximum at S-10 (17.24%) and minimum at S-14 (7.97%) (Refer Table-3.8).

The higher percentage of silt is observed in the station S-13 (>90%). Similarly a higher sand content (44.75%) and clay content(17.24%) was recorded at station S-10 during this survey. The higher percentage of silt and clay content is also due to the mixing of fresh water from the Korrataliyar River, Pulicat channel and the Buckingham canal in the coastal area. Overall, the sand, silt and clay content indicate a silty sand type of sediment in the study area.



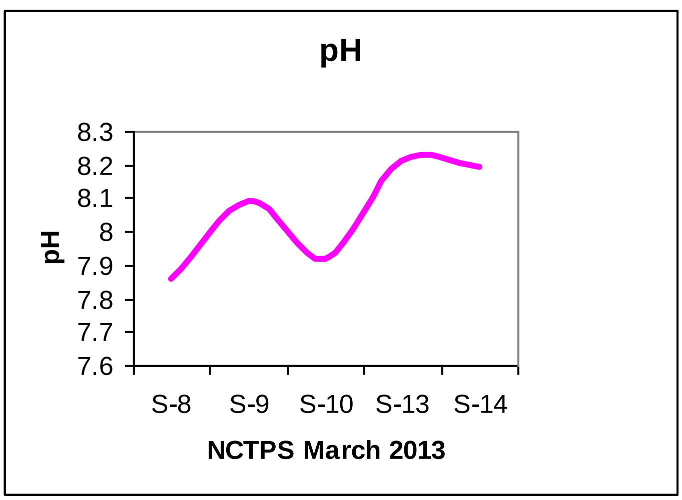
Total Organic Carbon

Total organic carbon values were recorded maximum at S-8 (5.037 mgC/g) and minimum at the station S-13 (2.139 mgC/g) (Refer Table-3.8).



pH

The pH in the sampling stations varied from 7.86 to 8.21. As evident from the following figure, the minimum level was recorded at S-8 and the maximum level was recorded at S-13 during March'13 (Refer Table-3.8).



Heavy Metals in Sediments

Heavy metals even in the dissolved form on entering the aquatic environment are absorbed by TSS in water and transported to the sediment on settling. Thus the sediment of areas receiving anthropogenic trace metals sustains their high concentrations relative to the baseline. Hence, aquatic sediments are useful indicators of trace metal pollution. The concentration of heavy metals at various sampling stations is given in Table-3.9

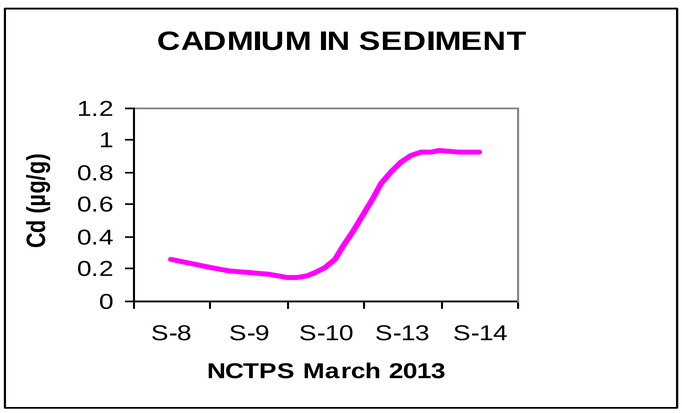
TABLE –3.9
Heavy Metals in Various Sediment Samples

Sl. No.	Station Code	µg/g					
		Cd	Cu	Fe	Pb	Zn	Hg
1.	S-1						
2.	S-2						
3.	S-3						
4.	S-4						
5.	S-5						
6.	S-6	**Unable to collect sediment samples due to concrete channel**					
7.	S-7						
8.	S-8	0.256	6.520	520.7	2.784	3.136	0.019
9.	S-9	0.176	11.270	5614.5	5.039	11.376	0.028
10.	S-10	0.208	10.420	6565.5	5.671	13.584	0.045
11.	S-11						
12.	S-12	**Unable to collect sediment samples due to concrete channel**					
13.	S-13	0.865	8.320	2281.8	4.740	6.400	0.033

Sl. No.	Station Code	µg/g					
		Cd	Cu	Fe	Pb	Zn	Hg
14.	S-14	0.923	11.570	3705.5	4.611	7.824	0.026

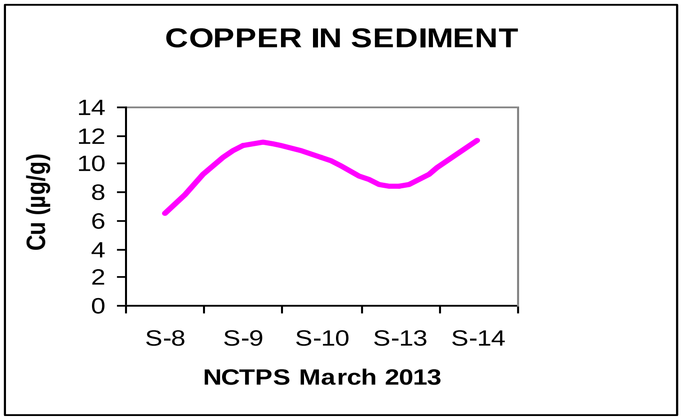
Cadmium

The cadmium level varied from 0.176 to 0.923 µg/g. The maximum cadmium was recorded at S-14 and the minimum of 0.176 was recorded at S-9 during March'13. The details are given in Table-3.9



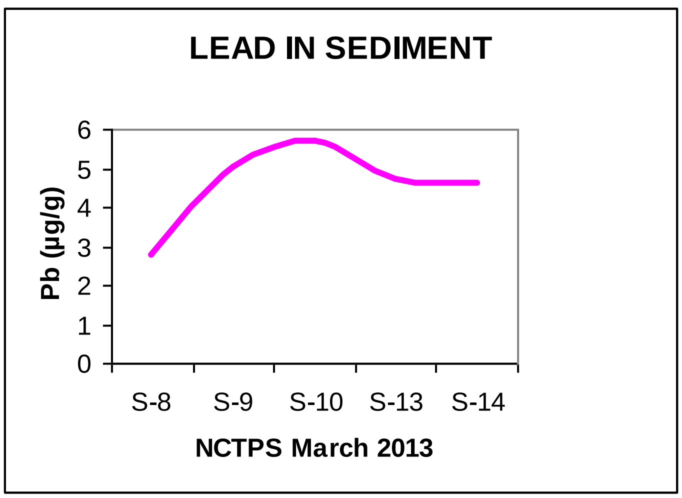
Copper

The copper in the sediments ranged from 6.52 to 11.57 µg/g. The maximum copper concentration of 11.57 µg/g was recorded at S-14 and the minimum of 6.52 was recorded S-8 (Refer Table-3.9).



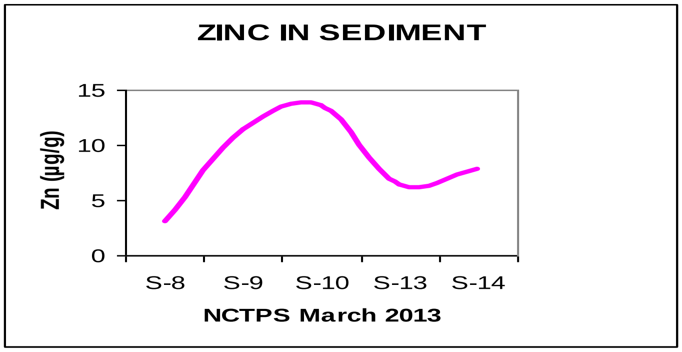
Lead

The lead level in the sediment ranged between 2.784 and 5.671 µg/g. The maximum lead concentration of 5.671 µg/g was recorded at S-10 during March'13 and minimum of 2.784 µg/g was recorded at S-8 during March'13 (Refer Table-3.9).



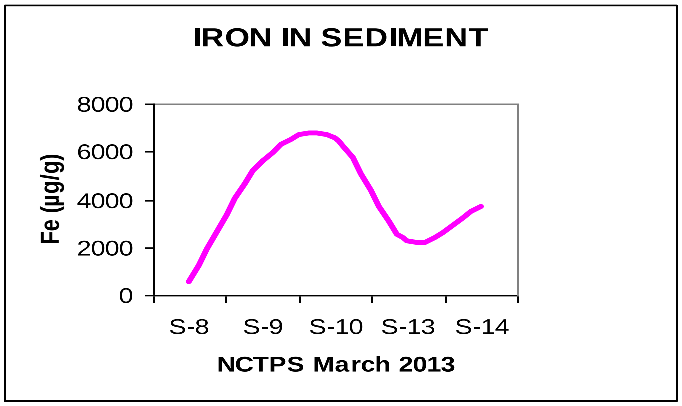
Zinc

The zinc fluctuated from 3.136 to 13.584 µg/g. The maximum concentration of 13.584 µg/g was recorded at S-10 during March'13 and the minimum of 3.136 µg/g was recorded at S-8 during March'13. The details of zinc concentration in various sediment samples is given in Table-3.9



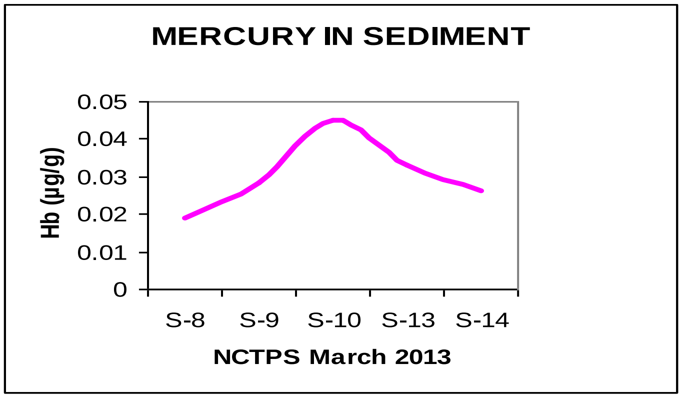
Iron

The iron concentration fluctuated from 520.7 to 6565.5 µg/g. The maximum iron concentration of 6565.5 µg/g was recorded at S-10 and the minimum of 520.7 µg/g was recorded at S-8 (Refer Table-3.9).



Mercury

The mercury level in the sediment varied from 0.019 to 0.045 µg/g. The maximum mercury 0.045 µg/g was recorded at S-10 and the minimum of 0.019 µg/g was recorded at S-8 (Refer Table-3.9).



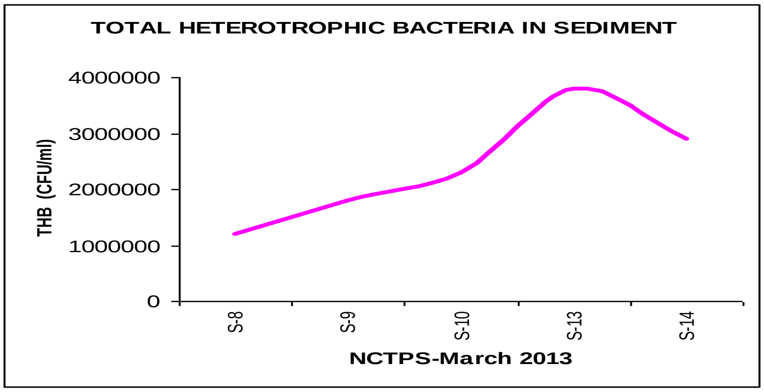
The variation of metal concentrations was drastic, caused by churning of the bottom sediments and their deposition along the shore by the waves, bringing changes in the beach profile and chemical concentrations. The enrichment of heavy metals in the sediment suggest that the region is moderately contaminated in some stations with excess amount of Fe, Cr, Cu, Ni, Pb and Zn, are directly related to the heavy input of industrial effluents from the industrial regions in the southern, western and northern parts of the city which are dominated by petrochemical, painting, thermal power plant and other chemical industries which is also exposed to wave and storm activities which are mainly due to the industrial activities in the region around Chennai.

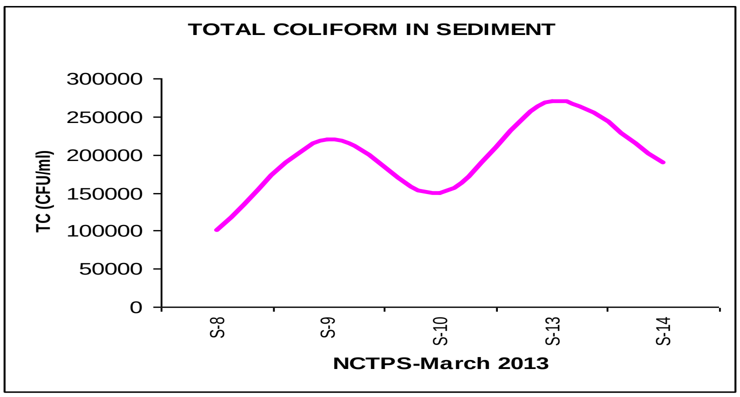
Sediment Samples

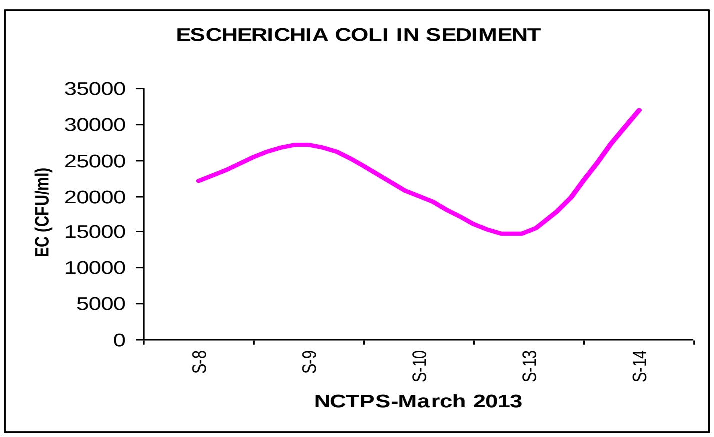
The Total Heterotrophic Bacteria (THB) varied from $12x10^5$ to $38x10^5$ CFU/g with maximum at S-13 and minimum at S-8 of sediment samples collected in North Chennai Thermal Power Station areas. The Total Coliform varied from $10x10^4$ to $27x10^4$ CFU/g with maximum at S-13 and minimum at S-8. The *Escherichia coli* Bacteria in sediment sample varied between $15x10^3$ to $32x10^3$ CFU/g with maximum at S-14 and minimum S-13 during the sample collection. *Faecal coliform* varied from $15x0^3$ to $27x10^3$ CFU/g with maximum at S-10 and minimum at S-13. The *Streptococcus faecalis* varied between $90x10^1$ to $23x10^2$ CFU/g. The minimum was recorded at S-10 and the maximum value was observed at S-13 and S-1 during March’13. The details are given in Table-3.10

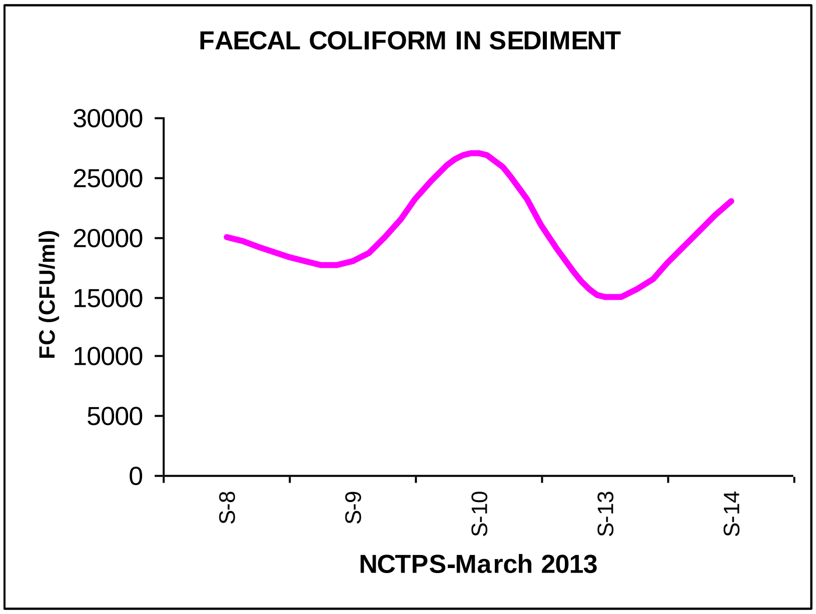
Table-3.10 Microbial Population in various sediment samples

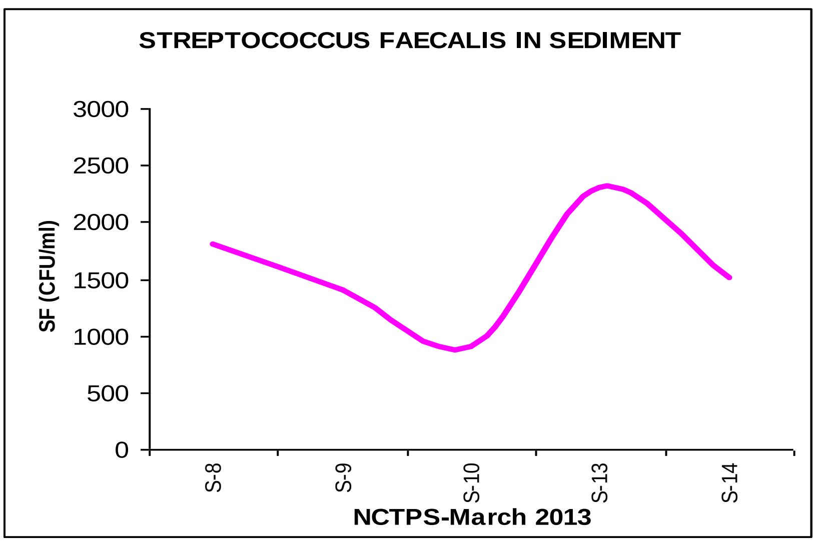
Sl. No.	St. Code	THB	TC	EC	FC	SF
1.	S-1	**Unable to collect sediment samples due to concrete channel**				
2.	S-2					
3.	S-3					
4.	S-4					
5.	S-5					
6.	S-6					
7.	S-7					
8.	S-8	12 x10^5	10x10^4	22 x10^3	20x10^3	18 x10^2
9.	S-9	18 x10^5	22 x10^4	27 x10^3	18 x10^3	14 x10^2
10.	S-10	23 x10^5	15 x10^4	20x10^3	27 x10^3	09 x10^2
11.	S-11	**Unable to collect sediment samples due to concrete channel**				
12.	S-12					
13.	S-13	38 x10^5	27 x10^4	15 x10^3	15 x10^3	23 x10^2
14.	S-14	29 x10^5	19 x10^4	32 x10^3	23 x10^3	15 x10^2


TOTAL HETEROTROPHIC BACTERIA IN SEDIMENT
THB (CFU/ml)
4000000
3000000
2000000
1000000
0
S-8
S-9
S-10
S-13
S-14
NCTPS-March 2013


TOTAL COLIFORM IN SEDIMENT
TC (CFU/ml)
300000
250000
200000
150000
100000
50000
0
S-8
S-9
S-10
S-13
S-14
NCTPS-March 2013


ESCHERICHIA COLI IN SEDIMENT
EC (CFU/ml)
35000
30000
25000
20000
15000
10000
5000
0
S-8
S-9
S-10
S-13
S-14
NCTPS-March 2013





MARINE ECOLOGY

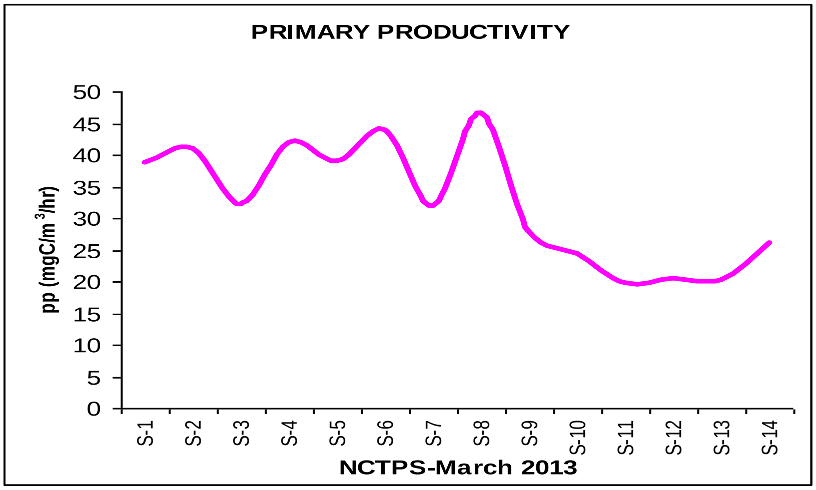
Primary Productivity

In the present study, the primary productivity in water samples varied from 19.759 to 46.628 (mgC/m^3/hr). The minimum was observed at S-11 and the maximum was recorded at S-8. The primary productivity observed at various stations is given in Table-3.11

TABLE –3.11

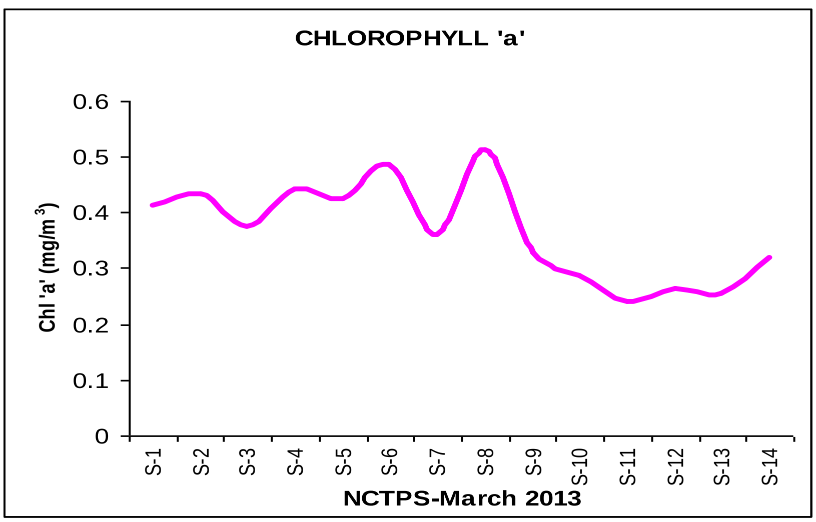
Biological Characteristics at Various Sediment Samples

S. No.	Station Code	PP (mg C/m³/hr)	Chl a (mg/m³)	Phaeopigment (mg/m³)	TB (ml/100m³)
1.	S-1	38.696	0.414	0.230	31.67
2.	S-2	41.063	0.433	0.241	33.58
3.	S- 3	32.129	0.374	0.208	42.15
4.	S-4	41.857	0.443	0.246	34.52
5.	S-5	39.145	0.425	0.236	43.19
6.	S-6	43.875	0.486	0.270	38.29
7.	S-7	31.842	0.359	0.200	36.41
8.	S-8	46.628	0.511	0.284	42.37
9.	S-9	27.723	0.328	0.182	34.97
10.	S-10	24.374	0.287	0.159	36.45
11.	S-11	19.759	0.239	0.133	31.54
12.	S-12	20.567	0.262	0.146	37.38
13.	S-13	20.355	0.254	0.141	26.94
14.	S-14	26.137	0.318	0.177	32.19



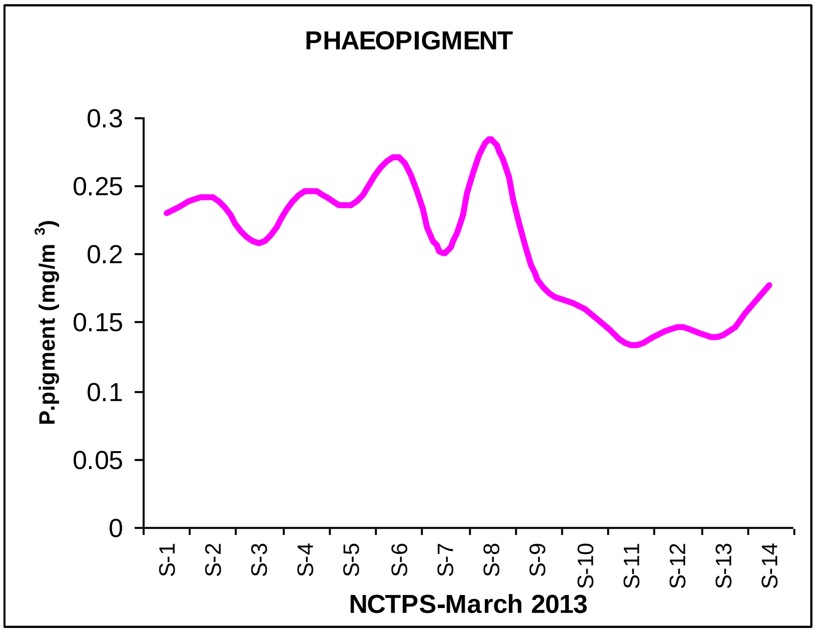
Chlorophyll 'a' (mg/m^3)

The chlorophyll '*a*' level fluctuated between 0.239 to 0.511 mg/m^3. The maximum chlorophyll 'a' (0.511 mg/m^3) was recorded at S-8 and the minimum (0.239 mg/m^3) was recorded at S-11 (Refer Table-3.11).



Phaeopigment (mg/m^3)

In the present study, the phaeopigment in water sample varied from 0.133 to 0.284 (mg/m^3) with maximum in S-8 and minimum in S-11 was recorded (Refer Table-3.11).



Phytoplanktons

A total of 24 phytoplankton taxa were identified from the samples collected. During the study period, species belonging to two groups namely diatoms, and dinoflagellates were recorded. Of these, diatoms were found to be the dominant group with 22 species in each station. Dinoflagellates formed next group with 2 species and in all the stations. Among the diatoms, *Asterionella glacialis, Chaetoceros affinis Nitzschia longissima Pleurosigma normanii Rhizosolenia alata, Skeletonema costatum* and *Triceratium favus* were found to be the commonly occurring species in the samples collected in various stations. Coming to dinoflagellates, *Ceratium favus,* and *Ceratium* sp. showed consistency in their occurrence in different stations of thermal power station waters. Density of phytoplankton varied from 2974 to 5662 No/l with maximum at S-8 and minimum in S-11 (Refer Table-3.12).

TABLE-3.12

Phytoplankton density at various marine water sampling sites

Sl. No	Name of the Species	No/l			
		S-11	S-12	S-13	S-14
1.	*Coscinodiscus radiatus*	12	24	10	16
2.	*Skeletonema costatum*	567	713	783	1200
3.	*Planktoniella sol*	139	121	125	154
4.	*Cyclotella* sp.	98	117	*	*
5.	*Triceratium favus*	28	27	28	40
6.	*Chaetoceros currvisetus*	331	226	240	182
7.	*Chaetoceros affinis*	371	189	*	*
8.	*Chaetoceros coarctatus*	202	198	210	285
9.	*Odontella mobiliensis*	18	18	14	19
10.	*Rhizosolenia styliformis*	26	22	26	21
11.	*Pleurosigma elongatum*	44	*	*	*
12.	*Pleurosigma normanii*	*	46	*	52
13.	*Pleurosigma directum*	*	*	53	*
14.	*Nitzschia longissima*	69	69	69	*
15.	*Navicula vanhoffeni*	145	139	99	121
16.	*Asterionella glacialis*	831	1032	1299	1426
17.	*Ceratium macroceros*	*	27	29	47
18.	*Ceratium furca*	37	45	*	*
19.	*Ceratium longipes*	36	20	34	24

Sl. No	Name of the Species	No/l			
		S-11	S-12	S-13	S-14
20.	*Ceratium bucephalum*	20	*	17	28
21.	*Protoperidinium oceanicum*	*	27	*	*
	Total	**2974**	**3060**	**3036**	**3615**

*** - Organisms not present**

Sl. No.	Name of the Species	No/l				
		S-4	S-5	S-7	S-9	S-10
1.	*Coscinodiscus radiatus*	16	9	9	16	20
2.	*Skeletonema costatum*	1199	1511	1064	1245	1315
3.	*Planktoniella sol*	111	70	99	114	132
4.	*Triceratium favus*	29	35	26	30	29
5.	*Chaetoceros currvisetus*	606	373	546	156	158
6.	*Chaetoceros coarctatus*	338	197	198	204	211
7.	*Odontella mobiliensis*	21	11	25	18	19
8.	*Leptocylindrus danicus*	*	*	*	*	145
9.	*Rhizosolenia styliformis*	16	*	17	28	23
10.	*Rhizosolenia alata*	*	18	*	*	*
11.	*Pleurosigma elongatum*	57	*	*	*	*
12.	*Pleurosigma normanii*	*	26	52	30	39
13.	*Nitzschia longissima*	50	62	34	56	70
14.	*Navicula vanhoffeni*	138	45	61	79	67
15.	*Asterionella glacialis*	2499	2499	1992	1711	1130
16.	*Ceratium macroceros*	37	26	18	29	29
17.	*Ceratium furca*	22	18	*	38	31
18.	*Ceratium longipes*	29	*	26	*	*
19.	*Ceratium bucephalum*	18	16	17	18	19
	Total	**5186**	**4916**	**4184**	**3772**	**3437**

*** - Organisms not present**

Sl. No	Name of the Species	No/l				
		S-1	S-2	S-3	S-6	S-8
1.	*Coscinodiscus radiatus*	35	9	12	14	12
2.	*Skeletonema costatum*	1390	1491	1268	1683	1398
3.	*Planktoniella sol*	70	63	107	86	78
4.	*Cyclotella* sp.	*	37	*	*	135
5.	*Triceratium* sp.	20	*	*	*	*
6.	*Triceratium favus*	*	27	34	32	42
7.	*Chaetoceros currvisetus*	370	354	126	307	405
8.	*Chaetoceros affinis*	*	*	120	*	*
9.	*Chaetoceros coarctatus*	279	330	*	214	490
10.	*Odontella mobiliensis*	18	18	16	16	20
11.	*Rhizosolenia styliformis*	19	22	25	*	18
12.	*Rhizosolenia alata*	*	*	*	12	*
13.	*Pleurosigma normanii*	53	63	50	58	61
14.	*Nitzschia longissima*	50	36	*	76	39
15.	*Navicula vanhoffeni*	*	54	102	57	73
16.	*Asterionella glacialis*	2485	2511	2260	2752	2803
17.	*Ceratium macroceros*	27	37	29	31	29
18.	*Ceratium furca*	*	27	20	29	39
19.	*Ceratium longipes*	35	*	25	*	*
20.	*Ceratium bucephalum*	19	28	17	19	20
	Total	**4870**	**5107**	**4211**	**5386**	**5662**

*** - Organisms not present**

Zooplanktons

In the present study, 3 groups of macro zooplankton namely, calanoids, cyclopoids, and harpacticoids and 3 groups of micro zooplankton namely, foraminiferans, spirotricha and larval forms and other group of rotatoria, appenticularia of various zooplankton were recorded. Among the zooplankton, calanoida were found to be the dominant group with 6 species; cyclopoida came next in the order with 5 species, harpacticoida came next dominant group with 6 species, coming to spirotricha, larval forms, foraminiferans, appenticularia and rotatoria came last with 6, 3, 1, 1, and1 species respectively.

Among the Calanoida, *Acartia danae, Acartia spinicauda,* Cyclopoida, *Oithona brevicornis, O.similis Copilia vitrea Corycaeus catus Corycaeus danae* Harpacticoida, *Labidocera pavo Longipedia weberi Macrosetella gracilis Metis jousseaumei Microsetella norvegica Microsetella rosea* were found to be the frequenters in the collections. In micro zooplankton, larval forms, Barnacle nauplii, Bivalve veliger, Copepod nauplii, Crustacean nauplii and Polychaete larvae were found to be common in all the stations.

zooplanktons varied from 3293 to 5080 No./m^3 with maximum in S-5 and minimum in S-13. The details are given in Table-3.13

TABLE-3.13

Zooplankton density at various marine water sampling sites

Sl. No.	Name of the Species	No/m³			
		S-11	S-12	S-13	S-14
1.	*Brachionus rubens*	159	62	70	53
2.	*Paracalanus parvus*	230	352	232	177
3.	*Acartia danae*	222	88	139	230
4.	*Acartia spinicauda*	317	528	309	265
5.	*Oithona brevicornis*	159	176	201	159
6.	*Oithona similis*	*	255	155	354
7.	*Corycaeus catus*	246	158	70	*
8.	*Copilia vitrea*	*	*	*	159
9.	*Microsetella rosea*	*	176	*	*
10.	*Microsetella norvegica*	*	*	309	345
11.	*Macrosetella gracilis*	317	238	77	*
12.	*Euterpina acutifrons*	214	176	216	336
13.	*Oikopleura parva*	206	246	77	256
14.	Shrimp zoea	*	*	54	*
15.	*Globigernia bulloides*	159	*	77	*
16.	*Tintinnopsis tubulosa*	*	*	232	150
17.	*Tintinnopsis cylindrica*	79	*	*	*
18.	*Tintinnopsis beroidea*	230	264	*	*
19.	*Tintinnopsis butzschi*	*	167	*	*

Sl. No.	Name of the Species	No/m^3			
		S-11	S-12	S-13	S-14
20.	*Favella philipiensis*	159	*	147	*
21.	*Favella brevis*	238	176	*	248
22.	Bivalve veliger	*	88	155	150
23.	Copepod nauplii	951	1056	773	884
	Total	**3886**	**4206**	**3293**	**3766**

*** - Organisms not present**

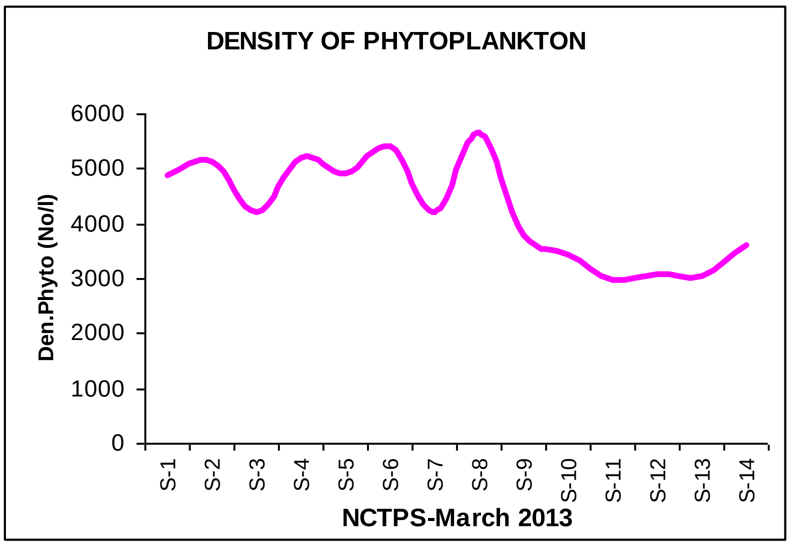
Sl. No.	Name of the Species	No/m^3				
		S-4	S-5	S-7	S-9	S-10
1.	*Brachionus rubens*	84	163	49	79	*
2.	*Eucalanus* sp.	*	81	*	*	*
3.	*Paracalanus parvus*	235	236	231	318	160
4.	*Nannocalanus minor*	251	244	247	159	80
5.	*Labidocera pavo*	*	81	*	*	*
6.	*Acartia danae*	168	228	165	238	152
7.	*Acartia spinicauda*	419	326	404	397	480
8.	*Oithona brevicornis*	335	220	247	159	224
9.	*Oithona similis*	503	570	412	230	400
10.	*Corycaeus catus*	251	163	148	222	160
11.	*Longipedia weberi*	*	163	82	79	*
12.	*Microsetella norvegica*	168	244	157	215	240
13.	*Euterpina acutifrons*	243	489	396	397	320
14.	*Oikopleura parva*	251	163	231	222	216
15.	Shrimp zoea	*	163	*	79	160
16.	*Tintinnopsis tubulosa*	84	244	*	159	208
17.	*Tintinnopsis beroidea*	84	81	82	*	144
18.	*Favella philipiensis*	168	244	247	159	136
19.	Bivalve veliger	84	81	82	79	128
20.	Copepod nauplii	838	896	824	794	881
	Total	**4166**	**5080**	**4004**	**3985**	**4089**

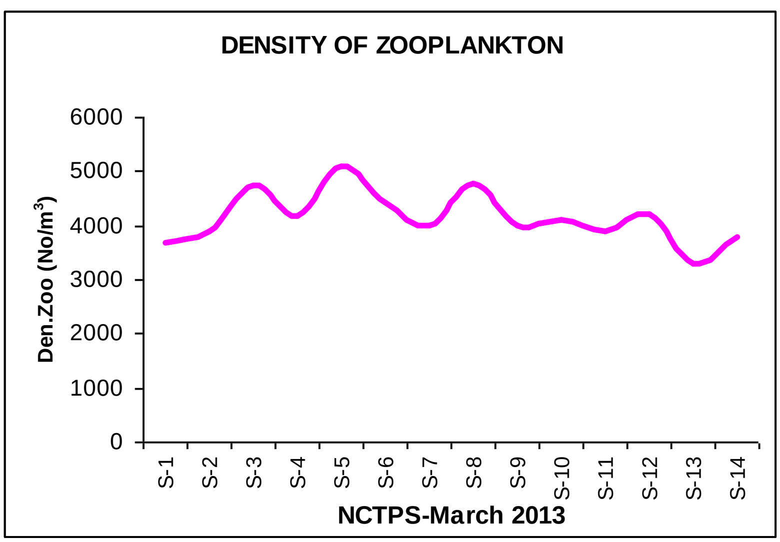
*** - Organisms not present**

Sl. No.	Name of the Species	No/m^3				
		S-1	S-2	S-3	S-6	S-8
1.	*Brachionus rubens*	79	84	235	169	247
2.	*Eucalanus* sp.	*	320	84	*	*
3.	*Paracalanus parvus*	159	253	168	254	82
4.	*Nannocalanus minor*	238	84	*	169	*
5.	*Labidocera pavo*	*	*	84	*	165
6.	*Acartia danae*	143	*	251	169	247
7.	*Acartia spinicauda*	476	421	402	339	412
8.	*Oithona brevicornis*	71	396	335	254	165
9.	*Oithona similis*	396	421	503	423	330
10.	*Corycaeus danae*	*	*	84	*	*
11.	*Corycaeus catus*	230	84	251	169	165
12.	*Microsetella norvegica*	151	168	394	254	313
13.	*Euterpina acutifrons*	238	236	251	339	412
14.	*Metis jousseaumei*	*	*	168	169	*
15.	*Oikopleura parva*	151	*	*	254	239
16.	Shrimp zoea	*	84	84	85	82
17.	*Tintinnopsis tubulosa*	230	227	293	169	330
18.	*Tintinnopsis beroidea*	159	*	*	85	165
19.	*Favella philipiensis*	238	168	168	254	247
20.	*Favella brevis*	79	*	210	*	*
21.	Bivalve veliger	159	84	84	85	165
22.	Copepod nauplii	476	842	671	762	989
	Total	**3673**	**3872**	**4720**	**4402**	**4755**

*** - Organisms not present**

The diatoms constituted the maximum with 91.67% to the total followed by dinoflagellates with 8.33% of the total. In zooplanktons, Calanoids were the major group contributing to over (20.68%), Cyclopoids contributed (17.24%) followed by Harpacticoids (20.68%) and tiny group of Foraminiferans (3.44%), Spirotricha (20.68%) larval forms (10.34%) and other group of Rotatoria (3.44%) and Appenticularia (3.44%).





Finfish Eggs and Larvae

The finfish eggs density in the study region ranged from 10 to 15 No/m^3. The minimum density was recorded at S-10 and the maximum density was observed at S-8 respectively. In the present investigation, 11 species of finfish eggs were recorded from all the stations monitored. The *Mugil cephalus* was found to be the dominant forms. The details of fin Fish egg at various sampling stations is given in Table-3.14

TABLE-3.14

Density of Finfish Eggs at Various Sampling Sites

Sl. No.	Name of the Species	No/m^3			
		S-11	S-12	S-13	S-14
	Enraulidae				
1.	*Stolephorus indicus*	*	*	*	1
2.	*Thryssa mystax*	2	1	3	2
	Clupeidae				
1.	*Sardinella longiceps*	3	3	4	2
	Chanidae				
1.	*Chanos chanos*	2	1	1	1
	Mugilidae				
1.	*Mugil cephalus*	4	4	3	3
2.	*Liza dussumieri*	1	2	1	*
	Teraponidae				
1.	*Terapon jarbua*	2	1	2	2
	Total	**14**	**12**	**14**	**11**

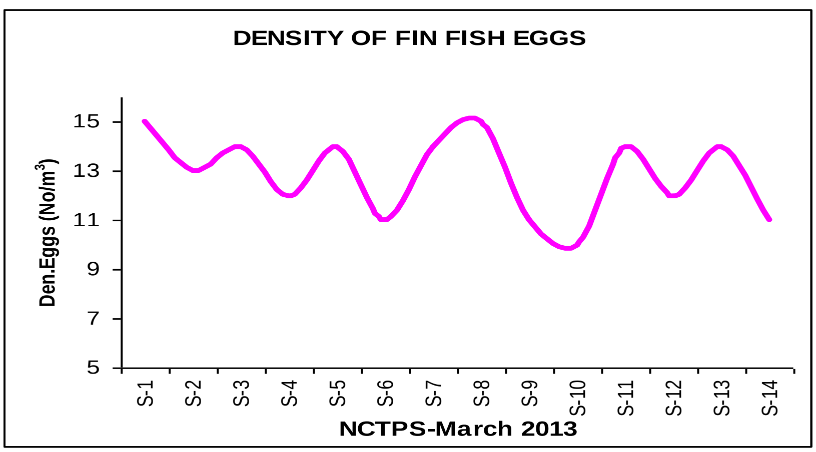
*** - Organisms not present**

Sl. No.	Name of the Species	No/m³				
		S-4	S-5	S-7	S-9	S-10
	Enraulidae					
1.	*Stolephorus indicus*	*	1	1	1	2
2.	*Thryssa mystax*	1	2	2	2	1
	Clupeidae					
1.	*Sardinella leiogaster*	*	*	*	*	*
2.	*Sardinella longiceps*	3	3	2	3	2
	Chanidae					
1.	*Chanos chanos*	2	2	3	1	2
	Mugilidae					
1.	*Mugil cephalus*	3	4	4	2	2
	Teraponidae					
1.	*Terapon jarbua*	3	2	2	2	1
	Total	**12**	**14**	**14**	**11**	**10**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^3				
		S-1	S-2	S-3	S-6	S-8
	Enraulidae					
1.	*Thryssa dussumieri*	1	2	*	*	*
2.	*Thryssa hamiltonii*	*	*	3	3	4
3.	*Thryssa mystax*	2	2	*	*	*
	Clupeidae					
1.	*Sardinella leiogaster*	*	*	3	2	3
2.	*Sardinella longiceps*	2	2	*	*	*
	Mugilidae					
1.	*Mugil cephalus*	5	4	5	4	5
2.	*Liza tade*	3	2	*	*	*
	Teraponidae					
1.	*Terapon jarbua*	2	1	3	2	3
	Total	**15**	**13**	**14**	**11**	**15**

*** - Organisms not present**



The finfish larvae observed from 1 to 5 No/m^3. The maximum number of finfish larvae observed at S-1 and the minimum number of finfish larvae recorded at S-12, S-13 and S-7 respectively. A total of 6 species of finfish larvae were identified from the study area with *Mugil cephalus* dominating (3/5 No/m^3, S-1) .The density of fin Fish larvae at various sampling stations is given in Table-3.15

TABLE-3.15

Density Finfish Larvae at Various Sampling Stations

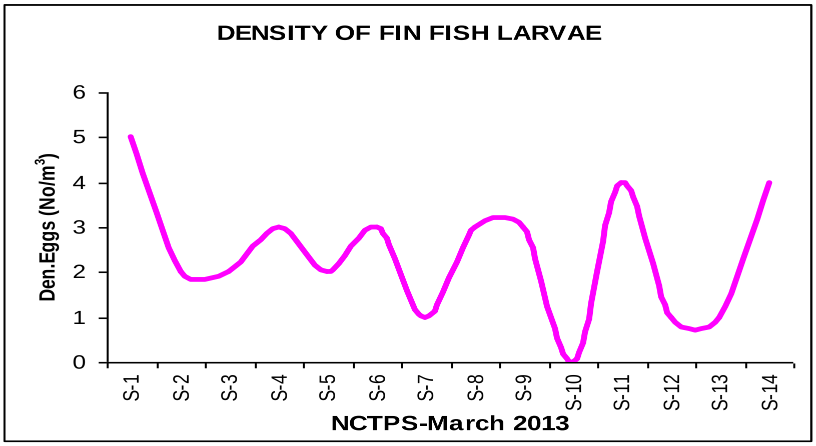
Sl. No.	Name of the Species	No/m^3			
		S-11	S-12	S-13	S-14
	Clupeidae				
1.	*Sardinella longiceps*	1	*	1	1
	Mugilidae				
1.	*Mugil cephalus*	2	1	*	2
2.	*Liza dussumieri*	1	*	*	
	Teraponidae				
1.	*Terapon jarbua*	*	*	*	1
	Total	**4**	**1**	**1**	**4**

Sl. No.	Name of the Species	No/m^3				
		S-4	S-5	S-7	S-9	S-10
	Enraulidae					
1.	*Thryssa mystax*	*	*	1	1	*
	Clupeidae					
1.	*Sardinella longiceps*	1	*	*	1	*

	Mugilidae					
1.	*Mugil cephalus*	1	2	*	1	*
	Teraponidae					
1.	*Terapon jarbua*	1	*	*	*	*
	Total	**3**	**2**	**1**	**3**	*****

Sl. No.	Name of the Species	No/m^3				
		S-1	**S-2**	**S-3**	**S-6**	**S-8**
	Enraulidae					
1.	*Thryssa mystax*	*	1	*	1	2
	Clupeidae					
1.	*Sardinella longiceps*	1	*	1	*	*
	Mugilidae					
1.	*Mugil cephalus*	3	1	1	2	*
2.	*Liza tade*	1	*	*	*	*
	Teraponidae					
1.	*Terapon jarbua*	*	*	*	*	1
	Total	**5**	**2**	**2**	**3**	**3**

*** - Organisms not present**



Benthos

Macrobenthos

A total of 45 species of macro fauna were found here. Of these, Polychaetes topped the list with 19 species. Bivalves were found with 5 species. Gastropods were found to be the next dominant group in the order of abundance with 7 species. Amphipods came next with 7 species and Isopods were found with 7 species.

Comparing the stations the maximum number of species was recorded in station-12 and minimum in station-6. Similarly, maximum population density of macro benthic organism was recorded at station-12 and minimum at station-6 of Thermal power station waters.

During this investigation, five groups of organisms namely Polychaetes, Bivalves, Gastropods, Amphipods and Isopods were recorded. Of these, Polychaetes constituted the dominant group followed by Bivalves, Gastropods, Amphipods and Isopods. Among the Polychaetes, *Ancistrosyllis parva, Armandia longicaudata, Cirratulus concinnus, Dorvillea gardineri, Exogone clavator, Nephtys sphaerocirrata, Notomastus aberans, Phyllodoce tubicola, Pisionidens indica, Polydora ciliate, Prionospio capensis, Sphaerosyllis erinaceu, Nephtys* *homgergi and Eunice Siciliensis* were found to be the most commonly occurring species in the samples collected in (TPS) Thermal power station waters. Coming to Bivalves, *Anadara* veligers, *Cardium* veligers, *Donax* veligers, *Meretrix* veligers *Perna viridis.* Gastropods *Nassarius* veligers, *Littorina* veligers, *Bullia* veligers, *Cerithedia cingulata, Natica* veligers, *Oliva* veligers, *Turritella* veligers were found to be common species in the collection. With respect to Amphipods namely *Gammarus* sp., *Grandidierella* sp., *Ampithoe romondi, A. rubricate, Caprella mendax Urothoe* sp. *Phaxocephalus holbolli.* Isopods such as, *Angeliera phreaticola, Jaeropsis beuriosi, Calabozoa pellucid, Paragnathia formica, Anthura gracilis, Sphaeroma serratum, Microjaera anisopoda* showed consistency in their occurrence in the samples collected.

COMMON SPECIES OF MACROBENTHOS

Cirratulus concinnus

Cirratulus africanus

Ancistrosyllis parva

Notomastus aberrans

Pisionidens indica

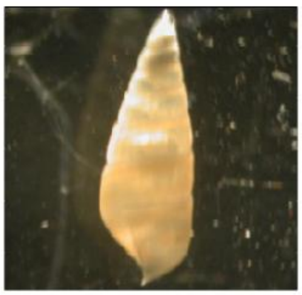
Anadara veligers

Meretrix veligers

Cardium veligers

Nassarius **veligers**

Cerithedia cingulata

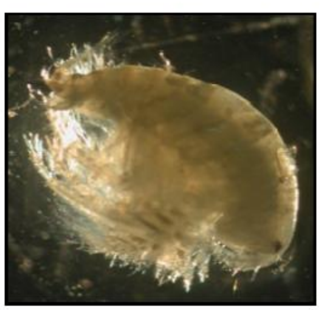


Turritella **veligers**

Gammarus **sp.**

Ampithoe rubricata

Ampithoe romondi



Urothoe **sp.**

Paragnathia formica

The population density varied from 1475 to 3025 No./m^2 with maximum at station-8 and minimum at S-9. The details are given in Table-3.16

TABLE-3.16

Density of Macrobenthos at Various Sampling Sites

Sl. No.	Name of the Species	No/m^2			
		S-11	S-12	S-13	S-14
	Polychaetes	**Unable to collect samples due to concrete channel**			
1.	*Ancistrosyllis parva*			50	*
2.	*Armandia longicaudata*			*	75
3.	*Armandia intermedia*			25	*
4.	*Cirratulus concinnus*			125	150
5.	*Cirratulus chrysoderma*			*	*
6.	*Cirratulus africanus*			75	25
7.	*Dorvillea gardineri*			*	*
8.	*Drilonereis falcata*			*	75
9.	*Exogone clavator*			125	*
10.	*Nephtys sphaerocirrata*			*	25
11.	*Notomastus aberans*			25	*
12.	*Phyllodoce tubicola*			150	100
13.	*Pisionidens indica*			175	225
14.	*Polydora ciliata*			*	50
15.	*Prionospio capensis*			25	*
16.	*Prionospio cirrifera*			*	25

Sl. No.	Name of the Species	No/m^2			
		S-11	S-12	S-13	S-14
17.	*Sphaerosyllis erinaceu*			*	50
18.	*Nephtys homgergi*			50	*
19.	*Eunice Siciliensis*			*	25
	Bivalves				
1.	*Anadara* veligers			25	*
2.	*Cardium* veligers			*	50
3.	*Donax* veligers			50	*
4.	*Meretrix* veligers			*	75
5.	*Perna viridis*			75	25
	Gastropods				
1.	*Nassarius* veligers			75	25
2.	*Littorina* veligers			*	100
3.	*Bullia* veligers			50	*
4.	*Cerithedia cingulata*			225	175
5.	*Natica* veligers			*	25
6.	*Oliva* veligers			150	100
7.	*Turritella* veligers			*	50
	Amphipods				
1.	*Gammarus* sp.			25	50

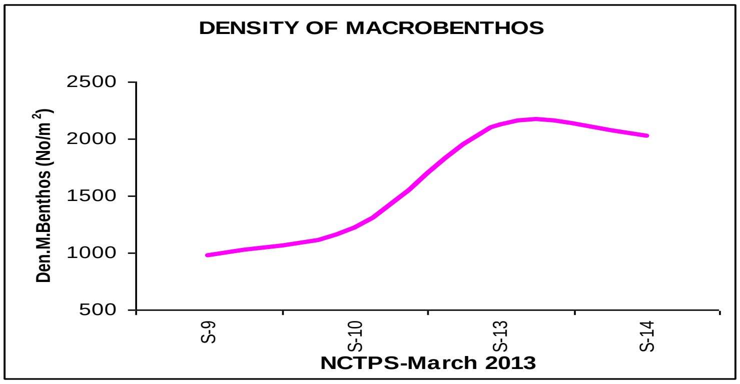
Sl. No.	Name of the Species	No/m^2			
		S-11	S-12	S-13	S-14
2.	*Grandidierella* sp.			*	75
3.	*Ampithoe romondi*			150	100
4.	*Ampithoe rubricata*			75	*
5.	*Caprella mendax*			*	50
6.	*Urothoe* sp.			125	75
7.	*Phaxocephalus holbolli*			75	*
	Isopods				
1.	*Angeliera phreaticola*			*	25
2.	*Jaeropsis beuriosi*			25	50
3.	*Calabozoa pellucida*			75	*
4.	*Paragnathia formica*			*	100
5.	*Anthura gracilis*			25	*
6.	*Sphaeroma serratum*			*	25
7.	*Microjaera anisopoda*			75	25
	Total			**2125**	**2025**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^2				
		S-4	S-5	S-7	S-9	S-10
	Polychaetes					
1.	*Ancistrosyllis parva*	Unable to collect sediment samples due to concrete channel			*	75
2.	*Armandia longicaudata*				25	*
3.	*Armandia intermedia*				*	25
4.	*Cirratulus concinnus*				50	*
5.	*Cirratulus africanus*				50	75
6.	*Dorvillea gardineri*				*	*
7.	*Drilonereis falcata*				75	50
8.	*Exogone clavator*				*	75
9.	*Nephtys sphaerocirrata*				50	*
10.	*Notomastus aberans*				*	75
11.	*Phyllodoce tubicola*				50	*
12.	*Pisionidens indica*				125	125
13.	*Polydora ciliata*				50	25
14.	*Prionospio capensis*				25	50
15.	*Nephtys homgergi*				25	25
16.	*Eunice Siciliensis*				*	*
	Bivalves					
1.	*Anadara* veligers				25	50
2.	*Cardium* veligers				50	*
3.	*Donax* veligers				*	125

Sl. No.	Name of the Species	No/m^2				
		S-4	S-5	S-7	S-9	S-10
4.	*Meretrix* veligers				75	50
5.	*Perna viridis*				25	*
	Gastropods					
1.	*Nassarius* veligers				50	75
2.	*Littorina* veligers				*	*
3.	*Bullia* veligers				75	25
4.	*Cerithedia cingulata*				25	100
5.	*Oliva* veligers				*	50
6.	*Turritella* veligers				50	75
	Amphipods					
1.	*Gammarus* sp.				75	25
2.	*Grandidierella* sp.				*	50
	Total				**975**	**1225**

The results of percentage composition of benthic fauna were viewed, Polychaetes constituted the maximum with 42.22% to the total benthic organisms. Bivalves, Gastropods, Amphipods and Isopods contributed 11.11%, 15.56%, 15.56%, and 15.56% respectively to the benthic samples collected.



Meiobenthos

In the present study, 73 species of meio-benthic fauna were recorded in (NCTPS) thermal power station waters. Of these, Foraminiferans topped the list with 31 species. Nematodes were found to be the next dominant group in the order of abundance with 13 species. Ostracodes and Harpacticoids came next with 8 and 7 species respectively. Coming to Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera came last with 5, 4, 3, 1 and 1 species respectively.

Comparing the stations the maximum number of species was recorded in station-14 and minimum in S-13. Similarly, maximum population density of meio-benthic organism was recorded at S-14 and minimum at S-13 of (NCTPS) thermal power station waters.

Altogether nine groups of meio-benthic organisms namely Foraminiferans, Nematodes Ostracodes, Harpacticoids, Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera were recorded. Of these, Foraminiferans were found to be dominant group followed by Nematodes, Ostracodes, Harpacticoids, Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera. Among the Foraminiferans *Ammonia beccarii, Amphisorus* sp., *Asterorotalia trispinosa, Bolivia abbreviate, Cornoboides advena, Cymbaloporetta bradyi, Rotalia calcar,* *Ammonia tepida, Ammonia elegans, Asterorotalia inflate,* and *Leptohalysis scotti.* Nematodes, *Daptonema conicum, Desmoscolex falcatus, Sipirinia* sp. *Microlaimus* sp were found to be the common species in the samples collected in various stations with respect to Ostracodes, *Conchoecia* sp. *Cyprideis* sp. *Keijella oertlii, Tanella estuarii, Philomedes globosus* were found to occur all the stations. Coming to Harpacticoids, *Apodopsyllus vermiculiformis, Canuella* sp. *Diarthrodes* sp. *Phyllothalestris mysis, Laophonte thoracica, Stenhelia* sp. was found to be common in the collection. with respect to Tanaidacea namely *Sphaerosyllis* sp. *Pogurapseudes largoensis, Heterotanais oerstedi,* Archiannelids *Polygordius sp. Protodrilus helgolandicus, Protodrilus brevis, Diurodrilus* sp. with respect to the Cumacea *Campylaspis* sp. *Gynodiastylis* sp. *Nannastacus* sp. Gastrotricha *Cephalodasys* sp. and Rotifera such as *Rotaria rotatoria, Campylaspis* sp*., Gynodiastylis* sp*., and Cephalodasys* sp*.,* showed consistency in their occurrence in the samples collected

The population density varied from 1349 to 1877 No/10 cm^2 with maximum at S-14 and minimum at S-13 during study period. The details of meio-benthos at various sampling locations is given in Table-3.17

TABLE-3.17

Density of Meiobenthos at Various Sampling Sites

Sl. No.	Name of the Species	No/10cm^2			
		S-11	S-12	S-13	S--14
	Nematodes				
1.	*Daptonema conicum*	**Unable to collect sediment samples due to concrete channel**		28	60
2.	*Desmoscolex falcatus*			15	19
3.	*Enoploides* sp.			35	43

Sl. No.	Name of the Species	No/10cm^2			
		S-11	S-12	S-13	S--14
4.	*Gonionchus* sp.			23	52
5.	*Pandolaimus* sp.			40	66
6.	*Polygastrophora* sp.			37	45
7.	*Pselionema* sp.			12	22
8.	*Quadricoma* sp.			4	8
9.	*Viscosia* sp.			26	22
10.	*Diodontolaimus* sp.			13	14
11.	*Neochromodora* sp.			122	135
12.	*Sipirinia* sp.			140	120
13.	*Microlaimus* sp.			75	69
	Foraminiferans				
1.	*Ammonia beccarii*			23	26
2.	*Amphisorus* sp.			5	9
3.	*Asterorotalia trispinosa*			22	42
4.	*Bolivia abbreviata*			16	55
5.	*Cornoboides advena*			28	40
6.	*Cymbaloporetta bradyi*			7	8
7.	*Discorbis* sp.			32	60
8.	*Eponides repandus*			27	42
9.	*Globigerinoides glutinata*			17	19

Sl. No.	Name of the Species	No/10cm²			
		S-11	S-12	S-13	S--14
10.	*Hauerina miocenica*			5	*
11.	*Lagena striata*			4	5
12.	*Lagena marginata*			*	7
13.	*Loxostoma perrectum*			3	*
14.	*Neoconorbina crustata*			6	8
15.	*Nonion depressulum*			25	24
16.	*Oridosalis umbonatus*			17	46
17.	*Quinqueloculina* sp.			35	55
18.	*Rosalina bertheloti*			13	23
19.	*Rosalina globularis*	**Unable to collect sediment samples due to concrete channel**		25	46
20.	*Rotalia calcar*			12	16
21.	*Ammonia tepida*			48	44
22.	*Ammonia elegans*			15	30
23.	*Asterorotalia inflata*			13	17
24.	*Leptohalysis scotti*			12	20
25.	*Lagena hexaona*			7	4
26.	*Rosalina lee*			20	52
27.	*Cancris indicus*			15	18
28.	*Cancris unicatus*			4	12
29.	*Spiroloculina* sp.			25	50
30.	*Textularia agglutinans*			37	39

Sl. No.	Name of the Species	No/10cm^2			
		S-11	S-12	S-13	S--14
31.	*Triloculina austriaca*			13	17
	Gastrotricha				
1.	*Cephalodasys* sp.			2	8
	Cumacea				
1.	*Campylaspis* sp.			3	*
2.	*Gynodiastylis* sp.			5	8
3.	*Nannastacus* sp.			*	*
	Harpacticoids				
1.	*Apodopsyllus vermiculiformis*			15	20
2.	*Canuella* sp.			10	19
3.	*Diarthrodes* sp.			6	8
4.	*Phyllothalestris mysis*			*	*
5.	*Laophonte thoracica*			3	7
6.	*Stenhelia* sp.			12	15
7.	*Tisbe furcata*			7	9
	Ostrocodes				
1.	*Conchoecia* sp.			23	39
2.	*Cyprideis* sp.			13	16
3.	*Keijella oertlii*			7	8
4.	*Leptocythere* sp.			16	22
5.	*Tanella indica*			6	9

Sl. No.	Name of the Species	No/10cm^2			
		S-11	S-12	S-13	S--14
6.	*Tanella kingmaii*			2	7
7.	*Tanella estuarii*			4	8
8.	*Philomedes globosus*			13	18
	Archiannelids				
1.	*Polygordius sp.*			23	19
2.	*Protodrilus helgolandicus*			7	8
3.	*Protodrilus brevis*			3	6
4.	*Diurodrilus* sp.			*	3
	Rotifera				
1.	*Rotaria rotatoria*			6	5
	Tanaidacea				
1.	*Sphaerosyllis* sp.			17	20
2.	*Pogurapseudes largoensis*			13	26
3.	*Heterotanais oerstedi*			15	18
4.	*Apseudes setosus*			10	30
5.	*Apseudes sipinosus*			7	12
	Total			**1349**	**1877**

Sl. No.	Name of the Species	No/10cm^2				
		S-4	S-5	S-7	S-9	S-10
	Nematodes					
1.	*Daptonema conicum*	**Unable to collect sediment samples due to concrete channel**			42	35
2.	*Desmoscolex falcatus*				13	19
3.	*Enoploides* sp.				26	46
4.	*Gonionchus* sp.				35	28
5.	*Pandolaimus* sp.				43	55
6.	*Polygastrophora* sp.				26	42
7.	*Pselionema* sp.				13	10
8.	*Quadricoma* sp.				7	8
9.	*Viscosia* sp.				18	32
10.	*Diodontolaimus* sp.				12	15
11.	*Neochromodora* sp.				114	135
12.	*Sipirinia* sp.				126	156
13.	*Microlaimus* sp.				62	88
	Foraminiferans					
1.	*Ammonia beccarii*				30	25
2.	*Amphisorus* sp.				3	8
3.	*Asterorotalia trispinosa*				26	34
4.	*Bolivia abbreviata*				30	23
5.	*Cornoboides advena*				24	39

Sl. No.	Name of the Species	No/10cm^2				
		S-4	S-5	S-7	S-9	S-10
6.	*Cymbaloporetta bradyi*				*	9
7.	*Discorbis* sp.	**Unable to collect sediment samples due to concrete channel**			55	46
8.	*Eponides repandus*				43	30
9.	*Globigerinoides glutinata*				15	19
10.	*Hauerina miocenica*				*	6
11.	*Lagena striata*				2	8
12.	*Lagena marginata*				*	3
13.	*Loxostoma perrectum*				4	7
14.	*Neoconorbina crustata*				3	9
15.	*Nonion depressulum*				40	32
16.	*Oridosalis umbonatus*				22	19
17.	*Quinqueloculina* sp.				53	46
18.	*Rosalina bertheloti*				17	15
19.	*Rosalina globularis*				22	32
20.	*Rotalia calcar*				19	14
21.	*Ammonia tepida*				60	52
22.	*Ammonia elegans*				23	18
23.	*Asterorotalia inflata*				16	19
24.	*Leptohalysis scotti*				18	15
25.	*Lagena hexaona*				5	*
26.	*Rosalina lee*				29	25

Sl. No.	Name of the Species	No/10cm^2				
		S-4	S-5	S-7	S-9	S-10
27.	*Cancris indicus*				13	17
28.	*Cancris unicatus*				7	6
29.	*Spiroloculina* sp.				33	28
30.	*Textularia agglutinans*				25	42
31.	*Triloculina austriaca*				16	15
	Gastrotricha					
1.	*Cephalodasys* sp.				*	4
	Cumacea					
1.	*Campylaspis* sp.				7	5
2.	*Gynodiastylis* sp.				3	6
3.	*Nannastacus* sp.				*	9
	Harpacticoids					
1.	*Apodopsyllus vermiculiformis*				13	19
2.	*Canuella* sp.				12	13
3.	*Diarthrodes* sp.				7	8
4.	*Phyllothalestris mysis*				*	5
5.	*Laophonte thoracica*				3	*
6.	*Stenhelia* sp.				10	16
7.	*Tisbe furcata*				4	9
	Ostrocodes					
1.	*Conchoecia* sp.				28	25

Sl. No.	Name of the Species	No/10cm²				
		S-4	S-5	S-7	S-9	S-10
2.	*Cyprideis* sp.				19	15
3.	*Keijella oertlii*				3	9
4.	*Leptocythere* sp.				14	18
5.	*Tanella indica*				4	7
6.	*Tanella kingmaii*				*	8
7.	*Tanella estuarii*				2	5
8.	*Philomedes globosus*				10	15
	Archiannelids					
1.	*Polygordius sp.*				18	28
2.	*Protodrilus helgolandicus*				4	9
3.	*Protodrilus brevis*				*	5
4.	*Diurodrilus* sp.				5	4
	Rotifera					
1.	*Rotaria rotatoria*				7	8
	Tanaidacea					
1.	*Sphaerosyllis* sp.				13	19
2.	*Pogurapseudes largoensis*				18	15
3.	*Heterotanais oerstedi*	**Unable to collect sediment samples due to concrete channel**			16	20
4.	*Apseudes setosus*				20	12
5.	*Apseudes sipinosus*				5	9
	Total				**1435**	**1655**

*** - Organisms not present**

Sl. No.	Name of the Species	No/10cm^2				
		S-1	S-2	S-3	S-6	S-8
	Nematodes					
1.	*Daptonema conicum*	**Unable to collect sediment samples due to concrete channel**		**Unable to collect sediment samples due to concrete channel**		55
2.	*Desmoscolex falcatus*					17
3.	*Enoploides* sp.					36
4.	*Gonionchus* sp.					42
5.	*Pandolaimus* sp.					53
6.	*Polygastrophora* sp.					32
7.	*Pselionema* sp.					18
8.	*Quadricoma* sp.					9
9.	*Viscosia* sp.					23
10.	*Diodontolaimus* sp.					16
11.	*Neochromodora* sp.					120
12.	*Sipirinia* sp.					115
13.	*Microlaimus* sp.					58
	Foraminiferans					
1.	*Ammonia beccarii*					42
2.	*Amphisorus* sp.					7
3.	*Asterorotalia trispinosa*					36
4.	*Bolivia abbreviata*					40
5.	*Cornoboides advena*					37

Sl. No.	Name of the Species	No/10cm^2				
		S-1	S-2	S-3	S-6	S-8
6.	*Cymbaloporetta bradyi*					5
7.	*Discorbis* sp.					60
8.	*Eponides repandus*					36
9.	*Globigerinoides glutinata*					18
10.	*Hauerina miocenica*					6
11.	*Lagena striata*					3
12.	*Lagena marginata*					*
13.	*Loxostoma perrectum*					8
14.	*Neoconorbina crustata*					7
15.	*Nonion depressulum*					28
16.	*Oridosalis umbonatus*					30
17.	*Quinqueloculina* sp.					64
18.	*Rosalina bertheloti*					19
19.	*Rosalina globularis*					37
20.	*Rotalia calcar*					17
21.	*Ammonia tepida*	**Unable to collect sediment samples due to concrete channel**		**Unable to collect sediment samples due to concrete channel**		35
22.	*Ammonia elegans*					28
23.	*Asterorotalia inflata*					14
24.	*Leptohalysis scotti*					19
25.	*Lagena hexaona*					*
26.	*Rosalina lee*					35

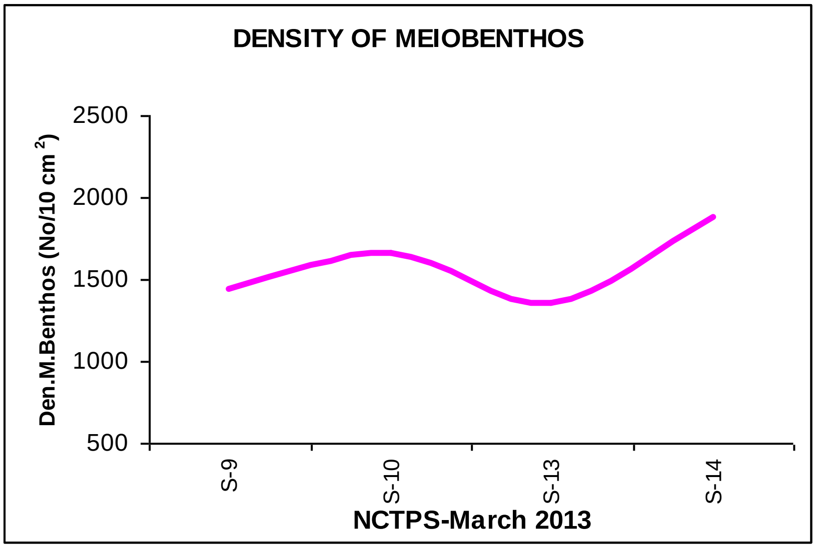
Sl. No.	Name of the Species	No/10cm^2				
		S-1	S-2	S-3	S-6	S-8
27.	*Cancris indicus*					20
28.	*Cancris unicatus*					9
29.	*Spiroloculina* sp.					42
30.	*Textularia agglutinans*					28
31.	*Triloculina austriaca*					20
	Gastrotricha					
1.	*Cephalodasys* sp.					6
	Cumacea					
1.	*Campylaspis* sp.					9
2.	*Gynodiastylis* sp.					*
3.	*Nannastacus* sp.					6
	Harpacticoids					
1.	*Apodopsyllus vermiculiformis*					18
2.	*Canuella* sp.					15
3.	*Diarthrodes* sp.					5
4.	*Phyllothalestris mysis*					3
5.	*Laophonte thoracica*					*
6.	*Stenhelia* sp.					19
7.	*Tisbe furcata*					6
	Ostrocodes					
1.	*Conchoecia* sp.					20
2.	*Cyprideis* sp.					14

Sl. No.	Name of the Species	No/10cm²				
		S-1	S-2	S-3	S-6	S-8
3.	*Keijella oertlii*			Unable to collect sediment samples due to concrete channel		5
4.	*Leptocythere* sp.					19
5.	*Tanella indica*					8
6.	*Tanella kingmaii*	Unable to collect sediment samples due to concrete channel				4
7.	*Tanella estuarii*					6
8.	*Philomedes globosus*					16
	Archiannelids					
1.	*Polygordius sp.*					20
2.	*Protodrilus helgolandicus*					6
3.	*Protodrilus brevis*					4
4.	*Diurodrilus* sp.					*
	Rotifera					
1.	*Rotaria rotatoria*					3
	Tanaidacea					
1.	*Sphaerosyllis* sp.					15
2.	*Pogurapseudes largoensis*					20
3.	*Heterotanais oerstedi*					19
4.	*Apseudes setosus*					23
5.	*Apseudes sipinosus*					8
	Total					**1641**

*** - Organisms not present**

When the results of percentage composition fauna were viewed, Foraminiferans, constituted the maximum with 42.47% of the total benthic organisms. Nematodes, Ostracodes, Harpacticoids, Tanaidacea, Archiannelids, Cumacea 17.81% 10.96% 9.59%

6.85% 5.48% 4.11% and Gastrotricha and Rotifera1.37% 1.37% each in to the total meio-benthic samples collected.



3.4 MARINE ECOLOGY (SEPTEMBER, 2013)

The Marine Ecological survey at NCTPS coastal areas was made by a team of experts from the Centre of Advanced Study in Marine Biology of Annamalai University during September 2013. Marine samples were collected from 14 Stations including intake and outfall of NCTPS. These Stations were located in the following latitude and longitude in which it is proposed to lay the intake (13°25'93.0"N & 80°33'36.0"E) and outfall (13°23'36.0"N & 80°32'70.0"E) systems.The lists of stations covered as a part of Marine EIA Study are given below:

- Station -1 is located near IInd Stage intake inside the Ennore port.
- Station -2 is located near to Ist Stage intake inside the Ennore port.
- Station -3 is located on Ist Stage intake (Cooling Water Pump House)
- Station -4 and 5 are located on intake channel with 100 m distance to each.
- Station 6 is located in the seal well.
- Station -7 is IInd stage outlet which is a concrete channel with 5 m depth running above the intake channel.

- Station -8 is also on the outlet channel (Pre cooling Channel), but not a concrete channel.
- Stations -9 and 10 are located parallel to out fall positions inside the NCTPS
- Stations -11and 12 are located in outlet with 50 m distance (Outlet positions).
- Stations -13 and 14 are located in Ennore creek mouth, which is parallel to the station -11 and 12..

The geographical locations of the sampling Stations are given in Table 3.18:

Table 3.18

Sampling locations and its geographical coordinates

S. No.	St. Code	Latitude	Longitude
1	S-1	13°25'93" N	80°33'36" E
2	S-2	13°25'68" N	80°33'46" E
3	S- 3	13°23'11" N	80°33'30" E
4	S-4	13°25'93" N	80°33'36" E
5	S-5	13°25'93" N	80°33'36" E

6	S-6	13°25'21" N	80°32'49" E
7	S-7	13°25'93" N	80°33'36" E
8	S-8	13°24'14" N	80°33'32" E
9	S-9	13°23'44" N	80°32'77" E
10	S-10	13°23'44" N	80°32'77" E
11	S-11	13°23'36" N	80°32'70" E
12	S-12	13°23'37" N	80°32'68" E
13	S-13	13°23'46" N	80°32'82" E
14	S-14	13°23'46" N	80°32'82" E

MATERIALS AND METHODS

Water and Sediment Sampling

Water samples were collected using Universal water sampler below the surface and transferred to the precleaned polypropylene and glass containers. Sediment samples were collected using a Peterson Grab, transferred to clean polythene bags and transported to the laboratory. The samples were air-dried. The station root and other debris were removed and stored for further analysis.

Water Analysis

Temperature, Salinity and pH:

The physical parameters like pH, temperature and salinity were measured in-situ in field condition. The subsurface temperature was measured with a mercury thermometer having ± 0.02°C accuracy and the pH of water was measured by a calibrated pH pen (pH ep-3 model). With the use of a hand refractometer (Erma Company, Japan), the salinity of samples was measured. Water samples collected for dissolved oxygen estimation were transferred carefully to BOD bottles. The DO was immediately fixed and these were brought to the laboratory for further analysis.

Preservation and Laboratory Analysis:

After collection, all samples were immediately cooled to 4°C and then brought to the laboratory in an insulated thermocool box. In the laboratory, water samples were filtered through Whatman GF/C filter paper and analyzed for organic matter and all other nutrients. Unfiltered samples were used for the estimation of total nitrogen and total phosphorus. All the analyses were carried out as per internationally used standard procedures for samples of aquatic origin. Briefly, the methods of analyses were as follows:

Dissolved Oxygen (DO):

The modified Winkler's method described by Strickland and Parsons (1972) was adopted for the estimation of dissolved oxygen fixed at the collection site. The values were expressed in mg/l.

Nitrate and Nitrite:

The nitrate and nitrite content of samples were analysed by following the method described by Strickland and Parsons (1972). The nitrite was estimated from highly coloured azo dye formed by the addition of N (1-Napthyl) ethylene diamine dihydro-chloride and sulfanilamide into the solution was then measured at 543 nm in a spectrophotometer. Same procedure was followed for the estimation of nitrate. For this, nitrate was reduced to nitrite by passing the sample through copper coated cadmium column. The calculated values were expressed in μmol of Nitrogen/l

Inorganic Phosphate (IP):

The single solution mixed reagent procedure developed by Murphy and Riley (1962) was followed for the estimation of dissolved inorganic phosphate levels in water samples. This involves the conversion of phosphate into phosphomolybdic acid which was then reduced to molybdinum blue color complexes and then the intensity of colour was measured at 882 nm in a spectrophotometer. The calculated value was expressed in µmol of Phosphorus/l.

Total Phosphorus (TP):

The Total Phosphate in samples was estimated by employing the method described by Menzel and Corwin (1964). This procedure involves the conversion of organically bound phosphate into inorganic phosphate by wet oxidation of samples with potassium persulphate in an autoclave for 30 min at 15 lbs pressure. The converted inorganic phosphate was then estimated by using the method described by Murphy and Riley (1962). The subtraction of original dissolved inorganic phosphate from total phosphate yielded the organic phosphate in the water sample. The calculated value was expressed in µmol of Phosphorus/l.

Reactive Silicate:

The reactive silicate content of water was estimated by following the method of Strickland and Parsons (1972). In this method the intensity of blue color formed by silico-molybdate complex was measured in a spectrophotometer at 810 nm and the calculated values were expressed in µmol of Silica/l

Sediment Analysis

For the analysis of textural composition and pH, the air-dried sediment samples were used as such. For all other analyses of organic matter and trace metals, sediment samples were ground to fine powder and dried in an oven at 110°C to constant weight for an hour.

Total Organic Carbon (TOC):

The estimation of total organic carbon in sediment was performed by adopting the method of El Wakeel and Riley (1956). The procedure involves chromic acid digestion and subsequent titration with ferrous ammonium sulphate solution in the presence of 1, 10 phenonthroline indicator. The values calculated are expressed in mg C/g of sediment.

Bacteriological Methods

Collection of samples:

Surface water samples were collected in 100 ml sterile screw capped bottles for bacteriological assessment. Enough air space was left in the bottles to allow thorough mixing. Precautionary measures were taken to avoid contamination through handling. Sediment samples were collected by employing an alcohol rinsed air-dried small Peterson's grab. The central portion of the collected sediment was aseptically transferred into sterile polyethylene bags using sterile spatula. All the samples were brought to the laboratory in portable icebox as soon as possible after collection and bacteriological analyses were done in the laboratory at CAS immediately after arrival, with necessary dilution.

Enumeration of Total Viable Counts (TVC):

TVC was enumerated by adopting the spread plate method using Zobell's Marine Agar medium (EA123, Hi-Media, Mumbai). The samples (water and sediment) were diluted using the sterile sea water and 0.1 ml of the diluted sample was pippeted into the petriplates containing Zobell's Marine Agar and it was spread using a 'L' shaped glass spreader. The plates after inaculation were incubated in an inverted position at a temperature of 28+2°C for 24 to 48 h. The colonies were counted and the population density expressed as colony forming unit (CFU) per ml or g of the sample. The bacterial colonies were picked up from the pertidishes and re-streaked in appropriate nutrient agar plates thrice before a pure culture was established in agar slants.

Enumeration of Total Coliforms:

Macconkey agar with 0.15% bile salt, crystal violet and NaCl has been recommended in accordance with USP/Nfxi (1) for the detection, isolation and enumeration of coliforms and intestinal pathogens in water, dairy products, pharmaceutical preparations, etc. The agar weighing 51.5 g in 1000 ml distilled water was heated upto the boiling point to dissolve the medium completely and sterilized by autoclaving at 15 lbs pressure (121°C) for 15 min. suitably diluted samples were inoculated in the petriplates containing medium and were incubated for 48 h. After incubation, the colonies of E. coli appeared with pink color.

M-FC agar is employed for detection and enumeration Fecal Coliforms by the membrane filter technique at higher temperature (44.5°C). The agar weighing 52 g was suspended in 1000 ml of distilled water and heated upto the boiling point to dissolve the medium completely, 10 ml of Rosolic acid (dissolved in 0.2 N NaOH) was added, heated with frequent agitation and boiled for 1 min. Then the medium was cooled to

50°C. Finally, the medium was poured into small 60 mm plates. Samples filtered by Millipore apparatus using 0.45µm Whatsman filter papers were impregnated in the petriplates. After 48 h of incubation, the colonies of E. coli appeared with blue color. 3.2.4. Enumeration of Streptococcus faecalis:

M-Enterococcus agar is recommended as a selective medium for membrane filtration procedure or as a direct plating medium for the isolation and enumeration of Enterococci in food, water and other sources. The agar medium weighing 41.5 g was suspended in 1000 ml distilled water and mixed thoroughly. Then it was heated with frequent agitation until the agar was dissolved and then, the medium was cooled to 50°C with the addition of 0.5 ml of polysorbate 80 and 2 ml of 10% aqueous solution of sodium carbonate. The finally the medium was poured into small 60 mm plates. Samples filtered by Millipore apparatus using 0.45µm Whatsman filter papers were impregnated in the petriplates. After 48 h of incubation the colonies of S. faecalis appeared with maroon color.

Primary Productivity (PP)

The primary productivity in the study area was estimated following the dark and light bottle method (Strickland and Parsons, 1972). The dissolved oxygen concentration during the experiment was determined by following modified Winkler's method.

Chlorophyll `a'

The samples were filtered through Whatman GF/C filter papers and the chlorophyll was extracted into 90% acetone. The resulting colored acetone extract was measured in a spectrophotometer at different wavelengths and the same acetone extracts were acidified and measured for the phaeo-pigments. The methodology is described in detail in APHA manual (1989).

Phytoplankton

Phytoplankton samples were collected from the surface waters of the study areas by towing a plankton net (mouth diameter 0.35 m) made of bolting silk [No.25 mesh size

48 μm) for half an hour. These samples were preserved in 5% neutralized formalin and used for qualitative analysis. For the quantitative analysis of phytoplankton, the settling method described by Sukhanovo (1978) was adopted. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope.

Phytoplankton was identified using the standard works of Hustedt (1930-1966), Venkataraman (1939), Cupp (1943), Subramanian (1946), Prescott (1954), Desikachary (1959 and 1987), Hendey (1964), Steidinger and Williams (1970) and Taylor (1976) and Anand et al. (1986)

Zooplankton

Zooplankton samples were collected from the surface waters of the study areas by horizontal towing of a plankton net with mouth diameter of 0.35 m, made of bolting silk (No. mesh size 33 mm) for half an hour. These samples were preserved in 5% neutralized formalin and used for quantitative analysis. The zooplankton was identified using the classical works of Dakin and Colefax (1940), Davis (1955), Kasthurirangan (1963) and Wickstead (1965) and Damodara Naidu (1981). For the quantitative analysis of zooplankton, a known quantity of water (100 l) was filtered through a bag net (0.33 mm mesh size) and filtrate was made up to 1 l in a wide mouthed enumerated using Utermohl's inverted plankton microscope. The plankton density is expressed as number of organisms/m3.

Benthic Community

For studying the benthic organisms, sediment samples were collected using a Petersen grab. The wet sediment was sieved with varying mesh sizes for segregating the organisms. The sieved organisms were stains with Rose Bengal and sorted to different groups. The number of organisms in each grab sample was expressed in number per meter square. According to size, benthic animals are divided into three groups. (i) macrobenthos (ii) meiobenthos and (iii) microbenthos (Mare, 1942). Macrobenthos are organisms which are retained in the sieve having mesh size between

0.5 and 1 mm. For Meiobenthos, the lowest size attributed is 63 µm and the upper limit depends upon the mesh size of the sieve used for separating macrobenthos from meiobenthos.

OBSERVATION REPORT

Water Quality

TABLE– 3.19

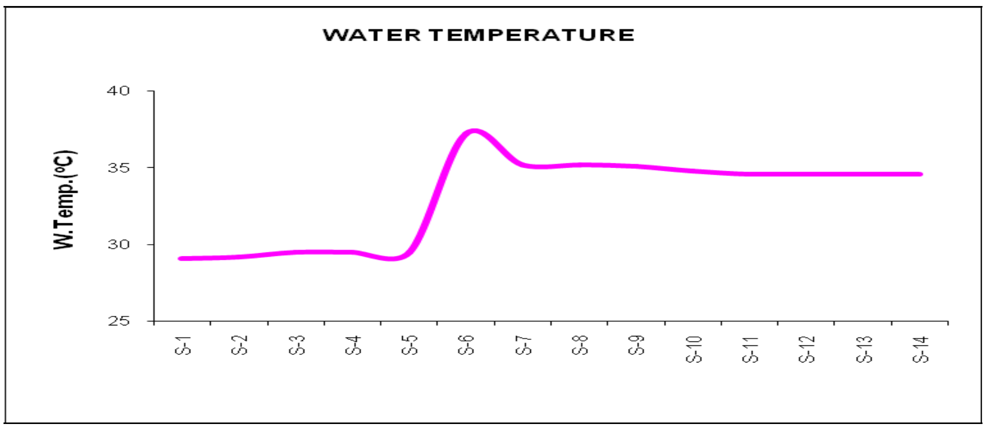
Physico - Chemical Properties of Water

Sl. No.	St. Code	Temp. (°C)	Salinity (‰)	pH	TSS (mg/l)	Turbidity (NTU)	DO (mg/l)	BOD (mg/l)
1.	S-1	29.1	35.0	8.0	72.6	12.5	5.527	0.400
2.	S-2	29.2	35.0	8.2	90.4	15.9	5.335	0.832
3.	S- 3	29.5	34.0	8.1	58.9	8.9	5.220	0.288
4.	S-4	29.5	36.0	8.0	70.8	14.9	5.165	0.320
5.	S-5	29.5	36.0	8.1	81.6	12.8	5.769	0.864
6.	S-6	29.5	35.0	8.2	57.6	13.8	5.446	0.976
7.	S-7	37.2	36.0	8.1	84.2	7.6	5.816	0.416
8.	S-8	35.2	35.0	8.1	85.8	10.9	5.561	0.528
9.	S-9	35.2	35.0	8.2	110.2	16.2	4.948	0.304
10.	S-10	35.1	35.0	8.2	98.6	15.3	5.151	1.056
11.	S-11	34.8	35.0	8.2	112.8	21.0	4.850	1.008

12.	S-12	34.6	35.0	8.1	103.5	20.3	5.044	1.040
13.	S-13	34.6	36.0	8.2	106.2	19.2	5.270	0.544
14.	S-14	34.6	36.0	8.1	107.3	16.3	4.837	0.528

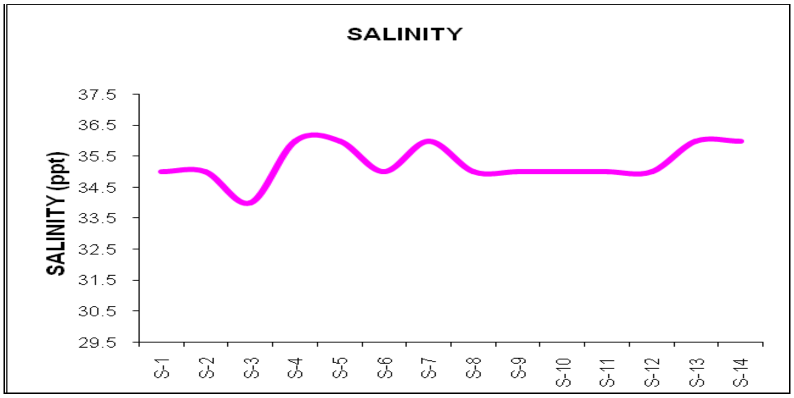
Water Temperature

The water temperature ranged from 29.1to 37.2°C with maximum at S-8 and minimum at S-1 respectively (Table-3.19).



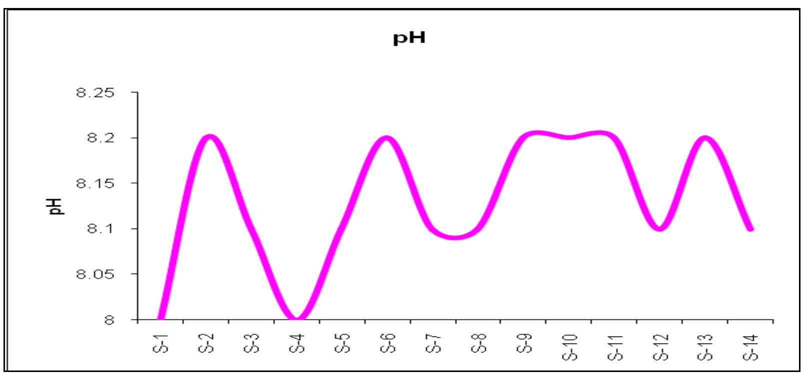
Salinity

The water salinity varied from 34 to 36 ‰ with maximum at S4, S5, S7, S13 and S14 and minimum at S-3 respectively (Table 3.19).



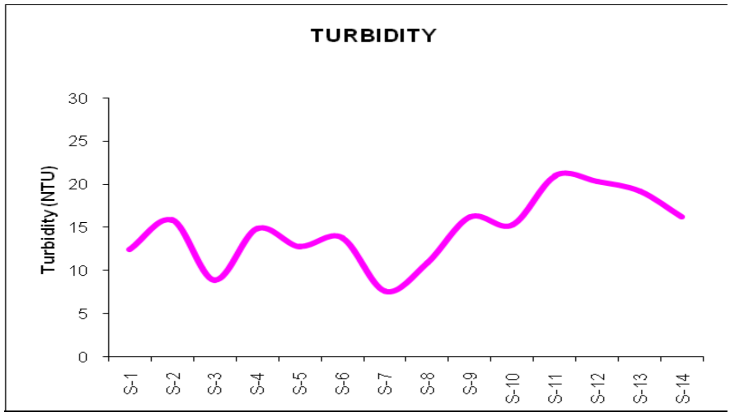
pH

The water pH varied from 8.0 to 8.2 (Table 3.19) with maximum in S2, S6, S9, S10, S11 & S13 and minimum in S-1 & 4 respectively.



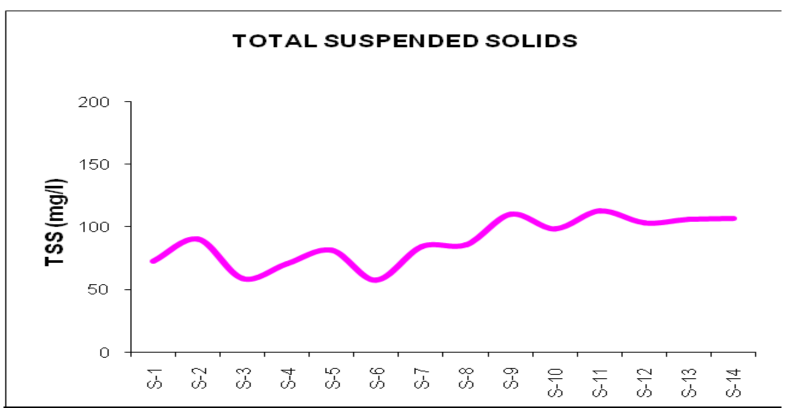
Turbidity

The turbidity values ranged from 7.6 to 21 NTU (Table 3.19) with maximum at S-11 and minimum at S-7.



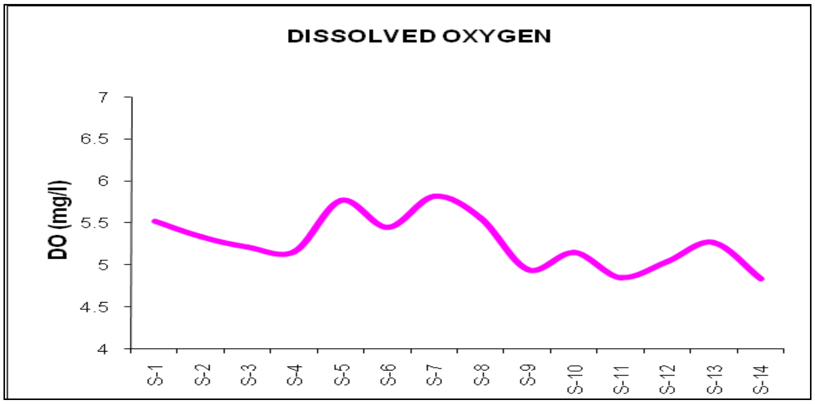
Total Suspended Solids

The TSS values ranged from 57.6 to 112.8 mg/l. The total suspended solids values showed minimum at S-6 and maximum (112.8 mg/l) in S- 11 (Table 3.19).



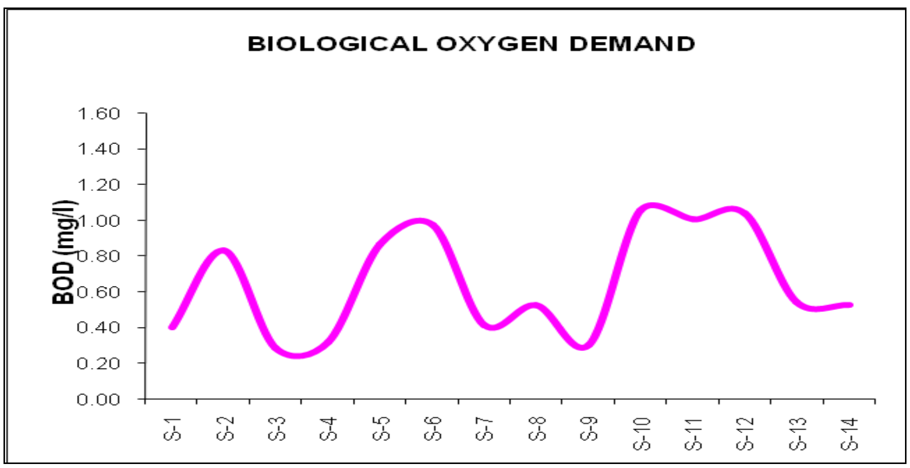
Dissolved Oxygen

Dissolved oxygen level in the water varied from 4.837 mg/l at S-14 to 5.816 mg/l maximum at S-7 and minimumwas recorded at S -14(Table 3.19).



Biological Oxygen Demand

The BOD values ranged between 0.288 and 1.056 mg/l. The Biological oxygen demand showed maximum at S-10 and minimum (0.288 mg/l) at S-3(Table 3.19).



Nutrients

Nutrients determine the potential fertility of an ecosystem and hence it is important to know their distribution and behaviour in different geographical locations and seasons. The productivity of an area is in turn, dependent on the availability of primary nutrients like nitrogen and phosphorus

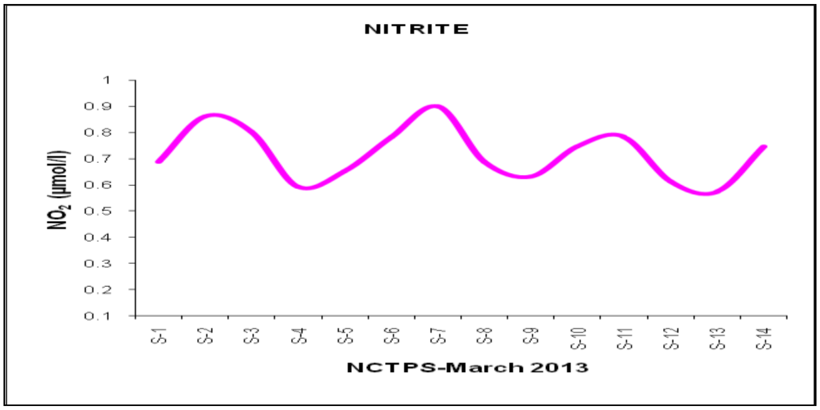
TABLE– 3.20

Nutrients in Water

S. No.	Station Code	Parameter (µmol/l)						
		NO2	NO3	NH4	TN	IP	TP	SiO4
1.	S-1	0.689	8.328	0.058	14.672	0.642	0.908	0.785
2.	S-2	0.862	5.955	0.141	14.498	0.566	1.784	0.412
3.	S- 3	0.804	9.602	0.116	14.287	0.755	1.698	0.468
4.	S-4	0.594	7.070	0.120	15.398	0.642	1.395	0.433
5.	S-5	0.651	5.919	0.133	13.208	0.227	0.869	0.426
6.	S-6	0.785	7.162	0.158	13.805	0.793	1.678	0.408
7.	S-7	0.900	8.330	0.033	13.285	0.340	1.758	0.454
8.	S-8	0.689	8.515	0.066	13.570	0.453	1.735	0.451
9.	S-9	0.632	6.258	0.083	13.036	0.415	1.102	0.628
10.	S-10	0.747	6.058	0.082	14.041	0.868	1.731	0.465
11.	S-11	0.785	5.128	0.119	15.094	0.378	1.729	0.487
12.	S-12	0.613	5.897	0.075	12.957	0.264	1.564	0.472
13.	S-13	0.575	7.091	0.100	14.232	0.831	1.263	0.430
14.	S-14	0.747	8.273	0.079	12.127	0.302	0.992	0.524

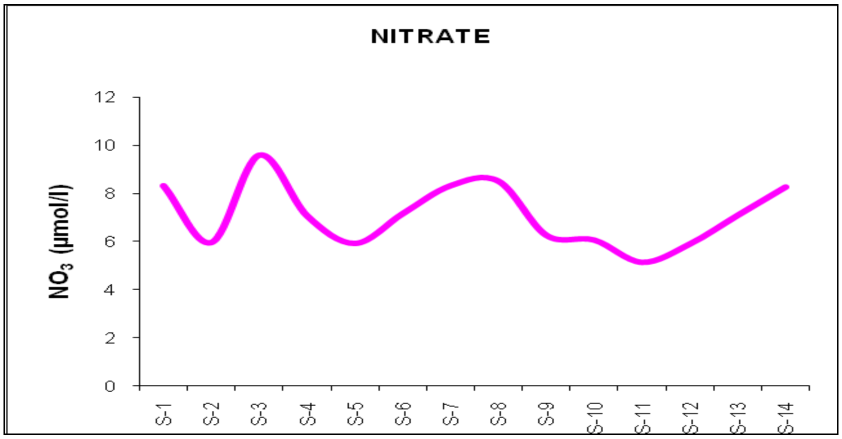
Nitrite

The nitrite varied from 0.575 to 0.900 µmol/l (Table 3.20). The minimum and maximum was recorded at S-13 and S-11respectively.



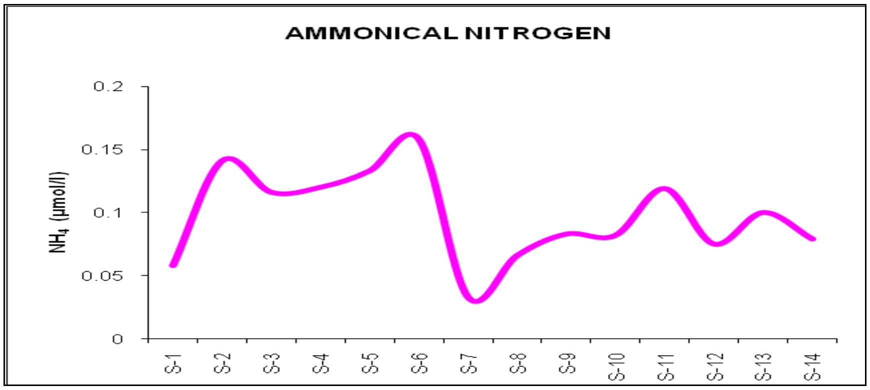
Nitrate

Nitrate content varied from 5.128 to 9.602 µmol/l (Table 3.20) with maximum at S-3 and minimum at S-11.



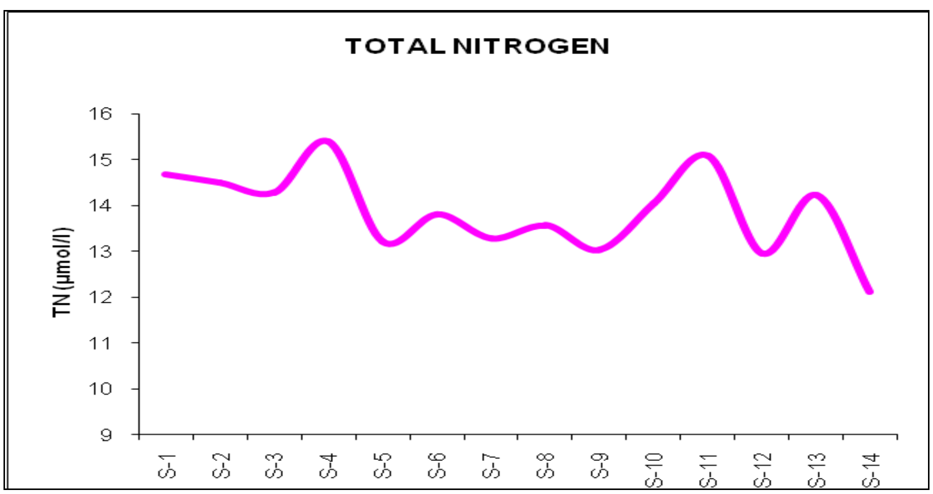
Ammonical Nitrogen

The ammonia concentration fluctuated from 0.003 to 0.158 µmol/l. The ammonia level in the water showed maximum (0.324 µmol/l) at S-3 and the minimum (0.108 µmol/l) at S-7 respectively (Table 3.20).



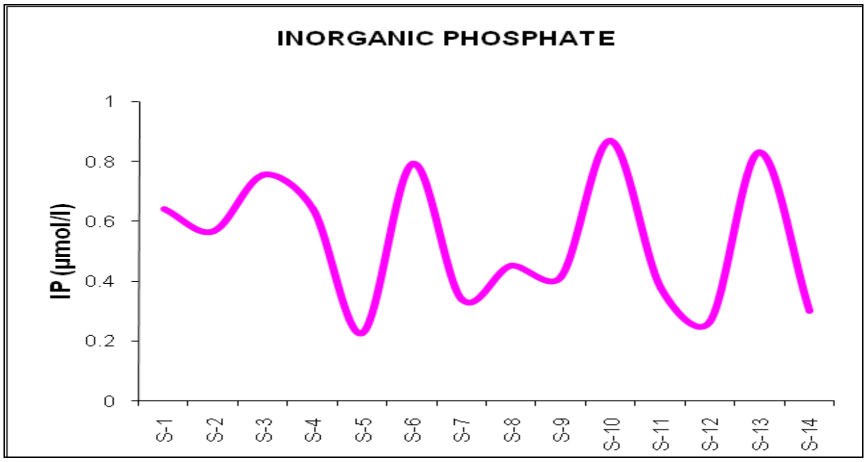
Total Nitrogen

Total nitrogen values were recorded maximum at S-3(12.127 µmol/l) and minimum at S-14 (15.398 µmol/l) (Table 3).



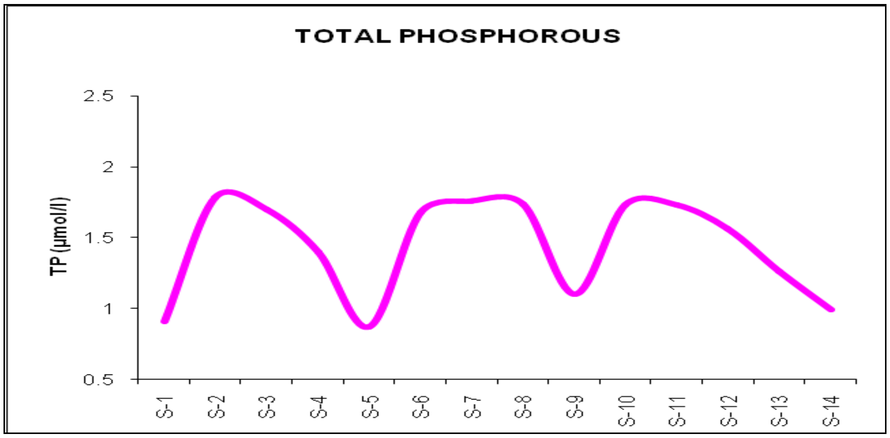
Inorganic Phosphate

Inorganic phosphate level was maximum at S-8 (0.868 µmol/l) and minimum value was recorded at S-5 (0.227 µmol/l) (Table 3.20).



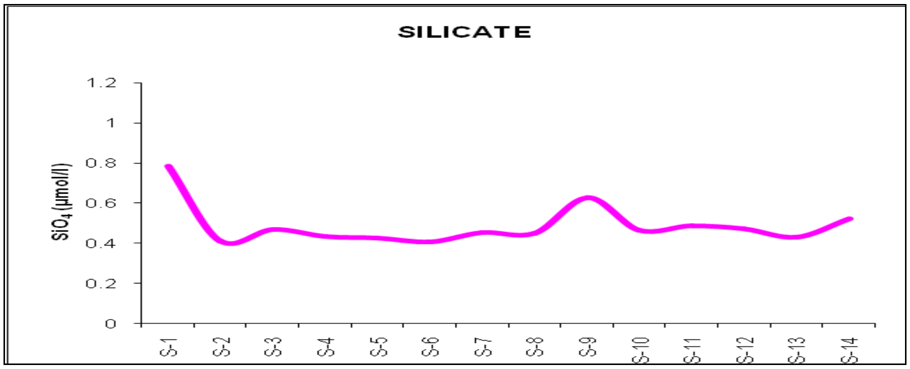
Total Phosphorus

The total phosphorus values ranged from 0.869 to 1.784 µmol/l. The maximum was recored at S-2 (1.784 µmol/l) and the minimum was recorded at S-5 (0.869 µmol/l) Table 3.20).



Reactive Silicate

The silicate values varied between 0.408 and 0.785 µmol/l. The maximum (1.035 µmol/l) and minimum (0.103 µmol/l) values were recored at S-1 and S-6 respectively (Table 3.20).



Oil & Grease

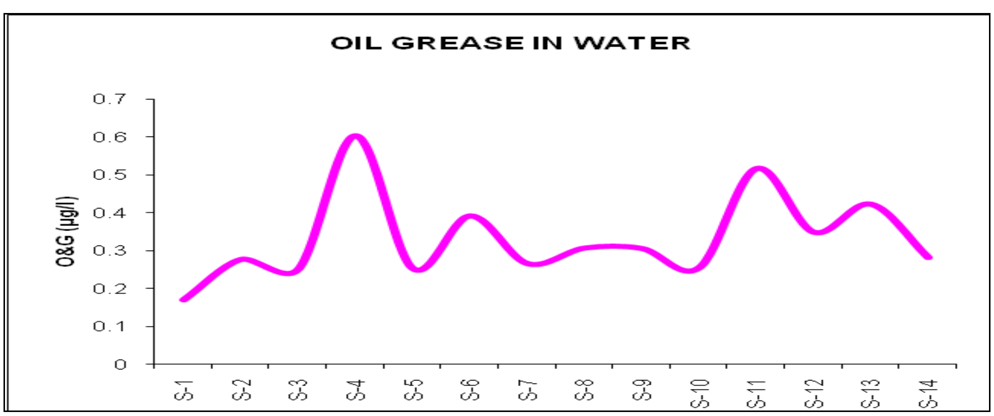
In NCTPS areas, the Oil & Grease in water fluctuated between 0.169 to 0.603 µg/l. The minimum concentration was recorded at S-1 and the maximum was recorded at S-4 during September'13 (Table 3.21).

TABLE – 3.21.

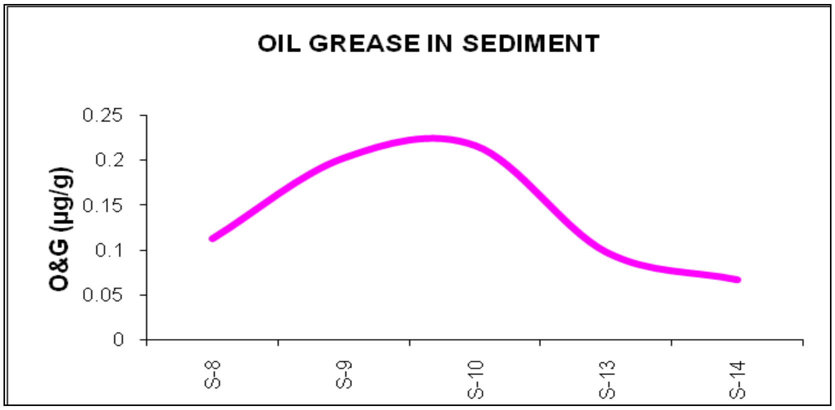
Oil & Grease in Water & Sediment

S. No.	Station Code	Water (µg/l)	Sediment (µg/g)
1.	S-1	0.169	Concrete bottom
2.	S-2	0.276	Concrete bottom
3.	S- 3	0.250	Concrete bottom

4.	S-4	0.603	Concrete bottom
5.	S-5	0.252	Concrete bottom
6.	S-6	0.391	Concrete bottom
7.	S-7	0.265	Concrete bottom
8.	S-8	0.306	0.113
9.	S-9	0.305	0.203
10.	S-10	0.254	0.217
11.	S-11	0.516	Concrete bottom
12.	S-12	0.348	Concrete bottom
13.	S-13	0.422	0.098
14.	S-14	0.281	0.067



In sediment, the Oil & Grease varied from 0.067 to 0.217 µg/g. The minimum was recorded at S-14 and the maximum concentration of PHC was recorded at S-10 during September’13 (Table 3.21).



Heavy Metals in Water

The concentrations of trace metals such as cadmium, lead, mercury, copper and zinc are very low but even at such low concentrations they can be bio accumulated by certain organisms and biomagnified up the food chain.

TABLE – 3.22.

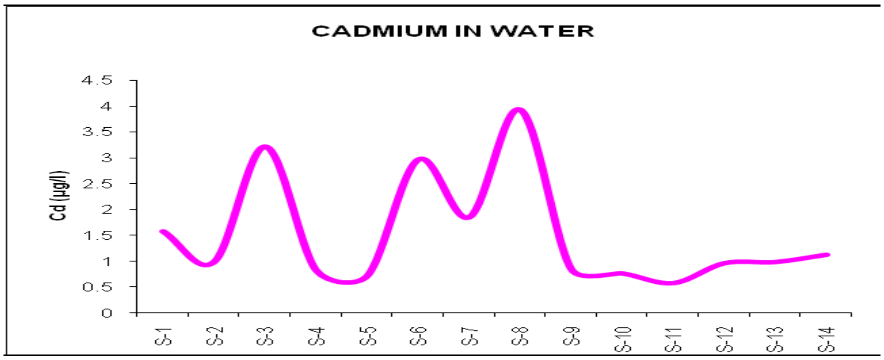
Heavy Metal in Water

Sl. No.	Parameters	Parameters (µg/l)					
		Cd	Cu	Fe	Pb	Zn	Hg
1.	S-1	1.583	6.515	37.773	2.989	22.310	BDL

2.	S-2	0.998	3.824	52.728	3.852	26.354	BDL
3.	S- 3	3.215	5.444	80.120	2.795	22.589	BDL
4.	S-4	0.831	3.140	78.432	1.985	33.416	BDL
5.	S-5	0.728	4.367	48.366	2.120	30.879	0.006
6.	S-6	2.965	5.877	62.024	3.587	34.652	0.006
7.	S-7	1.856	4.296	50.778	3.587	30.714	0.006
8.	S-8	3.925	4.207	68.868	2.883	28.654	0.012
9.	S-9	0.855	5.028	60.723	2.958	24.658	0.006
10.	S-10	0.774	3.659	79.695	3.258	23.507	0.018
11.	S-11	0.588	5.004	53.762	3.384	25.417	0.016
12.	S-12	0.971	6.034	33.534	4.120	31.250	BDL
13.	S-13	0.993	6.482	54.909	3.965	32.936	0.008
14.	S-14	1.133	5.633	78.473	2.508	27.031	0.006

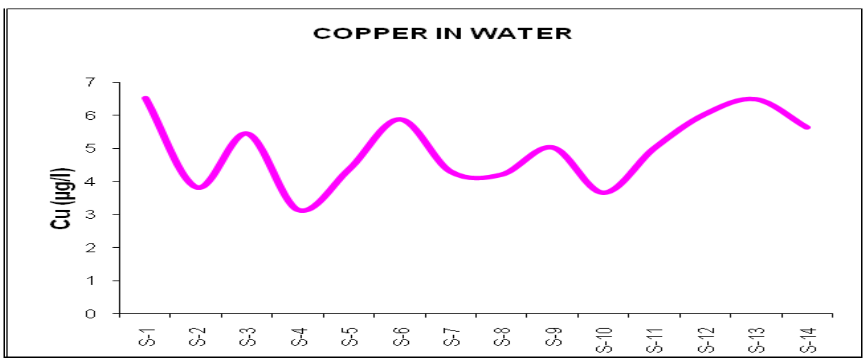
Cadmium

The cadmium level varied from 0.558 to 3.925 µg/l. The maximum cadmium was recorded at S-8 and the minimum of 0.558 µg/l was recorded S-11 (Table 3.22).



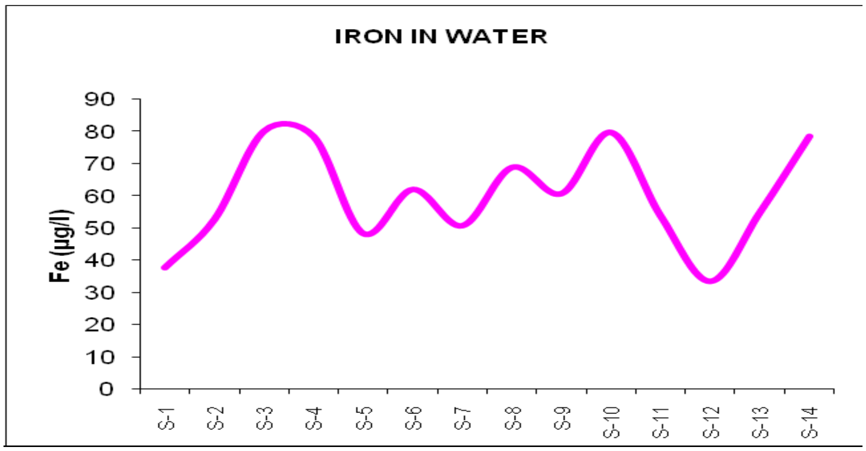
Copper

The copper level in the study area varied from 3.140 to 6.515 µg/l. The maximum copper was recorded at S-1 and minimum of 3.140 µg/l was recorded S-4 (Table 3.22).



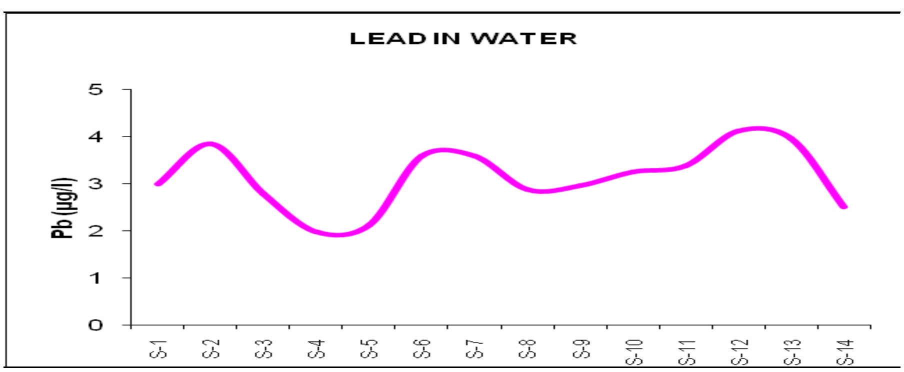
Iron

The iron level varied between 33.534 and 80.12 µg/l. The maximum iron was recorded at S-3 and the minimum iron was recorded at S-12 (Table 3.22).



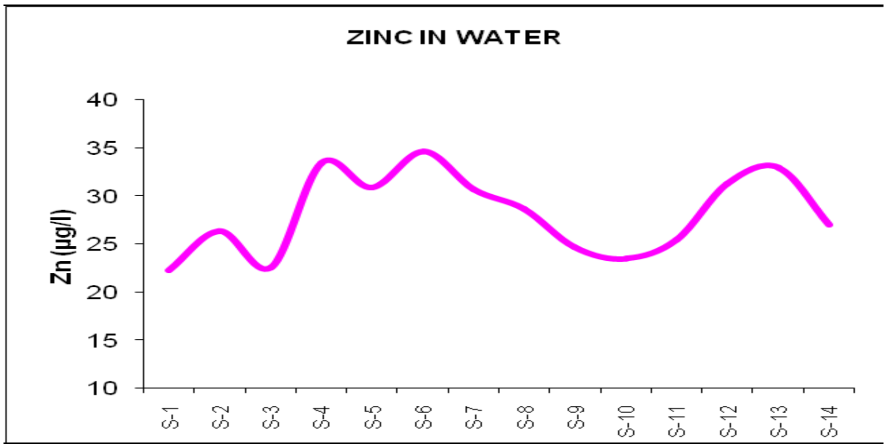
Lead

The lead level in the study area fluctuated between 1.985 and 4.120 µg/l. The maximum of 4.120 µg/l was observed at S-12 during September'13 and the minimum of 1.985 µg/l was recorded at S-4 (Table 3.22).



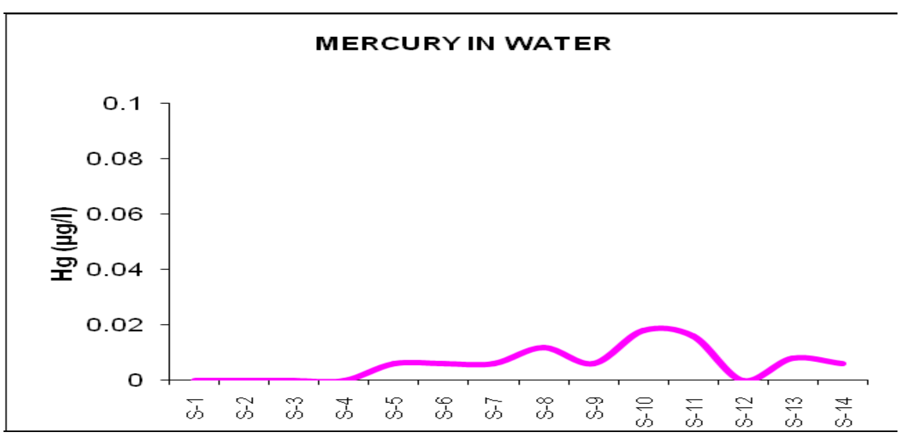
Zinc

The zinc level in the study areas varied between 22.310 and 34.652 µg/l. The maximum zinc was recorded at S-6 and the minimum of 22.310 was recorded at S-1 during September’13 (Table 3.22).



Mercury

The mercury level in the study areas varied from 0.006 to 0.018 µg/l. The maximum mercury was recorded at S-10 and the minimum mercury was recorded at S-14, S-9, S-5, S-6 & S-7 (Table 3.22).



<u>Sediment Characteristics</u>

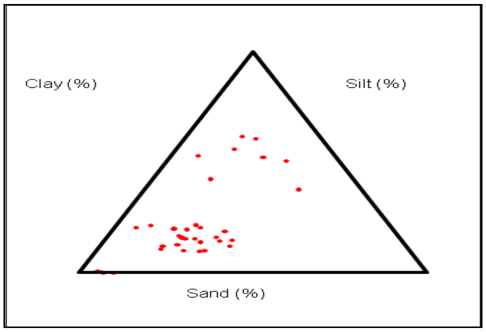
TABLE– 3.23.

Soil Texture, Total Organic Carbon & pH of Sediment

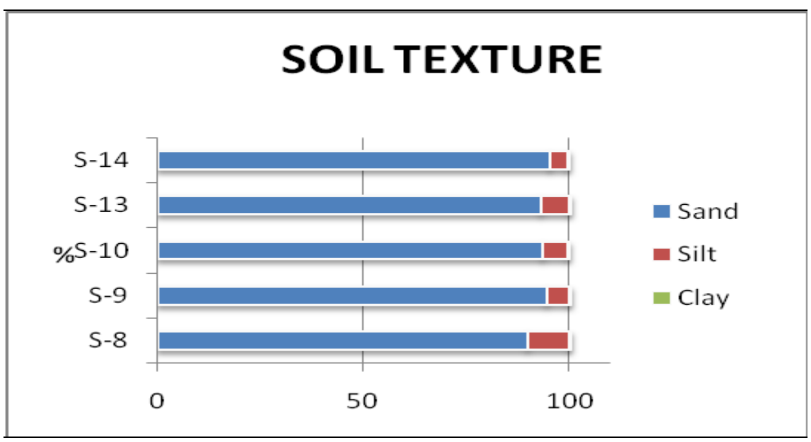
S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (mgC/g)	pH
1.	S-1	Concrete bottom				
2.	S-2	Concrete bottom				
3.	S- 3	Concrete bottom				
4.	S-4	Concrete bottom				
5.	S-5	Concrete bottom				
6.	S-6	Concrete bottom				
7.	S-7	Concrete bottom				
8.	S-8	90.064	9.921	0.015	4.589	7.95
9.	S-9	94.606	5.243	0.151	2.872	7.97
10.	S-10	93.452	6.35	0.198	2.643	8.05
11.	S-11	Concrete bottom				
12.	S-12	Concrete bottom				
13.	S-13	93.127	6.834	0.040	1.989	8.28
14.	S-14	95.162	4.58	0.258	2.156	8.18

Soil Texture (%)

As evident from the following figure, the Ennore coastal area is sandy silt in nature.



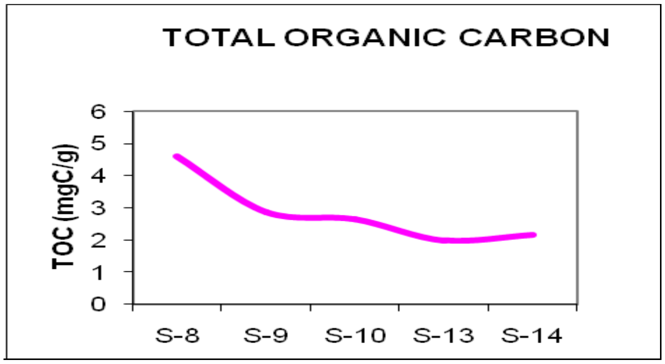
The sand content varied from 90.063 to 95.162 % with the maximum of 93.162 % at S-14 and the minimum sand content was recorded in the Station S-8 and the silt content found to maximum at S-8 (9.921 %) and minimum at S-14 (4.58 %) .



The clay fraction found to be maximum at S-14 (0.258 %) and minimum at S-8 (0.015 %) (Table 3.23).

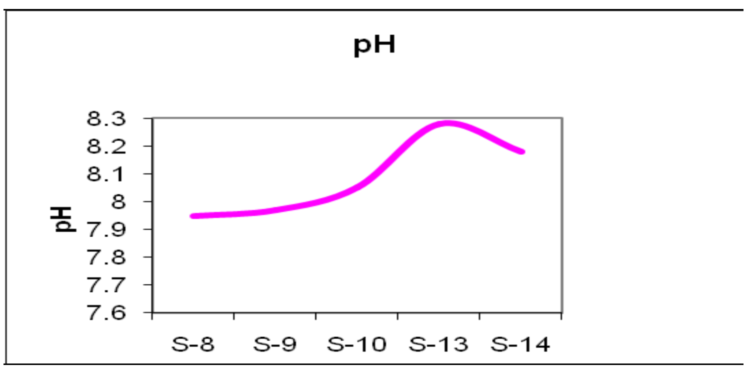
Total Organic Carbon

Total organic carbon values were recorded maximum at S-8 (4.589 mgC/g) and minimum at the Station S-13 (1.989 mgC/g) (Table 3.23).



pH

The pH in the sampling Stations varied from 7.95 to 8.28. As evident from the following figure, the minimum level was recorded at S-8 and the maximum level was recorded at S-13 during September'13 (Table 3.23).



Heavy Metals in Sediment

Heavy metals even in the dissolved form on entering the aquatic environment are absorbed by TSS in water and transported to the sediment on settling. Thus the sediment of areas receiving anthropogenic trace metals sustains their high concentrations relative to the baseline. Hence, aquatic sediments are useful indicators of trace metal pollution.

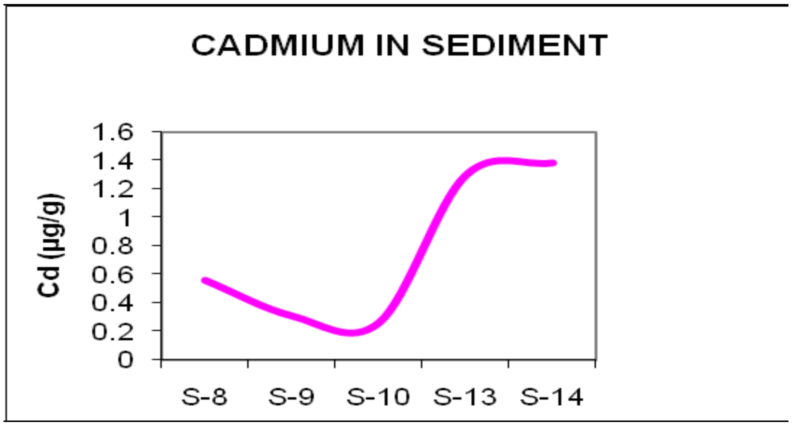
TABLE – 3.24.

Heavy Metals in Sediment

Sl. No.	Station Code	µg/g					
		Cd	Cu	Fe	Pb	Zn	Hg
1	S-1	Concrete bottom					
2	S-2	Concrete bottom					
3	S- 3	Concrete bottom					
4	S-4	Concrete bottom					
5	S-5	Concrete bottom					
6	S-6	Concrete bottom					
7	S-7	Concrete bottom					
8	S-8	0.562	7.986	4213.02	3.658	4.658	0.008
9	S-9	0.312	11.265	5206.32	7.089	10.213	0.010
10	S-10	0.264	9.897	6018.15	6.299	9.12	0.006
11	S-11	Concrete bottom					
12	S-12	Concrete bottom					
13	S-13	1.298	10.400	2852.25	5.925	8.325	0.012
14	S-14	1.385	12.465	4631.88	5.764	9.654	0.014

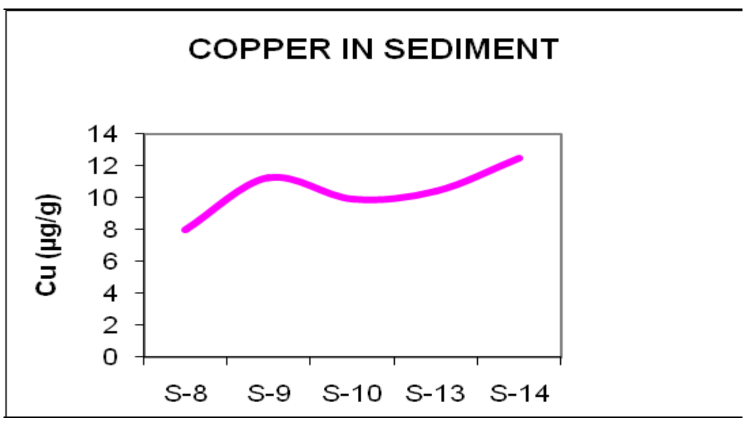
Cadmium

The cadmium level varied from 0.264 to 1.385 µg/g. The maximum cadmium was recorded at S-14 and minimum was recorded at S-10 during September'13.



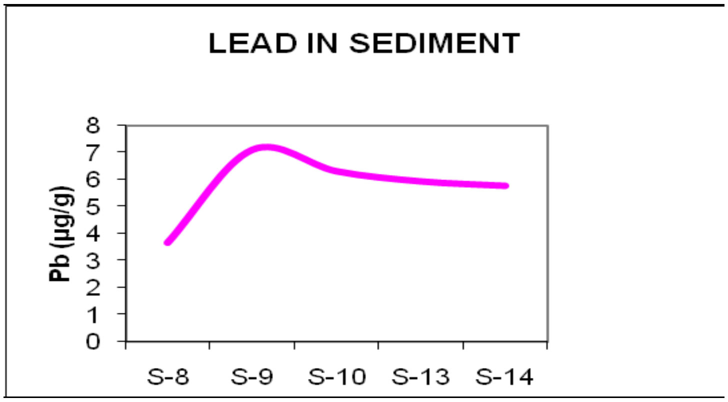
Copper

The copper in the sediments ranged from 7.986 to 12.465 µg/g. The maximum copper concentration was recorded at S-14 and minimum was recorded at S-8 (Table 3.27).



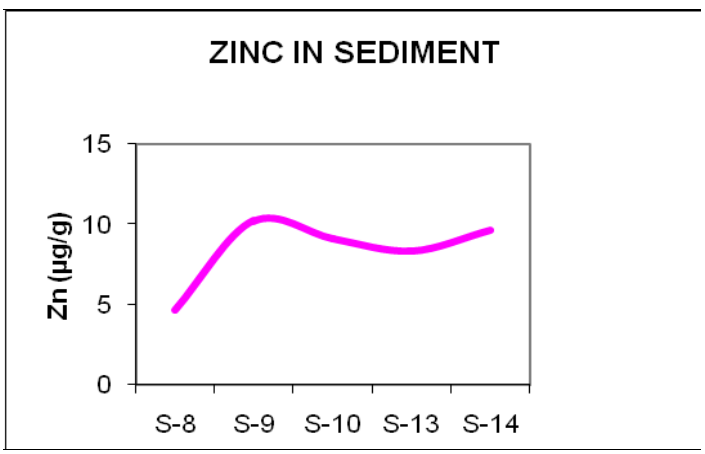
Lead

The lead level in the sediment ranged between 3.658 and 7.089 µg/g. The maximum lead concentration of 7.089 µg/g was recorded at S-9 during September'13 and minimum of 3.658 µg/g was recorded at S-8 during September'13 (Table 3.24).



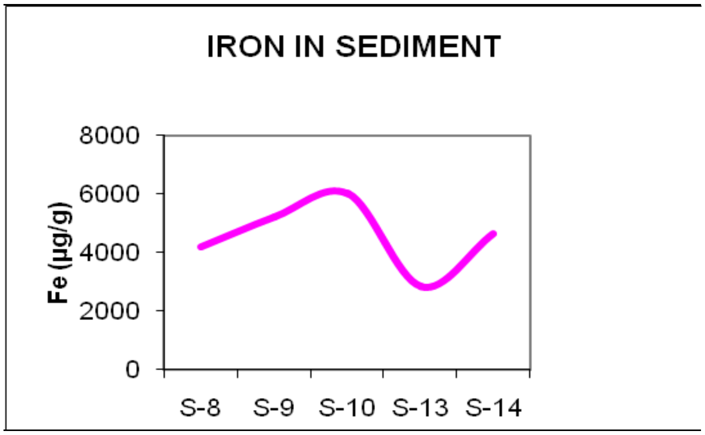
Zinc

The zinc fluctuated from 4.658 to 10.213 µg/g. The maximum concentration was recorded at S-9 during September'13 and the minimum at S-8 during September'13 (Table 3.24).



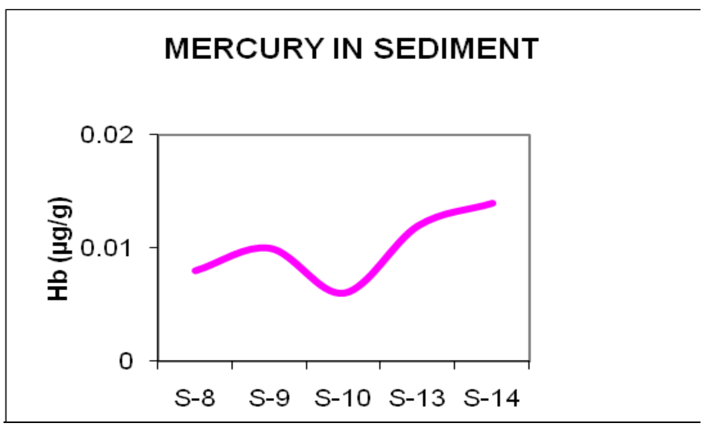
Iron

The iron concentration fluctuated from 2852.25 to 6018.15 µg/g. The maximum iron concentration of 6018.15 µg/g was recorded at S-10 and the minimum of 2852.25 µg/g was recorded at S-13 (Table 3.24).



Mercury

The mercury level in the sediment varied from 0.006 to 0.014 µg/g. The maximum mercury 0.014 µg/g was recorded at S-14 and the minimum of 0.006 µg/g was recorded at S-10 (Table 3.24).



Microbiology

Water Sample

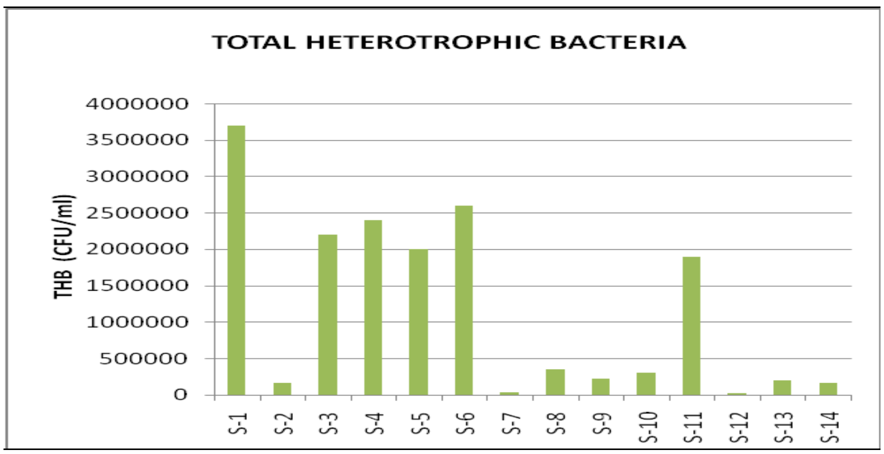
The Total Heterotrophic Bacteria (THB) varied from 23x103 to 37x105 with maximum at S-1 and minimum at S-12 of water samples collected from North Chennai Thermal Power Plant areas.

TABLE – 3.25.

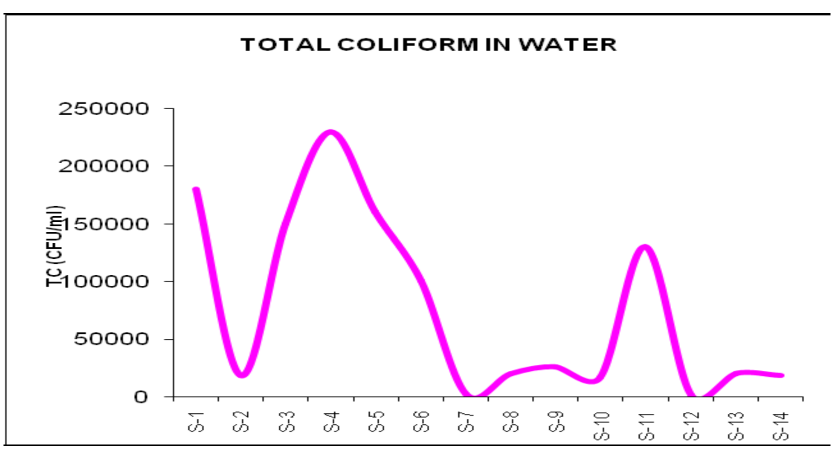
Microbial Populations in Water

Sl. No.	St. Code	THB	TC	EC	FC	SF
1.	S-1	37x105	18x104	22x103	05x102	13x102
2.	S-2	16x104	18x103	10x102	14	23x101
3.	S- 3	22x105	15x104	10x103	07x102	12x102
4.	S-4	24x105	23x104	28x103	15x103	10x102
5.	S-5	20x105	16x104	30x103	08x102	29x102
6.	S-6	26x105	10x104	15x103	22x102	16x102
7.	S-7	34x103	25x102	25x101	16x101	20
8.	S-8	35x104	20x103	21x102	22	17x101
9.	S-9	22x104	26x103	18x102	19x102	20x101
10.	S-10	30x104	17x103	13x102	24x102	25x101

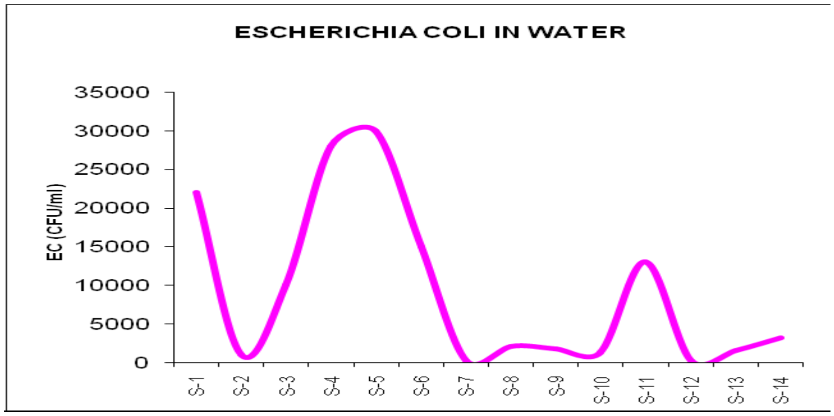
11.	S-11	19x105	13x104	13x103	10x103	08x102
12.	S-12	23x103	14x102	20x101	22x101	32
13.	S-13	20x104	20x103	15x102	28x102	24x101
14.	S-14	16x104	18x103	32x102	13x102	13x101



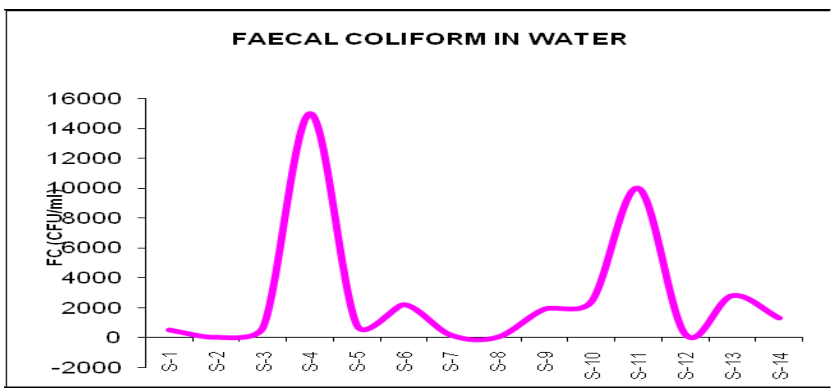
The Total Coliform varied from 14x102 to 23x104 with maximum at S-4 and minimum at S-12.



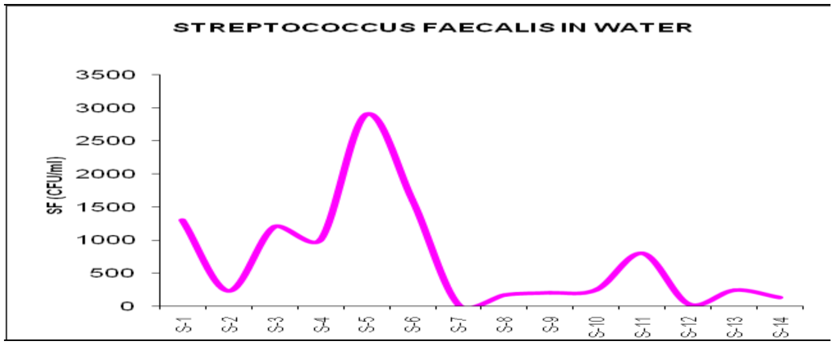
The Escherichia coli Bacteria in water sample varied from 20x101 to 30x103 CFU/ml with maximum at S-5 and minimum at S-12 during the present survey.



Faecal coliform varied between 14 to 15x103 with maximum at S-4 and minimum at S-2.



The Streptococcus faecalis varied from 20 to 29x102. The minimum and maximum values observed at S-11 and S-5 respectively during September'13 (Table 3.25).



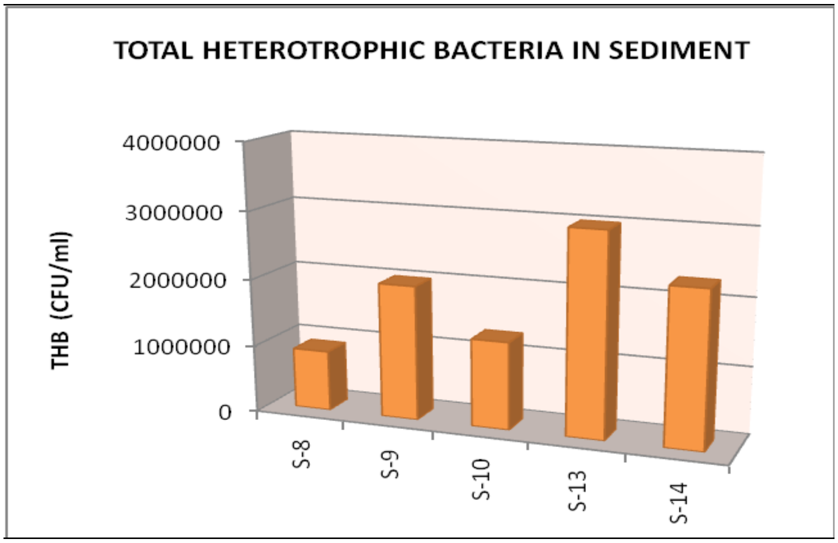
Sediment Sample

The Total Heterotrophic Bacteria (THB) varied from 90 x104 to 30x105 CFU/g with maximum at S-13 and minimum at S-8 of sediment samples collected in North Chennai Thermal Power Station areas

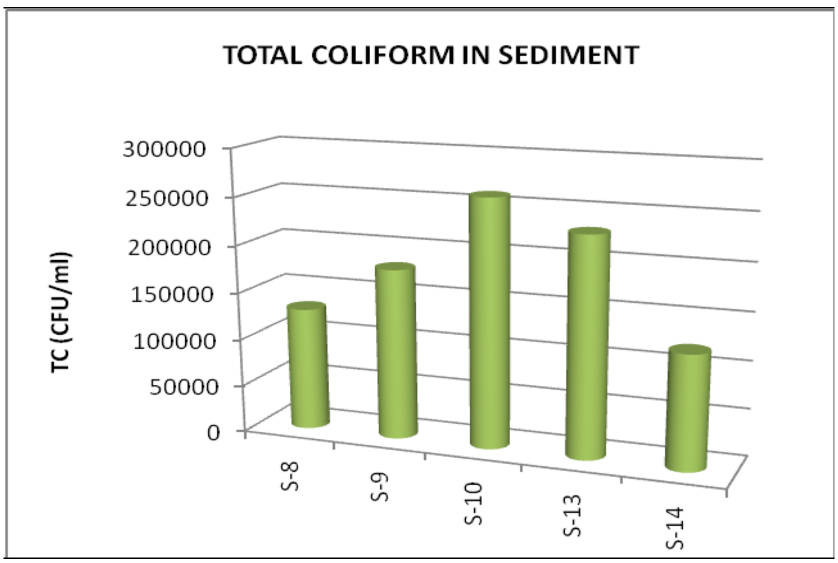
TABLE – 3.26.

Microbial Populations in Sediment

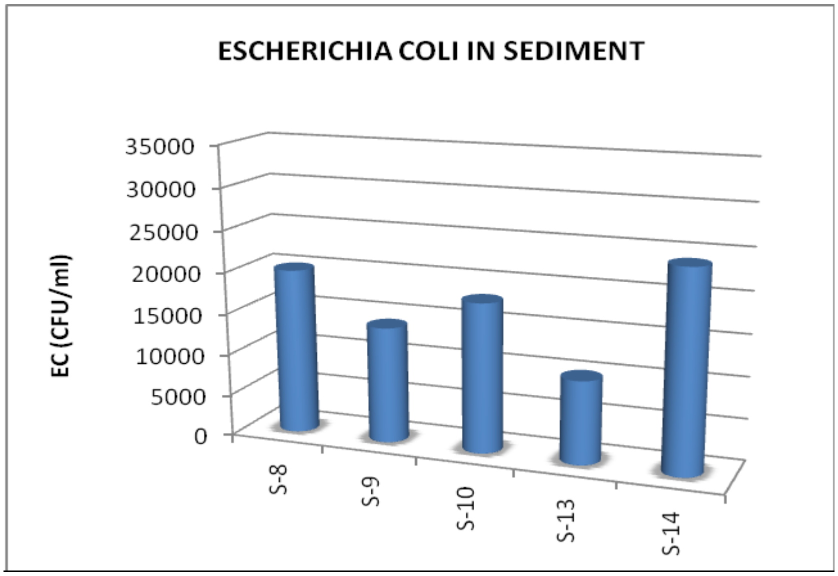
Sl. No.	St. Code	THB	TC	EC	FC	SF
1.	S-1	Concrete bottom				
2.	S-2	Concrete bottom				
3.	S- 3	Concrete bottom				
4.	S-4	Concrete bottom				
5.	S-5	Concrete bottom				
6.	S-6	Concrete bottom				
7.	S-7	Concrete bottom				
8.	S-8	09x105	13x104	20x103	16x103	15x102
9.	S-9	20x105	18x104	14x103	25x103	06x102
10.	S-10	13x105	26x104	18x103	12x103	19x102
11.	S-11	Concrete bottom				
12.	S-12	Concrete bottom				
13.	S-13	30x105	23x104	10x103	08x103	14x102
14.	S-14	23x105	12x104	24x103	21x103	10x102



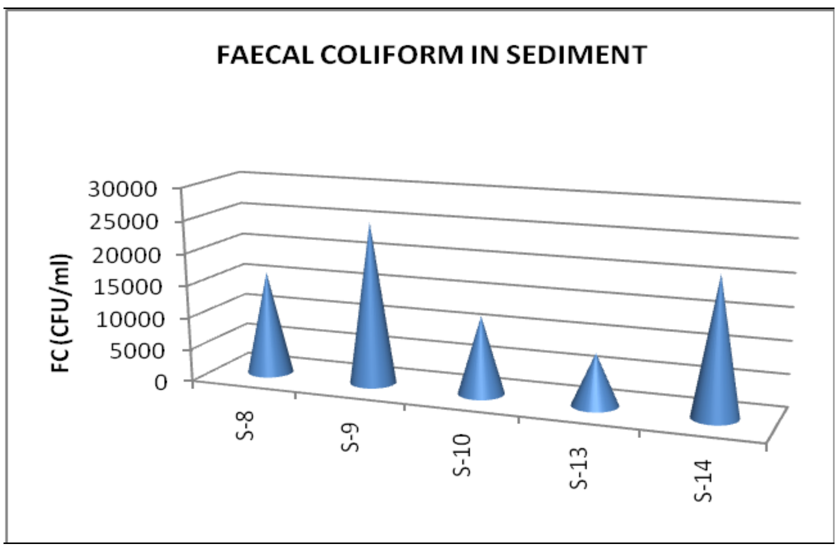
The Total Coliform varied from 12x104 to 26x104 CFU/g with maximum at S-10 and minimum at S-14.



The Escherichia coli Bacteria in sediment sample varied between $10x10^3$ to $24x10^3$ CFU/g with maximum at S-14 and minimum at S-13 during this survey.



Faecal coliform varied from 80x02 to 25x10³ CFU/g with maximum at S-9 and minimum at S-13.



The Streptococcus faecalis varied between 60x101 to 19x102 CFU/g. The minimum was recorded at S-9 and the maximum value was observed at S-10 during September’13 (Table 3.26).

TABLE – 3.27.

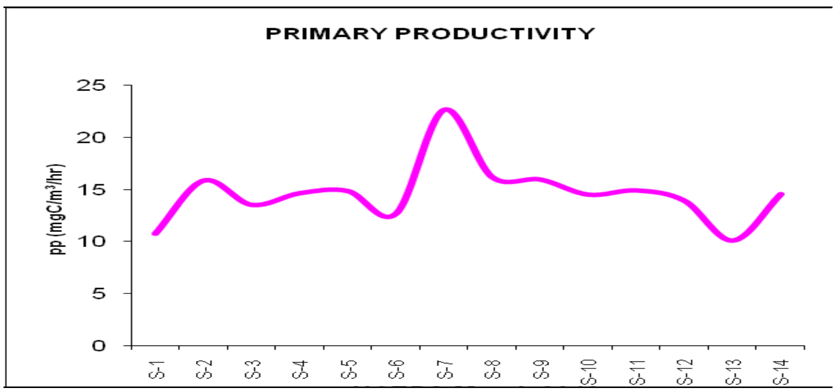
Biological Characteristics

S. No.	Station Code	PP (mg C/m3/hr)	Chl a (mg/m3)	Phaeopigment (mg/m3)	TB (ml/100m3)
1.	S-1	10.74	0.128	0.075	18.19
2.	S-2	15.84	0.184	0.108	27.58
3.	S- 3	13.51	0.160	0.094	22.47
4.	S-4	14.63	0.168	0.099	27.90
5.	S-5	14.84	0.176	0.104	17.74
6.	S-6	12.66	0.144	0.085	18.64
7.	S-7	22.64	0.264	0.155	17.28
8.	S-8	16.18	0.192	0.113	22.47
9.	S-9	15.95	0.184	0.108	26.88
10.	S-10	14.49	0.168	0.099	23.84
11.	S-11	14.90	0.176	0.104	25.36
12.	S-12	13.90	0.160	0.094	26.05
13.	S-13	10.08	0.120	0.071	25.53
14.	S-14	14.54	0.168	0.099	25.87

Biological Characteristics

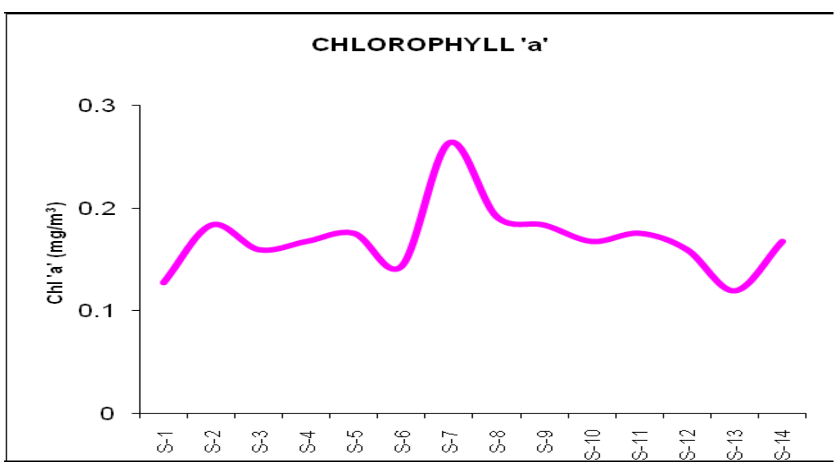
Primary Productivity (mgC/m3/hr)

In the present study, the primary productivity in water samples varied from 10.08 to 22.640 (mgC/m3/hr). The minimum was observed at S-1 and the maximum was recorded at S-11 (Table-3.27).



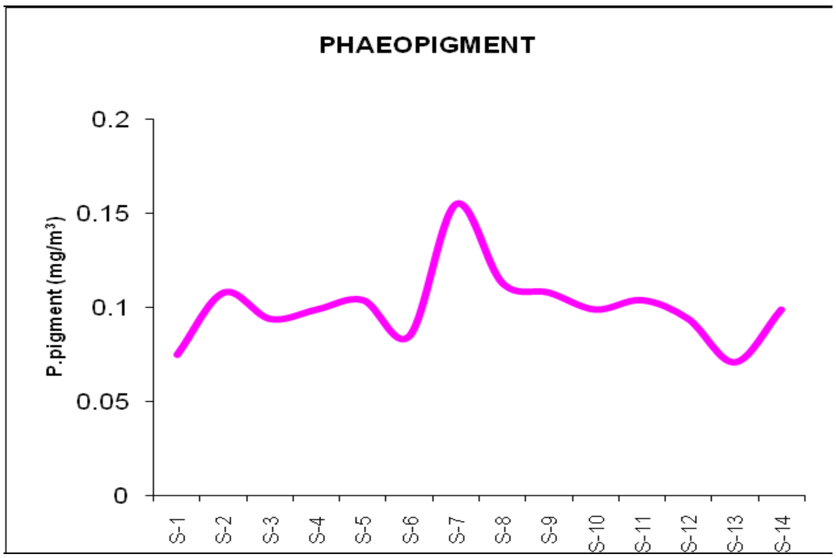
Chlorophyll ‘a’ (mg/m3)

The chlorophyll ‘a’ level fluctuated between 0.120 to 0.260 mg/m3. The maximum chlorophyll ‘a’ (0.260 mg/m3) was recorded at S-11 and the minimum (0.120 mg/m3) was recorded at S-1 (Table-3.27).



Phaeopigment (mg/m3)

In the present study, the phaeopigment in water sample varied from 0.07 to 0.160 (mg/m3) with maximum in S-11 and minimum in S-1 was recorded (Table 3.27).



Plankton

Phytoplankton

A total of 23 phytoplankton species were identified from the samples collected. During this study period, species belonging to groups namely diatoms, and dinoflagellates. Of these, diatoms were found to be the dominant group with 22 species in each Station. Dinoflagellates formed next group with 2 species and in all the Stations. Among the diatoms, Asterionella glacialis, Chaetoceros affinis Nitzschia longissima Pleurosigma normanii Rhizosolenia alata, Skeletonema costatum and Triceratium favus were found to be common species occurring in all the samples collected in various Stations. Coming to dinoflagellates, Ceratium favus, and Ceratium sp. showed consistency in their occurrence in different Stations of Thermal Power Station waters.

TABLE-3.28.

Phytoplankton

Sl. No.	Name of the Species	No/l				
		S1	S2	S3	S4	S5
20.	Coscinodiscus centralis	83	38	104	45	64
21.	Coscinodiscus gigas	*	19	*	14	9
22.	Skeletonema costatum	199	193	237	279	282
23.	Planktoniella sol	53	28	*	36	47
24.	Thalassiosira subtilis	98	377	578	561	659
25.	Ditylum brightwelli	331	*	*	*	*
26.	Lithodesmium undulatum	75	123	85	*	*
27.	Triceratium favus	37	46	24	27	28
28.	Chaetoceros indicus	*	132	*	155	145
29.	Chaetoceros affinis	177	71	132	81	99
30.	Biddulphia sp.	113	37	75	36	55
31.	Biddulphia pulchella	*	*	*	*	*
32.	Odontella pulchella	*	64	71	43	46
33.	Pleurosigma normanii	55	112	38	*	*
34.	Navicula vanhoffeni	148	*	*	107	72
35.	Navicula henneydii	*	*	138	*	33

36.	Ceratium furca	18	*	19	*	*
37.	Ceratium longiceps	*	*	*	*	*
38.	Protoperidinium oceanicum	*	*	16	*	*
39.	Phormidium sp.	837	785	876	1044	834
	Total	2224	2025	2393	2428	2373

Sl. No	Name of the Species	No/l				
		S6	S7	S8	S9	S10
21.	Coscinodiscus centralis	57	77	81	55	57
22.	Coscinodiscus gigas	10	*	*	7	11
23.	Skeletonema costatum	174	230	201	248	174
24.	Planktoniella sol	38	*	39	37	48
25.	Thalassiosira subtilis	533	129	578	534	527
26.	Ditylum brightwelli	*	378	*	*	*
27.	Lithodesmium undulatum	80	146	116	*	77
28.	Triceratium favus	29	29	29	46	29
29.	Chaetoceros indicus	*	*	*		145
30.	Chaetoceros affinis	197	749	145	173	*
31.	Biddulphia sp.	67	140	67	74	57
32.	Biddulphia pulchella	*	*	*	*	57

33.	Odontella pulchella	49	39	50	52	*
34.	Pleurosigma normanii	57	58	39	32	57
35.	Navicula vanhoffeni	*	*	*	56	*
36.	Navicula henneydii	103	130	68	*	117
37.	Ceratium furca	29	*	25	23	12
38.	Ceratium longipes	*	*	*	*	19
39.	Protoperidinium oceanicum	*	*	*	*	16
40.	Phormidium sp.	811	1293	757	748	770
	Total	2234	3398	2195	2085	2173

Sl. No	Name of the Species	No/l			
		S11	S12	S13	S14
1.	Coscinodiscus centralis	62	65	48	62
2.	Coscinodiscus gigas	11	12	*	11
3.	Skeletonema costatum	82	235	*	221
4.	Planktoniella sol	48	39	25	48
5.	Cyclotella sp.	*	*	*	*
6.	Thalassiosira subtilis	18	412	326	18
7.	Lithodesmium undulatum	*	156	*	*

8.	Triceratium favus	36	49	42	36
9.	Chaetoceros currvisetus	41	164	*	141
10.	Chaetoceros affinis	70	195	225	70
11.	Biddulphia sp.	*	73	77	*
12.	Biddulphia pulchella	53	*	51	53
13.	Odontella mobiliensis	51	*	*	51
14.	Pleurosigma normanii	43	*	38	43
15.	Navicula vanhoffeni	*	177	96	*
16.	Navicula henneydii	27	*	67	27
17.	Ceratium furca	18	33	24	18
18.	Phormidium sp.	143	*	880	713
	Total	703	1610	1899	1512

* - Organisms not present

Zooplankton

In the present study, 3 groups of zooplankton namely, calanoids, cyclopoids, and harpacticoids and 3 groups of micro zooplankton namely, foraminiferans, spirotricha and larval forms and other group of rotatoria, appenticularia of various zooplankton were recorded. Among the zooplankton, calanoida were found to be the dominant group with 6 species; cyclopoida came next in the order with 5 species and harpacticoida also came dominant group with 6 species, coming to spirotricha, larval forms, foraminiferans, appenticularia and rotatoria came last with 6, 3, 1, 1, and1 species respectively.

Among the Calanoida, Acartia danae, Acartia spinicauda, Cyclopoida, Oithona brevicornis, O.similis Copilia vitrea Corycaeus catus Corycaeus danae Harpacticoida, Labidocera pavo Longipedia weberi Macrosetella gracilis Metis jousseaumei Microsetella norvegica Microsetella rosea were found to be the frequenters in the collections. In micro zooplankton, larval forms, Barnacle nauplii, Bivalve veliger, Copepod nauplii, Crustacean nauplii and Polychaete larvae were found to be common in all the Stations.

TABLE-3.29.

ZOOPLANKTON

Sl. No.	Name of the Species	No/m3				
		S1	S2	S3	S4	S5
1.	Paracalanus pavus	626	533	444	626	447
2.	Paracalanus sp.	179	266	355	268	*
3.	Pontella sp.	*	*	*	*	89
4.	Nannocalanus minor	*	178	178	268	268
5.	Acrocalanus gracilis	179	*	*	89	*
6.	Acartia danae	*	*	*	*	89
7.	Acartia spinicauda	536	533	444	447	536
8.	Oithona brevicornis	*	355	266	179	268
9.	Oithona similis	447	621	533	626	626

10.	Corycaeus danae	*	*	89	89	*
11.	Microsetella rosea	536	533	355	357	357
12.	Microsetella norvegica	89	*	178	*	179
13.	Euterpina acutifrons	357	266	266	179	268
14.	Sagitta enflata	179	*	*	*	*
15.	Oikopleura parva	*	89	89	*	89
16.	Globigerina bulloides	268	266	266	268	268
17.	Tintinnopsis tubulosa	179	*	*	179	*
18.	Tintinnopsis beroides	*	*	*	*	179
19.	Tintinnopsis butzschi	*	*	*	*	*
20.	Favella brevis	*	178	178	*	*
21.	Favella philipiensis	*	89	89	268	*
22.	Bivalve veliger	*	89	89	89	89
23.	Copepod nauplii	894	888	888	894	804
	Total	4469	4884	4707	4826	4556

Sl. No.	Name of the Species	No/m3				
		S6	S7	S8	S9	S10
23.	Paracalanus pavus	355	533	355	*	536
24.	Paracalanus sp.	266	266	178	*	*

25.	Pontella sp.	*	*	*	536	89
26.	Nannocalanus minor	*	*	*	268	268
27.	Acrocalanus gracilis	266	178	89	*	*
28.	Acartia danae	178	*	533	*	*
29.	Acartia spinicauda	444	355	*	179	357
30.	Oithona brevicornis	266	266	355	357	268
31.	Oithona similis	533	621	533	626	536
32.	Corycaeus danae	*	*	*	*	*
33.	Microsetella rosea	266	533	444	536	357
34.	Microsetella norvegica	355	*	*	*	*
35.	Euterpina acutifrons	178	266	266	*	268
36.	Sagitta enflata	*	*	*	*	*
37.	Oikopleura parva	89	89	178	*	*
38.	Globigerina bulloides	178	266	*	*	*
39.	Tintinnopsis tubulosa	266	*	*	626	179
40.	Tintinnopsis beroides	*	*	266	*	*
41.	Tintinnopsis butzschi	*	89	*	*	89
42.	Favella brevis	*	*	*	89	89
43.	Favella philipiensis	*	*	*	*	*
44.	Bivalve veliger	89	89	178	179	89

45.	Copepod nauplii	799	888	799	536	804
	Total	4528	4439	4174	3932	3929

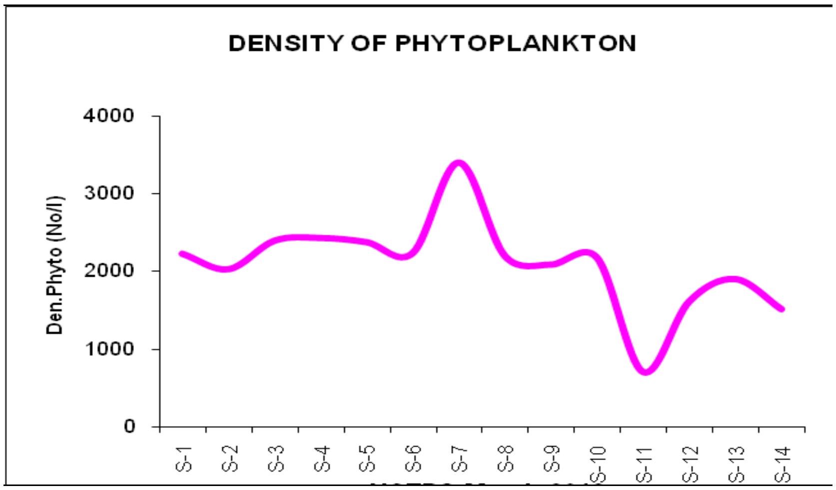
Sl. No.	Name of the Species	No/m3			
		S11	S12	S13	S14
24.	Paracalanus pavus	477	239	557	637
25.	Rhincalanus sp.	*	*	80	159
26.	Nannocalanus minor	239	159	*	239
27.	Acrocalanus gracilis	*	*	159	*
28.	Acartia spinicauda	80	239	239	*
29.	Oithona brevicornis	239	239	*	239
30.	Oithona similis	477	477	477	477
31.	Microsetella rosea	239	239	239	318
32.	Euterpina acutifrons	159	159	80	159
33.	Tintinnopsis tubulosa	159	159	239	239
34.	Favella brevis	80	80	159	159
35.	Bivalve veliger	159	239	*	80
36.	Gastropod veliger	80	159	80	*
37.	Crustacean nauplii	637	*	*	*
38.	Copepod nauplii	*	716	875	557

Total	3025	3104	3184	3263

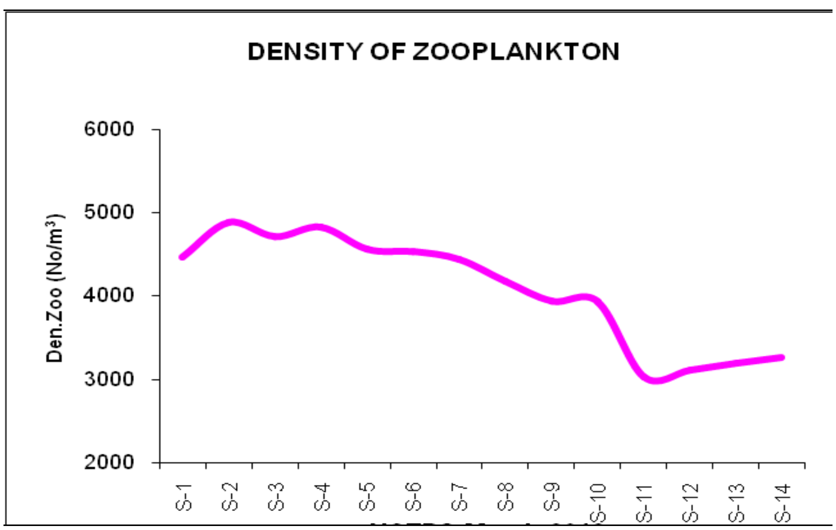
* - Organisms not present

Population density

The phytoplankton density varied from 703to 3398 No/l with maximum at S-7 and minimum in S-11 (Table-3.28).



Likewise in zooplankton density varied from 3025 to 4884No./m3 with maximum in S-2and minimum in S-11 (Table-3.29).



Percentage composition

When the results of percentage composition of phytoplankton were viewed, diatoms constituted the maximum with 91.67% to the total followed by dinoflagellates with 8.33% of the total. Likewise, in zooplankton, Calanoids were the major group contributing to over (20.68%), Cyclopoids contributed (17.24%) followed by Harpacticoids (20.68%) and tiny group of Foraminiferans (3.44%), Spirotricha (20.68%) larval forms (10.34%) and other group of Rotatoria (3.44%) and Appenticularia (3.44%).

Finfish Eggs and Larvae

The finfish eggs density in the study region ranged from 14 to 22 No/m3. The minimum density was recorded at S-10 and the maximum density was observed at S-2 & 7 respectively. In the present investigation, 14 species of finfish eggs were recorded from all the Stations monitored. The Mugil cephalus was found to be the dominant forms (Table 3.30).

TABLE-3.30.

FINFISH EGGS IN WATER SAMPLES

Sl. No.	Name of the Species	No/m3				
		S1	S2	S3	S4	S5
Enraulidae						
1.	Stolephorus heterolobus	2	3	*	2	*
2.	Stolephorus indicus	1	*	2	1	2
3.	Stolephorus sp.	*	2	*	*	*
4.	Thryssa mystax	2	2	2	3	2
5.	Thryssa sp.		1	*		

Clupeidae						
1.	Sardinella gibbosa	1	2	2	*	*
2.	Sardinella longiceps	2		*	1	1
Synodontidae						
1.	Saurida sp.	*	2	*	*	*
Mugilidae						
1.	Mugil cephalus	3	4	2	4	4
2.	Liza tade	3	2	2	2	1
3.	Liza dussumieri	1		2	*	*
Teraponidae						
1.	Terapon jarbua	3	3	3	4	3
Scombridae						
1.	Scomberomorus sp.	*	1	2	2	*
2.	Scomberomorus commersoniana	3	*	1	1	2
	Total	21	22	18	20	15

Sl. No.	Name of the Species	No/m3				
		S6	S7	S8	S9	S10
Enraulidae						
1.	Stolephorus heterolobus	1	3	*	3	2
2.	Stolephorus indicus	1	*	1	*	*

3.	Stolephorus sp.	*	1	*	1	*
4.	Thryssa mystax	1	2	2	2	2
5.	Thryssa sp.	*	1	*		
Clupeidae						
1.	Sardinella gibbosa	2	2	*	2	1
2.	Sardinella longiceps	2		*	*	*
Carangidae						
1.	Carangoides malabaricus	*	*	*	1	1
Mugilidae						
1.	Mugil cephalus	3	4	3	3	2
2.	Liza tade	3	2	2	*	*
3.	Liza dussumieri	2		1	3	3
Teraponidae						
1.	Terapon jarbua	2	3	2	2	2
Scombridae						
1.	Scomberomorus sp.	*	2	3	1	2
2.	Scomberomorus commersoniana	3	2	2	*	*
	Total	20	22	16	18	14

Sl. No.	Name of the Species	No/m3			
		S11	S12	S13	S14
Enraulidae					
1.	Stolephorus heterolobus	2	2	3	3
2.	Stolephorus sp.	*	1	1	2
3.	Thryssa mystax	2	2	2	3
Clupeidae					
1.	Sardinella gibbosa	1	1	2	2
Synodontidae					
1.	Saurida sp.	1	1	1	2
Mugilidae					
1.	Mugil cephalus	2	2	3	3
2.	Liza dussumieri	3	2	2	3
Teraponidae					
1.	Terapon jarbua	2	3	3	2
Scombridae					
1.	Scomberomorus sp.	1	2	1	1
	Total	14	16	18	21

* - Organisms not present

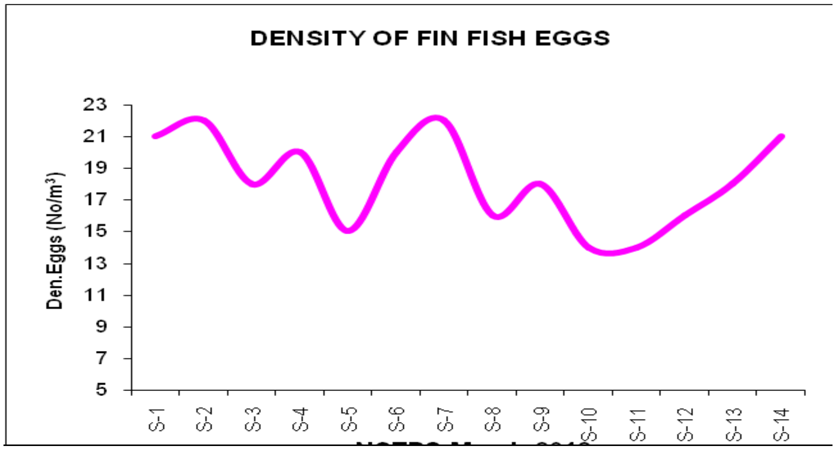
TABLE-3.31.

Finfish Larvae in Sediments

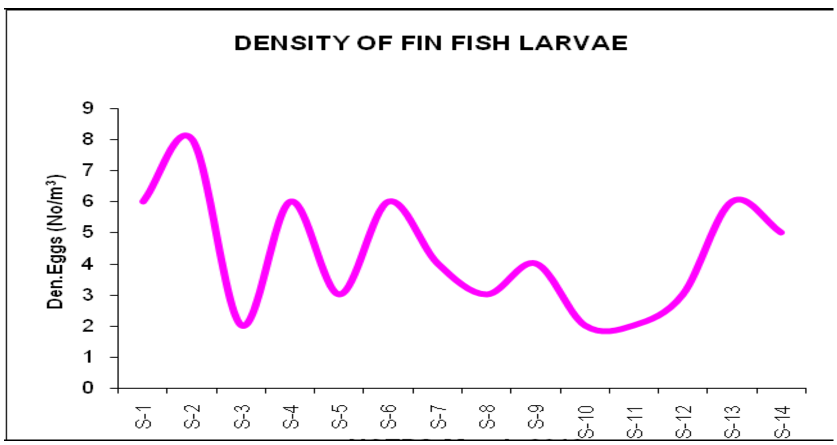
Sl. No.	Name of the Species	No/m3				
		S1	S2	S3	S4	S5
Enraulidae						
1.	Stolephorus heterolobus	1	1	*	*	*
2.	Stolephorus indicus	1	*	*	*	1
3.	Thryssa mystax	*	2	1	1	1
	Thryssa sp.		1	*		
Clupeidae						
1.	Sardinella gibbosa	*	1	*	*	*
2.	Sardinella longiceps	1	*	*	1	*
Mugilidae						
1.	Mugil cephalus	1	1	1	1	*
2.	Liza tade	1	1	*	*	*
3.	Liza dussumieri		*	*		
	Teraponidae					
1.	Terapon jarbua	1	1	*	2	*
Scombridae						
1.	Scomberomorus sp.	*	*	*	1	*
2.	Scomberomorus commersoniana	*	*	*	*	1
	Total	6	8	2	6	3

Sl. No.	Name of the Species	No/m3				
		S6	S7	S8	S9	S10
Enraulidae						
1.	Stolephorus heterolobus	*	*	*	1	1
2.	Stolephorus indicus	*	*	1	*	*
3.	Thryssa mystax	*	2	*	1	*
4.	Thryssa sp.	*	1	*		
Clupeidae						
1.	Sardinella gibbosa	1	*	*	*	1
2.	Sardinella longiceps	*	*	*	*	*
Mugilidae						
1.	Mugil cephalus	2	*	*	1	*
2.	Liza tade	*	*	1	*	*
3.	Liza dussumieri	1	*	*		
Teraponidae						
1.	Terapon jarbua	1	*	*	1	*
Scombridae						
1.	Scomberomorus sp.	*	1	*	*	*
2.	Scomberomorus commersoniana	1	*	1	*	*
	Total	6	4	3	4	2

Sl. No.	Name of the Species	No/m3			
		S11	S12	S13	S14
Enraulidae					
1.	Stolephorus heterolobus	1	*	1	3
2.	Stolephorus sp.	*	1	*	*
3.	Thryssa mystax	*	1	1	*
Clupeidae					
1.	Sardinella gibbosa	1	*	*	1
Synodontidae					
1.	Saurida sp.	*	*	*	*
Mugilidae					
1.	Mugil cephalus	*	*	1	*
2.	Liza dussumieri	*	*	*	1
Teraponidae					
1.	Terapon jarbua	*	*	*	*
Scombridae					
1.	Scomberomorus sp.	*	*	*	*
	Total	2	3	6	5



The finfish larvae observed from 2 to 8 No/m3. The maximum number of finfish larvae observed at S12 & S2 and the minimum number of finfish larvae recorded at S-3.



A total of 12 species of finfish larvae were identified from the study area with Mugil cephalus dominating the populations (Table 3.31).

Benthos

Macrobenthos

A total of 33 species of macro fauna were recorded in the present study areas. Of these, Polychaetes topped the list with 19 species. Bivalves were found with 5 species. Gastropods were found to be the next dominant group in the order of abundance with 7 species. Amphipods came next with 7 species and Isopods were found with 7 species.

Comparing the Stations the maximum number of species was recorded at Station-8 and minimum in Station-10. Similarly, maximum population density of macro benthic organism was recorded at Station-8 and minimum at Station-10 of (TPS) Thermal power Station waters.

During this investigation, five groups of organisms namely Polychaetes, Bivalves, Gastropods, Amphipods and Isopods were recorded. Of these, Polychaetes constituted the dominant group followed by Bivalves, Gastropods, Amphipods and Isopods. Among the Polychaetes, Ancistrosyllis parva, Armandia longicaudata, Cirratulus concinnus, Dorvillea gardineri, Exogone clavator, Nephtys sphaerocirrata, Notomastus aberans, Phyllodoce tubicola, Pisionidens indica, Polydora ciliate, Prionospio capensis, Sphaerosyllis erinaceu, Nephtys homgergi and Eunice Siciliensis were found to be the most commonly occurring species in the samples collected in (TPS) Thermal power Station waters. Coming to Bivalves, Anadara veligers, Cardium veligers, Donax veligers, Meretrix veligers Perna viridis. Gastropods Nassarius veligers, Littorina veligers, Bullia veligers, Cerithedia cingulata, Natica veligers, Oliva veligers, Turritella veligers were found to be common species in the collection. With respect to Amphipods namely Gammarus sp., Grandidierella sp., Ampithoe romondi, A. rubricate, Caprella mendax Urothoe sp. Phaxocephalus holbolli. Isopods such as, Angeliera phreaticola, Jaeropsis beuriosi, Calabozoa pellucid, Paragnathia formica, Anthura gracilis, Sphaeroma serratum, Microjaera anisopoda showed consistency in their occurrence in the samples collected.

TABLE-3.32.

Macrobenthos in Sediments

Sl. No.	Name of the Species	No/m2				
		S1	S2	S3	S4	S5
Polychaetes		CONCRETE BOTTOM				
1.	Armandia intermedia					
2.	Chaettopterus sp.					
3.	Goniada emerita					
4.	Nereis sp.					
5.	Pygospio elegans					
6.	Tharyx sp.					
7.	Pista sp.					
8.	Prionospio pinnata					
Bivalves						
1.	Anadara granosa					
2.	Anadara veligers					
3.	Placenta placenta					
Gastropods						

1.	Cerithedia cingulata					
	Amphipods					
1.	Gammarus sp.					
2.	Grandidierella sp.					
3.	Ampithoe rubricata					
4.	Harnella incerta					
Isopods						
1.	Mirocerberus sp.					
	Total					

Sl. No.	Name of the Species	No/m2				
		S6	S7	S8	S9	S10
Polychaetes		CONCRETE BOTTOM				
1	Goniada emerita			50	*	*
2	Capitella capitata			100	25	*
3	Pisione sp.			50	*	*
4	Nereis sp.			25	*	*
5	Pista sp.			25	*	*
6	Prionospio pinnata			50	*	100
9	Ampharete acutifrons			*	75	*

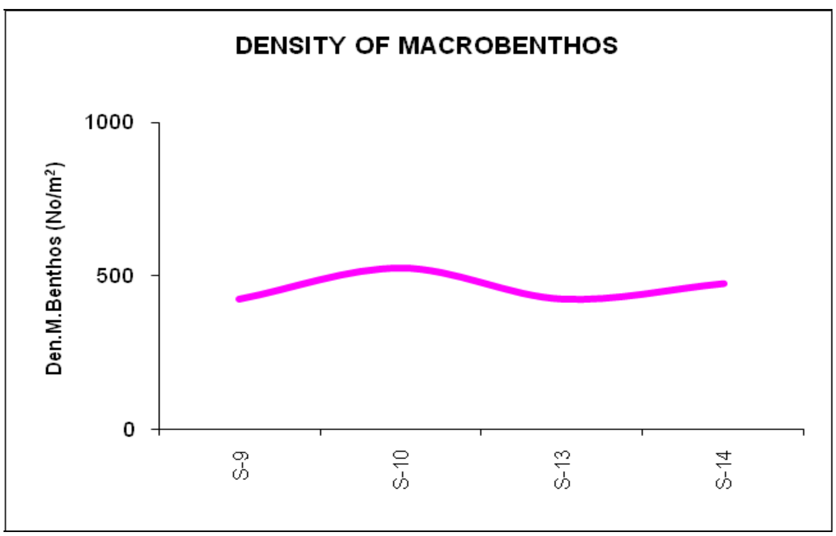
10	Cirratulus chrysoderma			*	*	75
11	Euchone sp.			*	50	50
12	Lumbrineris sp.			*	50	*
13	Maldane sarsi			*	*	100
14	Nereis sp.			*	25	*
15	Notomastus aberans			*	25	*
16	Prionospio cirrifera			*	*	50
17	Sabellides sp.			*	50	25
Bivalves						
1	Anadara veligers			25	*	50
2.	Placenta placenta			50	75	*
	Gastropods				*	*
1.	Turritella attenuata			50	*	*
Amphipods						
1.	Ampithoe rubricata			50	*	*
2.	Harnella incerta			*	50	*
Isopods						
1	Jaeropsis beuroisi			*	*	25
2	Mirocerberus sp.			*	*	*
	Total			450	425	525

Sl. No.	Name of the Species	No/m2			
		S11	S12	S13	S14
Polychaetes		CONCRETE BOTTOM			
1.	Armandia intermedia			50	*
2.	Chaettopterus sp.			*	25
3.	Goniada emerita			75	*
4.	Nereis sp.			50	*
5.	Pygospio elegans			*	25
6.	Tharyx sp.			*	50
7.	Pista sp.			*	25
8.	Prionospio pinnata			25	75
Bivalves					
1.	Anadara granosa			*	50
2.	Anadara veligers			75	*
3.	Placenta placenta			25	*
Gastropods					
1.	Cerithedia cingulata			25	75
Amphipods					

1.	Gammarus sp.			25	*
2.	Grandidierella sp.			*	75
3.	Ampithoe rubricata			*	25
4.	Harnella incerta			75	*
Isopods					
1.	Mirocerberus sp.			*	50
	Total			425	475

Population density

The population density of macrobenthos varied from 425 to 525 No./m2 with maximum at Station-6 and minimum at S-13 & S-9 (Table 3.32).



Percentage composition

The results of percentage composition of benthic fauna were viewed, Polychaetes constituted the maximum with 42.22% to the total benthic organisms. Bivalves, Gastropods, Amphipods and Isopods contributed 11.11%, 15.56%, 15.56%, and 15.56% respectively to the benthic samples collected.

Meiobenthos

In the present study, 30 species of meio-benthic fauna were recorded in (NCTPS) thermal power Station waters. Of these, Foraminiferans topped the list with 31 species. Nematodes were found to be the next dominant group in the order of abundance with 13 species. Ostracodes and Harpacticoids came next with 8 and 7 species respectively. Coming to Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera came last with 5, 4, 3, 1 and 1 species respectively.

Comparing the Stations the maximum number of species was recorded in Station-4 and minimum in S-8 Similarly, maximum population density of meio-benthic organism was recorded at S-14 and minimum at S-8 of (NCTPS) thermal power Station waters.

Altogether nine groups of meio-benthic organisms namely Foraminiferans, Nematodes Ostracodes, Harpacticoids, Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera were recorded. Of these, Foraminiferans were found to be dominant group followed by Nematodes, Ostracodes, Harpacticoids, Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera. Among the Foraminiferans Ammonia beccarii, Amphisorus sp., Asterorotalia trispinosa, Bolivia abbreviate, Cornoboides advena, Cymbaloporetta bradyi, Rotalia calcar, Ammonia tepida, Ammonia elegans, Asterorotalia inflate, and Leptohalysis scotti. Nematodes Daptonema conicum, Desmoscolex falcatus, Sipirinia sp. Microlaimus sp were found to be the common species in the samples collected in various Stations with respect to Ostracodes, Conchoecia sp. Cyprideis sp. Keijella oertlii, Tanella estuarii, Philomedes globosus were found to occur all the Stations. Coming to Harpacticoids, Apodopsyllus vermiculiformis, Canuella sp. Diarthrodes sp. Phyllothalestris mysis, Laophonte thoracica, Stenhelia sp. was found to be common in the collection. with respect to Tanaidacea namely Sphaerosyllis sp. Pogurapseudes largoensis, Heterotanais oerstedi, Archiannelids Polygordius sp. Protodrilus helgolandicus, Protodrilus brevis, Diurodrilus sp. with respect to the Cumacea Campylaspis sp. Gynodiastylis sp. Nannastacus sp. Gastrotricha Cephalodasys sp. and Rotifera such as Rotaria rotatoria, Campylaspis sp., Gynodiastylis sp., and Cephalodasys sp., showed consistency in their occurrence in the samples collected

TABLE-3.33.

Meiobenthos in Sediments

<table>
<tr><th rowspan="2">Sl. No.</th><th rowspan="2">Name of the Species</th><th colspan="5">No/10cm2</th></tr>
<tr><th>S1</th><th>S2</th><th>S3</th><th>S4</th><th>S5</th></tr>
<tr><td colspan="2">Nematodes</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1.</td><td>Enoploides sp.</td><td colspan="5" rowspan="8">Concrete bottom</td></tr>
<tr><td>2.</td><td>Quadricoma sp.</td></tr>
<tr><td>3.</td><td>Tricoma sp.</td></tr>
<tr><td>4.</td><td>Synonchus sp.</td></tr>
<tr><td>5.</td><td>Echinotheristus sp.</td></tr>
<tr><td colspan="2">Forminiferans</td></tr>
<tr><td>1.</td><td>Cibicides refulgens</td></tr>
<tr><td>2.</td><td>Globigerinoides sacculifer</td></tr>
</table>

3.	Quinquiloculina lamarckiana					
4.	Rosalina floidana					
5.	Rosalina vilardeboana					
6.	Bolivina abbreviata					
7.	Cornoboides advena					
8.	Eliphidium sp.					
9.	Eponides repandus					
10.	Rosalina globularis					
11.	Spiroloculina sp.					
Oligochaetes						
1.	Grania pusilla					
Harpacticoids						
1.	Canuella sp.					
2.	Laophonte thoracica					
	Ostrocodes					
1.	Cyprideis sp.					
2.	Cypretta foveata					
3.	Cyprideis lengae					
4.	Stenocypris major					
Rotifera						
1.	Lecane psammophila					
	Total					

Sl. No.	Name of the Species	No/10 cm2				
		S6	S7	S8	S9	S10
Nematodes						
1.	Enoploides sp.	Concrete bottom			*	1
2.	Quadricoma sp.				3	1
3.	Daptonema conicum			5		
4.	Tricoma sp.			2	*	1
5.	Synonchus sp.			1	1	*
6.	Echinotheristus sp.			2	1	5
Forminiferans						
1.	Bolivina rhomboides			1		
2.	Cibicides refulgens			4	6	*
3.	Globigerinoides sacculifer			1	*	2
4.	Eliphidium sp.			1	*	2
5.	Rosalina globularis			3	5	*
6.	Spiroloculina sp.			5	3	*
7.	Quinquiloculina lamarckiana				1	2
8.	Rosalina floidana				1	*

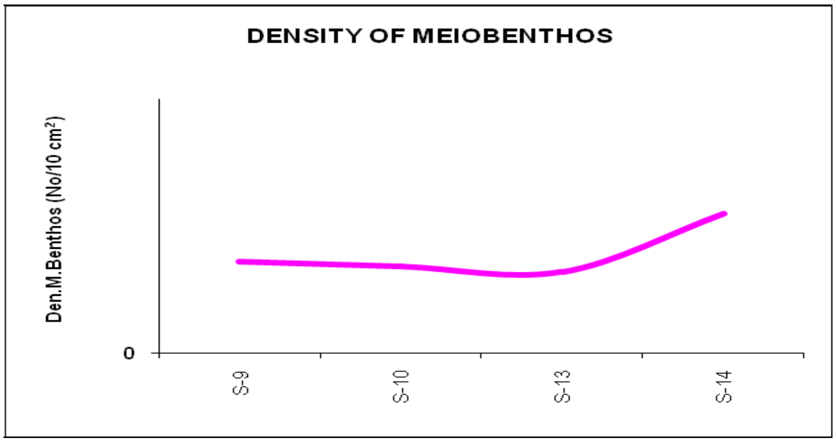
9.	Rosalina vilardeboana				*	1
10.	Bolivina abbreviata				*	5
11.	Cornoboides advena				2	*
12.	Eponides repandus				3	*
Oligochaetes						
1.	Grania pusilla				*	4
Harpacticoids						
1.	Microsetella sp.			1		
2.	Canuella sp.				1	*
3.	Laophonte thoracica				*	1
Ostrocodes						
1.	Cypretta foveata				2	*
2.	Cyprideis lengae				*	5
3.	Stenocypris major				1	*
4.	Cyprideis sp.			1	1	2
	Rotifera					
1.	Lecane psammophila			1	5	2
	Total			28	36	34

Sl. No.	Name of the Species	No/10cm2			
		S11	S12	S13	S14
Nematodes					
1.	Daptonema conicum	Concrete bottom		2	4
2.	Enoploides sp.			2	*
3.	Quadricoma sp.			2	*
4.	Tricoma sp.			*	3
5.	Synonchus sp.			2	*
6.	Echinotheristus sp.			3	7
Forminiferans					
1.	Bolivina rhomboides			*	1
2.	Cibicides refulgens			3	*
3.	Globigerinoides sacculifer			2	3
4.	Quinquiloculina lamarckiana			*	3
5.	Rosalina floidana			3	*
6.	Bolivina abbreviata			1	*
7.	Cornoboides advena			1	*
8.	Eliphidium sp.			2	3

9.	Eponides repandus		*	2
10.	Rosalina globularis		3	2
11.	Spirillina limbata		1	1
12.	Spiroloculina sp.		*	1
Oligochaetes				
1.	Grania pusilla		*	5
Harpacticoids				
1.	Laophonte thoracica		*	2
2.	Microsetella sp.		1	1
Ostrocodes				
1.	Cyprideis sp.		2	3
2.	Tanella indica		*	5
3.	Cypretta foveata		*	1
4.	Cyprideis lengae		2	3
5.	Eucythere argus		*	2
Rotifera				
1.	Lecane psammophila		*	3
	Total		32	55

Population density

The population density of meibenthos varied from 28 to 55 No/10 cm2 with maximum at S-14 and minimum at S-8 during the present study period (Table 3.33).



Percentage composition

When the results of percentage composition fauna were viewed, Foraminiferans, constituted the maximum with 42.47% of the total benthic organisms. Nematodes, Ostracodes, Harpacticoids, Tanaidacea, Archiannelids, Cumacea 17.81% 10.96% 9.59% 6.85% 5.48% 4.11% and Gastrotricha and Rotifera1.37% 1.37% each in to the total meio-benthic samples collected.

3.5 MARINE ECOLOGY (JANUARY, 2014)

The Marine Ecological survey at NCTPS coastal areas was made by a team of experts from the Centre of Advanced Study in Marine Biology of Annamalai University during January 2014. Marine samples were collected from 14 Stations including intake and outfall of NCTPS. These Stations were located in the following latitude and longitude in which it is proposed to lay the intake (13°25'93.0"N & 80°33'36.0"E) and outfall (13°23'36.0"N & 80°32'70.0"E) systems.

The lists of stations covered as a part of Marine EIA Study are given below:

- Station -1 is located near IInd Stage intake inside the Ennore port.
- Station -2 is located near to Ist Stage intake inside the Ennore port.
- Station -3 is located on Ist Stage intake (Cooling Water Pump House)
- Station -4 and 5 are located on intake channel with 100 m distance to each.
- Station 6 is located in the seal well.
- Station -7 is IInd stage outlet which is a concrete channel with 5 m depth running above the intake channel.
- Station -8 is also on the outlet channel (Pre cooling Channel), but not a concrete channel.
- Stations -9 and 10 are located parallel to out fall positions inside the NCTPS
- Stations -11and 12 are located in outlet with 50 m distance (Outlet positions).
- Stations -13 and 14 are located in Ennore creek mouth, which is parallel to the station -11 and 12..

The geographical locations of the sampling Stations are given in the following Table 3.34:

Table 3.34

Sampling locations and its geographical coordinates

S. No.	St. Code	Latitude	Longitude
1.	S- 1	13°23’11” N	80°33’30” E
2.	S-2	13°25’93” N	80°33’36” E

3.	S-3	13°25'93" N	80°33'36" E
4.	S-4	13°25'21" N	80°32'49" E
5.	S-5	13°25'93" N	80°33'36" E
6.	S-6	13°24'14" N	80°33'32" E
7.	S-7	13°23'46" N	80°32'82" E
8.	S-8	13°25'93" N	80°33'36" E
9.	S-9	13°25'68" N	80°33'46" E
10.	S-10	13°23'46" N	80°32'82" E
11.	S-11	13°23'44" N	80°32'77" E
12.	S-12	13°23'44" N	80°32'77" E
13.	S-13	13°23'36" N	80°32'70" E
14.	S-14	13°23'37" N	80°32'68" E

MATERIALS AND METHODS

Water and Sediment Sampling

Water samples were collected using Universal water sampler below the surface and transferred to the precleaned polypropylene and glass containers. Sediment samples were collected using a Peterson Grab, transferred to clean polythene bags and transported to the laboratory. The samples were air-dried. The station root and other debris were removed and stored for further analysis.

Water Analysis

Temperature, Salinity and pH

The physical parameters like pH, temperature and salinity were measured in-situ in field condition. The subsurface temperature was measured with a mercury thermometer having ± 0.02°C accuracy and the pH of water was measured by a calibrated pH pen (pH ep-3 model). With the use of a hand refractometer (Erma Company, Japan), the salinity of samples was measured. Water samples collected for dissolved oxygen estimation were transferred carefully to BOD bottles. The DO was immediately fixed and these were brought to the laboratory for further analysis.

Preservation and Laboratory Analysis

After collection, all samples were immediately cooled to 4°C and then brought to the laboratory in an insulated thermocool box. In the laboratory, water samples were filtered through Whatman GF/C filter paper and analyzed for organic matter and all other nutrients. Unfiltered samples were used for the estimation of total nitrogen and total phosphorus. All the analyses were carried out as per internationally used standard procedures for samples of aquatic origin. Briefly, the methods of analyses were as follows

Dissolved Oxygen (DO)

The modified Winkler's method described by Strickland and Parsons (1972) was adopted for the estimation of dissolved oxygen fixed at the collection site. The values were expressed in mg/l.

Nitrate and Nitrite

The nitrate and nitrite content of samples were analysed by following the method described by Strickland and Parsons (1972). The nitrite was estimated from highly coloured azo dye formed by the addition of N (1-Napthyl) ethylene diamine dihydro-chloride and sulfanilamide into the solution was then measured at 543 nm in a spectrophotometer. Same procedure was followed for the estimation of nitrate. For this, nitrate was reduced to nitrite by passing the sample through copper coated cadmium column. The calculated values were expressed in μmol of Nitrogen/l

Inorganic Phosphate (IP)

The single solution mixed reagent procedure developed by Murphy and Riley (1962) was followed for the estimation of dissolved inorganic phosphate levels in water samples. This involves the conversion of phosphate into phosphomolybdic acid which was then reduced to molybdinum blue color complexes and then the intensity of colour was measured at 882 nm in a spectrophotometer. The calculated value was expressed in µmol of Phosphorus/l.

Total Phosphorus (TP)

The Total Phosphate in samples was estimated by employing the method described by Menzel and Corwin (1964). This procedure involves the conversion of organically bound phosphate into inorganic phosphate by wet oxidation of samples with potassium persulphate in an autoclave for 30 min at 15 lbs pressure. The converted inorganic phosphate was then estimated by using the method described by Murphy and Riley (1962). The subtraction of original dissolved inorganic phosphate from total phosphate yielded the organic phosphate in the water sample. The calculated value was expressed in µmol of Phosphorus/l.

Reactive Silicate

The reactive silicate content of water was estimated by following the method of Strickland and Parsons (1972). In this method the intensity of blue color formed by silico-molybdate complex was measured in a spectrophotometer at 810 nm and the calculated values were expressed in µmol of Silica/l

Sediment Analysis

For the analysis of textural composition and pH, the air-dried sediment samples were used as such. For all other analyses of organic matter and trace metals, sediment samples were ground to fine powder and dried in an oven at 110°C to constant weight for an hour.

Total Organic Carbon (TOC)

The estimation of total organic carbon in sediment was performed by adopting the method of El Wakeel and Riley (1956). The procedure involves chromic acid digestion and subsequent titration with ferrous ammonium sulphate solution in the presence of 1, 10 phenonthroline indicator. The values calculated are expressed in mg C/g of sediment.

Bacteriological Methods

Collection of samples

Surface water samples were collected in 100 ml sterile screw capped bottles for bacteriological assessment. Enough air space was left in the bottles to allow thorough mixing. Precautionary measures were taken to avoid contamination through handling. Sediment samples were collected by employing an alcohol rinsed air-dried small Peterson's grab. The central portion of the collected sediment was aseptically transferred into sterile polyethylene bags using sterile spatula. All the samples were brought to the laboratory in portable icebox as soon as possible after collection and bacteriological analyses were done in the laboratory at CAS immediately after arrival, with necessary dilution.

Enumeration of Total Viable Counts (TVC)

TVC was enumerated by adopting the spread plate method using Zobell's Marine Agar medium (EA123, Hi-Media, Mumbai). The samples (water and sediment) were diluted using the sterile sea water and 0.1 ml of the diluted sample was pippeted into the petriplates containing Zobell's Marine Agar and it was spread using a 'L' shaped glass spreader. The plates after inaculation were incubated in an inverted position at a temperature of 28+2°C for 24 to 48 h. The colonies were counted and the population density expressed as colony forming unit (CFU) per ml or g of the sample. The bacterial colonies were picked up from the pertidishes and re-streaked in appropriate nutrient agar plates thrice before a pure culture was established in agar slants.

Enumeration of Total Coliforms

Macconkey agar with 0.15% bile salt, crystal violet and NaCl has been recommended in accordance with USP/Nfxi (1) for the detection, isolation and enumeration of coliforms and intestinal pathogens in water, dairy products, pharmaceutical preparations, etc. The agar weighing 51.5 g in 1000 ml distilled water was heated upto the boiling point to dissolve the medium completely and sterilized by autoclaving at 15 lbs pressure (121°C) for 15 min. suitably diluted samples were inoculated in the petriplates containing medium and were incubated for 48 h. After incubation, the colonies of E. coli appeared with pink color.

M-FC agar is employed for detection and enumeration Fecal Coliforms by the membrane filter technique at higher temperature (44.5°C). The agar weighing 52 g was suspended in 1000 ml of distilled water and heated upto the boiling point to dissolve the medium completely, 10 ml of Rosolic acid (dissolved in 0.2 N NaOH) was added, heated with frequent agitation and boiled for 1 min. Then the medium was cooled to 50°C. Finally, the medium was poured into small 60 mm plates. Samples filtered by Millipore apparatus using 0.45µm Whatsman filter papers were impregnated in the petriplates. After 48 h of incubation, the colonies of E. coli appeared with blue color.

Enumeration of Streptococcus faecalis

M-Enterococcus agar is recommended as a selective medium for membrane filtration procedure or as a direct plating medium for the isolation and enumeration of Enterococci in food, water and other sources. The agar medium weighing 41.5 g was suspended in 1000 ml distilled water and mixed thoroughly. Then it was heated with frequent agitation until the agar was dissolved and then, the medium was cooled to 50°C with the addition of 0.5 ml of polysorbate 80 and 2 ml of 10% aqueous solution of sodium carbonate. The finally the medium was poured into small 60 mm plates. Samples filtered by Millipore apparatus using 0.45µm Whatsman filter papers were impregnated in the petriplates. After 48 h of incubation the colonies of S. faecalis appeared with maroon color.

Primary Productivity (PP)

The primary productivity in the study area was estimated following the dark and light bottle method (Strickland and Parsons, 1972). The dissolved oxygen concentration during the experiment was determined by following modified Winkler's method.

Chlorophyll `a'

The samples were filtered through Whatman GF/C filter papers and the chlorophyll was extracted into 90% acetone. The resulting colored acetone extract was measured in a spectrophotometer at different wavelengths and the same acetone extracts were acidified and measured for the phaeo-pigments. The methodology is described in detail in APHA manual (1989).

Phytoplankton

Phytoplankton samples were collected from the surface waters of the study areas by towing a plankton net (mouth diameter 0.35 m) made of bolting silk [No.25 mesh size 48 µm) for half an hour. These samples were preserved in 5% neutralized formalin and used for qualitative analysis. For the quantitative analysis of phytoplankton, the settling method described by Sukhanovo (1978) was adopted. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope.

Phytoplankton was identified using the standard works of Hustedt (1930-1966), Venkataraman (1939), Cupp (1943), Subramanian (1946), Prescott (1954), Desikachary

(1959 and 1987), Hendey (1964), Steidinger and Williams (1970) and Taylor (1976) and Anand et al. (1986)

Zooplankton

Zooplankton samples were collected from the surface waters of the study areas by horizontal towing of a plankton net with mouth diameter of 0.35 m, made of bolting silk (No. mesh size 33 mm) for half an hour. These samples were preserved in 5% neutralized formalin and used for quantitative analysis. The zooplankton was identified using the classical works of Dakin and Colefax (1940), Davis (1955), Kasthurirangan (1963) and Wickstead (1965) and Damodara Naidu (1981). For the quantitative analysis of zooplankton, a known quantity of water (100 l) was filtered through a bag net (0.33 mm mesh size) and filtrate was made up to 1 l in a wide mouthed enumerated using Utermohl's inverted plankton microscope. The plankton density is expressed as number of organisms/m3.

Benthic Community

For studying the benthic organisms, sediment samples were collected using a Petersen grab. The wet sediment was sieved with varying mesh sizes for segregating the organisms. The sieved organisms were stains with Rose Bengal and sorted to different groups. The number of organisms in each grab sample was expressed in number per meter square. According to size, benthic animals are divided into three groups. (i) macrobenthos (ii) meiobenthos and (iii) microbenthos (Mare, 1942). Macrobenthos are organisms which are retained in the sieve having mesh size between 0.5 and 1 mm. For Meiobenthos, the lowest size attributed is 63 µm and the upper limit depends upon the mesh size of the sieve used for separating macrobenthos from meiobenthos.

OBSERVATION REPORT

Water Quality

TABLE– 3.35

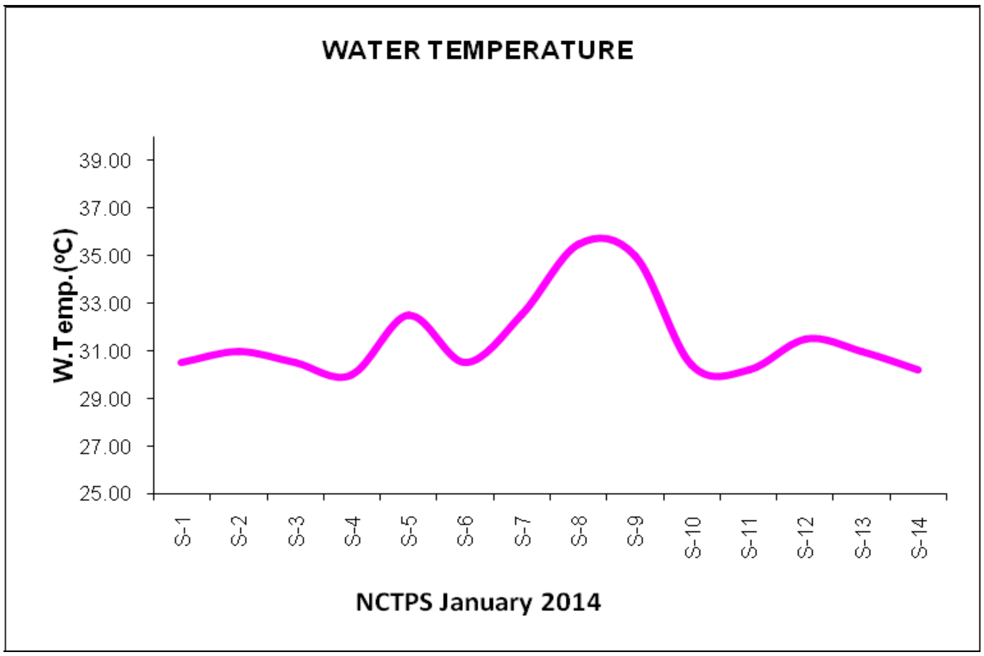
Physico - Chemical Properties of Water

Sl. No.	St. Code	Temp. (°C)	Salinity (‰)	pH	TSS (mg/l)	Turbidity (NTU)	DO (mg/l)	BOD (mg/l)
1.	S-1	30.50	33.0	8.2	145.2	19	5.32	0.587
2.	S-2	31.00	32.5	8.2	132.4	15	5.45	0.526
3.	S- 3	30.50	32.5	8.2	95.3	11	5.2	0.635
4.	S-4	30.00	32.0	8.2	120.4	16	5.24	0.485
5.	S-5	32.50	33.5	8.3	104.5	19	5.48	0.328
6.	S-6	30.50	33.0	8.3	125.8	28	5.11	0.752
7.	S-7	32.50	32.0	8.2	142.0	19	5.11	0.623
8.	S-8	35.50	32.0	8.2	125.3	21	5.17	0.485
9.	S-9	35.00	33.0	8.3	120.2	15	5.38	0.558
10.	S-10	30.40	33.0	8.3	58.6	10	5.0	0.532
11.	S-11	30.20	32.0	8.1	110.4	16	5.12	0.752
12.	S-12	31.50	32.0	8.2	115.8	13	5.12	0.657
13.	S-13	31.00	32.5	8.3	104.6	18	4.99	0.963

14.	S-14	30.20	32.5	8.3	65.3	10	5.11	0.854

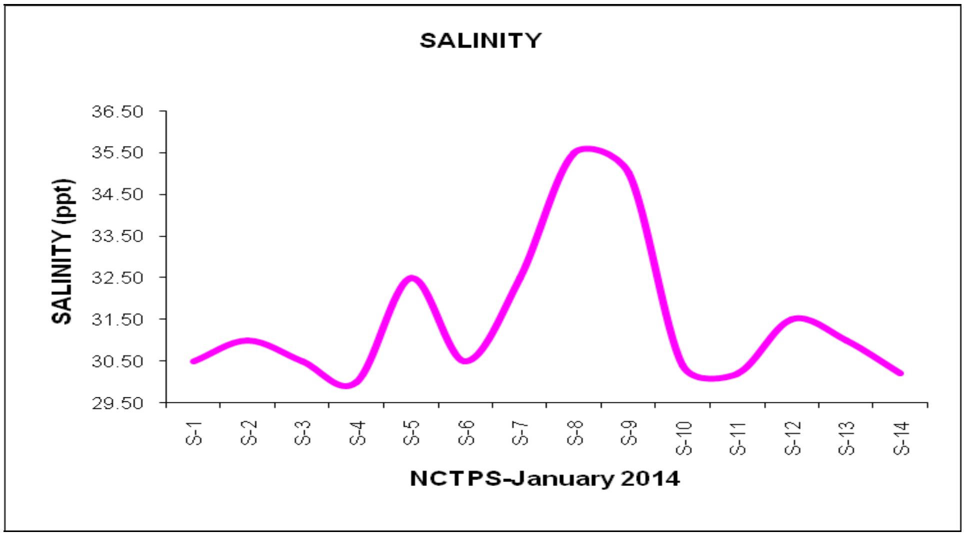
Water Temperature

The water temperature ranged from 30.00 to 35.5°C with maximum at S-8 and minimum at S-4 respectively (Table-3.35).



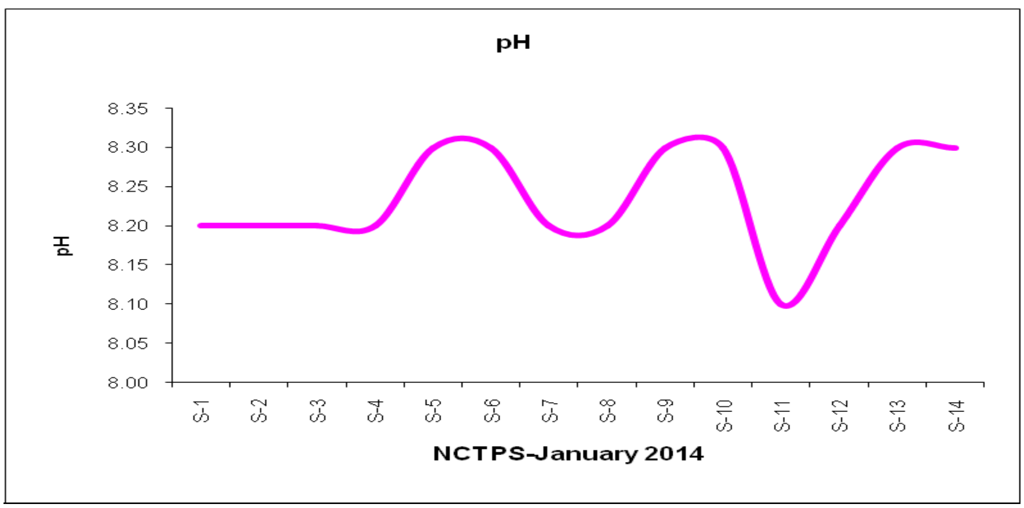
Salinity

The water salinity varied from 32.0 to 33.5 ‰ with maximum at S5 and minimum at S4, S7, S8, S11 and S12 respectively (Table 3.35).



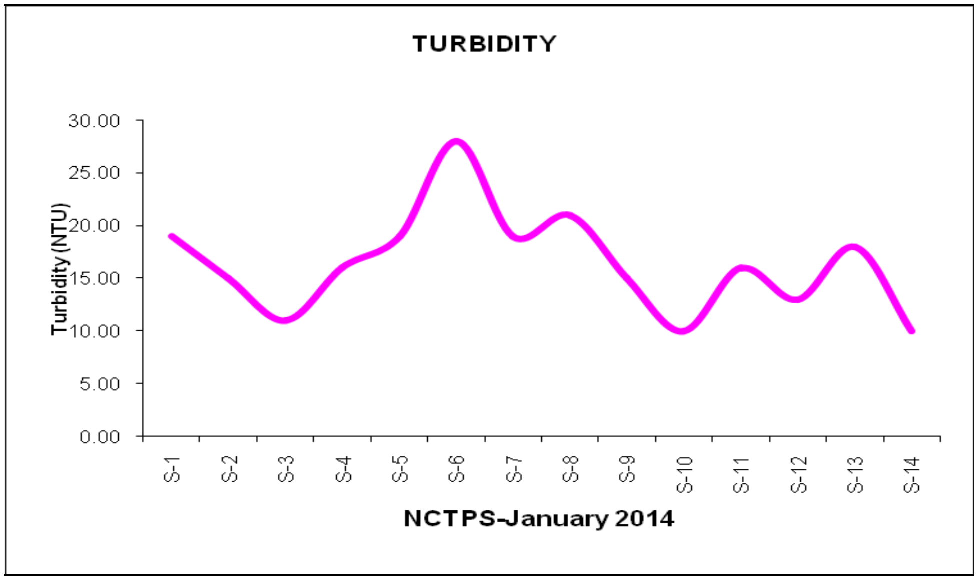
pH

The water pH varied from 8.1 to 8.3 (Table 3.35) with maximum in S5, S6, S9, S10, S13 & S14 and minimum in S11 respectively.



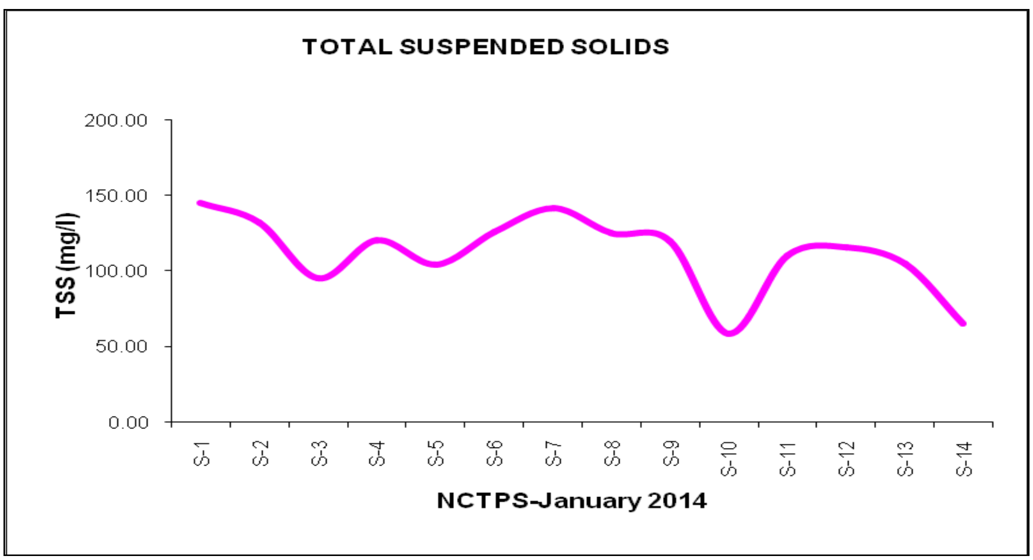
Turbidity

The turbidity values ranged from 10 to 28 NTU (Table 3.35) with maximum at S6 and minimum at S14.



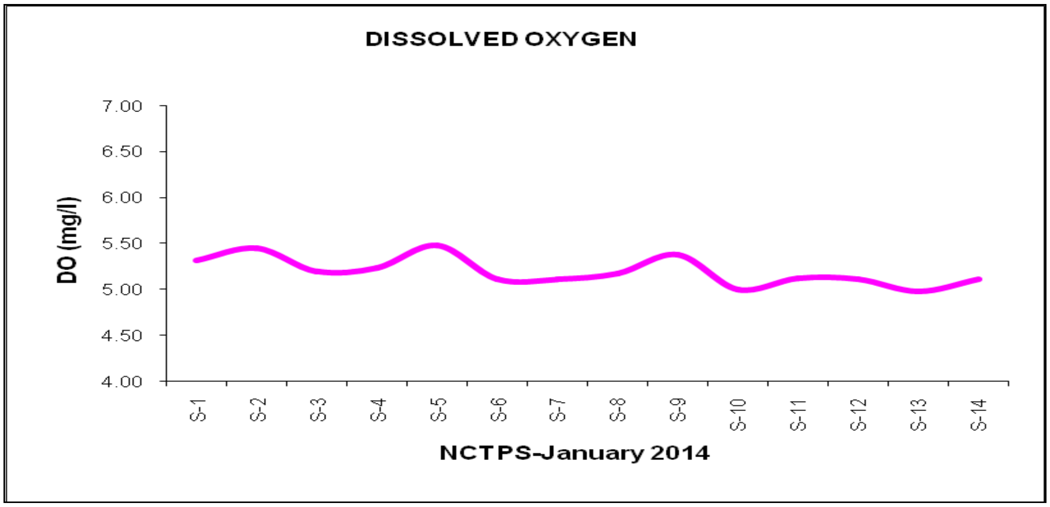
Total Suspended Solids

The TSS values ranged from 58.6 to 145 mg/l. The total suspended solids values showed minimum at S10 and maximum in S1 (Table 3.35).



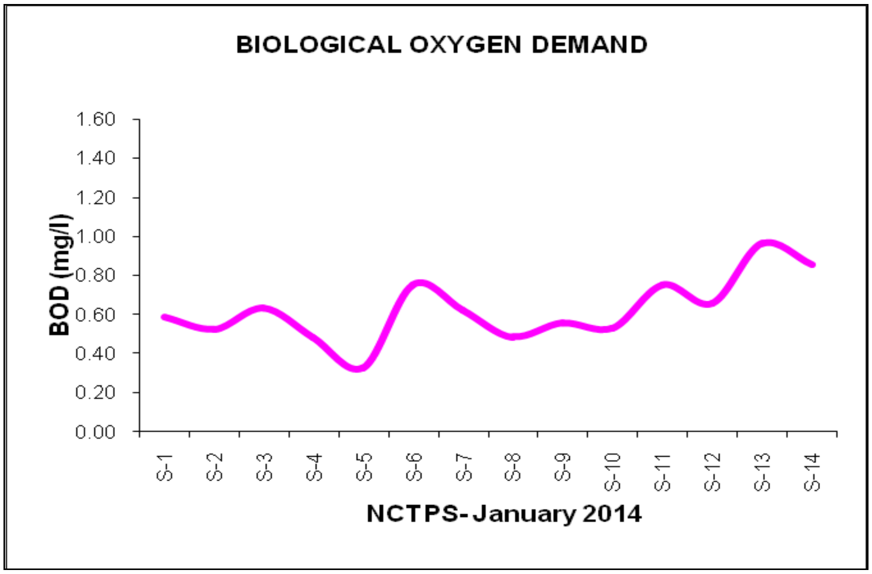
Dissolved Oxygen

Dissolved oxygen level in the water varied from 4.99 mg/l at S-14 to 5.48mg/l maximum at S5 and minimumwas recorded at S13 (Table 3.35).



Biological Oxygen Demand

The BOD values ranged between 0.328 and 0.963 mg/l. The Biological oxygen demand showed maximum at S13 and minimum at S5 (Table 3.35).



Nutrients

Nutrients determine the potential fertility of an ecosystem and hence it is important to know their distribution and behaviour in different geographical locations and seasons. The productivity of an area is in turn, dependent on the availability of primary nutrients like nitrogen and phosphorus

TABLE– 3.36

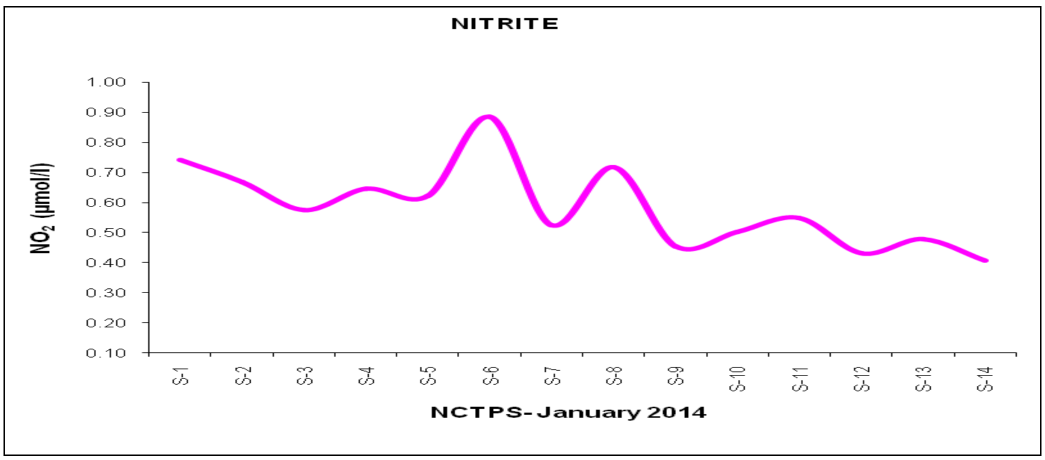
Nutrients in Water

S. No.	Station Code	Parameter (µmol/l)						
		NO2	NO3	NH4	TN	IP	TP	SiO4
1.	S-1	0.743	1.575	0.384	15.618	1.178	1.764	0.320
2.	S-2	0.670	0.924	0.290	16.905	0.278	2.886	0.924
3.	S- 3	0.575	0.934	0.200	17.219	0.969	3.048	0.322
4.	S-4	0.646	0.925	0.210	15.599	0.693	2.876	0.512
5.	S-5	0.623	0.718	0.311	18.443	0.485	2.979	0.304
6.	S-6	0.886	1.058	0.405	14.672	0.372	2.894	0.505
7.	S-7	0.526	0.923	0.135	15.926	0.623	2.406	0.450
8.	S-8	0.718	1.063	0.301	15.362	0.969	2.624	0.517
9.	S-9	0.455	0.566	0.218	16.671	0.449	2.748	1.242
10.	S-10	0.503	0.854	0.270	18.735	0.831	3.030	1.004
11.	S-11	0.550	0.690	0.198	16.740	0.900	3.098	1.048
12.	S-12	0.431	0.536	0.135	15.885	1.385	3.168	0.320

13.	S-13	0.479	0.550	0.176	15.152	1.247	3.119	0.754
14.	S-14	0.408	0.723	0.244	16.794	0.207	3.188	0.124

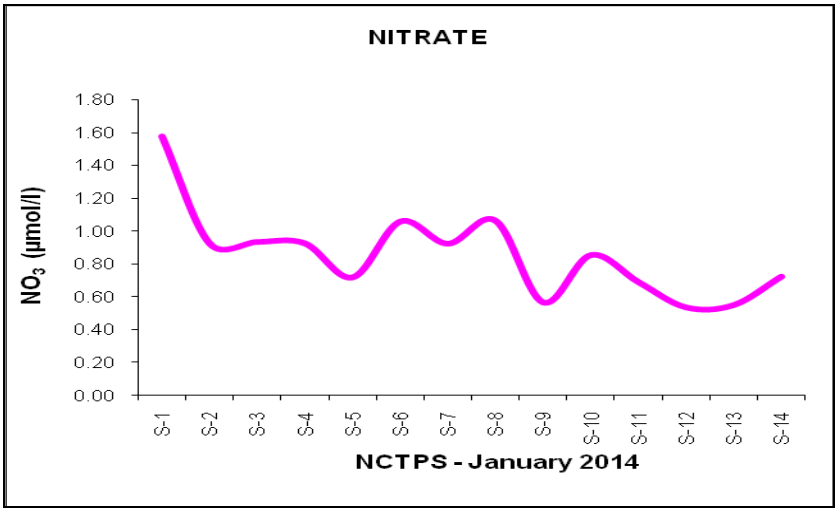
Nitrite

The nitrite varied from 0.408 to 0.886 µmol/l (Table 3.36). The minimum and maximum was recorded at S-6 and S-14 respectively.



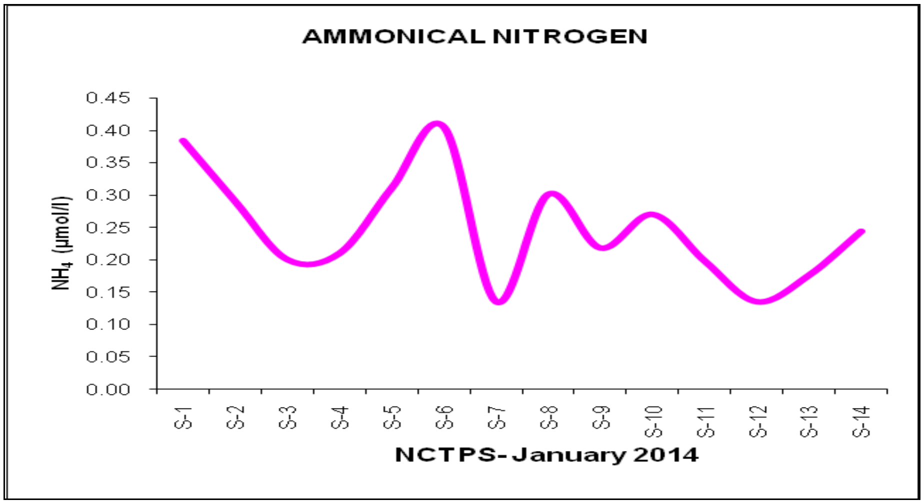
Nitrate

Nitrate content varied from0.536 to 1.575 µmol/l (Table 3.36) with maximum at S-1 and minimum at S-12.



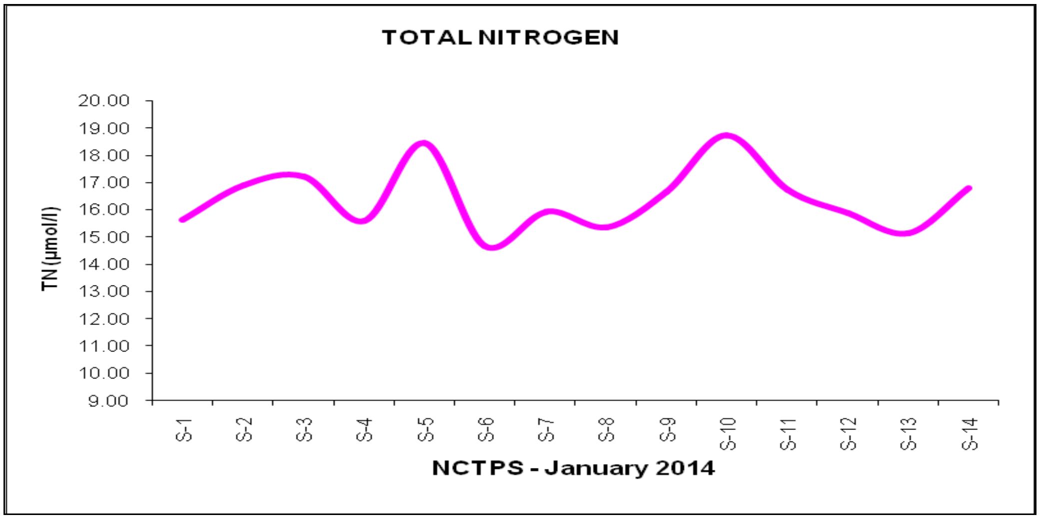
Ammonical Nitrogen

The ammonia concentration fluctuated from 0.135 to 0.405 µmol/l. The ammonia level in the water showed maximum at S-6 and the minimum at S-7 & 12 respectively (Table 3.36).



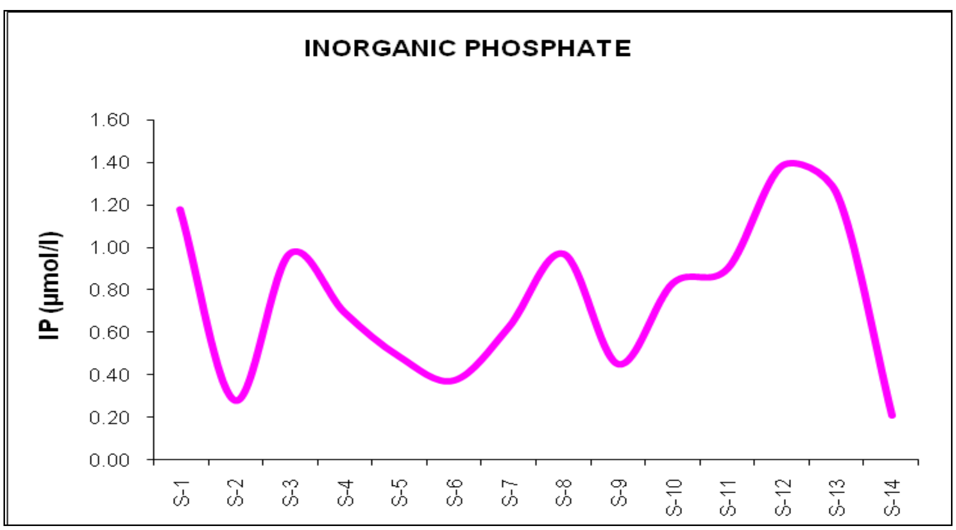
Total Nitrogen

Total nitrogen values were recorded maximum at S- 10 (18.735 µmol/l) and minimum at S-6 (14.672 µmol/l) (Table 3.36).



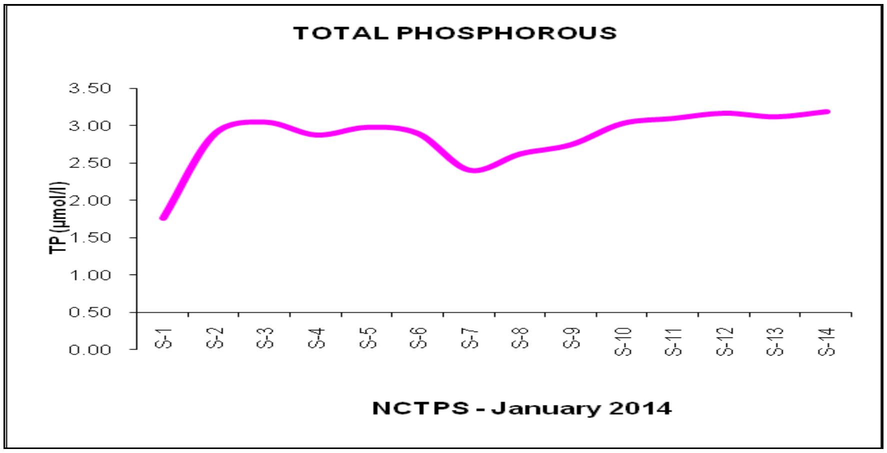
Inorganic Phosphate

Inorganic phosphate level was maximum at S-12 (1.385µmol/l) and minimum value was recorded at S-14 (0.207 µmol/l) (Table 3.36).



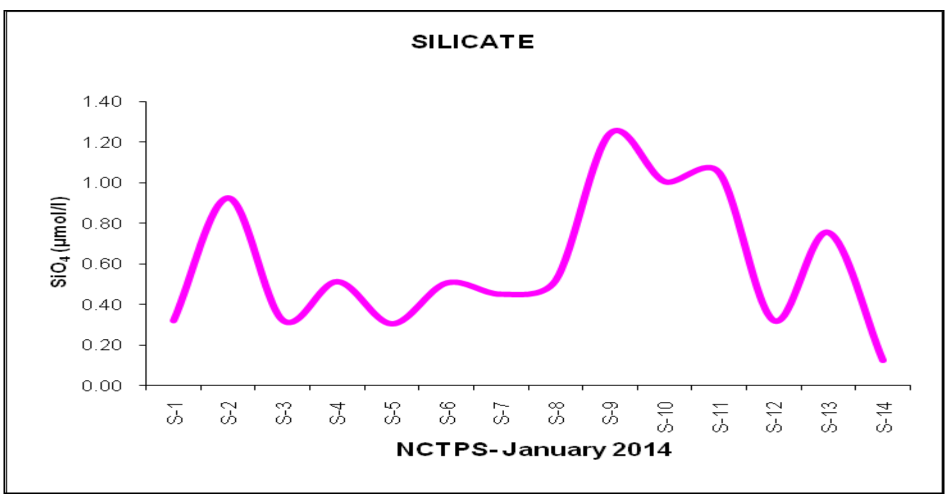
Total Phosphorus

The total phosphorus values ranged from 1.764 to 3.188 µmol/l. The maximum was recored at S-14 and the minimum was recorded at S-1 (Table 3.36).



Reactive Silicate

The silicate values varied between 0.320 and 1.242 µmol/l. The maximum (1.242 µmol/l) and minimum (0.320µmol/l) values were recored at S-1 and S-9 respectively (Table 3.36).



OIL & GREASE

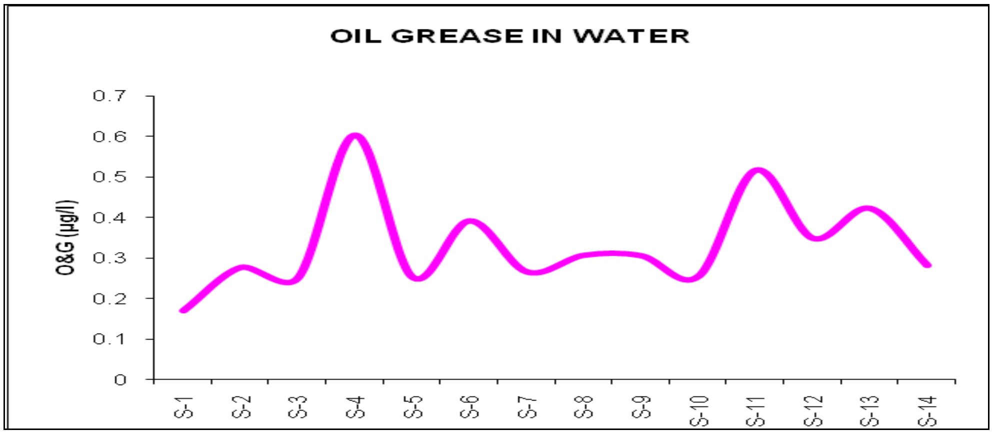
In NCTPS areas, the Oil & Grease in water fluctuated between 0.169 to 0.603 µg/l. The minimum concentration was recorded at S-1 and the maximum was recorded at S-4 during January 2014 (Table 3.37).

TABLE – 3.37

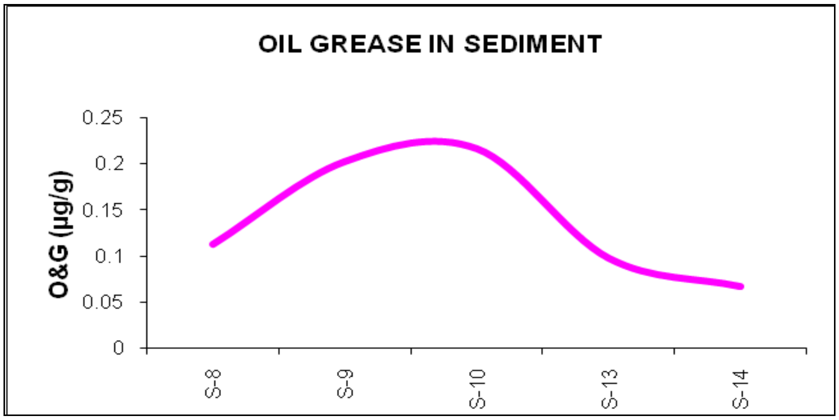
Oil & Grease in Water & Sediment

S. No.	Station Code	Water (µg/l)	Sediment (µg/g)
1.	S-1	0.169	Concrete bottom
2.	S-2	0.276	Concrete bottom
3.	S- 3	0.250	Concrete bottom
4.	S-4	0.603	Concrete bottom
5.	S-5	0.252	Concrete bottom
6.	S-6	0.391	Concrete bottom
7.	S-7	0.265	Concrete bottom
8.	S-8	0.306	0.113
9.	S-9	0.305	0.203
10.	S-10	0.254	0.217
11.	S-11	0.516	Concrete bottom
12.	S-12	0.348	Concrete bottom

13.	S-13	0.422	0.098
14.	S-14	0.281	0.067



In sediment, the Oil & Grease varied from 0.067 to 0.217 µg/g. The minimum was recorded at S-14 and the maximum concentration of PHC was recorded at S-10 during January 2014 (Table 3.37).



Heavy Metals in Water

The concentrations of trace metals such as cadmium, lead, mercury, copper and zinc are very low but even at such low concentrations they can be bio accumulated by certain organisms and biomagnified up the food chain.

TABLE – 3.38

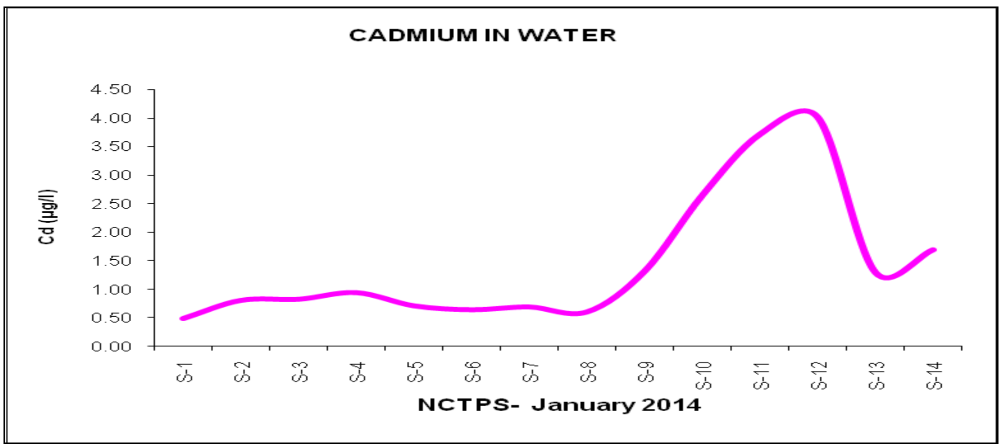
Heavy Metal in Water

Sl. No.	Parameters	Parameters (µg/l)					
		Cd	Cu	Fe	Pb	Zn	Hg
1.	S-1	0.490	5.004	53.762	4.384	25.184	0.024
2.	S-2	0.809	7.034	33.534	4.739	28.314	0.038
3.	S- 3	0.828	7.482	54.909	5.391	35.781	0.026
4.	S-4	0.944	6.633	78.473	2.508	30.859	0.022
5.	S-5	0.713	5.028	60.723	3.080	26.276	0.053
6.	S-6	0.645	3.659	79.695	3.790	44.589	0.017
7.	S-7	0.693	3.140	78.432	2.370	27.846	0.006
8.	S-8	0.606	4.367	48.366	2.430	35.733	0.012
9.	S-9	1.319	6.515	37.773	3.949	21.828	0.014
10.	S-10	2.646	5.877	62.024	5.509	33.936	0.043
11.	S-11	3.715	6.444	80.120	3.790	27.491	0.011
12.	S-12	4.014	6.207	68.868	2.883	25.961	0.027

13.	S-13	1.299	3.824	52.728	4.305	26.276	0.013
14.	S-14	1.694	4.296	50.778	5.430	33.095	0.029

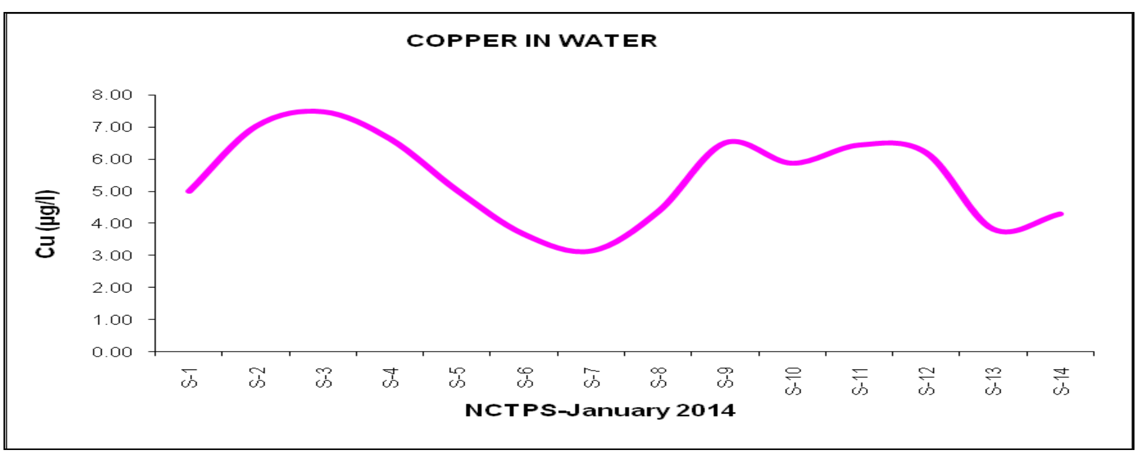
Cadmium

The cadmium level varied from 0.490 to 4.014 µg/l. The maximum cadmium was recorded at S-12 and the minimum was recorded S-1 (Table 3.38).



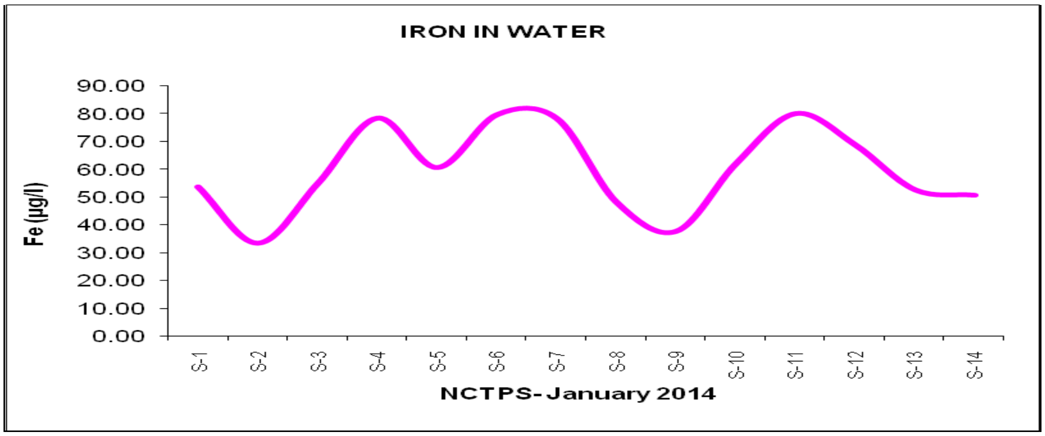
Copper

The copper level in the study area varied from 3.140 to 6.515 µg/l. The maximum copper was recorded at S-9 and minimum was recorded S-7 (Table 3.38).



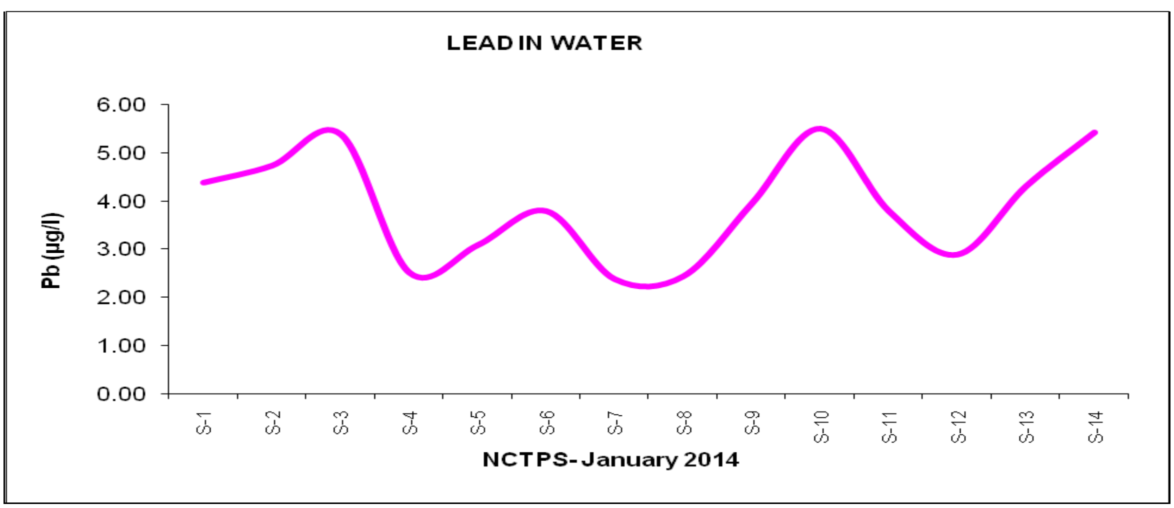
Iron

The iron level varied between 33.534 and 80.12 µg/l. The maximum iron was recorded at S-11 and the minimum iron was recorded at S-2 (Table 3.38).



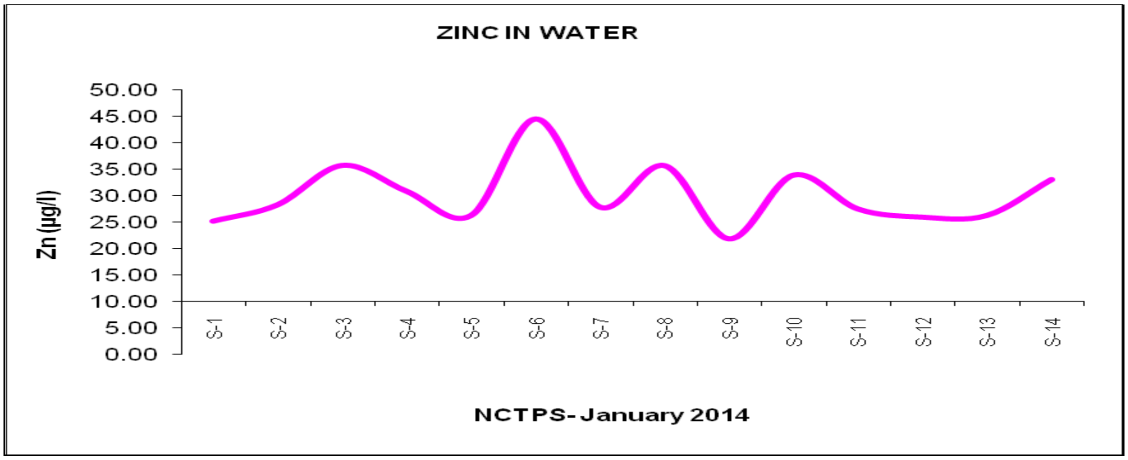
Lead

The lead level in the study area fluctuated between 2.370 and 5.509 µg/l. The maximum of 5.509 µg/l was observed at S-10 and the minimum of 2.370 µg/l was recorded at S-7 (Table 3.38).



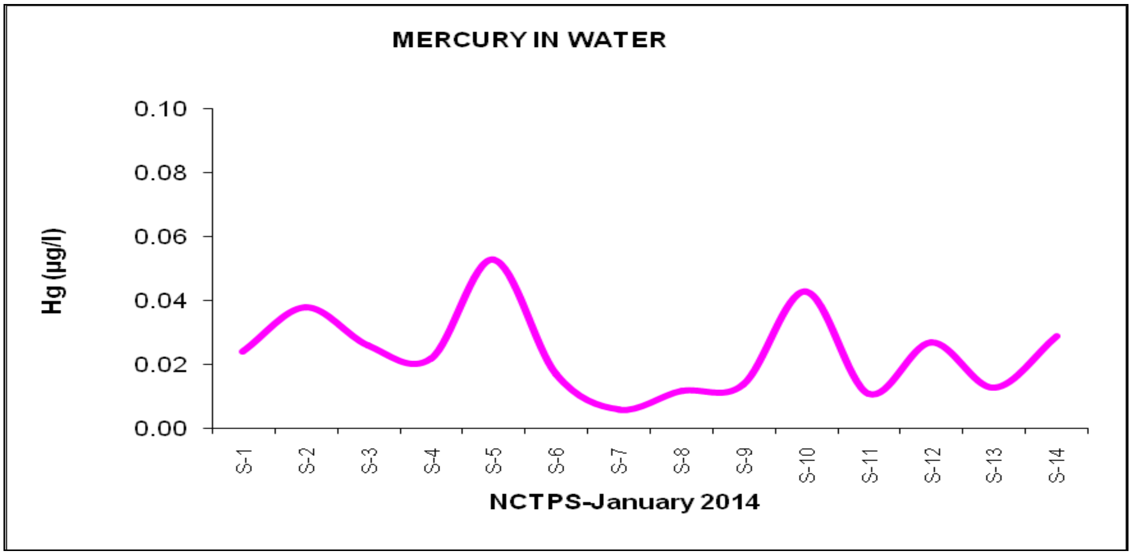
Zinc

The zinc level in the study areas varied between 21.828 and 44.589 µg/l. The maximum zinc was recorded at S-6 and the minimum of 21.828 was recorded at S-9 (Table 3.38).



Mercury

The mercury level in the study areas varied from 0.006 to 0.053 µg/l. The maximum mercury was recorded at S-5 and the minimum mercury was recorded at S-7 (Table 3.38).



Sediment Characteristics

TABLE– 3.39.

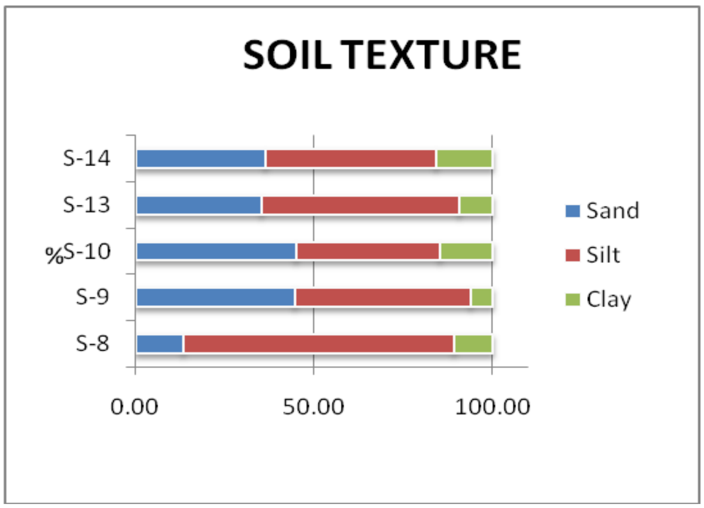
Soil Texture, Total Organic Carbon & pH of Sediment

S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (mgC/g)	pH
1.	S-1	Concrete bottom				
2.	S-2	Concrete bottom				
3.	S- 3	Concrete bottom				
4.	S-4	Concrete bottom				
5.	S-5	Concrete bottom				
6.	S-6	Concrete bottom				
7.	S-7	Concrete bottom				
8.	S-8	90.064	9.921	0.015	4.589	7.95
9.	S-9	94.606	5.243	0.151	2.872	7.97
10.	S-10	93.452	6.35	0.198	2.643	8.05
11.	S-11	Concrete bottom				
12.	S-12	Concrete bottom				
13.	S-13	93.127	6.834	0.040	1.989	8.28

14.	S-14	95.162	4.58	0.258	2.156	8.18

Soil Texture (%)

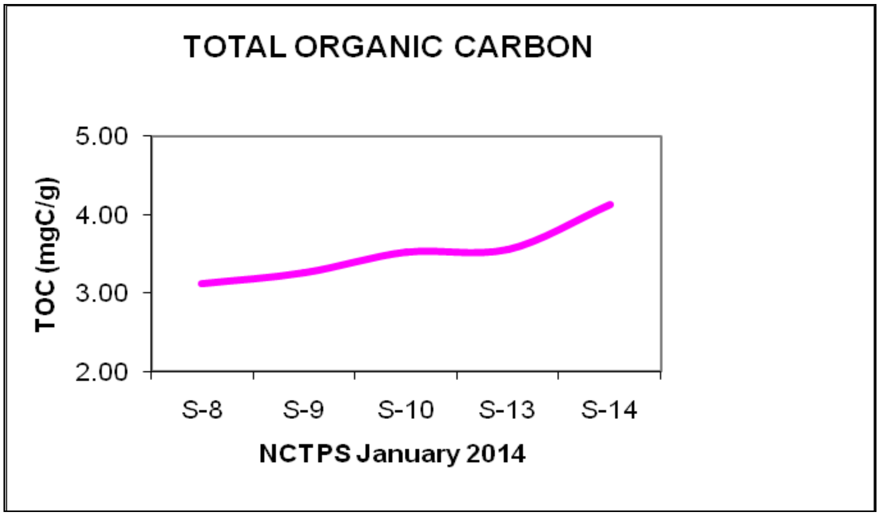
The sand content varied from 90.063 to 95.162 % with the maximum of 93.162 % at S-14 and the minimum sand content was recorded in the Station S-8 and the silt content found to maximum at S-8 (9.921 %) and minimum at S-14 (4.58 %) .



The clay fraction found to be maximum at S-14 (0.258 %) and minimum at S-8 (0.015 %) (Table 3.39).

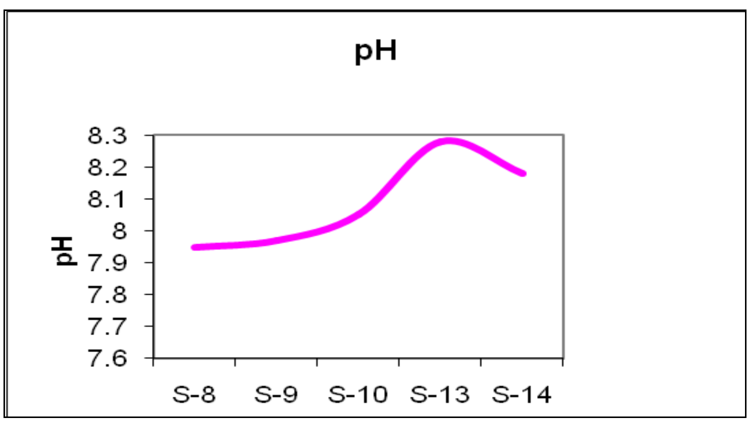
Total Organic Carbon

Total organic carbon values were recorded maximum at S-8 (4.589 mgC/g) and minimum at the Station S-13 (1.989 mgC/g) (Table 3.39).



pH

The pH in the sampling Stations varied from 7.95 to 8.28. As evident from the following figure, the minimum level was recorded at S-8 and the maximum level was recorded at S-13 during January 2014 (Table 3.39).



Heavy Metals in Sediment

Heavy metals even in the dissolved form on entering the aquatic environment are absorbed by TSS in water and transported to the sediment on settling. Thus the sediment of areas receiving anthropogenic trace metals sustains their high concentrations relative to the baseline. Hence, aquatic sediments are useful indicators of trace metal pollution.

TABLE – 3.40.

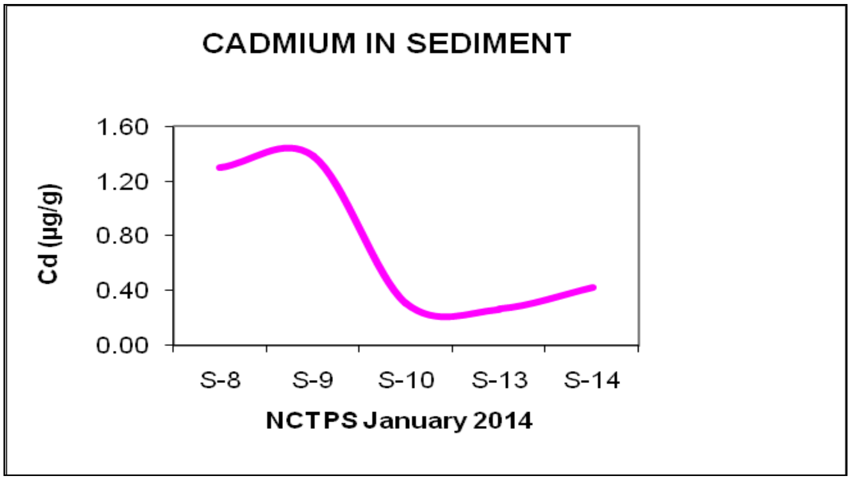
Heavy Metals in Sediment

Sl. No.	Station Code	µg/g					
		Cd	Cu	Fe	Pb	Zn	Hg
1	S-1	Concrete bottom					
2	S-2	Concrete bottom					
3	S- 3	Concrete bottom					
4	S-4	Concrete bottom					
5	S-5	Concrete bottom					
6	S-6	Concrete bottom					
7	S-7	Concrete bottom					
8	S-8	1.2975	10.400	2852.3	5.925	7.360	0.041
9	S-9	1.3845	14.463	4631.9	5.764	8.998	0.034
10	S-10	0.312	13.025	8206.9	7.089	15.622	0.053
11	S-11	Concrete bottom					
12	S-12	Concrete bottom					

13	S-13	0.264	14.088	7018.1	6.299	13.082	0.036
14	S-14	0.425	8.620	859.2	3.261	5.213	0.027

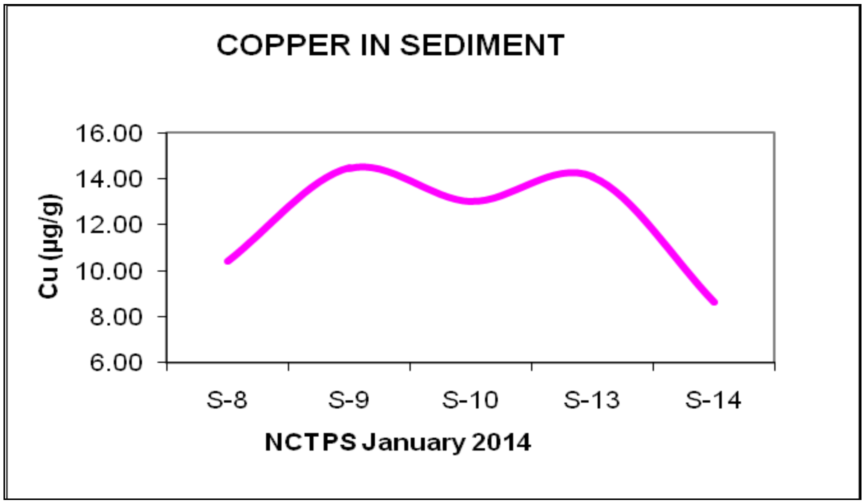
Cadmium

The cadmium level varied from 0.264 to 1.385 µg/g. The maximum cadmium was recorded at S-9 and minimum was recorded at S-13.



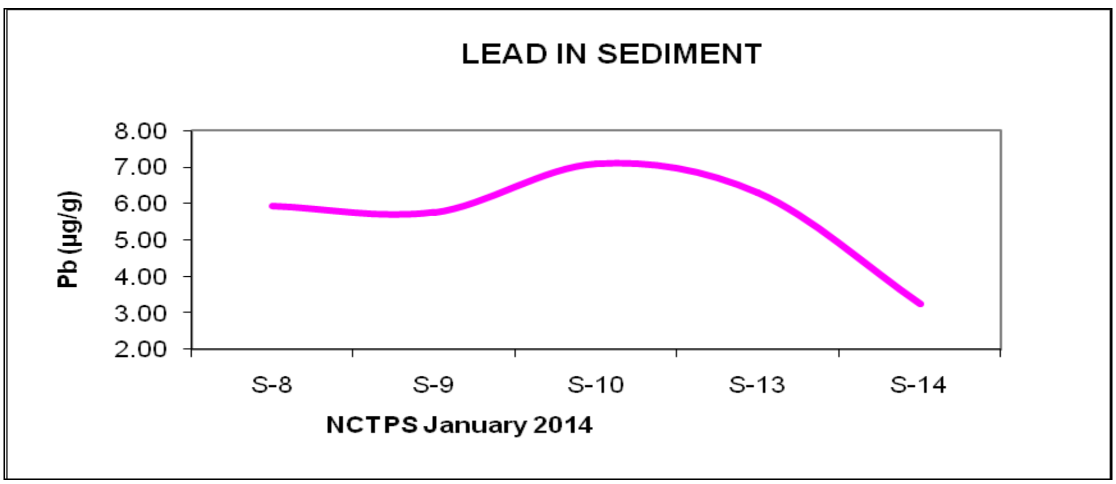
Copper

The copper in the sediments ranged from 8.260 to 14.463 µg/g. The maximum copper concentration was recorded at S-9 and minimum was recorded at S-14 (Table 3.40).



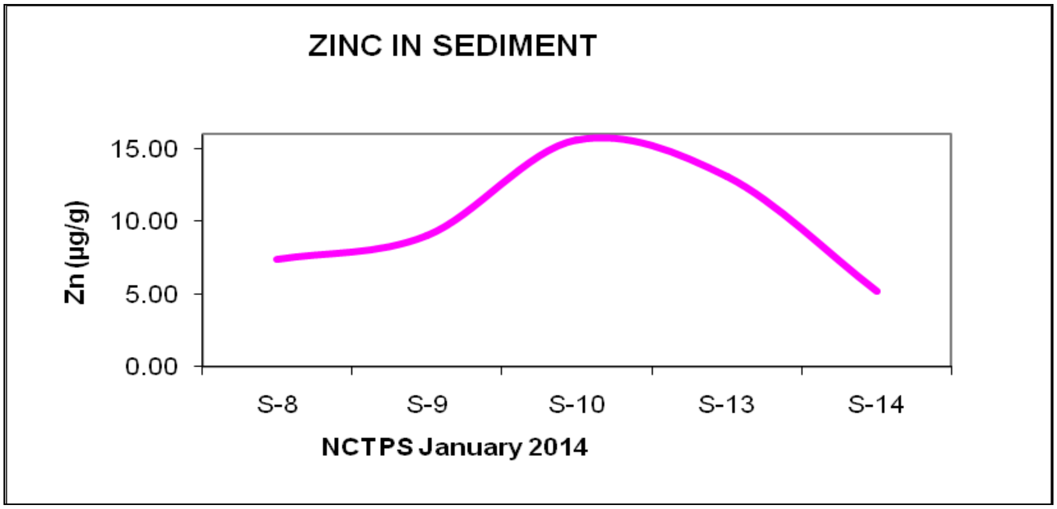
Lead

The lead level in the sediment ranged between 3.261 and 7.089 µg/g. The maximum lead concentration was recorded at S-10 and minimum at S-14 during the sampling period (Table 3.40).



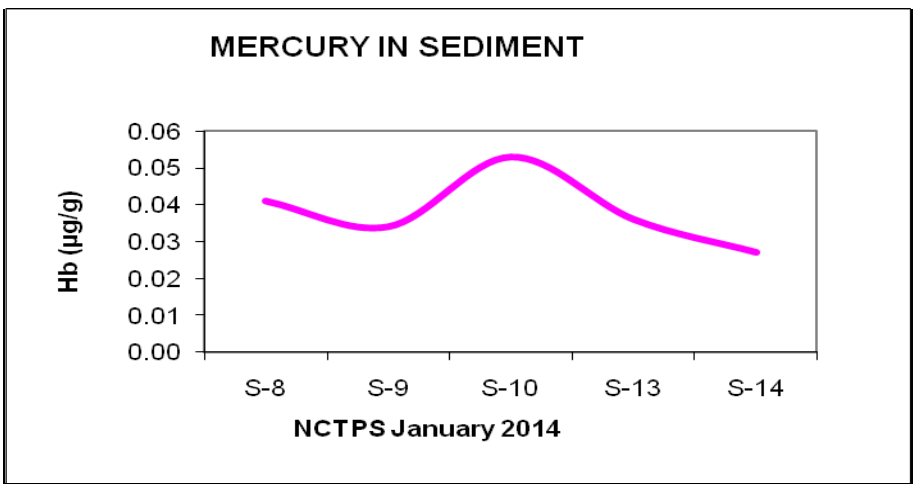
Zinc

The zinc fluctuated from 5.231 to 15.622 µg/g. The maximum concentration was recorded at S-10 and the minimum at S-14 (Table 3.40).



Mercury

The mercury level in the sediment varied from 0.027 to 0.053 µg/g. The maximum was recorded at S-10 and the minimum at S-14 (Table 3.40).



Microbiology

Water Sample

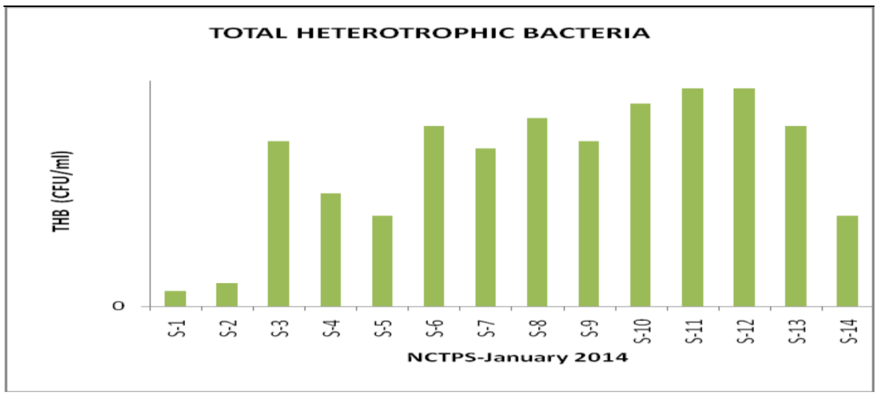
The Total Heterotrophic Bacteria (THB) varied from 23x103 to 37x105 with maximum at S-1 and minimum at S-12 of water samples collected from North Chennai Thermal Power Plant areas.

TABLE – 3.41

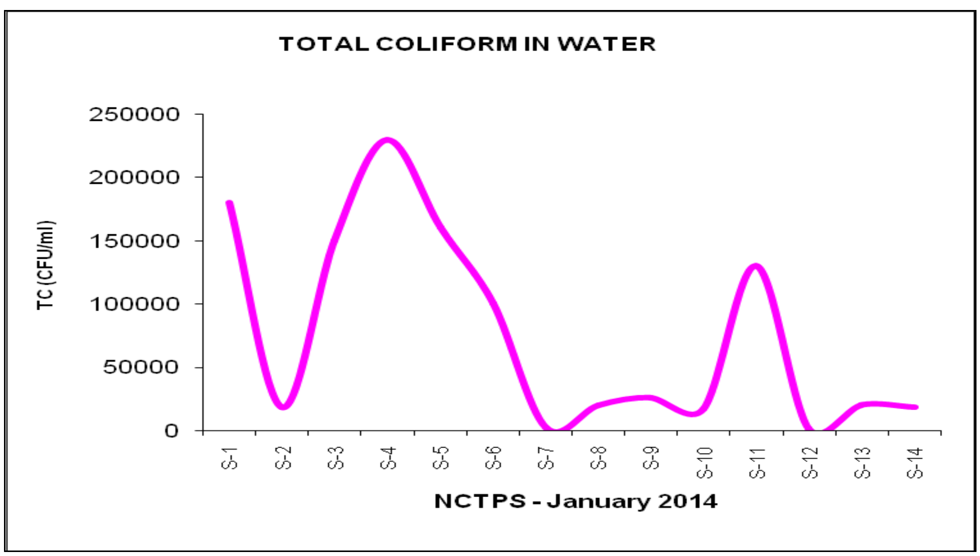
Microbial Populations in Water

The Total heterotrophic bacteria varied between $20x10^3$ to $21\ x10^5$ with maximum at S-7 and minimum at S-1.

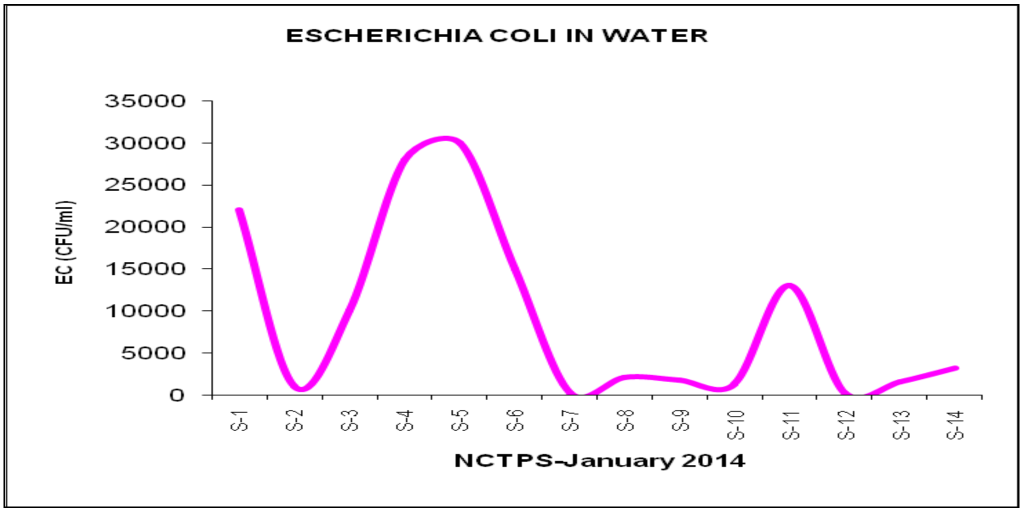
Sl. No.	St. Code	THB	TC	EC	FC	SF
1.	S-1	$20x10^3$	$18x10^2$	$33\ x10^1$	$10x10^1$	18
2.	S-2	$31\ x10^3$	$15x10^2$	$28\ x10^1$	$11x10^1$	28
3.	S- 3	$22\ x10^4$	$10x10^3$	$20\ x10^1$	$15x10^1$	$26\ x10^1$
4.	S-4	$15\ x10^4$	$13x10^2$	$37\ x10^1$	$10x10^1$	$15x10^1$
5.	S-5	$12x10^4$	$22x10^2$	$24\ x10^1$	$12x10^1$	$31x10^1$
6.	S-6	$24\ x10^4$	$13x10^1$	$17\ x10^1$	$10x10^1$	$22x10^1$
7.	S-7	$21\ x10^5$	$18x10^2$	$25\ x10^2$	$13x10^1$	$14x10^1$
8.	S-8	$25\ x10^4$	$15x10^1$	$34\ x10^2$	$11x10^1$	$15x10^1$
9.	S-9	$22x10^4$	$18x10^2$	$30\ x10^1$	$08x10^1$	$11x10^2$
10.	S-10	$27\ x10^4$	$14x10^2$	$23\ x10^1$	$10x10^1$	$16x10^2$
11.	S-11	$29\ x10^4$	$10x10^1$	$16\ x10^1$	$11x10^1$	$20x10^2$
12.	S-12	$29\ x10^4$	$12x10^2$	$25\ x10^1$	50	$18x10^1$
13.	S-13	$24\ x10^4$	$11x10^1$	$14\ x10^1$	30	$19x10^1$
14.	S-14	$12\ x10^4$	$10x10^2$	10 x101	25	$13x10^1$



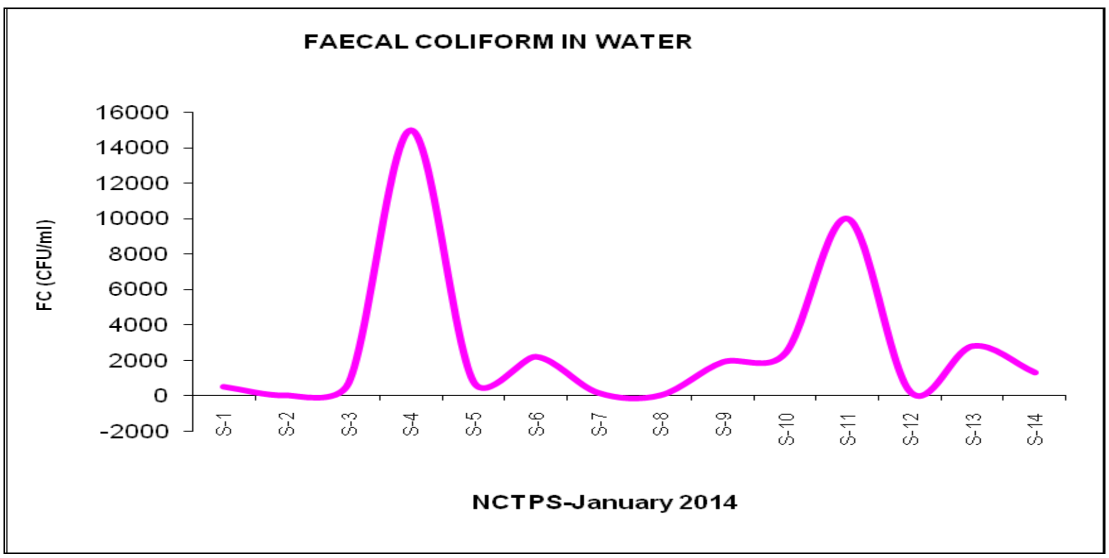
The Total Coliform varied from 10x10^{1} to 10x10^{3} with maximum at S-3and minimum at S-11.



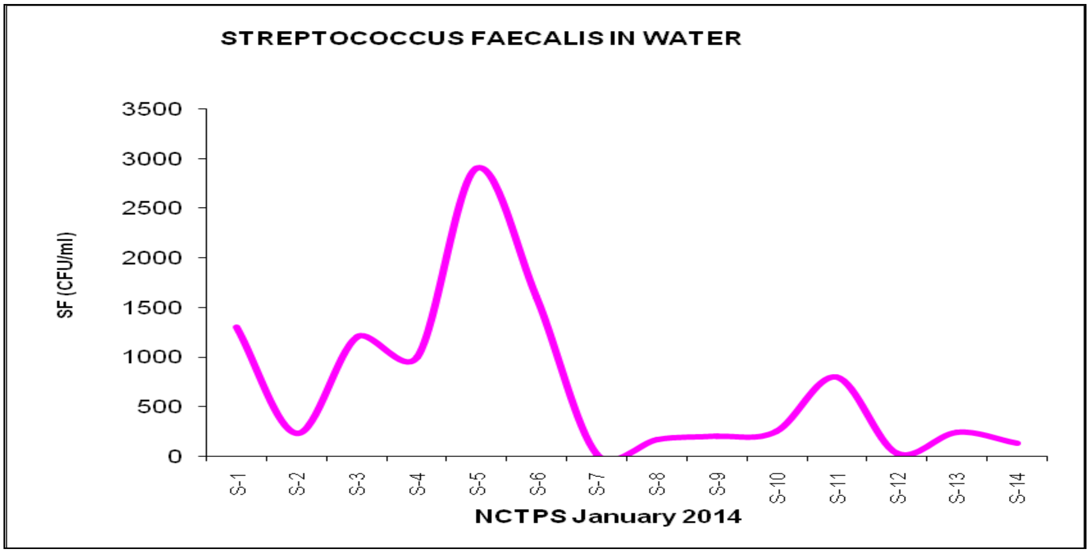
The Escherichia coli Bacteria in water sample varied from 20x10^{1} to 30x10^{3} CFU/ml with maximum at S-5 and minimum at S-12 during the present survey.



Faecal coliform varied between 25 to 13x10^{1} with maximum at S-7 and minimum at S-14.



The Streptococcus faecalis varied from 18 at S1 to 20x10^{2} at S11 respectively during January 2014 (Table 3.41).



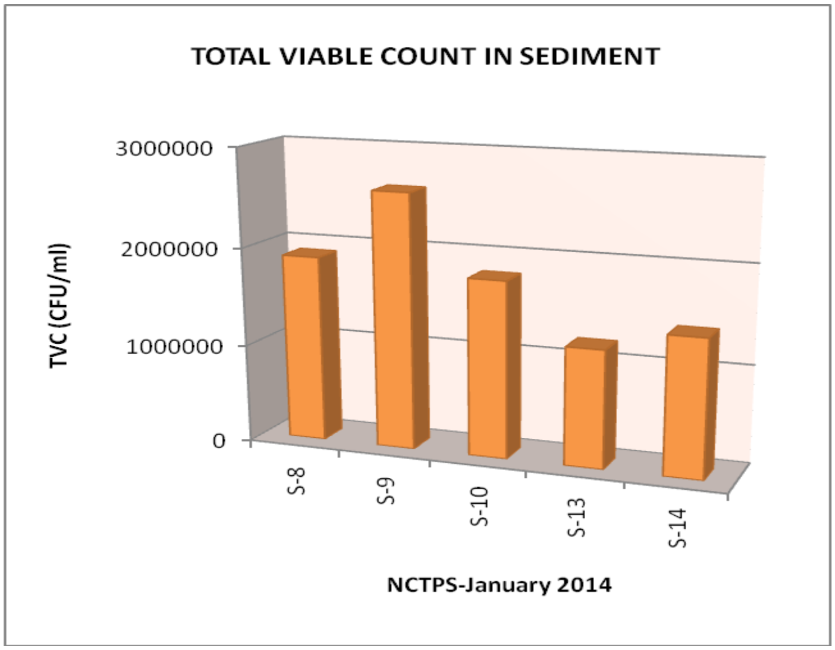
Sediment Sample

The Total Heterotrophic Bacteria (THB) varied from 90 x10^4 to 30x10^5 CFU/g with maximum at S-13 and minimum at S-8 of sediment samples collected in North Chennai Thermal Power Station areas.

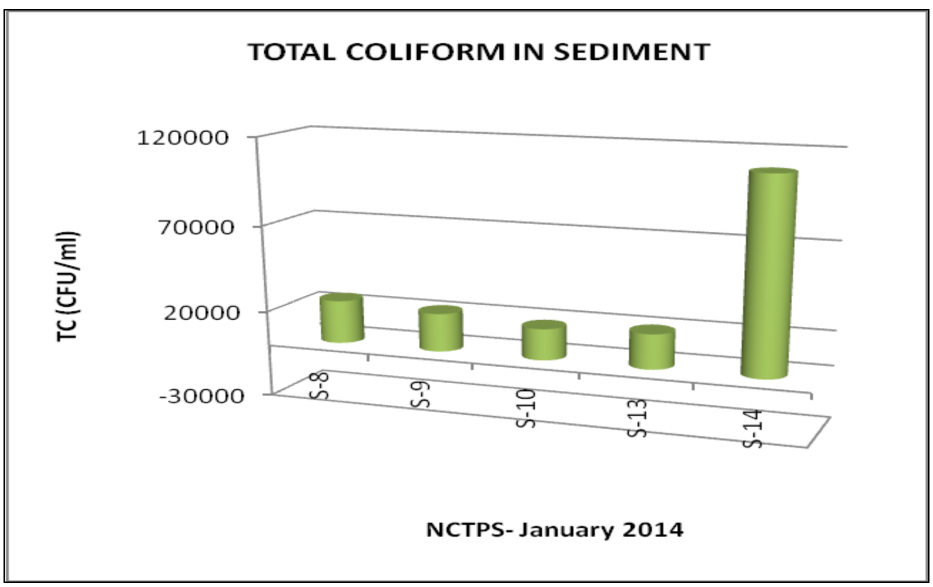
TABLE – 3.42

Microbial Populations in Sediment

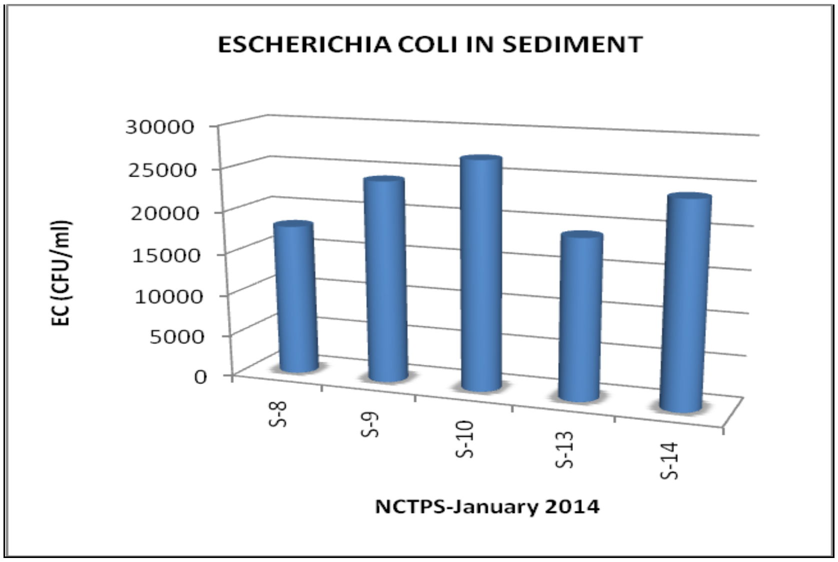
Sl. No.	St. Code	TVC	TC	EC	FC	SF
1.	S-1	Concrete bottom				
2.	S-2	Concrete bottom				
3.	S- 3	Concrete bottom				
4.	S-4	Concrete bottom				
5.	S-5	Concrete bottom				
6.	S-6	Concrete bottom				
7.	S-7	Concrete bottom				
8.	S-8	$19 x10^5$	$25 x10^3$	$18 x10^3$	$16 x10^3$	$20 x10^2$
9.	S-9	$26 x10^5$	$22 x10^3$	$24 x10^3$	$21 x10^3$	$13 x10^2$
10.	S-10	$18 x10^5$	$18 x10^3$	$27x10^3$	$19 x10^3$	$11 x10^2$
11.	S-11	Concrete bottom				
12.	S-12	Concrete bottom				
13.	S-13	$12 x10^5$	$20 x10^3$	$19 x10^3$	$18 x10^3$	$14 x10^2$
14.	S-14	$14 x10^5$	$11x10^4$	$24 x10^3$	$17x10^3$	$14 x10^2$



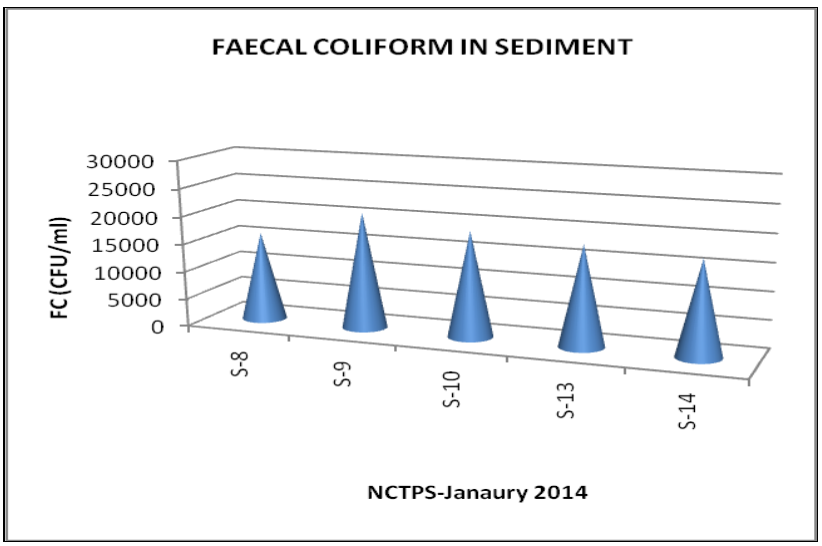
The Total Viable Count (TVC) varied from $12x10^5$ to $26x10^5$ CFU/g with maximum at S9 and minimum at S-13 of sediment samples collected in North Chennai Thermal Power Station areas.



The Total Coliform varied from $12x10^4$ to $26x10^4$ CFU/g with maximum at S-10 and minimum at S-14.



The Escherichia coli Bacteria in sediment sample varied between $10x10^3$ to $24x10^3$ CFU/g with maximum at S-13 and minimum at S-14 during this survey.



The Streptococcus faecalis varied between 8x103 to 25x103 CFU/g. The minimum was recorded at S-13 and the maximum value was observed at S-10 during January 2014 (Table 3.42).

Biological Characteristics

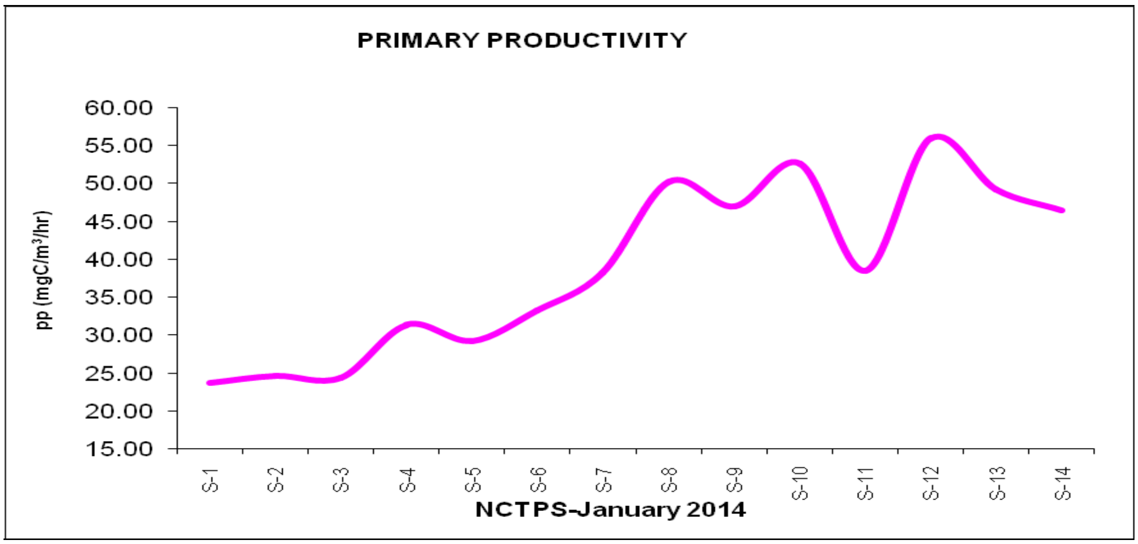
TABLE – 3.43
Biological Characteristics

S. No.	Station Code	PP (mg C/m3/hr)	Chl a (mg/m3)	Phaeopigment (mg/m3)	TB (ml/100m3)
1.	S-1	23.711	0.299	0.166	37.848
2.	S-2	24.680	0.328	0.183	44.856
3.	S- 3	24.426	0.318	0.176	32.328
4.	S-4	31.364	0.398	0.221	38.628
5.	S-5	29.249	0.359	0.199	43.740
6.	S-6	33.268	0.410	0.228	41.964
7.	S-7	38.210	0.449	0.250	43.692
8.	S-8	50.228	0.554	0.308	41.424
9.	S-9	46.974	0.531	0.295	51.828
10.	S-10	52.650	0.608	0.338	45.948
11.	S-11	38.555	0.468	0.260	50.580

12.	S-12	55.954	0.639	0.355	50.844
13.	S-13	49.276	0.541	0.301	40.296
14.	S-14	46.435	0.518	0.288	38.004

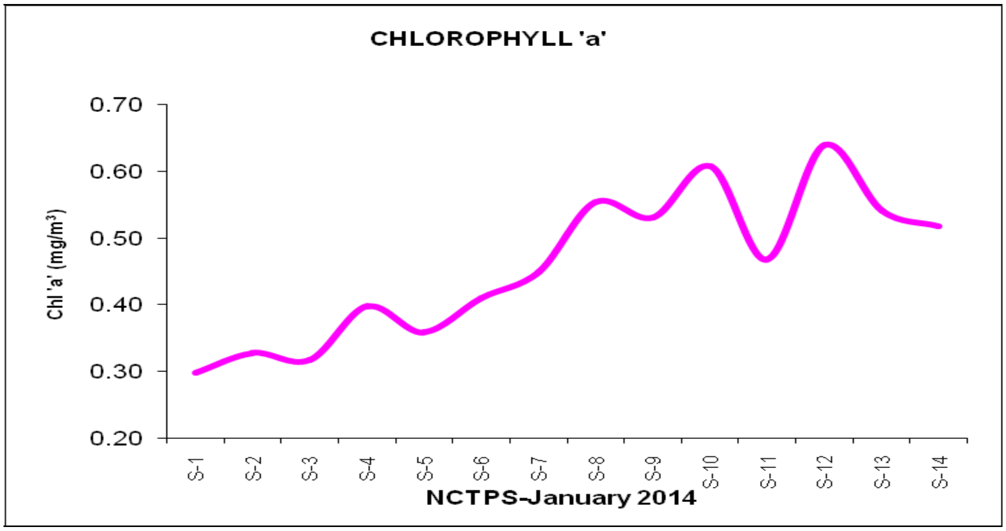
Primary Productivity (mgC/m3/hr)

In the present study, the primary productivity in water samples varied from 23.71 to 55.95 (mgC/m3/hr). The minimum was observed at S-1 and the maximum was recorded at S-12 (Table-3.43).



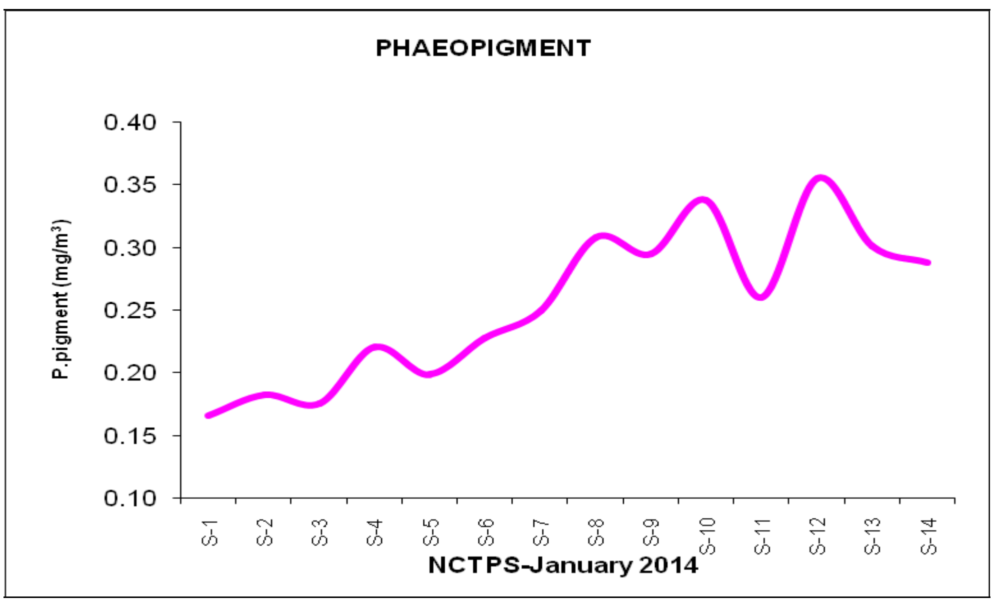
Chlorophyll 'a' (mg/m3)

The chlorophyll 'a' level fluctuated between 0.30 to 0.64 mg/m3. The maximum chlorophyll 'a' was recorded at S-12 and the minimum at S-1 (Table-3.43).



Phaeopigment (mg/m3)

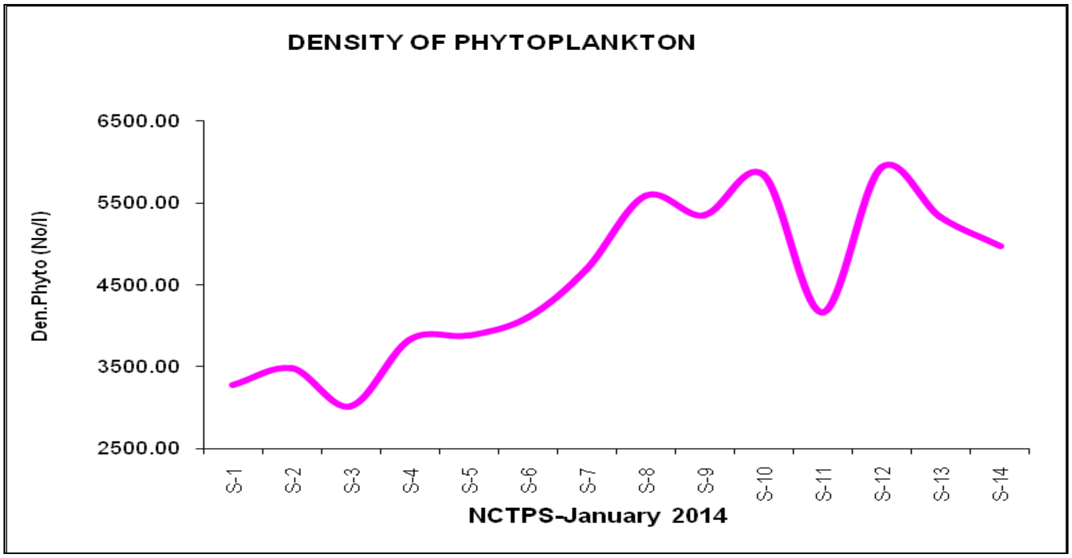
In the present study, the phaeopigment in water sample varied from 0.17 to 0.36 (mg/m3) with maximum in S-12 and minimum in S-1 was recorded (Table 3.43).



Plankton

Phytoplankton

The phytoplankton density varied from 3,017 to 5,935 No/l with maximum at S-12 and minimum in S-3 (Table-3.44).



A total of 24 phytoplankton species were identified from the samples collected. During this study period, species belonging to groups namely diatoms, and dinoflagellates. Of these, diatoms were found to be the dominant group with 22 species in each Station. Dinoflagellates formed next group with 2 species and in all the Stations. Among the diatoms, Asterionella glacialis, Chaetoceros affinis, Nitzschia longissima Pleurosigma normanii, Rhizosolenia alata, Skeletonema costatum and Triceratium favus were found to be common species occurring in all the samples collected in various Stations. Coming to dinoflagellates, Ceratium favus, and Ceratium sp. showed consistency in their occurrence in different Stations of Thermal Power Station waters.

TABLE-3.44

Phytoplankton

Sl. No	Name of the Species	No/l			
		S-1	S-2	S-3	S-4
22.	Coscinodiscus radiatus	37	56	28	44
23.	Skeletonema costatum	592	745	807	1108
24.	Planktoniella sol	164	153	124	182
25.	Cyclotella sp.	123	149	*	210
26.	Triceratium favus	53	59	52	68
27.	Chaetoceros currvisetus	315	258	244	210
28.	Chaetoceros affinis	320	221	*	13
29.	Chaetoceros coarctatus	227	230	234	300
30.	Odontella mobiliensis	43	50	38	47
31.	Rhizosolenia styliformis	51	54	50	40
32.	Pleurosigma elongatum	69	*	*	9
33.	Pleurosigma normanii	*	78	*	80
34.	Pleurosigma directum	*	*	77	
35.	Nitzschia longissima	94	101	93	58
36.	Navicula vanhoffeni	170	171	123	149
37.	Asterionella glacialis	856	910	995	1100
38.	Ceratium macroceros		59	53	75
39.	Ceratium furca	62	77	*	28

40.	Ceratium longipes	61	52	58	52
41.	Ceratium bucephalum	45	*	41	56
42.	Protoperidinium oceanicum	*	59	*	*
	Total	3282	3482	3017	3829

* - Organisms not present

Sl. No.	Name of the Species	No/l				
		S-5	S-6	S-7	S-8	S-9
40.	Coscinodiscus radiatus	47	40	43	41	38
41.	Skeletonema costatum	1027	1100	1098	1224	1450
42.	Planktoniella sol	159	138	133	136	99
43.	Triceratium favus	56	54	60	54	64
44.	Chaetoceros currvisetus	185	180	580	631	402
45.	Chaetoceros coarctatus	238	228	232	363	226
46.	Odontella mobiliensis	46	42	59	46	40
47.	Leptocylindrus danicus	172	145	*	*	40
48.	Rhizosolenia styliformis	50	52	51	41	50
49.	Rhizosolenia alata	127	235	*	*	47
50.	Pleurosigma elongatum	242	*	*	82	*
51.	Pleurosigma normanii	66	54	86	*	55

52.	Nitzschia longissima	97	80	68	75	91
53.	Navicula vanhoffeni	94	103	95	163	74
54.	Asterionella glacialis	956	1500	2026	2524	2500
55.	Ceratium macroceros	56	53	52	62	55
56.	Ceratium furca	58	62		47	47
57.	Ceratium longipes	150	*	60	54	28
58.	Ceratium bucephalum	57	42	51	43	45
	Total	3883	4108	4694	5586	5351

* - Organisms not present

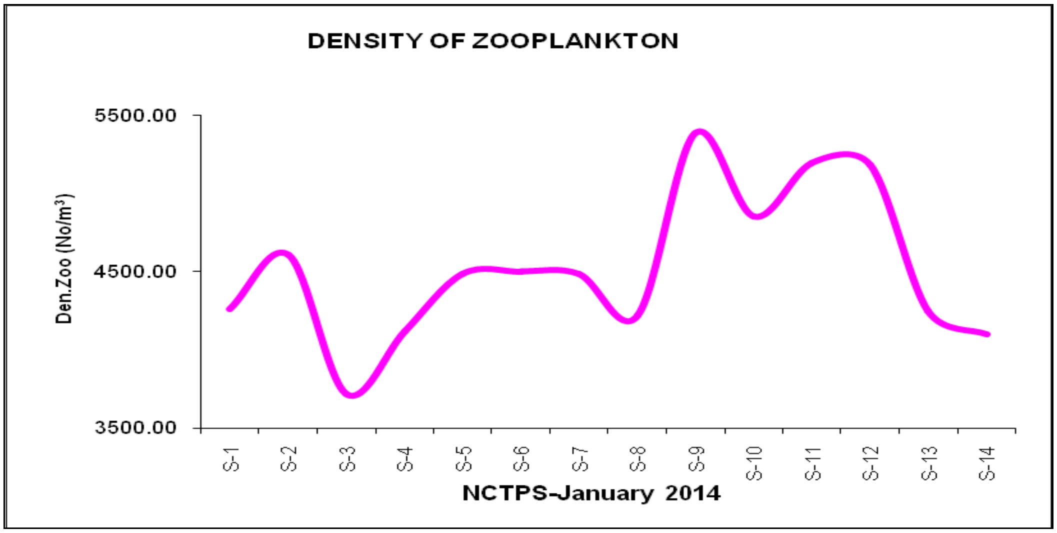
Sl. No	Name of the Species	No/l				
		S-10	S-11	S-12	S-13	S-14
41.	Coscinodiscus radiatus	42	32	39	37	60
42.	Skeletonema costatum	1711	1100	1400	1385	1325
43.	Planktoniella sol	114	127	105	91	95
44.	Cyclotella sp.	15	168	162	65	*
45.	Triceratium sp.	21	*	25	*	45
46.	Triceratium favus	60	54	69	55	*
47.	Chaetoceros currvisetus	335	146	653	382	395
48.	Chaetoceros affinis		140	*	*	*
49.	Chaetoceros coarctatus	242	*	517	358	304

50.	Odontella mobiliensis	44	36	47	46	43
51.	Rhizosolenia styliformis	200	45	45	50	44
52.	Rhizosolenia alata	40	*	*	*	*
53.	Pleurosigma normanii	86	70	88	91	78
54.	Nitzschia longissima	104	*	66	64	75
55.	Navicula vanhoffeni	85	122	100	82	*
56.	Asterionella glacialis	2500	1950	2450	2450	2351
57.	Ceratium macroceros	59	49	56	65	52
58.	Ceratium furca	57	40	66	55	*
59.	Ceratium longipes	80	45	*	*	60
60.	Ceratium bucephalum	47	37	47	56	44
	Total	5842	4161	5935	5332	4971

* - Organisms not present

Zooplankton

Likewise in zooplankton density varied from 3,718 to 5,388 No/m3 with maximum in S-9 and minimum in S-3 (Table-3.45).



In the present study, 3 groups of zooplankton namely, calanoids, cyclopoids, and harpacticoids and 3 groups of micro zooplankton namely, foraminiferans, spirotricha and larval forms and other group of rotatoria, appenticularia of various zooplankton were recorded. Among the zooplankton, calanoida were found to be the dominant group with 6 species; cyclopoida came next in the order with 5 species and harpacticoida also came dominant group with 6 species, coming to spirotricha, larval forms, foraminiferans, appenticularia and rotatoria came last with 6, 3, 1, 1, and1 species respectively.

Among the Calanoida, Acartia danae, Acartia spinicauda, Cyclopoida, Oithona brevicornis, O.similis Copilia vitrea Corycaeus catus Corycaeus danae Harpacticoida,

Labidocera pavo Longipedia weberi Macrosetella gracilis Metis jousseaumei Microsetella norvegica Microsetella rosea were found to be the frequenters in the collections. In micro zooplankton, larval forms, Barnacle nauplii, Bivalve veliger, Copepod nauplii, Crustacean nauplii and Polychaete larvae were found to be common in all the Stations.

TABLE-3.45
Zooplankton

Sl. No.	Name of the Species	No/m3			
		S-1	S-2	S-3	S-4
39.	Brachionus rubens	184	87	95	78
40.	Paracalanus parvus	255	377	257	202
41.	Acartia danae	247	113	164	255
42.	Acartia spinicauda	342	553	334	290
43.	Oithona brevicornis	184	201	226	184
44.	Oithona similis	*	280	180	379
45.	Corycaeus catus	271	183	95	*
46.	Copilia vitrea	*		*	184
47.	Microsetella rosea	*	201	*	*
48.	Microsetella norvegica	*		334	370
49.	Macrosetella gracilis	342	263	102	*
50.	Euterpina acutifrons	239	201	241	361
51.	Oikopleura parva	231	271	102	281
52.	Shrimp zoea	*	*	79	*
53.	Globigernia bulloides	184	*	102	*
54.	Tintinnopsis tubulosa	*	*	257	175
55.	Tintinnopsis cylindrica	104	*	*	*

56.	Tintinnopsis beroidea	255	289	*	*
57.	Tintinnopsis butzschi	*	192	*	*
58.	Favella philipiensis	184		172	*
59.	Favella brevis	263	201		273
60.	Bivalve veliger	*	113	180	175
61.	Copepod nauplii	976	1081	798	909
	Total	4261	4606	3718	4116

* - Organisms not present

Sl. No.	Name of the Species	No/m3				
		S-5	S-6	S-7	S-8	S-9
21.	Brachionus rubens	*	104	74	109	158
22.	Eucalanus sp.	*	125	*		106
23.	Paracalanus parvus	185	343	256	260	250
24.	Nannocalanus minor	105	195	352	276	245
25.	Labidocera pavo	*	15	*		106
26.	Acartia danae	177	263	190	193	253
27.	Acartia spinicauda	505	422	429	421	351
28.	Oithona brevicornis	249	184	272	360	245
29.	Oithona similis	425	255	437	528	595
30.	Corycaeus catus	185	247	173	276	175
31.	Longipedia weberi	*	104	107		190

32.	Microsetella norvegica	265	240	182	193	243
33.	Euterpina acutifrons	345	422	421	268	514
34.	Oikopleura parva	241	247	256	276	193
35.	Shrimp zoea	185	104	*		188
36.	Tintinnopsis tubulosa	233	184	*	121	254
37.	Tintinnopsis beroidea	169		107	109	106
38.	Favella philipiensis	161	125	272	158	260
39.	Bivalve veliger	153	104	107	109	106
40.	Copepod nauplii	906	819	849	563	850
	Total	4489	4502	4484	4220	5388

* - Organisms not present

Sl. No.	Name of the Species	No/m3				
		S-10	S-11	S-12	S-13	S-14
46.	Brachionus rubens	194	260	272	109	104
47.	Eucalanus sp.	*	109	*	345	*
48.	Paracalanus parvus	279	193	107	278	184
49.	Nannocalanus minor	194	*	*	109	263
50.	Labidocera pavo	*	109	190	*	*
51.	Acartia danae	194	276	272	*	168
52.	Acartia spinicauda	364	427	437	446	501
53.	Oithona brevicornis	279	360	190	421	96

54.	Oithona similis	448	528	355	446	421
55.	Corycaeus danae	*	109	*	*	*
56.	Corycaeus catus	194	276	190	109	255
57.	Microsetella norvegica	279	419	338	193	176
58.	Euterpina acutifrons	364	276	437	261	263
59.	Metis jousseaumei	194	193	*	*	*
60.	Oikopleura parva	279	*	264	*	176
61.	Shrimp zoea	110	109	107	109	*
62.	Tintinnopsis tubulosa	194	318	355	252	255
63.	Tintinnopsis beroidea	110	*	190		184
64.	Favella philipiensis	279	193	272	193	263
65.	Favella brevis	*	235	*	*	104
66.	Bivalve veliger	110	109	190	109	184
67.	Copepod nauplii	787	696	1014	867	501
	Total	4852	5195	5180	4247	4098

* - Organisms not present

Population density

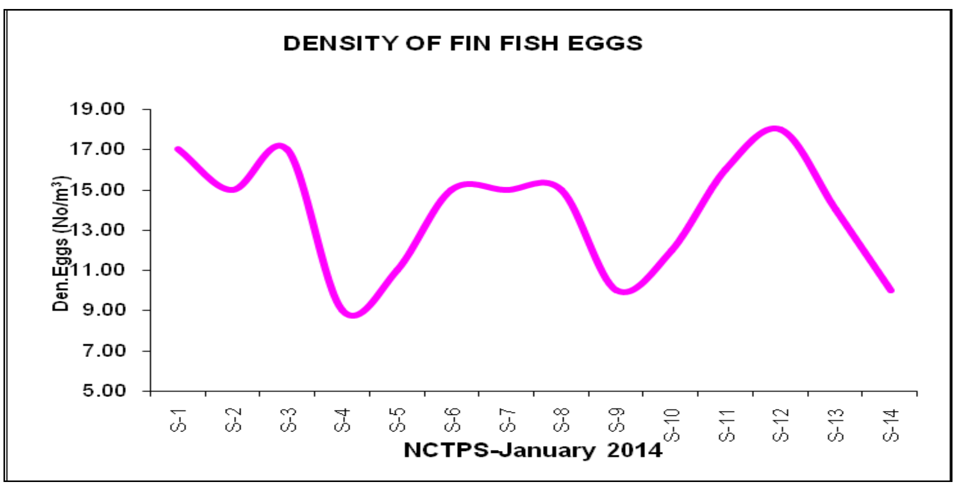
The phytoplankton density varied from 703to 3398 No/l with maximum at S-7 and minimum in S-11 (Table-3.44).Likewise in zooplankton density varied from 3025 to 4884No./m3 with maximum in S-2and minimum in S-11 (Table-3.45).

Percentage composition

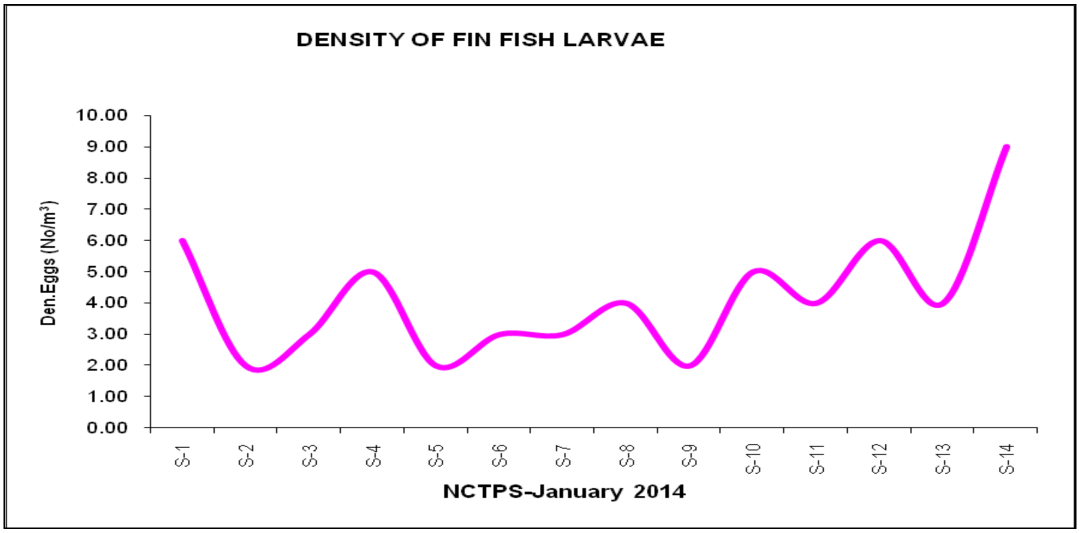
When the results of percentage composition of phytoplankton were viewed, diatoms constituted the maximum with 91.67% to the total followed by dinoflagellates with 8.33% of the total. Likewise, in zooplankton, Calanoids were the major group contributing to over (20.68%), Cyclopoids contributed (17.24%) followed by Harpacticoids (20.68%) and tiny group of Foraminiferans (3.44%), Spirotricha (20.68%) larval forms (10.34%) and other group of Rotatoria (3.44%) and Appenticularia (3.44%).

Finfish Eggs and Larvae

The finfish eggs density in the study region ranged from 9 to 18 No/m3. The minimum density was recorded at S-4 and the maximum density was observed at S-12. In the present investigation, 11 species of finfish eggs were recorded from all the stations monitored. The Mugil cephalus and Sardinella longiceps were found to be the dominant forms (Table 3.46).



The finfish larvae observed from 2 to 9 No/m3. The maximum number of finfish larvae observed at S14 and the minimum number of finfish larvae recorded at S-2, S-5 and S-9 respectively.



A total of 6 species of finfish larvae were identified from the study area with Mugil cephalus and Thryssa mystax dominating the populations (Table 3.47).

TABLE-3.46.

Finfish Eggs

Sl. No.	Name of the Species	No/m3			
		S-1	S-2	S-3	S-4
	Enraulidae				
1	Stolephorus indicus	1	1	*	1
2	Thryssa mystax	2	2	2	2
	Clupeidae				
1	Sardinella longiceps	4	2	5	1
	Chanidae				
1	Chanos chanos	1	2	2	1
	Mugilidae				

1	Mugil cephalus	3	3	2	2
2	Liza dussumieri	2	3	3	*
	Teraponidae				
1	Terapon jarbua	4	2	3	2
	Total	17	15	17	9

* - Organisms not present

Sl. No.	Name of the Species	No/m3				
		S-5	S-6	S-7	S-8	S-9
	Enraulidae					
1	Stolephorus indicus	3	2	1	1	1
2	Thryssa mystax	2	3	2	1	2
	Clupeidae					
1	Sardinella longiceps	1	3	4	4	2
	Chanidae					
1	Chanos chanos	1	2	2	3	1
	Mugilidae					
1	Mugil cephalus	2	3	3	2	3
	Teraponidae					
1	Terapon jarbua	2	2	3	4	1
	Total	11	15	15	15	10

* - Organisms not present

Sl. No.	Name of the Species	No/m3				
		S-10	S-11	S-12	S-13	S-14
	Enraulidae					
1	Thryssa dussumieri	*	1	1	2	1
2	Thryssa hamiltonii	3	4	4	*	*
3	Thryssa mystax	*	*	*	3	1
	Clupeidae					
1	Sardinella leiogaster	2	4	4	*	*
2	Sardinella longiceps	1	*	*	2	2
	Mugilidae					
1	Mugil cephalus	5	3	4	2	3
2	Liza tade	*	*	1	3	2
	Teraponidae					
1	Terapon jarbua	1	4	4	2	1
	Total	12	16	18	14	10

* - Organisms not present

TABLE-3.47.

Finfish Larvae

Sl. No.	Name of the Species	No/m3			
		S-1	S-2	S-3	S-4
	Clupeidae				
1	Sardinella longiceps	2	*	2	1
	Mugilidae				
1	Mugil cephalus	3	2	*	1
2	Liza dussumieri	1	*	*	1
	Teraponidae				
1	Terapon jarbua	*	*	1	2
	Total	6	2	3	5

Sl. No.	Name of the Species	No/m3				
		S-5	S-6	S-7	S-8	S-9
	Enraulidae					
1	Thryssa mystax	*	1	2	1	1
	Clupeidae					
1	Sardinella longiceps	1	1	*	*	*
	Mugilidae					
1	Mugil cephalus	1	1	1	2	1

	Teraponidae					
1	Terapon jarbua	*	*	*	1	*
	Total	2	3	3	4	2

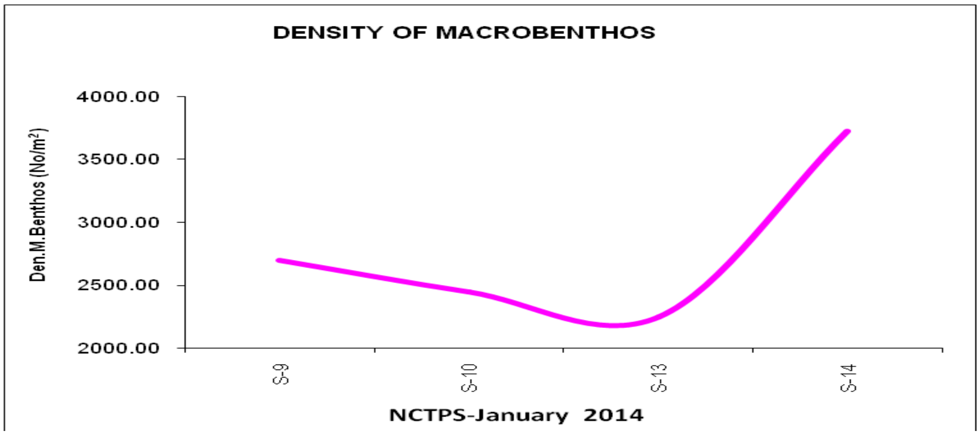
Sl. No.	Name of the Species	No/m3				
		S-10	S-11	S-12	S-13	S-14
	Enraulidae					
1	Thryssa mystax	1	*	3	1	1
	Clupeidae					
1	Sardinella longiceps	1	2	1	*	2
	Mugilidae					
1	Mugil cephalus	2	1	1	2	3
2	Liza tade	*	*	*	*	2
	Teraponidae					
1	Terapon jarbua	1	1	1	1	1
	Total	5	4	6	4	9

* - Organisms not present

Benthos

Macrobenthos

Population density



The population density of macrobenthos varied from 2,250 to 3,725 No/m2 with maximum at S-12 and minimum at S-6 (Table 3.48).

A total of 45 species of macro fauna were recorded in the present study areas. Of these, Polychaetes topped the list with 19 species. Bivalves were found with 5 species. Gastropods were found to be the next dominant group in the order of abundance with 7 species. Amphipods came next with 7 species and Isopods were found with 7 species.

Comparing the Stations the maximum number of species was recorded at Station-12 and minimum in Station-6. Similarly, maximum population density of macro benthic organism was recorded at Station-12 and minimum at Station-6 of (TPS) Thermal power Station waters.

During this investigation, five groups of organisms namely Polychaetes, Bivalves, Gastropods, Amphipods and Isopods were recorded. Of these, Polychaetes constituted the dominant group followed by Bivalves, Gastropods, Amphipods and Isopods. Among the Polychaetes, Ancistrosyllis parva, Armandia longicaudata, Cirratulus concinnus, Dorvillea gardineri, Exogone clavator, Nephtys sphaerocirrata, Notomastus aberans, Phyllodoce tubicola, Pisionidens indica, Polydora ciliate, Prionospio capensis, Sphaerosyllis erinaceu, Nephtys homgergi and Eunice Siciliensis were found to be the most commonly occurring species in the samples collected in (TPS) Thermal power Station waters. Coming to Bivalves, Anadara veligers, Cardium veligers, Donax veligers, Meretrix veligers Perna viridis. Gastropods Nassarius veligers, Littorina veligers, Bullia veligers, Cerithedia cingulata, Natica veligers, Oliva veligers, Turritella veligers were found to be common species in the collection. With respect to Amphipods namely Gammarus sp., Grandidierella sp., Ampithoe romondi, A. rubricate, Caprella mendax Urothoe sp. Phaxocephalus holbolli. Isopods such as, Angeliera phreaticola, Jaeropsis beuriosi, Calabozoa pellucid, Paragnathia formica, Anthura gracilis, Sphaeroma serratum, Microjaera anisopoda showed consistency in their occurrence in the samples collected.

TABLE-3.48.

Macrobenthos

Sl. No.	Name of the Species	No/m2			
		S-1	S-2	S-3	S-4
	Polychaetes	Unable to collect samples due to concrete channel			
1.	Ancistrosyllis parva			75	*
2.	Armandia longicaudata			*	100
3.	Armandia intermedia			50	*
4.	Cirratulus concinnus			150	175
5.	Cirratulus africanus			100	50
6.	Drilonereis falcata			*	100

7.	Exogone clavator		150	*
8.	Nephtys sphaerocirrata		*	50
9.	Notomastus aberans		50	*
10.	Phyllodoce tubicola		175	125
11.	Pisionidens indica		200	250
12.	Polydora ciliata		*	75
13.	Prionospio capensis		50	*
14.	Prionospio cirrifera		*	50
15.	Sphaerosyllis erinaceu		*	75
16.	Nephtys homgergi		75	*
17.	Eunice Siciliensis		*	50
	Bivalves			
1.	Anadara veligers		25	25
2.	Cardium veligers		50	75
3.	Donax veligers		75	*
4.	Meretrix veligers		*	75
5.	Perna viridis		100	50
	Gastropods			
1.	Nassarius veligers		25	25
2.	Littorina veligers		100	50
3.	Bullia veligers		75	150
4.	Cerithedia cingulata		250	125
5.	Natica veligers		*	50
6.	Oliva veligers		175	125
7.	Turritella veligers		*	75

* - Organisms not present

Sl. No.	Name of the Species	No/m2			
		S-1	S-2	S-3	S-4
	Amphipods	Unable to collect samples due to concrete channel			
1.	Gammarus sp.			25	25
2.	Grandidierella sp.			50	75
3.	Ampithoe romondi			175	100
4.	Ampithoe rubricata			100	75
5.	Caprella mendax			*	75
6.	Urothoe sp.			150	100
7.	Phaxocephalus holbolli			100	25
	Isopods				
1.	Angeliera phreaticola			25	50
2.	Jaeropsis beuriosi			50	75
3.	Calabozoa pellucida			100	*
4.	Paragnathia formica			*	125
5.	Anthura gracilis			50	*
6.	Sphaeroma serratum			*	25
7.	Microjaera anisopoda			100	25
	Total			2875	2700

* - Organisms not present

Sl. No.	Name of the Species	No/m2				
		S-5	S-6	S-7	S-8	S-9
	Polychaetes					
1.	Ancistrosyllis parva	100	*	Unable to collect sediment samples due to concrete channel		
2.	Armandia longicaudata	*	50			
3.	Armandia intermedia	50	*			
4.	Cirratulus concinnus	*	75			
5.	Cirratulus africanus	100	75			
6.	Dorvillea gardineri	*	*			
7.	Drilonereis falcata	75	100			
8.	Exogone clavator	100	*			
9.	Nephtys sphaerocirrata	*	75			
10.	Notomastus aberans	100	*			
11.	Phyllodoce tubicola	*	75			
12.	Pisionidens indica	150	150			
13.	Polydora ciliata	50	75			
14.	Prionospio capensis	75	50			
15.	Nephtys homgergi	50	50			
16.	Eunice Siciliensis	*	*			
	Bivalves					
1.	Anadara veligers	75	50			
2.	Cardium veligers	25	75			
3.	Donax veligers	150	25			

4.	Meretrix veligers	75	100	
5.	Perna viridis	*	50	
	Gastropods			
1.	Nassarius veligers	100	75	
2.	Littorina veligers	25	25	
3.	Bullia veligers	50	100	
4.	Cerithedia cingulata	125	50	
5.	Oliva veligers	75	*	
6.	Turritella veligers	100	75	

Sl. No.	Name of the Species	No/m2				
		S-5	S-6	S-7	S-8	S-9
	Amphipods					
1.	Gammarus sp.	25	25			
2.	Grandidierella sp.	50	100			
3.	Ampithoe romondi	75	75			
4.	Ampithoe rubricata	100	*			
5.	Caprella mendax	*	150			
6.	Urothoe sp.	150	*			
7.	Phaxocephalus holbolli	50	50			
	Isopods					
1.	Angeliera phreaticola	25	150			

2.	Jaeropsis beuriosi	100	25			
3.	Calabozoa pellucida	50	50			
4.	Paragnathia formica	*	75			
5.	Anthura gracilis	75	*			
6.	Sphaeroma serratum	100	50			
7.	Microjaera anisopoda	*	100			
	Total	2450	2250			

* - Organisms not present

Sl. No.	Name of the Species	No/m2				
		S-10	S-11	S-12	S-13	S-14
	Polychaetes	Unable to collect sediment samples due to concrete channel			Unable to collect sediment samples due to concrete channel	
1.	Ancistrosyllis parva			50		
2.	Armandia longicaudata			*		
3.	Armandia intermedia			75		
4.	Cirratulus concinnus			*		
5.	Cirratulus chrysoderma			50		
6.	Cirratulus africanus			*		
7.	Dorvillea gardineri			75		
8.	Drilonereis falcata			*		
9.	Exogone clavator			50		
10.	Nephtys sphaerocirrata			*		

11.	Notomastus aberans		50	
12.	Phyllodoce tubicola		*	
13.	Pisionidens indica		175	
14.	Polydora ciliata		*	
15.	Prionospio capensis		75	
16.	Prionospio cirrifera		*	
17.	Sphaerosyllis erinaceu		100	
18.	Nephtys homgergi		*	
19.	Eunice Siciliensis		50	
	Bivalves		*	
1.	Anadara veligers		25	
2.	Cardium veligers		100	
3.	Donax veligers		*	
4.	Meretrix veligers		175	
5.	Perna viridis		75	
	Gastropods		25	
1.	Nassarius veligers		100	
2.	Littorina veligers		50	
3.	Bullia veligers		*	
4.	Cerithedia cingulata		1675	

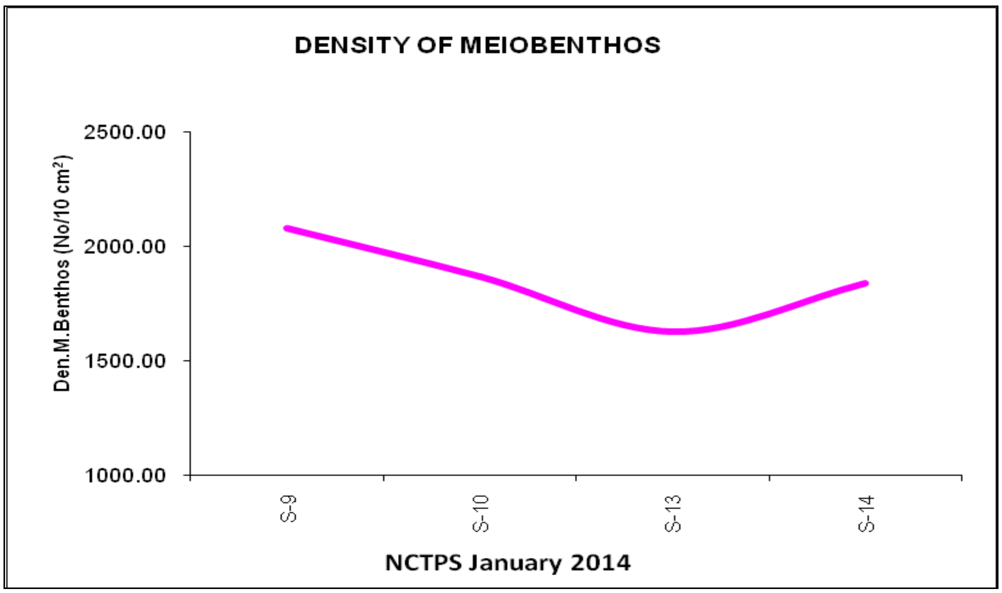
Sl. No.	Name of the Species	No/m2				
		S-10	S-11	S-12	S-13	S-14
5.	Natica veligers	Unable to collect sediment samples due to concrete channel		*	Unable to collect sediment samples due to concrete channel	
6.	Oliva veligers			100		
7.	Turritella veligers			*		
	Amphipods					
1.	Gammarus sp.			25		
2.	Grandidierella sp.			75		
3.	Ampithoe romondi			*		
4.	Ampithoe rubricata			100		
5.	Caprella mendax			*		
6.	Urothoe sp.			150		
7.	Phaxocephalus holbolli			*		
	Isopods					
1.	Angeliera phreaticola			25		
2.	Jaeropsis beuriosi			50		
3.	Calabozoa pellucida			*		
4.	Paragnathia formica			75		
5.	Anthura gracilis			100		
6.	Sphaeroma serratum			*		
7.	Microjaera anisopoda			50		
	Total			3725		

* - Organisms not present

Meiobenthos

Population density

The population density of meibenthos varied from 1,630 to 2,081 No/10 cm2 with maximum at S-4 and minimum at S-6 during the present study period (Table 3.49).



In the present study, 73 species of meio-benthic fauna were recorded in (NCTPS) thermal power Station waters. Of these, Foraminiferans topped the list with 31 species. Nematodes were found to be the next dominant group in the order of abundance with 13 species. Ostracodes and Harpacticoids came next with 8 and 7 species respectively. Coming to Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera came last with 5, 4, 3, 1 and 1 species respectively.

Comparing the stations the maximum number of species was recorded in Station-4 and minimum in S-6 Similarly, maximum population density of meio-benthic organism was recorded at S-4 and minimum at S-12 of (NCTPS) thermal power Station waters.

Altogether nine groups of meio-benthic organisms namely Foraminiferans, Nematodes Ostracodes, Harpacticoids, Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera were recorded. Of these, Foraminiferans were found to be dominant group followed by Nematodes, Ostracodes, Harpacticoids, Tanaidacea, Archiannelids, Cumacea, Gastrotricha and Rotifera. Among the Foraminiferans Ammonia beccarii, Amphisorus sp., Asterorotalia trispinosa, Bolivia abbreviate, Cornoboides advena, Cymbaloporetta bradyi, Rotalia calcar, Ammonia tepida, Ammonia elegans, Asterorotalia inflate, and Leptohalysis scotti. Nematodes Daptonema conicum, Desmoscolex falcatus, Sipirinia sp. Microlaimus sp were found to be the common species in the samples collected in various Stations with respect to Ostracodes, Conchoecia sp. Cyprideis sp. Keijella oertlii, Tanella estuarii, Philomedes globosus were found to occur all the stations. Coming to Harpacticoids, Apodopsyllus vermiculiformis, Canuella sp., Diarthrodes sp. Phyllothalestris mysis, Laophonte thoracica, Stenhelia sp. was found to be common in the collection. with respect to Tanaidacea namely Sphaerosyllis sp. Pogurapseudes largoensis, Heterotanais oerstedi, Archiannelids Polygordius sp. Protodrilus helgolandicus, Protodrilus brevis, Diurodrilus sp. with respect to the Cumacea Campylaspis sp. Gynodiastylis sp. Nannastacus sp. Gastrotricha Cephalodasys sp. and Rotifera such as Rotaria rotatoria, Campylaspis sp., Gynodiastylis sp., and Cephalodasys sp., showed consistency in their occurrence in the samples collected

TABLE-3.49

Meiobenthos

Sl. No.	Name of the Species	No/10cm2			
		S-1	S-2	S-3	S--4
	Nematodes				
1.	Daptonema conicum	Unable to collect		33	63

2.	Desmoscolex falcatus	sediment samples due to concrete channel	20	22
3.	Enoploides sp.		40	46
4.	Gonionchus sp.		28	55
5.	Pandolaimus sp.		45	69
6.	Polygastrophora sp.		42	48
7.	Pselionema sp.		17	25
8.	Quadricoma sp.		9	11
9.	Viscosia sp.		31	25
10.	Diodontolaimus sp.		18	17
11.	Neochromodora sp.		127	138
12.	Sipirinia sp.		145	123
13.	Microlaimus sp.		80	72
	Foraminiferans			
1.	Ammonia beccarii		28	29
2.	Amphisorus sp.		10	12
3.	Asterorotalia trispinosa		27	45
4.	Bolivia abbreviata		21	58
5.	Cornoboides advena		33	43
6.	Cymbaloporetta bradyi		12	11
7.	Discorbis sp.		37	63
8.	Eponides repandus		32	45
9.	Globigerinoides glutinata		22	22
10.	Hauerina miocenica		10	*
11.	Lagena striata		9	8
12.	Lagena marginata		*	10

13.	Loxostoma perrectum			8	*
14.	Neoconorbina crustata			11	11
15.	Nonion depressulum			30	27
16.	Oridosalis umbonatus			22	49
17.	Quinqueloculina sp.			40	58
18.	Rosalina bertheloti			18	26
19.	Rosalina globularis			30	49

* - Organisms not present

Sl. No.	Name of the Species	No/10cm2			
		S-1	S-2	S-3	S--4
20.	Rotalia calcar			17	19
21.	Ammonia tepida			53	47
22.	Ammonia elegans			20	33
23.	Asterorotalia inflata			18	20
24.	Leptohalysis scotti			17	23
25.	Lagena hexaona			12	7
26.	Rosalina lee			25	55
27.	Cancris indicus			20	21
28.	Cancris unicatus			9	15
29.	Spiroloculina sp.			30	53
30.	Textularia agglutinans			42	42
31.	Triloculina austriaca			18	20
	Gastrotricha				

1.	Cephalodasys sp.		7	11
	Cumacea			
1.	Campylaspis sp.		8	*
2.	Gynodiastylis sp.		10	11
	Harpacticoids			
1.	Apodopsyllus vermiculiformis		20	23
2.	Canuella sp.		15	22
3.	Diarthrodes sp.		11	11
4.	Laophonte thoracica		8	10
5.	Stenhelia sp.		17	18
6.	Tisbe furcata		12	12
	Ostrocodes			
1.	Conchoecia sp.		28	42
2.	Cyprideis sp.		18	19
3.	Keijella oertlii		12	11
4.	Leptocythere sp.		21	25
5.	Tanella indica		11	12
6.	Tanella kingmaii		7	10
7.	Tanella estuarii		9	11
8.	Philomedes globosus		18	21
	Archiannelids			
1.	Polygordius sp.		28	22

* - Organisms not present

Sl. No.	Name of the Species	No/10cm2			
		S-1	S-2	S-3	S--4
2.	Protodrilus helgolandicus			12	11
3.	Protodrilus brevis			8	9
4.	Diurodrilus sp.			*	6
	Rotifera				
1.	Rotaria rotatoria			11	8
	Tanaidacea				
1.	Sphaerosyllis sp.			22	23
2.	Pogurapseudes largoensis			18	29
3.	Heterotanais oerstedi			20	21
4.	Apseudes setosus			15	33
5.	Apseudes sipinosus			12	15
	Total			1694	2081

* - Organisms not present

Sl. No.	Name of the Species	No/10cm2				
		S-5	S-6	S-7	S-8	S-9
	Nematodes					
1.	Daptonema conicum	38	45	Unable to collect sediment samples due to concrete channel		
2.	Desmoscolex falcatus	22	16			
3.	Enoploides sp.	49	29			
4.	Gonionchus sp.	31	38			

5.	Pandolaimus sp.	58	46	
6.	Polygastrophora sp.	45	29	
7.	Pselionema sp.	13	16	
8.	Quadricoma sp.	11	10	
9.	Viscosia sp.	35	21	
10.	Diodontolaimus sp.	18	15	
11.	Neochromodora sp.	138	117	
12.	Spirinia sp.	159	129	
13.	Microlaimus sp.	91	65	
	Foraminiferans			
1.	Ammonia beccarii	28	33	
2.	Amphisorus sp.	11	6	
3.	Asterorotalia trispinosa	37	29	
4.	Bolivia abbreviata	26	33	
5.	Cornoboides advena	42	27	
6.	Cymbaloporetta bradyi	12	*	
7.	Discorbis sp.	49	58	
8.	Eponides repandus	33	46	
9.	Globigerinoides glutinata	22	18	
10.	Hauerina miocenica	9	*	
11.	Lagena striata	11	5	
12.	Lagena marginata	6	*	
13.	Loxostoma perrectum	10	7	

14.	Neoconorbina crustata	12	6			
15.	Nonion depressulum	35	43			
16.	Oridosalis umbonatus	22	25			

Sl. No.	Name of the Species	No/10cm2				
		S-5	S-6	S-7	S-8	S-9
17.	Quinqueloculina sp.	49	56	Unable to collect sediment samples due to concrete channel		
18.	Rosalina bertheloti	18	20			
19.	Rosalina globularis	35	25			
20.	Rotalia calcar	17	22			
21.	Ammonia tepida	55	63			
22.	Ammonia elegans	21	26			
23.	Asterorotalia inflata	22	19			
24.	Leptohalysis scotti	18	21			
25.	Lagena hexaona	*	8			
26.	Rosalina lee	28	32			
27.	Cancris indicus	20	16			
28.	Cancris unicatus	9	10			
29.	Spiroloculina sp.	31	36			
30.	Textularia agglutinans	45	28			
31.	Triloculina austriaca	18	19			
	Gastrotricha					

1.	Cephalodasys sp.	7	*			
	Cumacea					
1.	Campylaspis sp.	8	10			
2.	Gynodiastylis sp.	9	6			
3.	Nannastacus sp.	12	*			
	Harpacticoids					
1.	Apodopsyllus vermiculiformis	22	16			
2.	Canuella sp.	16	15			
3.	Diarthrodes sp.	11	10			
4.	Phyllothalestris mysis	8	*			
5.	Laophonte thoracica	*	6			
6.	Stenhelia sp.	19	13			
7.	Tisbe furcata	12	7			
	Ostrocodes					
1.	Conchoecia sp.	28	31			

Sl. No.	Name of the Species	No/10cm2				
		S-5	S-6	S-7	S-8	S-9
2.	Cyprideis sp.	18	22	Unable to collect sediment samples due to concrete channel		
3.	Keijella oertlii	12	6			
4.	Leptocythere sp.	21	17			
5.	Tanella indica	10	7			

6.	Tanella kingmaii	11	*			
7.	Tanella estuarii	8	5			
8.	Philomedes globosus	18	13			
	Archiannelids					
1.	Polygordius sp.	31	21			
2.	Protodrilus helgolandicus	12	7			
3.	Protodrilus brevis	8	*			
4.	Diurodrilus sp.	7	8			
	Rotifera					
1.	Rotaria rotatoria	11	10			
	Tanaidacea					
1.	Sphaerosyllis sp.	22	16			
2.	Pogurapseudes largoensis	18	21			
3.	Heterotanais oerstedi	23	19			
4.	Apseudes setosus	15	23			
5.	Apseudes sipinosus	12	8			
	Total	1868	1630			

* - Organisms not present

Sl. No.	Name of the Species	No/10 cm2				
		S-10	S-11	S-12	S-13	TPS-14

	Nematodes	Unable to collect sediment samples due to concrete channel		Unable to collect sediment samples due to concrete channel
1.	Daptonema conicum		58	
2.	Desmoscolex falcatus		20	
3.	Enoploides sp.		39	
4.	Gonionchus sp.		45	
5.	Pandolaimus sp.		56	
6.	Polygastrophora sp.		35	
7.	Pselionema sp.		21	
8.	Quadricoma sp.		12	
9.	Viscosia sp.		26	
10.	Diodontolaimus sp.		19	
11.	Neochromodora sp.		123	
12.	Sipirinia sp.		118	
13.	Microlaimus sp.		61	
	Foraminiferans			
1.	Ammonia beccarii		45	
2.	Amphisorus sp.		10	
3.	Asterorotalia trispinosa		39	
4.	Bolivia abbreviata		43	
5.	Cornoboides advena		40	
6.	Cymbaloporetta bradyi		8	
7.	Discorbis sp.		63	
8.	Eponides repandus		39	

9.	Globigerinoides glutinata			21		
10.	Hauerina miocenica			9		
11.	Lagena striata			6		
13.	Loxostoma perrectum			11		
14.	Neoconorbina crustata			10		
15.	Nonion depressulum			31		
16.	Oridosalis umbonatus			33		
17.	Quinqueloculina sp.			67		

Sl. No.	Name of the Species	No/10 cm2				
		S-10	S-11	S-12	S-13	S-14
18.	Rosalina bertheloti			22		
19.	Rosalina globularis	Unable to collect sediment samples due to concrete channel		40	Unable to collect sediment samples due to concrete channel	
20.	Rotalia calcar			20		
21.	Ammonia tepida			38		
22.	Ammonia elegans			31		
23.	Asterorotalia inflata			17		
24.	Leptohalysis scotti			22		
26.	Rosalina lee			38		
27.	Cancris indicus			23		
28.	Cancris unicatus			12		
29.	Spiroloculina sp.			45		

30.	Textularia agglutinans		31	
31.	Triloculina austriaca		23	
	Gastrotricha			
1.	Cephalodasys sp.		9	
	Cumacea			
1.	Campylaspis sp.		12	
2.	Gynodiastylis sp.		*	
3.	Nannastacus sp.		9	
	Harpacticoids			
1.	Apodopsyllus vermiculiformis		21	
2.	Canuella sp.		18	
3.	Diarthrodes sp.		8	
4.	Phyllothalestris mysis		6	
5.	Laophonte thoracica		*	
6.	Stenhelia sp.		22	
7.	Tisbe furcata		9	
	Ostrocodes			
1.	Conchoecia sp.		23	
2.	Cyprideis sp.		17	
3.	Keijella oertlii		8	

Sl. No.	Name of the Species	No/10 cm2				
		S-10	S-11	S-12	S-13	S-14
4.	Leptocythere sp.	Unable to collect sediment samples due to concrete channel		22	Unable to collect sediment samples due to concrete channel	
5.	Tanella indica			11		
6.	Tanella kingmaii			7		
7.	Tanella estuarii			9		
8.	Philomedes globosus			19		
	Archiannelids					
1.	Polygordius sp.			23		
2.	Protodrilus helgolandicus			9		
3.	Protodrilus brevis			7		
	Tanaidacea					
1.	Sphaerosyllis sp.			18		
2.	Pogurapseudes largoensis			23		
3.	Heterotanais oerstedi			22		
4.	Apseudes setosus			26		
5.	Apseudes sipinosus			11		
	Total			1839		

* - Organisms not present

3.6 SUMMARY OF BASELINE ENVIRONMENTAL STATUS

The Baseline Environmental Status of the proposed project area reveals the following:

The marine water quality and sediment analysis indicates that there is no coastal pollution in the project area

- The heavy metals analysed in the marine water and sediment samples indicate that all the parameters are well within the WHO standard.
- No rare, endangered or threatened Marine Floral and Faunal species is reported in and around project area
- The marine ecological survey of the project area indicates that the availability of primary Nutrient like Nitrogen and Phosphorus are available in moderate level and hence the project area has moderate productivity.
- The present study revealed predominantly the normal seasonal variations for this area under investigation. However, the outfall areas recorded slightly elevated temperature and the associated bilogical variables exihibited a decreasing trend interms of plankton and benthos.
- The various parameters monitored as part of marine ecological survey indicates that the project area is as good as any other normal coastal environment.

CHAPTER 4

ASSESSMENT OF IMPACTS AND MITIGATION MEASURES

4.1 GENERAL

This chapter aims to predict/forecast impacts of the activities that interfere with natural marine environment. The basis for determining the change in future environmental quality in Marine environment is the current baseline data collected through field studies. The predictions focused on activities, which are likely to have significant impacts due to intake and outfall discharge of the Ennore SEZ thermal power plant.

4.2 IMPACTS ON MARINE ENVIRONMENT

IIT, Madras has undertaken the study of thermal dispersion characteristics of the Ennore creek for the purpose of assessing the Marine Environmental impact due to the cooling water discharge for all the 5 power stations discharging into the existing pre-cooling water channel of the North Chennai Thermal Power station. The report of the same is enclosed as Annexure-II.Based on this study and marine ecological survey, the following impacts are described below:

Impact of Temperature changes

The pre cooling channel receives highest discharges of 2,00,000 cum at thermal differential of about 5^0C, the lowest discharge from stage III plant at 10,000 cum at 5^0C in temperature differential. Based on the Modeling study, it is observed that the stage I discharges dilutes the discharges from SEZ. The discharge at Stage I weir will have only 35.28^0C temperature at the rate of 1, 05,000 m^3/hr Cumec. This indicates that the region near the weir is at a temperature of about 35^0C due to the mixing of discharge from stage I weir and stage II weir. From this confluence in the region, the discharge starts loosing heat by means of turbulence mixing and wind induced surface flux. The water temperature becomes 1^0C less by the mid channel by which time the discharge from NTECL and stage III will interact. Finally the mixed water will have the outfall temperature about 33.3^{0}C, which is 3.3^{0}C above ambient temperature.

Hence it can be concluded that as the outfall temperature increase is only about 3.3^{0}C above ambient temperature which is below the stipulated limit of 5^{0}C. Hence there shall be negligible / insignificant impact on the marine organism.

Impact of salinity changes

The pre-cooling channel receives a total discharge of 3, 20,000 cumec. The brine is present only in the blow down discharges of 3 plants (Vallur,Ennore SEZ and NCTPS-III).The average salinity differential of these discharges is 10.39 g/l. However, when all the discharges get mixed, the outfall discharge will have insignificant salinity differential of only 1.53g/l. This is because of large once-through discharges of other plants. The corresponding dilution is 680. Usually, outfall designs must ensure dilution 50-100 within a short distance. In comparison, the present outfall will have already highly diluted discharge which will not have any impact on marine environment.

Changes to salinity can play a significant role in the growth and size of aquatic life and the marine species disturbance. Changes in the salinity can play two opposite roles on the marine organisms' existence; it can be of benefit for some of these organisms such as shellfish and at the same time can have an adverse impact on other species. The salinity observed in the project area ranges between 31 ppt to 33 ppt.

Water salinity changes may influence the development of species and the propagation activity and faster individual growth. The salinity around the outlet discharge is about 33 ppt, where as the average seawater salinity is 34.7ppt (CSIR-NIO). The salinity of seawater might not be remarkably different in profile from the surface to the bottom of the sea. A direct relationship can be made between the rates of change of environmental salinity and the effects on marine organisms such as population, size and behavior (Gunter, 1961). However, some of the sampling evidences for some fish species indicate that these fish are not very sensitive to the salinity fluctuation (Perez, 1969). It is belived that there is a direct negative correlation between the number of marine species and the salinity increment of the seawater (Gunter, 1961). There are very limited numbers of documented studies or experiments have been done about the impacts of salinity and temperature fluctuation on the flora species and on sedentary organism.

Hence it can be concluded that as the out fall salinity value is almost close to actual seawater salinity level, there shall be negligible / insignificant impact on the marine organism.

4.3 ENVIRONMENTAL MANAGEMENT PLAN

The aim of the Environmental Management Plan (EMP) is to ensure that the stress/load on the ecosystem is within its carrying capacity. It is important that certain management measures are taken and strictly implemented from the beginning of the planning process to minimize the risk factors in order to protect the marine environment.

In the proposed project, the outfall temperature shall be increased only by 3.3 ^{o}C from the ambient temperature, which is well below the standard prescribe by the statutory authority.Hence,no specific management measures is suggested.However,it is recommended that TANGEDCO should implement all the good practices for outfall management to further enhance the protection of the Marine Environment.

CHAPTER – 5

ENVIRONMENTAL MONITORING PROGRAM

5.1 GENERAL

Monitoring is an essential component for sustainability of any developmental project. It is an integral part of any environmental assessment process. As a first step towards the maintenance of quality of the marine ecology of the study area, critical locations are to be carefully selected and designated monitoring sites for periodic monitoring with respect to water quality, sediment quality and flora and fauna. To understand these variations it is necessary to conduct periodic monitoring seasonally. The parameters to be monitored are given below.

5.2 MARINE WATER & SEDIMENT QUALITY

The frequency of monitoring shall be once in a season. The parameters to be monitored are as follows:

Marine Water

- Salinity
- Temperature
- pH
- Dissolved Oxygen
- BOD
- Nitrates
- Ammonical Nitrogen
- Phosphates
- Chlorides
- Zinc
- Cadmium
- Lead
- Mercury
- Oil & Grease

Sediments

- pH
- Texture
- Oil & Grease

- Total Volatile Solids
- Organic matter
- Chlorides
- Phosphates
- Nitrates
- Sulphates
- Sodium
- Potassium
- Total Kjeldahl Nitrogen
- Zinc
- Nickel
- Cadmium
- Copper
- Lead
- Mercury

Detailed studies to be conducted to study the phytoplankton population, genetic diversity, zooplankton biomass, population and group density, macro-benthic biomass, population and group diversity, Marine water and sediment samples will also be analysed for the following biological parameters.

Biological Parameters to be analysed

Marine Water

- Primary productivity, mg C/m^3 day
- Chlorophylla, mg/m^3
- Phaeophytin, mg/m^3
- Phytoplanktons
  - ➢ Abundance
  - ➢ Number and name of groups, present
  - ➢ Total number and name of species of each group present
  - ➢ Density (Total numbers of individual of each species/l)
  - ➢ Total Biomass
- ***Zooplankton***
  - ➢ Abundance
  - ➢ Number and name of groups, present
  - ➢ Total number and name of species of each group present
  - ➢ Density (Total numbers of individual of each species/l)
  - ➢ Total Biomass

Sediments

- ***Benthic organisms***
- Meio-benthos and Macros-benthos
  - Abundance (Nos./10 cm^2)
  - Number and name of each group, present
  - Total number and name of species of each group present
  - Density (Total numbers of individuals of each species/m^2)
  - Total Biomass, (mg/m^2)

CHAPTER – 6
CONCLUSIONS

The Marine EIA Study was carried out to identify the impacts of outfall of the proposed Ennore SEZ and NCTPS stage III Thermal Power projects in the NCTPS Complex on marine environment. The conclusions of the study are as follows:

- Based on the modelling study carried out by IIT,Madras,the temperature of outfall with 3,20,000 cu.m/hr discharge will be at about 3.3^{o}C higher than ambient conditions. This temperature further reduces to about 0.4^{0}C, ie., almost reaches ambient temperature at a distance of 2.0km from the outfall.Hence there will be marginal / insignificant impact.

- The present creek dilutes and disperses the outfall water temperature well as there is good tidal exchange between ennore creek and sea, which indicates a positive effect of the total discharges in the pre-cooling channel.

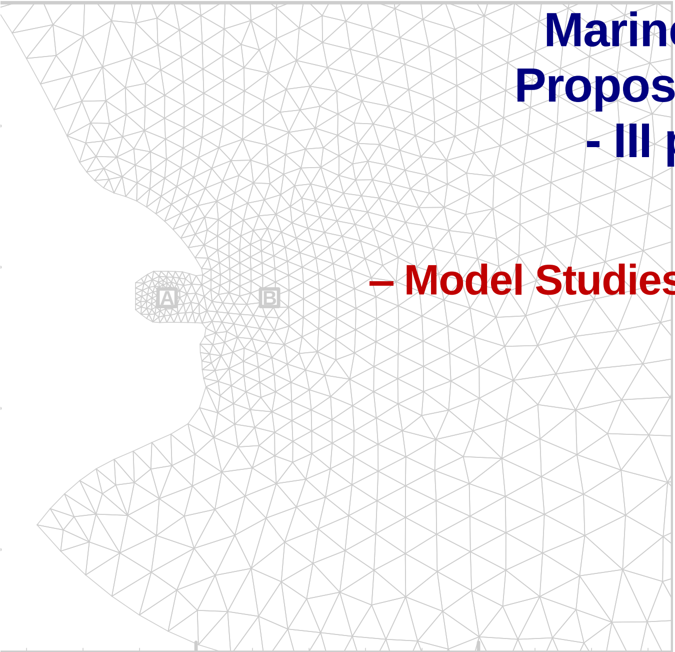
- The average salinity differential of the discharges blowdown from closed cycle discharges of 3 plants of NCTPP III,Vallur and Ennore SEZ is 10.39 g/l. However, when all the discharges get mixed, the outfall discharge will have a salinity differential of only 1.53g/l. Hence, the present outfall which will have highly diluted discharge will have marginal / insignificant impacts.

- The marine water quality and ecology in and around the proposed outfall area is that of any normal coastal environment during the study period.

- The project area has biological features charecteristics of any normal coastal area in the occurence, abuandance and bio diversity of biological community of phytoplankton, zooplankton, benthos and fishes. The area is devoid of mangrove vegetation,Seaweeds and corel reefs. No rare, endangered, threatend marine speices were recorded during marine survey.

- For the maintenance of quality of the marine ecology of the sudy area, critical locations and designated monitoring sites are to be carefully selected for periodic monitoring with respect to marine water, sediment, flora and fauna.

- The outfall of the proposed Ennore SEZ and NCTPS stage III Thermal Power projects in the NCTPS Complex would not change the quality of existing natural coastal environment.



Marine EIA/EMP studies for Outfall of Proposed Ennore SEZ & NCTPS Stage - III projects in the NCTPC Complex

– Model Studies for Complex Tidal Hydrodynamics and Thermal & Salinity Dispersion

Client

TANGEDCO, Chennai

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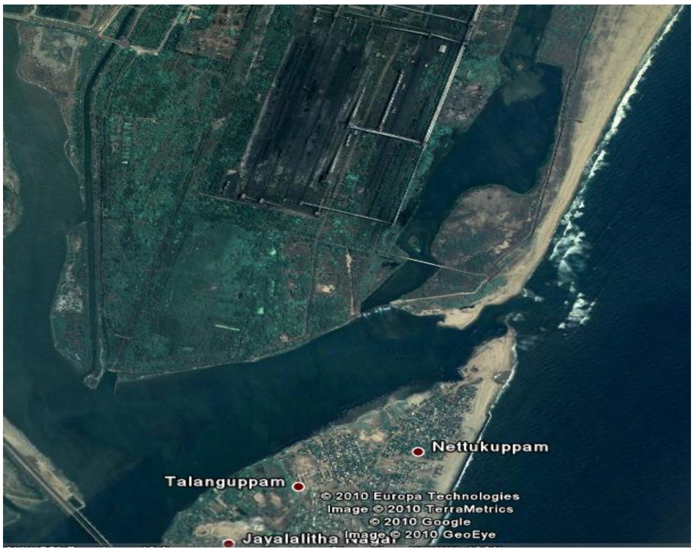

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EXECUTIVE SUMMARY

The North Chennai Thermal Power Station (NCTPS) is located in Ennore village, Thiruvallur Taluk, Tamil Nadu. The site is about 30 km north of Chennai city. Presently 3 units of 210 MW are under operation in the North Chennai Thermal Power Station Complex (Stage-I). It uses "Once Through" sea water cooling system for this power plant. The quantum of 90,000 m^3/hr is discharged into the Pre-Cooling Channel of about 4.5 km length and finally discharged into the Bay of Bengal. Presently, TANGEDCO is also implementing (i) 2 x 600 MW North Chennai Thermal Power Project Stage – II with once through cooling system for both units. The water requirement for NCTPP Stage – II is 2,00,000 m^3/hr; and in Joint Venture with M/s. NTPC, is also establishing 3 x 500 MW Vallur Thermal Power Project and the units have been proposed to cooled through "Closed Cycle System". The quantity of coolant water is about 20,000 m^3/hr. The coolant water is proposed to be discharged at the middle of the Pre-Cooling Channel.

TANGEDCO is also proposing to establish a 2 x 800 MW Ennore SEZ Thermal Power Project in NCTPS Ash Dyke area with "Closed Cycle System". The quantity of coolant water is about 15,000 m^3/hr. The coolant water is proposed to be discharged into the NCTPS Pre-Cooling Channel at the weir; and TANGEDCO also proposes to implement 1 x 800 MW North Chennai Thermal Power Project Stage – III within the NCTPS Complex. and it will be cooled through "Closed Cycle System". and for the NCTPP Stage – III is 10,000 m^3/hr. The coolant water is proposed to be discharged into the NCTPS Pre-Cooling Channel.

Under this study, IIT Madras have investigates the thermal dispersion due to the discharge of cooling water coming from proposed power plants in the vicinity. Based on this study, the following findings are brought out.

(1) The temperature of outfall with 3,20,000 cu.m/hr discharge will be at about 3.3 deg. C higher than ambient conditions.

(2) The present creek dilutes and disperses the outfall water temperature well. There is good tidal exchange between ennore creek and sea, indicating a positive effect of the total discharges in the pre-cooling channel.

(3) With the improved condition, the creek temperature will go up by about 2 degree, adjacent to the outfall (within a radious of about 300m) and about 1.0 degree

overall during the tidal cycle. This effect will be felt for a duration of about 30 min during a tidal cycle. But, there will be complete dilution of the outfall water and flushing to the sea. Hence, there will not be any cumulative effect.

(4) Outside the creek, on the sea side, there will be a thermal plume with an increased temperature of about 0.4 deg. C spreading offshore (easterly) to a distance of about 2km. Beyond this, the plume will disappear.

CONTENTS

TABLE

1.0 BACKGROUND

The North Chennai Thermal Power Station is located in Ennore village, Thiruvallur Taluk, Tamil Nadu. The site is about 30 km north of Chennai city. Presently 3 units of 210 MW are under operation in the North Chennai Thermal Power Station Complex (Stage-I). It uses "Once Through" sea water cooling system for this power plant. The quantum of 90,000 m^3/hr is discharged into the Pre-Cooling Channel of about 4.5 km length and finally discharged into the Bay of Bengal.

Presently, TANGEDCO is implementing (i) 2 x 600 MW North Chennai Thermal Power Project Stage – II with once through cooling system for both units. The water requirement for NCTPP Stage – II is 2,00,000 m^3/hr. Simultaneously, TANGEDCO, in Joint Venture with M/s. NTPC is establishing 3 x 500 MW Vallur Thermal Power Project and the units have been proposed to cooled through "Closed Cycle System". The quantity of coolant water is about 20,000 m^3/hr. The coolant water is proposed to be discharged at the middle of the Pre-Cooling Channel.

TANGEDCO is also proposing to establish a 2 x 800 MW Ennore SEZ Thermal Power Project in NCTPS Ash Dyke area and the units have been proposed to cooled through "Closed Cycle System". The quantity of coolant water is about 15,000 m^3/hr. The coolant water is proposed to be discharged into the NCTPS Pre-Cooling Channel at the weir. TANGEDCO also proposes to implement 1 x 800 MW North Chennai Thermal Power Project Stage – III within the NCTPS Complex. and it will be cooled through "Closed Cycle System". and for the NCTPP Stage – III is 10,000 m^3/hr. The coolant water is proposed to be discharged into the NCTPS Pre-Cooling Channel.

TANGEDCO has entrusted IIT Madras with the task of studying the thermal dispersion characteristics of the ennore creek for the purpose of assessing the Marine Environmental Impact due to the cooling water discharge for all the above Power Stations discharging into the existing Pre-Cooling water channel of the North Chennai Thermal Power Station and suggest Marine Environmental Mitigation Measures for Environmentally safe discharge of the cooling water as per Ministry of Environment and Forests (MOEF), Government of India stipulations.

Objective of this study

The main objective of the project is to investigate the thermal dispersion due to the discharge of cooling water coming from proposed power plants in the vicinity. The scope of work is as follows.

1. Investigate the tide induced hydrodynamics in the backwater area adjoining the pre-cooling channel. This will include the effect of outfall discharge from the plant and the flushing at Ennore Creek.

2. Mathematical model study on the dispersion characteristics of effluent due to the thermal discharge.

3. Obtain the general thermal dispersion patterns over the subject area considering the following outfall water discharges and their operating temperature. The ambient water temperature is taken as 30 deg. C.

Table.1. Details of thermal discharges in the pre-cooling channel.

Facility	**Discharge (m^3/hr)**	**Temperature (Deg. C more than ambient)**	**Salinity rise (g/l)**
(1) Existing North Chennai Thermal Power Station Stage-I (3 x 210 MW)	90,000	5 (at the pre-cooling cooling channel weir)	0
(2) Existing North Chennai Thermal Power Project Stage–II (2 x 600 MW) - partly commissioned.	2,00,000	5 (at the pre-cooling cooling channel weir)	0
(3) Vallur Thermal Power Project (3 x 500 MW) – under execution	20,000	5* (at the pre-cooling cooling channel)	55
(4) Proposed North Chennai Thermal Power Station Stage–III (1 x 800 MW).	10,000	5* (at the pre-cooling cooling channel)	40
(5) Proposed Ennore SEZ Thermal Power Project (2 x 800 MW)	15,000	5* (at the pre-cooling cooling channel weir)	40

*- ***As indicated by TANGEDCO, the blowdown water temperature of these discharges will be at ambient conditions. However, for simulating worst case scenario, the study considers 5 degree temperature rise of the blow down discharge.***

1.1 Location of the Project

The pre-cooling channel is located north of Ennore creek. The power plants are located on the western side of the channel. The location of the Creek, Pre-cooling channel and the various discharged are given Fig.1. Figure 2 shows the CRZ map of the site. Figures 3 and 4 show the overall layout of the pre-cooling channel as envisaged by TANGEDCO originally. Figures 5 shows the bathymetrical details of the pre-cooling channel. It is clear from the CRZ map and Figs. 3-5 that the pre-cooling channel in not tidally driven. It's invert level at the outfall location in above the HHWS on the creek (+0.89 CD; 0.43m above HTL). Hence, the hydraulics of the pre-cooling channel is isolated from Ennore creek. While the Ennore Creek is tidally oscillated, the pre-cooling channel carries only the flow of the discharges from various power stations.

2.0 HYDRAULICS AND THERMAL DISPERSION OF PRE-COOLING CHANNEL

2.1 Modelling the flow

The pre-cooling channel and it's shorelines are modelled as detailed in Fig.6. The average grid size used was about 5-10m. The average depth in the channel is about 0.85m. The details of the various conditions in the channel has been analysed and presented in Annexure-I. Figure 7 shows the average depth averaged velocity in the channel as vector plot. Recalling from Table-1, the Stage-II discharge is predominant and is seen dominating the flow from Stage-I weir. The flow from all upstream discharges get mixed the lagoon area where the discharges from NTECL and Stage-III NCTPS also join the pre-cooling channel. The general range of the water current velocity is seen to be about 0.9-1.3m/s. It is also observed that the flow is mostly concentrated on the eastern side of the channel. At the outfall location, the width of the channel becomes about 130m. At this location, supercritical flow exists (Annexure-I). Hence, velocities of over 2m/s is observed here. Figure 8 brings out the contour plot of velocity magnitudes over the channel supporting the above observations. There is scope for improving the flow conditions in the channel by carrying out suitable maintenance works.

2.2 Salinity dilution in the combined effluent water

The pre-cooling channel receives a total discharge of 3,20,000 cumec (94.44 m^3/s). The brine is present only in the blow down discharges of 3 plants as indicated in Table.1. The average salinity differential of these discharges is 10.39 *g/l*. However, when all the discharges get mixed, the outfall discharge will have a salinity differential of only 1.53*g/l* (because of large once-through discharges of other plants). The corresponding dilution is

680. Usually, outfall designs must ensure dilution 50-100 within a short distance. In comparison, the present outfall will have already highly diluted discharge which will not be sensed by the receiving waters.

2.3 Thermal dispersion in the pre-cooling channel

The pre-cooling channel receives highest discharges of 2,00,000 cumec at thermal differential of about 5 deg. The lowest discharge is from Stage-III plant at 10,000 cumec at 5 degree temperature differential. The effluent loads are imposed as boundary conditions of flow and temperature at the corresponding locations as shown in Fig.6 for the purpose of computing thermal dispersion in the pre-cooling channel. The effect of wind has been considered as below in Table.2. The pre-cooling channel banks have been modelled as non-conducting walls. The outfall has been set without any temperature value. This allows the model to calculate the temperature at the outfall with all the above effects and arrive at the temperature of discharge at the Ennore Creek confluence.

Table.2. Wind effect on thermal dispersion in pre-cooling channel.

Calculating surface fluxes: Bulk formulas for calculating the surface fluxes (including the wind stress)

$$\tau = \rho_a C_D U_{10}^2$$
$$Q_S = \rho_a C_p C_S U_{10} (t_s - t_a)$$
$$Q_L = \rho_a L_E C_L U_{10} (q_s - q_a)$$

C_p	Specific heat capacity of air	$1030\ \mathrm{J{\cdot}kg^{-1}{\cdot}K^{-1}}$
C_D	Drag coefficient (see 4.3)	$(0.50 + 0.071\,U_{10}) \times 10^{-3}$
C_L	Latent heat transfer coefficient	1.2×10^{-3}
C_S	Sensible heat transfer coefficient	1.0×10^{-3}
L_E	Latent heat of evaporation	2.5×10^{6} J/kg
q	Specific humidity of air	kg (water vapor)/kg (air)
q_a	Specific humidity of air 10 m above the sea	kg (water vapor)/kg (air)
q_s	Specific humidity of air at the sea surface	kg (water vapor)/kg (air)
Q_S	Sensible heat flux	$\mathrm{W/m^2}$
Q_L	Latent heat flux	$\mathrm{W/m^2}$
τ	Wind stress	Pascals
t_a	Temperature of the air 10 m above the sea	K or °C
t_s	Sea-surface temperature	K or °C

The calculated temperature pattern due to thermal dispersion of hotwater from the 5 power plants is shown in Fig.9. Since Stage-I discharge dilutes the SEZ discharge, the discharge at the stage-I weir will have only 35.28 deg. C (30+5.28 deg. C) temperature at the rate of 105 cumec. This indicates the region near the weir is at a temperature of about 34.9-35 deg due to mixing of the discharge from stage-I weir and stage-II weir. From this confluence region, the discharge starts losing heat by means of turbulence mixing and wind induced surface flux. An average wind of 3m/s is taken for including wind induced temperature loss. The water temperature becomes 1 deg less by the mid-channel by which time the discharge from NTECL and Stage-III will interact. Finally, the mixed water will have a outfall temperature of about 33.3 deg. C (3.3 degree above ambient).

3.0 TIDAL HYDRAULICS AND THERMAL DISPERSION OF ENNORE CREEK

3.1 Modelling the flow

The details of tidal model are provided in Annexure-II. The area covered for tidal hydraulics is shown in Fig.10 along with the bathymetry. The tidal hydraulics of the creek is very complex. The flow in the creek interacts with Buckingham canal; Ennore backwater and the open sea - which in turn interacts with the flow in and out of Ennore harbour. Thus the solution domain for the present problem is the water spread of all the above water bodies. Since an unstructured approach is being used in the present model, no hybrid meshing scheme is needed. The Domain of study is represented by a number of bodies representing exterior coastal lines and interior islands. This is basically the geometric configuration of the coastal boundaries at Ennore Creek as given in Fig.10.

Methodology

This data for the entire area has been obtained from the hydrographic chart available in the Department of Ocean Engineering, IIT Madras. Exact water depths for the proposed plant area is obtained from survey data. After performing the mesh generation process for the study area as discussed earlier, the final mesh (Fig.11.) has come out good and has very fine elements near the coastlines and shallower water depths. The average mesh size is found to be about 20m which is very fine for a simulation such as this. The mesh is coarser near the offshore boundaries where the water depths are greater. The interpolated bathymetry on the mesh is given in Fig.11. showing contours at regular intervals. The figure suggests an impressive representation of the bed profile in the computational model.

Boundary Conditions

The present solver could work with tide elevation boundary conditions alone. 15 day tidal elevations are used as boundary conditions along the open boundary at Bay of Bengal

(Fig.12). The creek mouth is 140m wide. Free radiation of velocities along the open boundaries is enabled on the South and North of sea spread, and the other connected water bodies. Natural boundary conditions are imposed along the coastal boundaries. The tide elevation shown in Fig.12 is from the with reference to MSL and is the reference water level for the simulations. For this purpose, the range of tide is about 0.6m. It is to be noted that, considering such a time series for the 15 days period covers the spring-neap variations of the astronomical tide and addresses all variations in the astronomical tides.

3.2 Tidal hydraulics

Rigorous validation of the model Ocirc 1.0 has been performed in the past (Murali et al., 2002). Accurate simulation of the tidal hydrodynamics at Ennore creek and near the proposed plant depends on the kind of computational mesh generated for the simulations. An unstructured meshing scheme was selected in order to accurately capture the boundaries of the port and the adjoining shoreline. The unstructured meshing scheme is capable of resolving all the boundary and bathymetry details in the study area. This is pictorially depicted in Fig.11. This typical computational mesh depicts the ability of the meshing algorithm to exactly discretise the study area. When comparing the results in terms of tidal currents, several locations were used to record current values. Figure 13 shows the locations and their numbering.

Simulated Tidal Conditions

The present tidal hydrodynamic conditions at the site are mainly characterized by alternating easterly and westerly flow adjacent to the project area. Formation of very weak localized eddies during the high and low water is observed. This indicates there can be marginal siltation during residual flow conditions. .

This flow patterns during flooding flow is given in Fig.14. The reference vector in the figure shows the size of the vector for a current of 1.0m/s. From this, the magnitudes of current at various locations of the project area can be deduced. The above figures show only velocity patterns in the study area at the time of occurrence of maximum velocities, which will be when the tide is crossing the mean level as it travels westwards in the creek area and north-south in the backwater area where the outfall is located. This flow is extracted from the simulations for the post-spring tide condition and hence represents maximum currents that would be prevailing in this area. It is observed that the maximum current in the nearshore can reach upto 0.4m/s while it can vary from 0.1m/s-0.4m/s near the outfall. The directionality of the currents is north-westerly. The currents are stronger in the shallower depths of 2m or less. Moreover, as the bathymetry details are almost parallel, the currents flow along the contours and clear streamlining is observed. This aspect is very encouraging as it will discourage sedimentation and also encourage dilution of hot water that is discharged at the mouth of the backwater at the creek. There is also a counter clockwise circulation seen at this time, which is a favourable situation for the plant's disposal.

This flow patterns during ebbing flow is given in Fig.15. Similar to the earlier plots, the above figures show only velocity patterns in the nearshore at the time of occurrence of maximum velocities, which will be when the tide is crossing the mean level as it travels northwards. This flow is extracted from the simulations for the post-spring tide condition and hence represents maximum currents that would be prevailing in this area. It is observed that the maximum current in the nearshore can reach upto 0.4m/s while it can vary from 0.1m/s-0.40m/s near the outfall. The directionality of the currents is south westerly. The currents are stronger in the shallower depths of 5m or less. As observed earlier, the streamlining of flow means that better dilution of outfall discharge and less sedimentation/siltation. This will have the following impacts.

- Less siltation will take place in the project area as there is some amount residual current present.
- Even during mean period, there will be some amount of dilution of the disposed water.
- The streamlined residual flow means continuous transport of fine sediments out of the project area.

The above observations are also supported by the residual circulation shown in Fig.16.

Finally, the temporal variations of currents at the proposed site of the outfall structures is shown in Fig.17 as time traces of tide levels and currents for a period a tidal spring-neap cycle. These are shown at the locations of proposed plant and outfall structures. The simulated tides are of the order of 1.1m in range. It is observed that the ebbing cycle possesses much higher current magnitudes (up to 0.7m/s) in spring tide and up to 0.5m/s in the neap tide. This increased flow during ebbing will have following benefits.

a) Ennore creek will have better water quality in terms of dilution of all the industrial effluents.
b) The higher water currents during ebbing will flush out sediments settled at the creek mouth, thereby providing natural maintenance of mouth.
c) There will be good dilution of the temperature with the ebbing flow flushing all the water from the creek.

3.3 Thermal dispersion of Ennore Creek

The creek receives highest discharges of about 3,20,000 cu.m/hr at thermal differential of about 3.3 deg. For simulation purposes, the discharge has been taken to be at 4 deg. thermal differential, i.e at 34 deg. C (with the reference of 30 deg.C). The effluent loads are imposed as boundary conditions of flow and temperature at the corresponding locations as shown in Fig.1 for the purpose of computing thermal dispersion in the pre-cooling channel. The effect of wind has been considered as shown in Table.2. The pre-cooling channel banks have been modelled as non-conducting walls. The ocean boundary has been set with free radiation condition. This allows the model to calculate the temperature at the open boundaries freely with all the above effects and arrive at the temperature of water at the Ennore Creek.

Figures 18-19 show the temperature dispersion pattern of the creek during the flooding cycle. The results are shown after 3 subsequent tidal cycles for identifying the effects of any cumulative increase of temperature in the creek. The results indicate that the thermal plume will spread up to the buckingham canal confluence and Ennore creek-Kortalaiyar river branch during flooding cycle. The temperature of the plume will be up to 2.0 deg. C more than ambient (32 deg. C) for a distance of about 1.5 km from the outfall location. Beyond which, the far-field thermal dispersion will take place. At the time of high tide, the thermal plume spreads for the entire creek due to slack conditions.

During the ebbing cycle the thermal plume is expected to further get flushed from the creek through 140m wide ennore creek mouth. These patterns are shown in Figs.20-21. Immediately after the commencement of the ebbing tide, the thermal plume shown temperature differentials of less than 1 deg. from ambient over most of the creek area (Fig.20 & 21). During the duration before occurrence of low tide, most of the creek gets flushed with the outfall area and adjoining northern shorelines showing the plume going from outfall to sea. Thus it is observed that there will be good flushing from the creek. However, due to the presence of the 1 deg. C temperature differential during the period before low tide, some of the heat will escape into the sea. Figure 21 indicates that the thermal plume with an increased temperature of about 0.4 deg. C will spread offshore to a distance of about 2km easterly. However, this plume disappears further in to the tide as shown in Fig.18. In order to observe any cumulative effects of temperature in the creek, the thermal plume is extracted in the next tidal cycle during high tide and the same is shown in Fig.22. This figure indicated that there will not be any cumulative effect. Thus, the net flow projected in the pre-cooling of NCTPS will have a cumulative positive effect in the creek and the creek mouth.

4.0 CONCLUSIONS

Detailed numerical model studies have been carried out to investigate the hydrodynamics of the NCTPS pre-cooling channel and Ennore creek and the corresponding thermal dispersion. The following conclusions are made.

(1) The temperature of outfall with 3,20,000 cu.m/hr discharge will be at about 3.3 deg. C higher than ambient conditions.

(2) The present creek dilutes and disperses the outfall water temperature well. There is good tidal exchange between ennore creek and sea, indicating a positive effect of the total discharges in the pre-cooling channel.

(3) With the improved condition, the creek temperature will go up by about 2 degree, adjacent to the outfall (within a radious of about 300m) and about 1.0 degree overall during the tidal cycle. This effect will be felt for a duration of about 30 min during a tidal cycle. But, there will be complete dilution of the outfall water and flushing to the sea. Hence, there will not be any cumulative effect.

(4) Outside the creek, on the sea side, there will be a thermal plume with an increased temperature of about 0.4 deg. C spreading offshore (easterly) to a distance of about 2km. Beyond this, the plume will disappear.

Prof.S.A.Sannasiraj **Prof.K.Murali** **Prof.V.Sundaravadivelu**

FIGURES

Fig.1. Location of the pre-cooling channel and 5 discharges

Fig.2. CRZ map of the project area

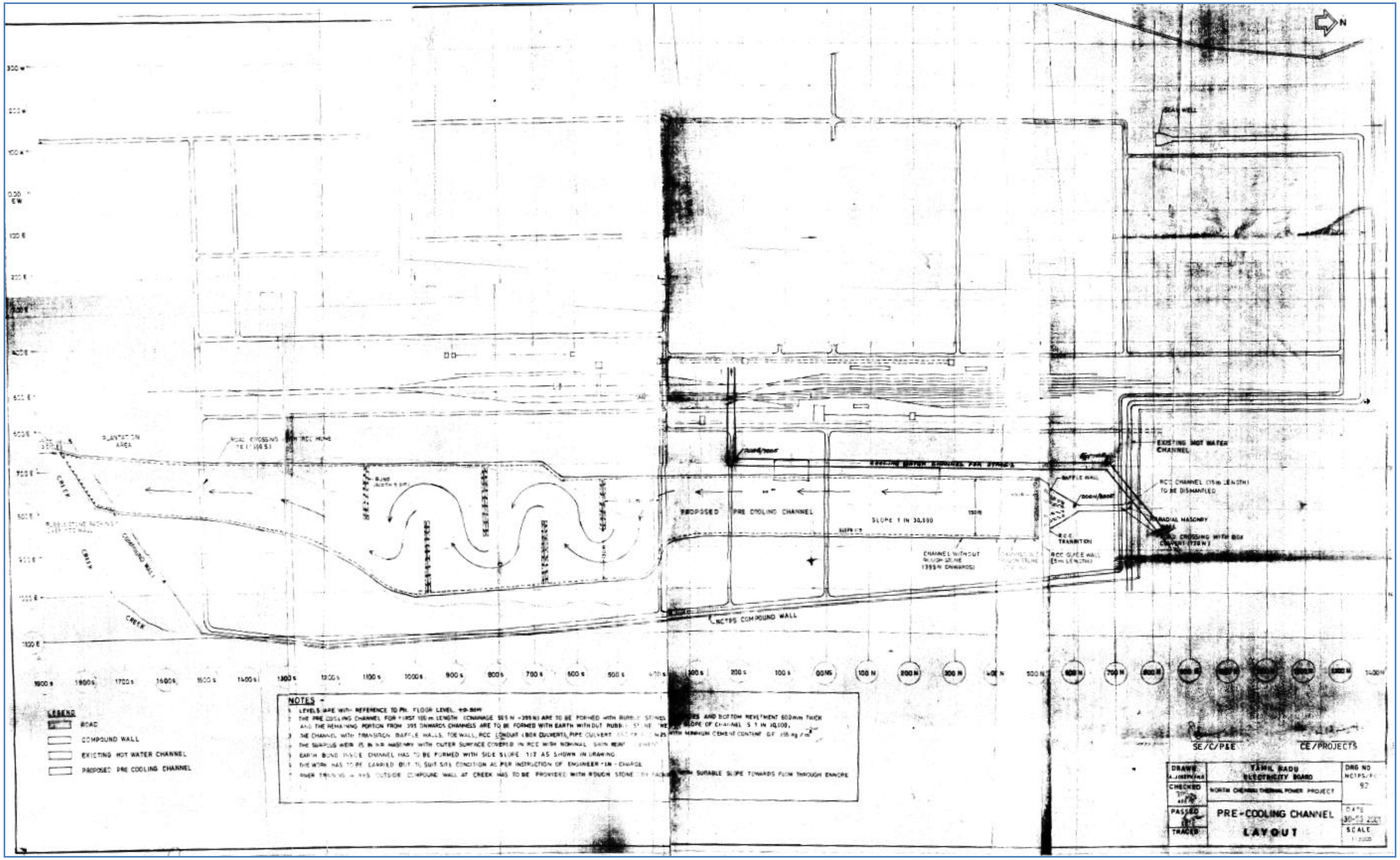


Fig.3. Plan view of pre-cooling channel as per drawing provided by TANGEDCO.

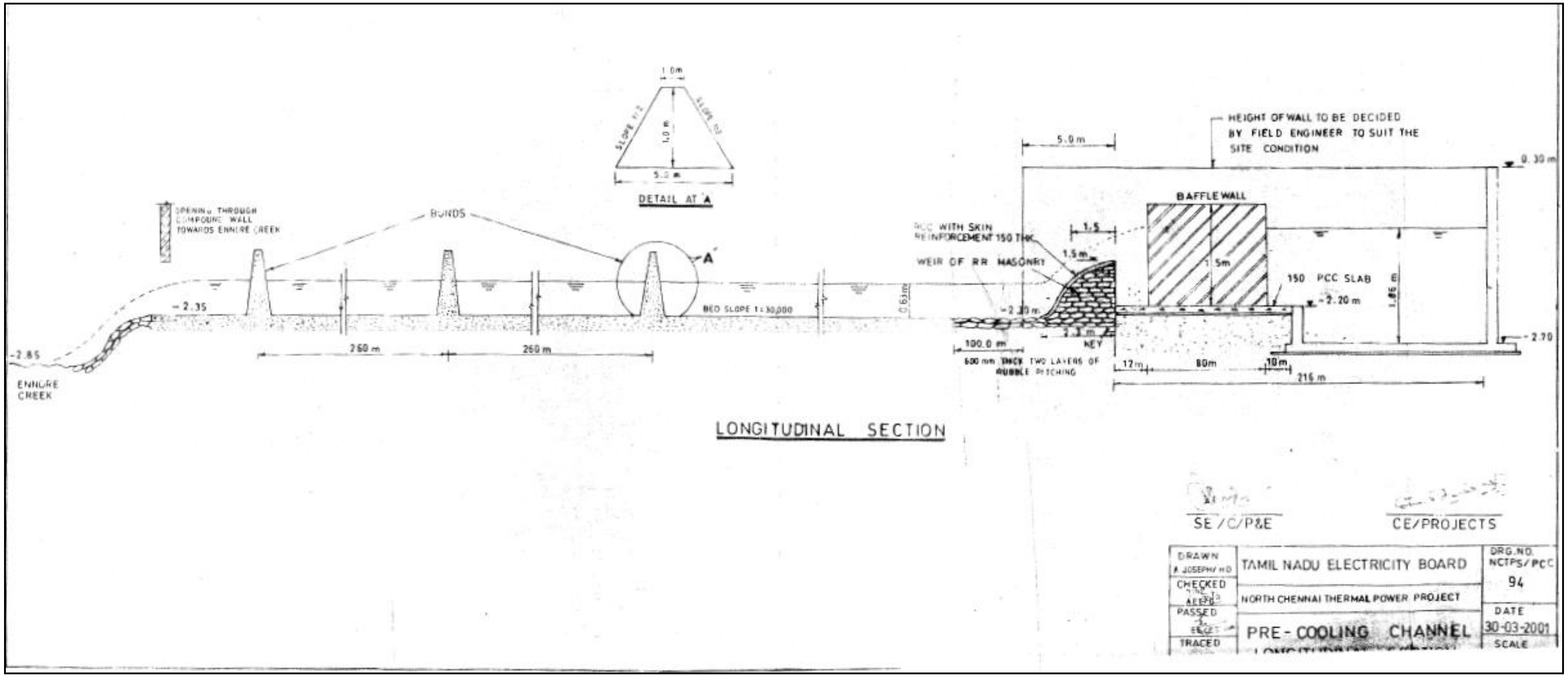


Fig.4. Longitudinal section view of pre-cooling channel as per drawing provided by BHEL.

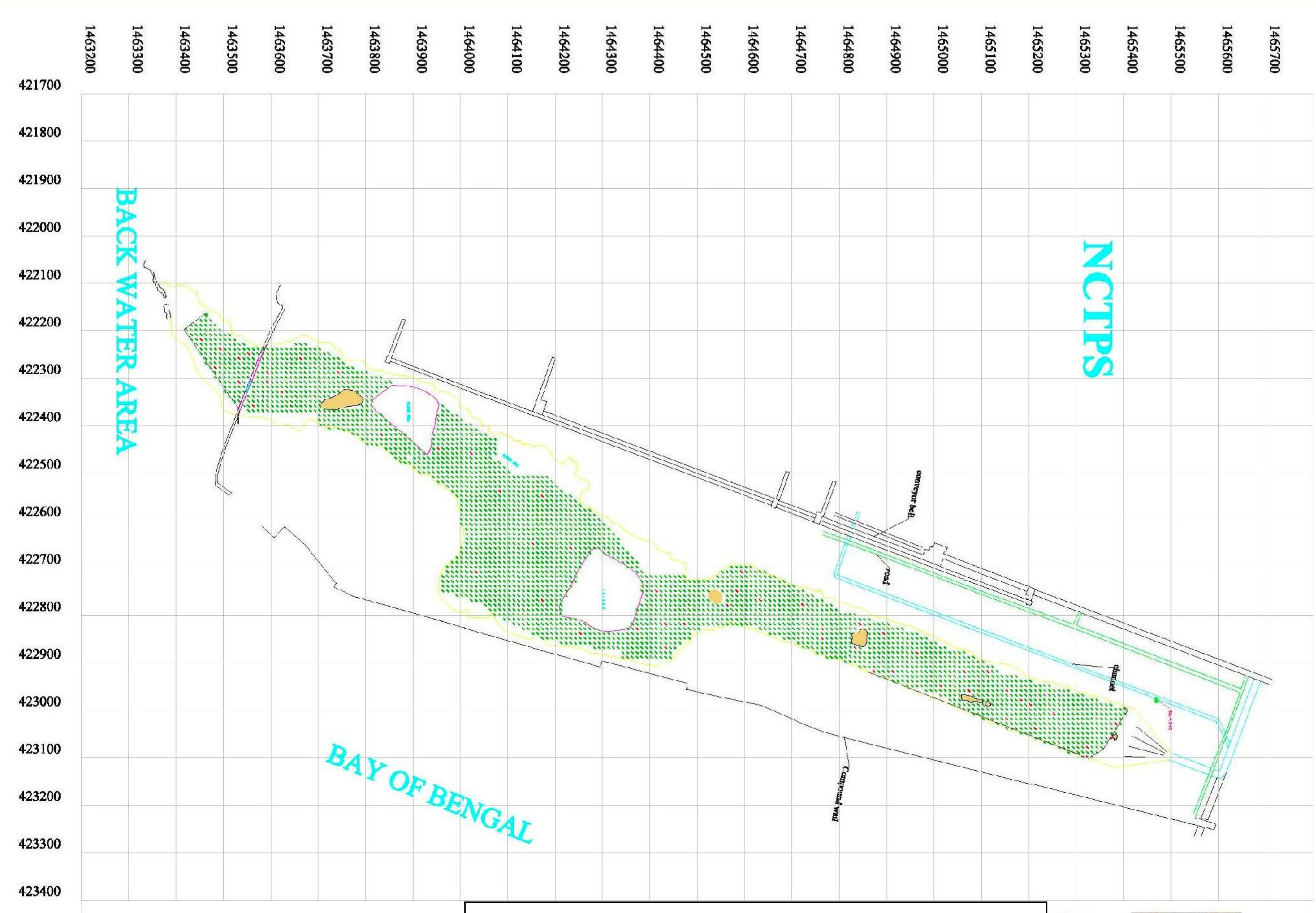


Fig.5. Bathymetry of Pre-cooling channel

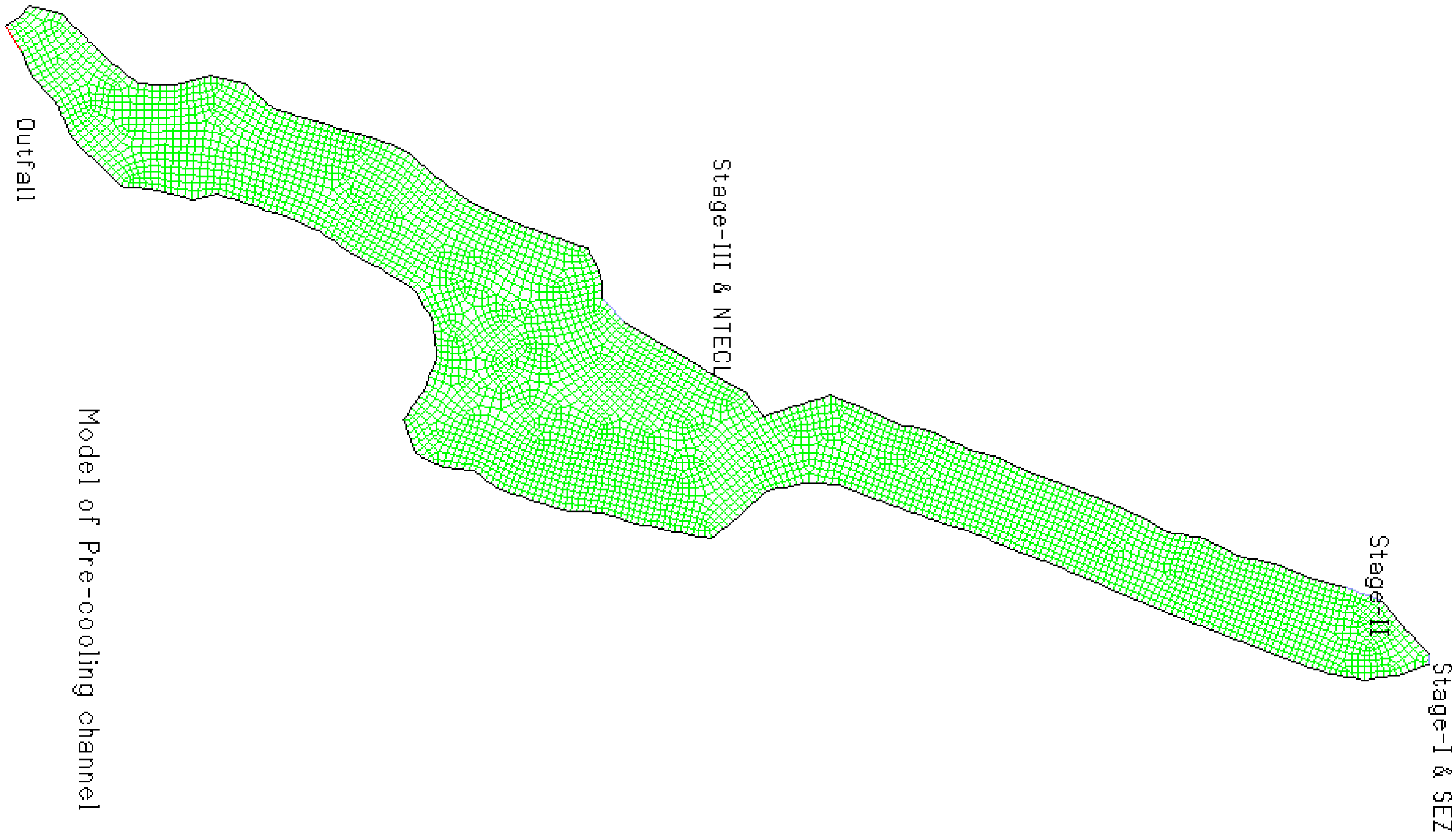


Fig.6. Computational domain and mesh for modelling pre-cooling channel.

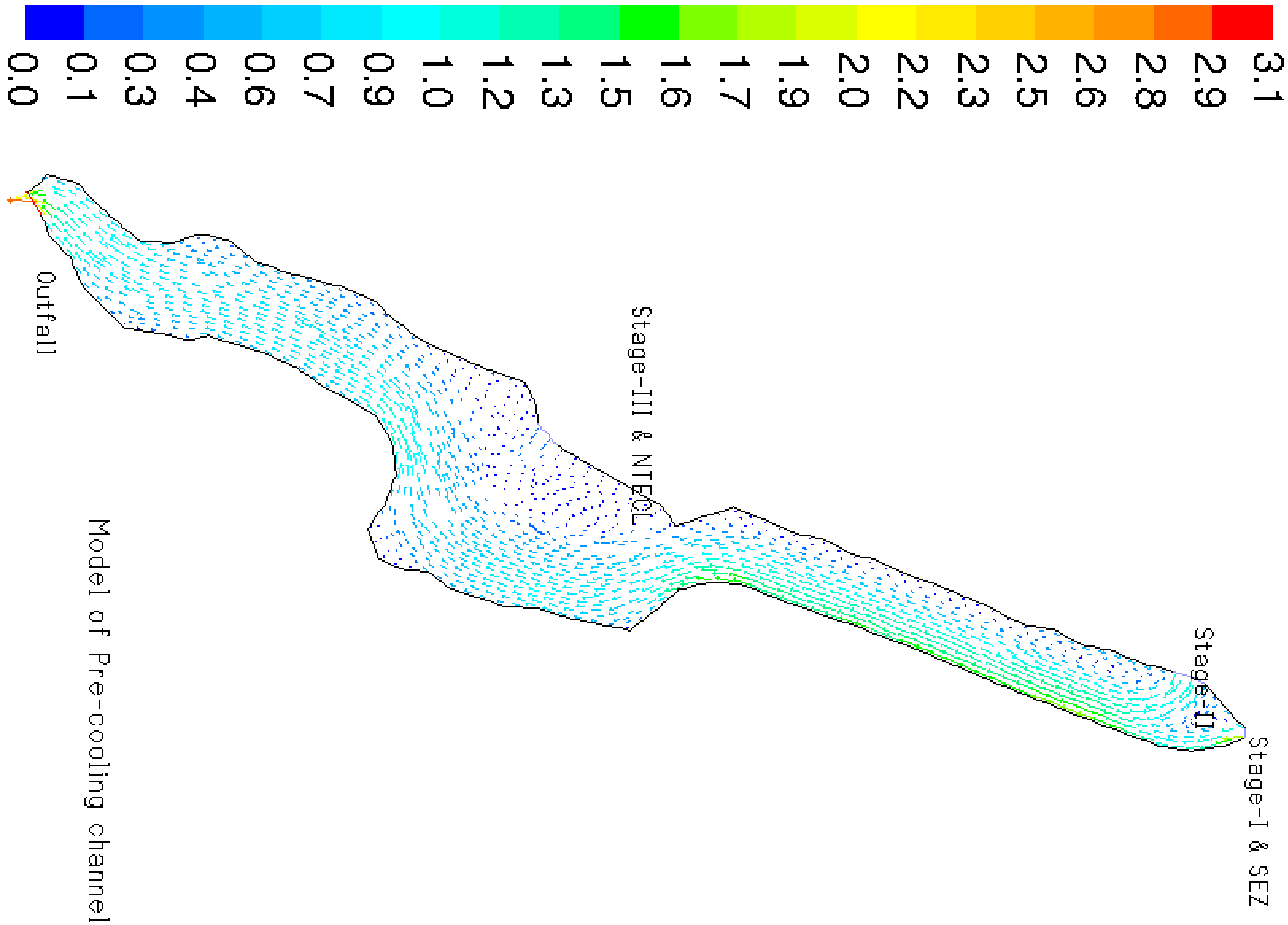


Fig.7. Flow pattern in the pre-cooling channel.

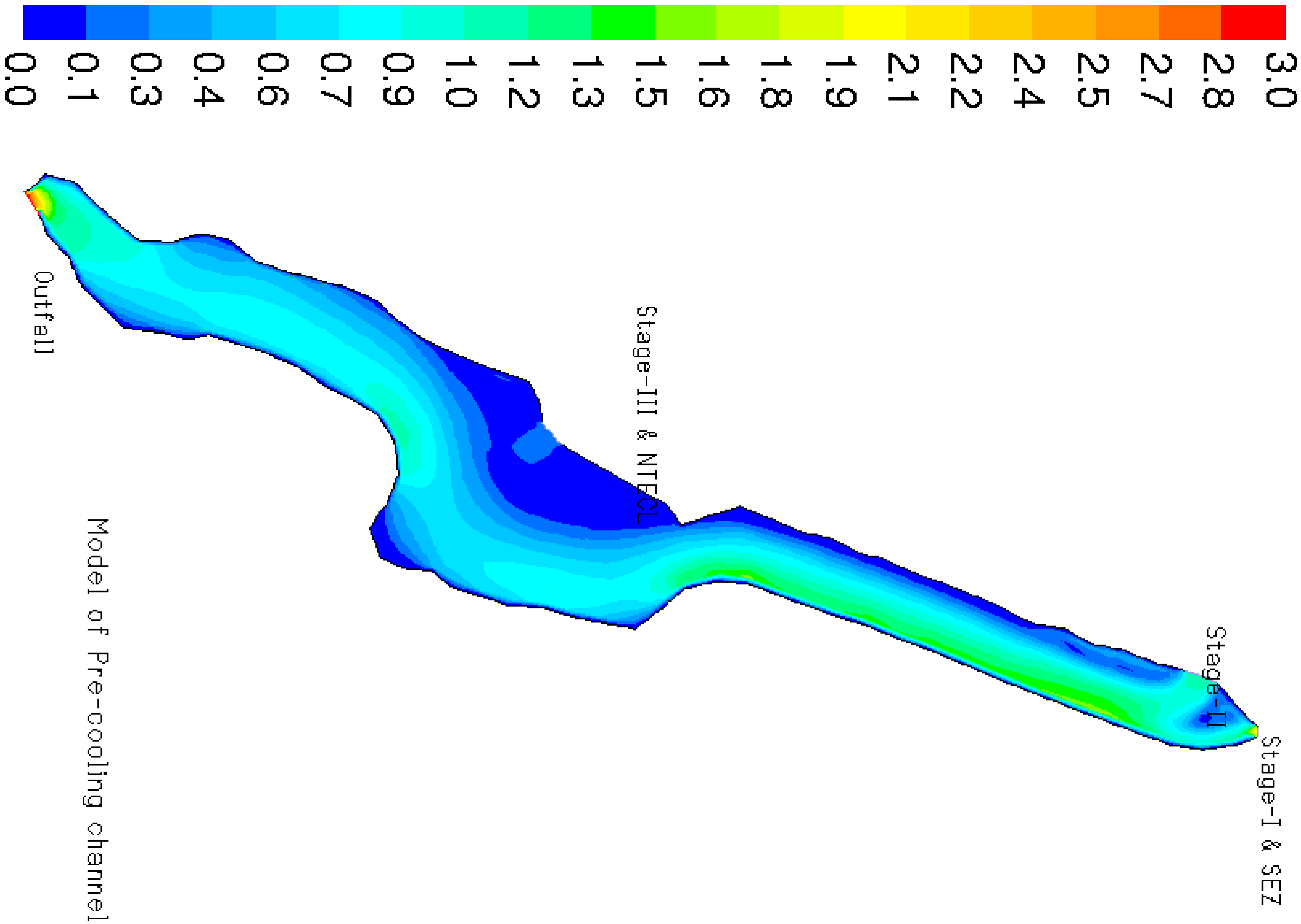


Fig.8. Velocity magnitudes in the pre-cooling channel.

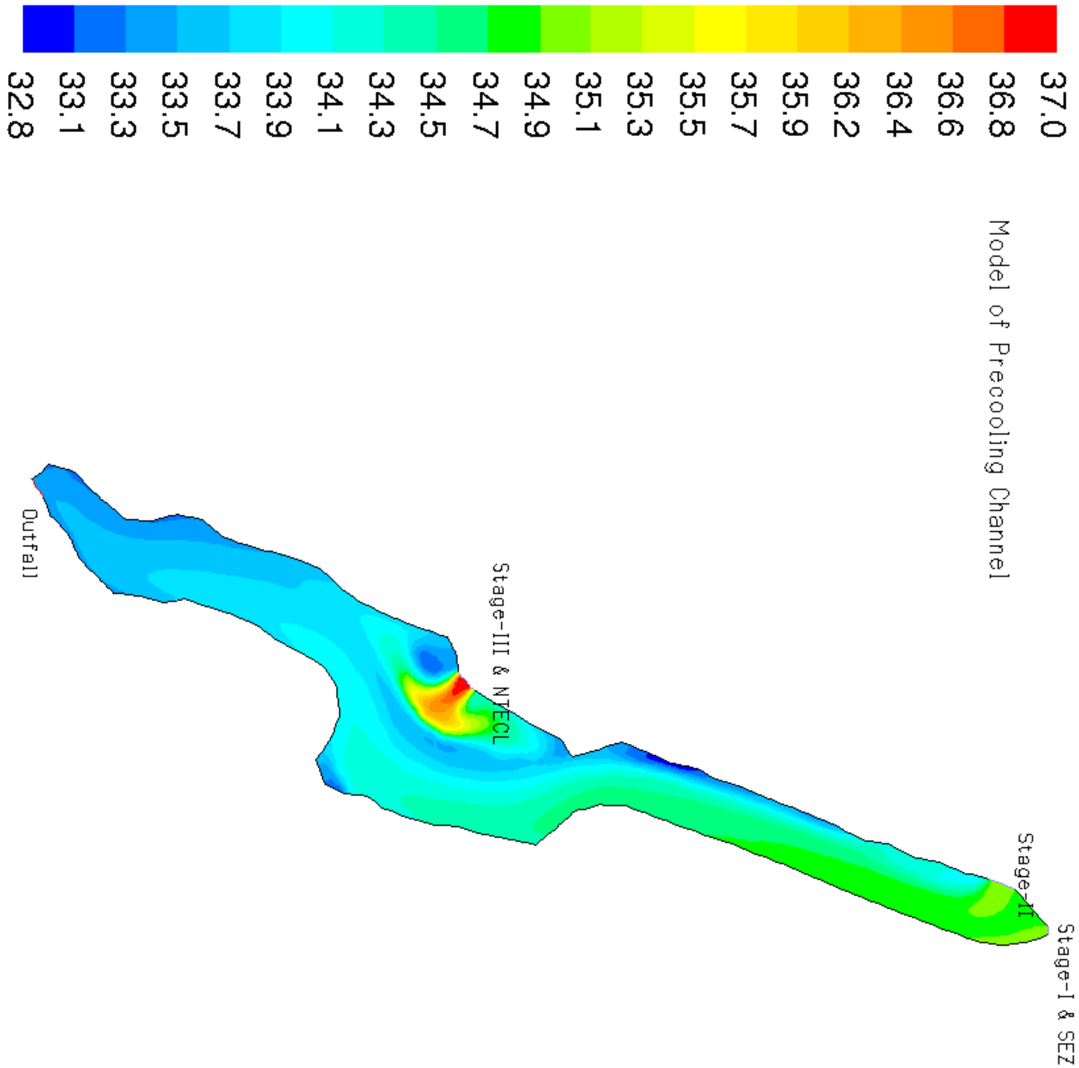


Fig.9. Temperature dispersion in the pre-cooling channel.

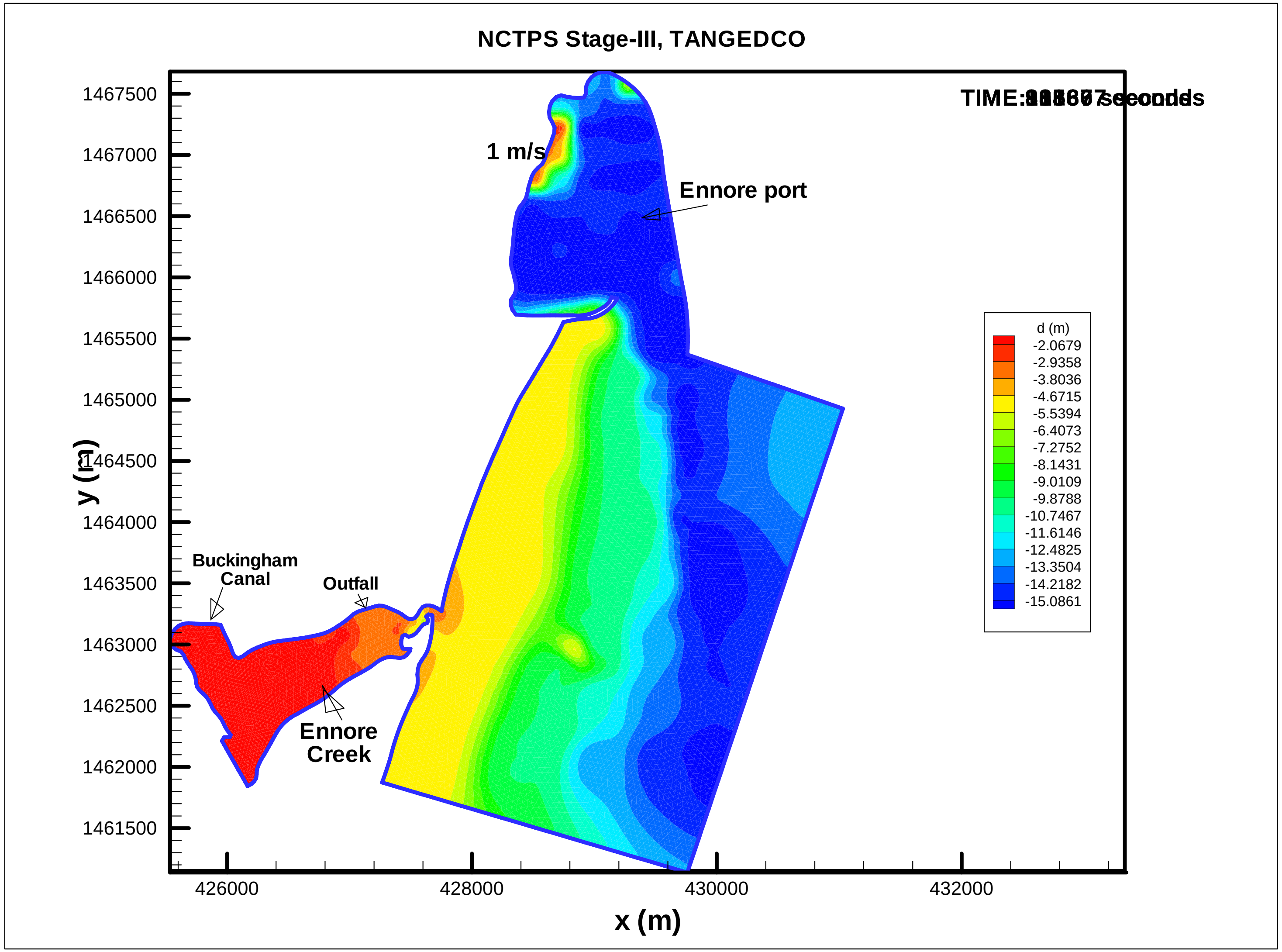


Fig.10. Bathymetry of Ennore creek and adjoining sea spread.

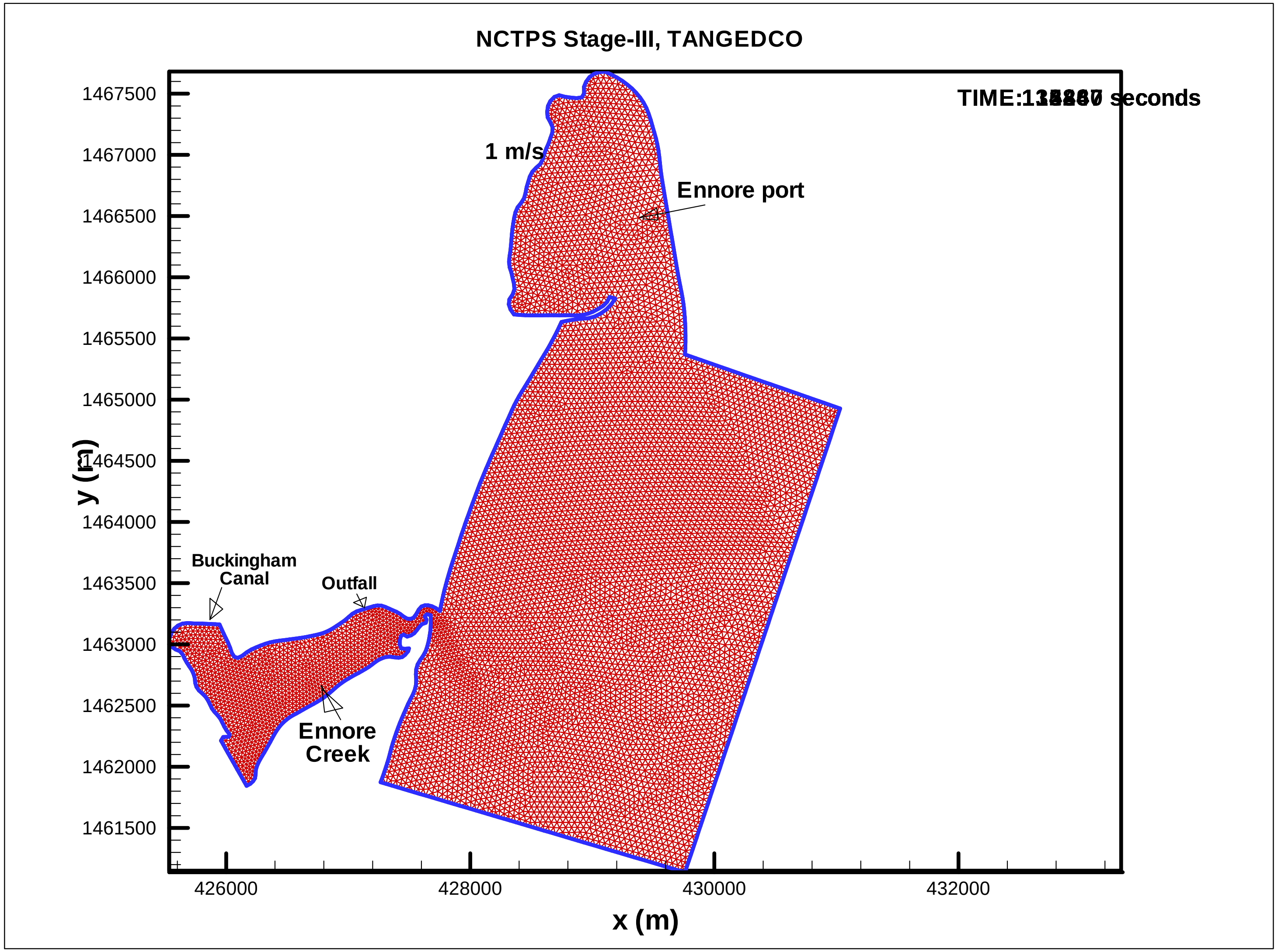


Fig.11. Computational domain considering for the tidal hydraulics study

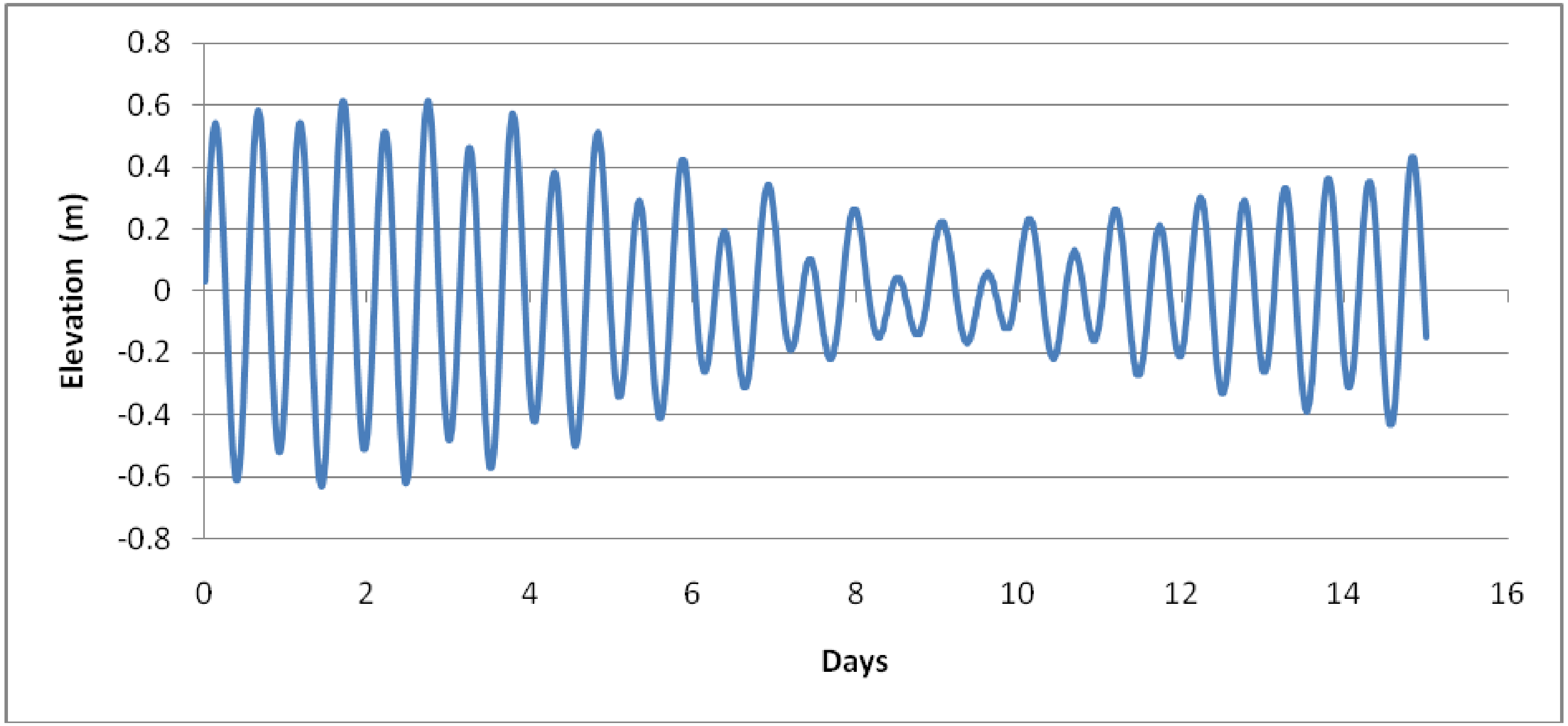


Fig.12. Tidal elevation boundary data used for the open boundary at Bay of Bengal

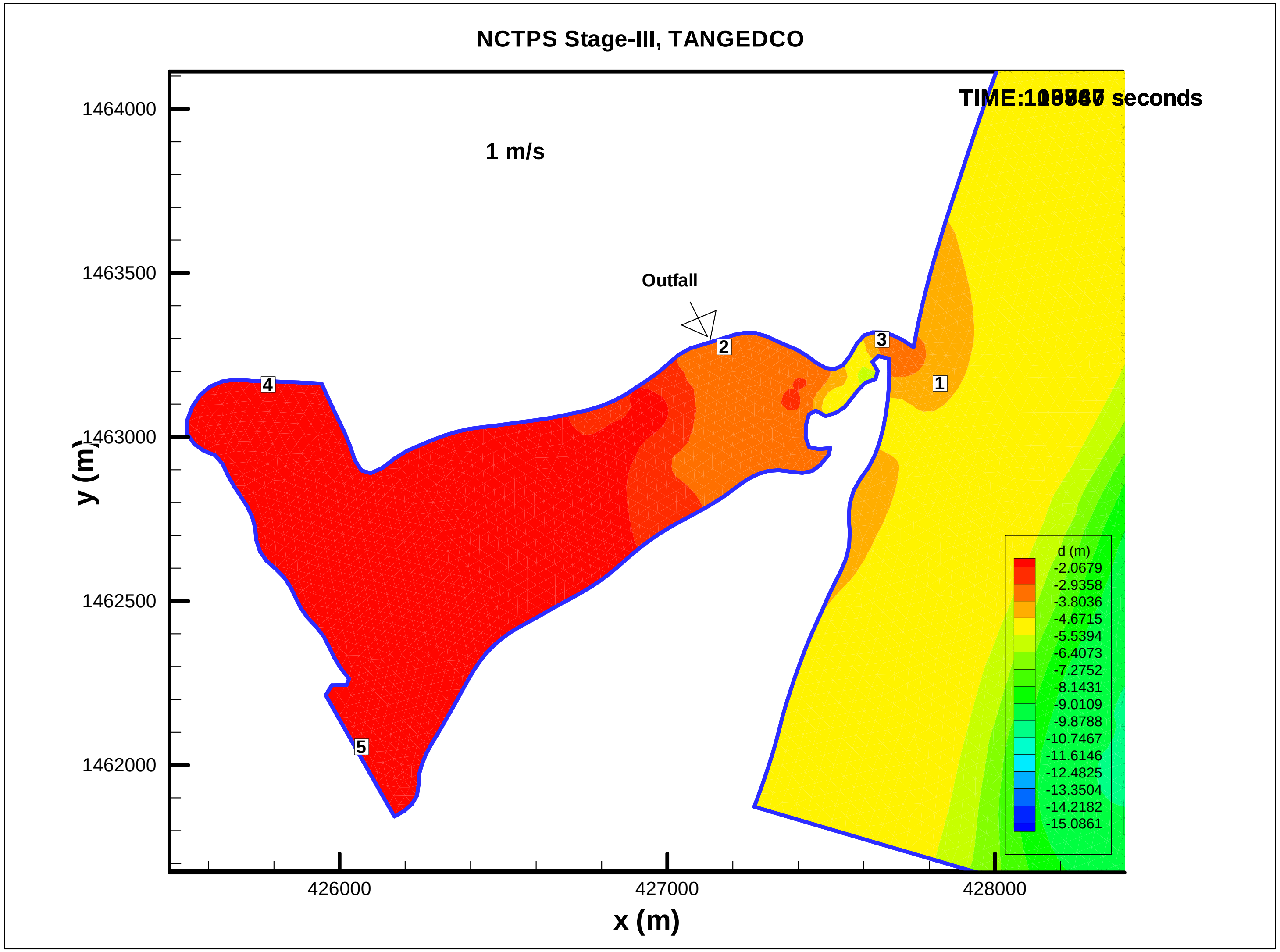


Fig.13. Locations of extraction of time series of velocities

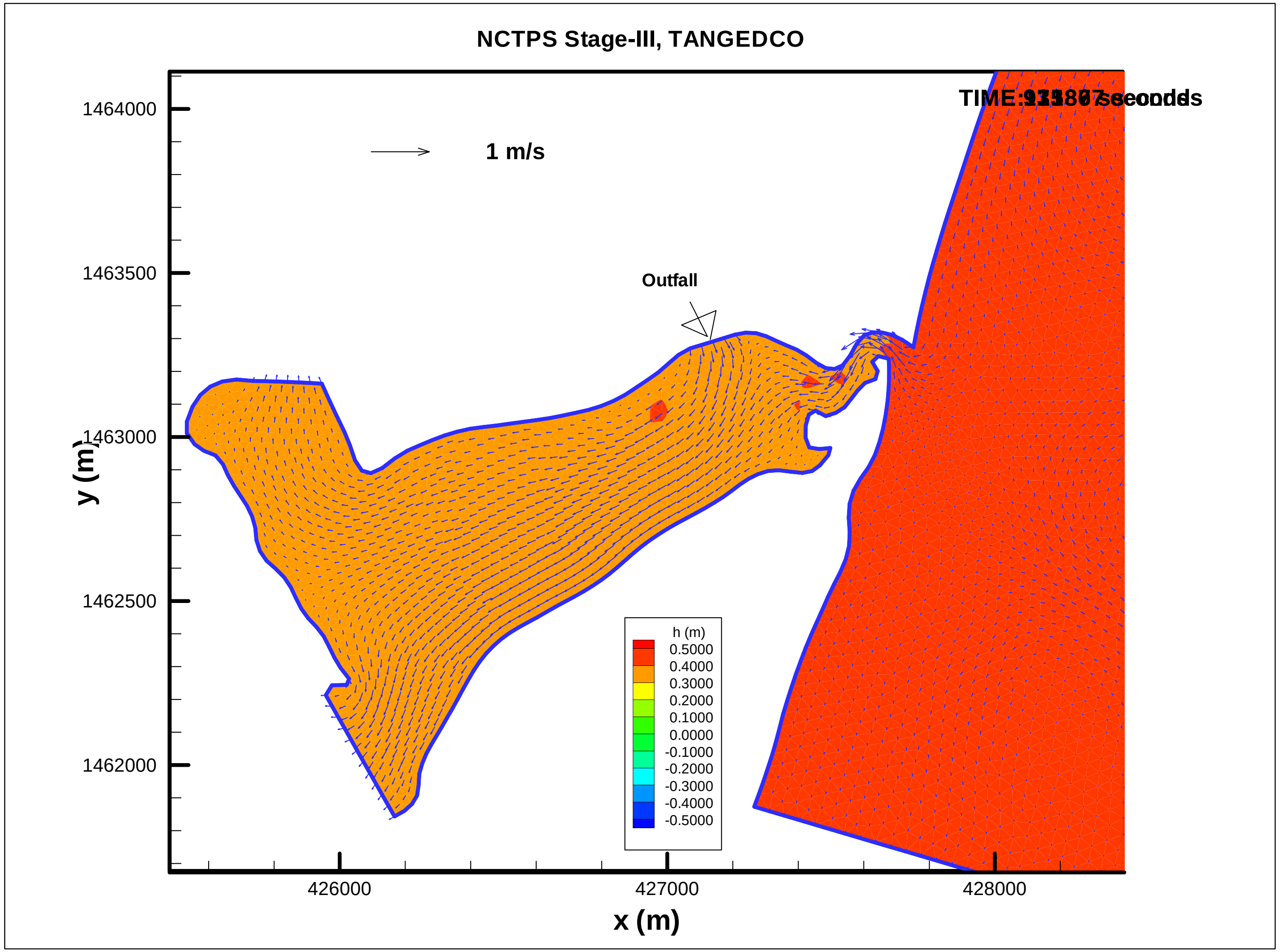


Fig.14.Typical currents during flooding in the creek and the sea

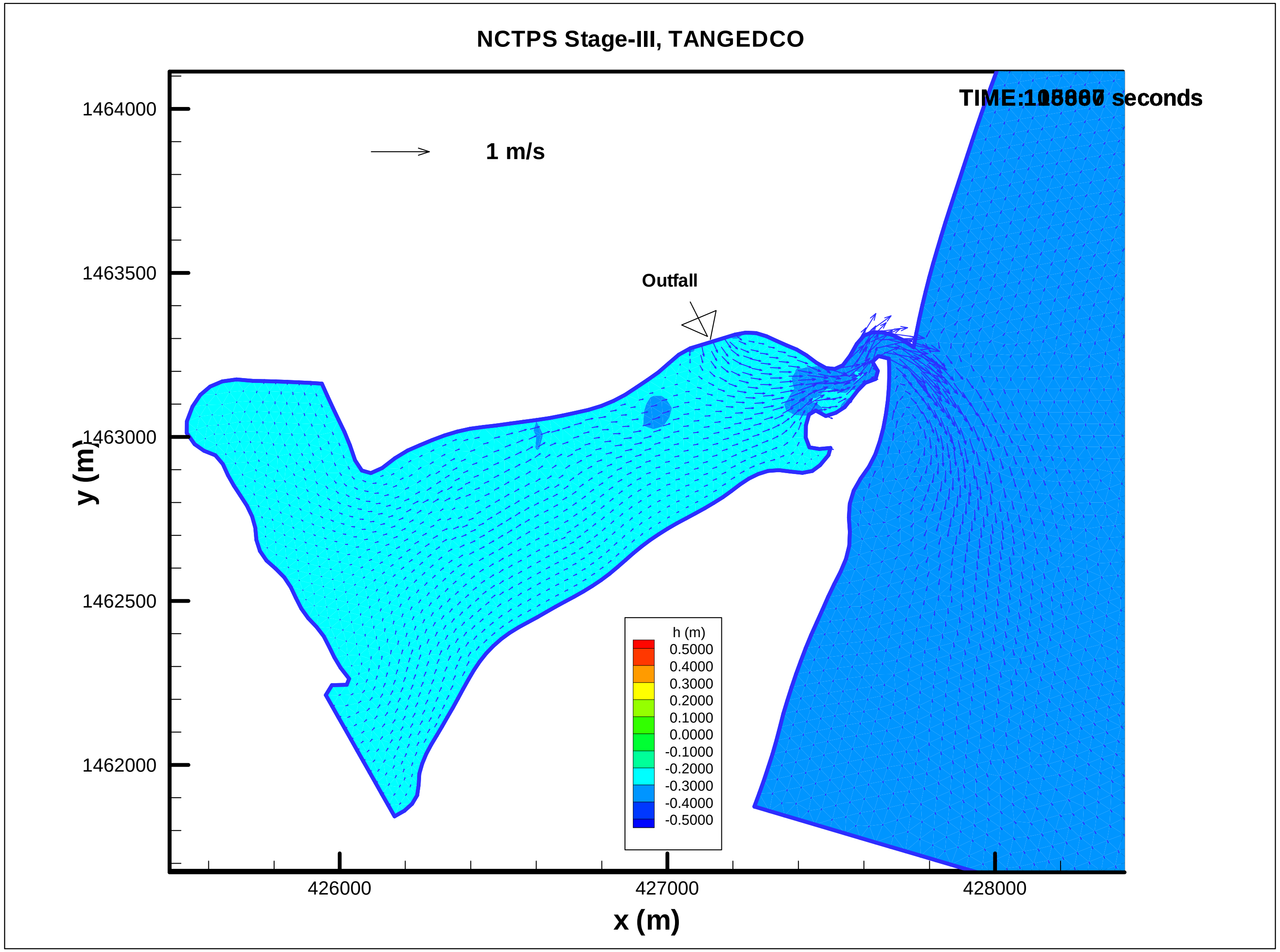


Fig.15. Typical currents during ebbing in the creek and the sea

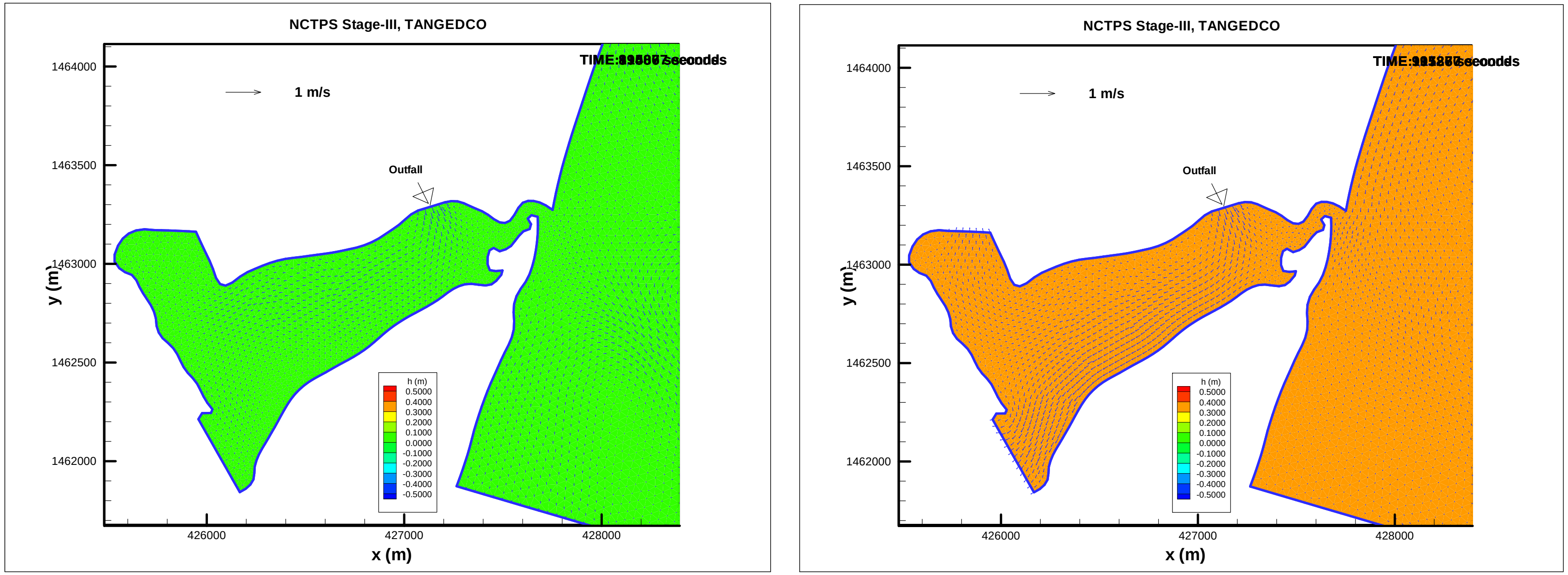
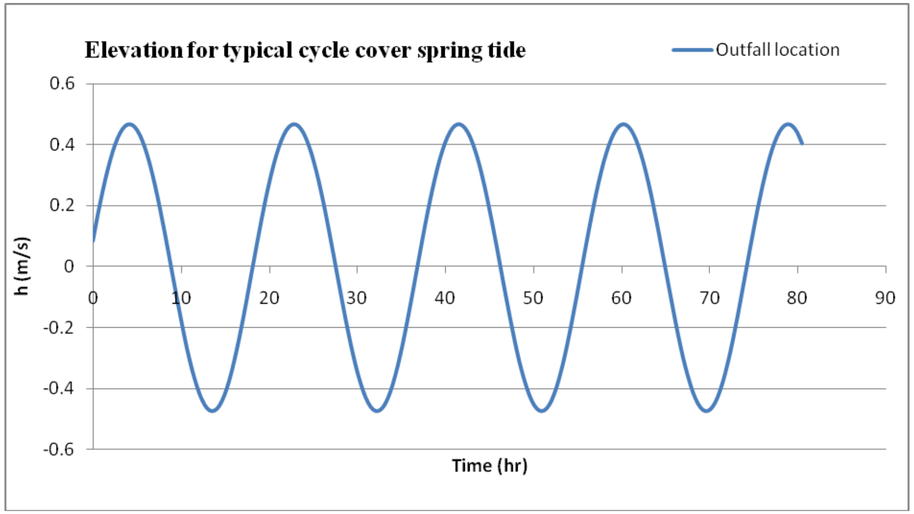


Fig.16. Typical residual currents before flooding and before ebbing in the creek and the sea



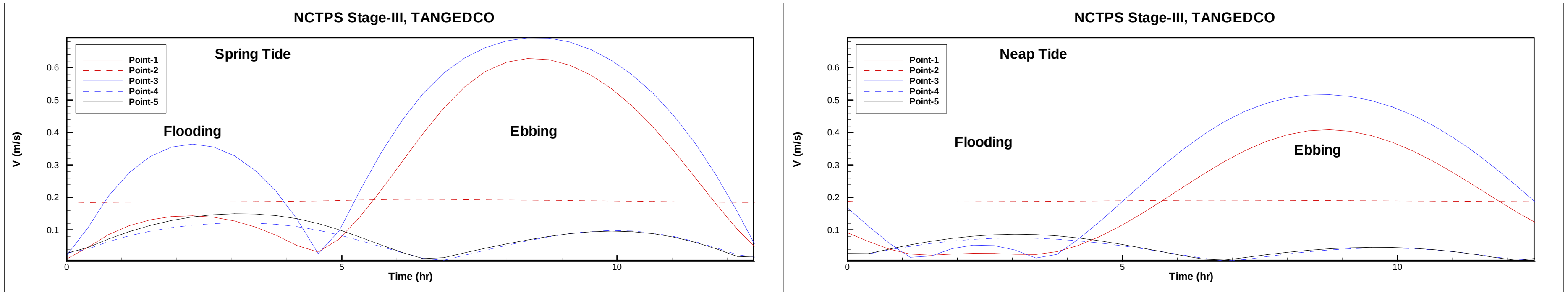


Fig.17.Time record of tide level and current at various locations given in Fig.13.

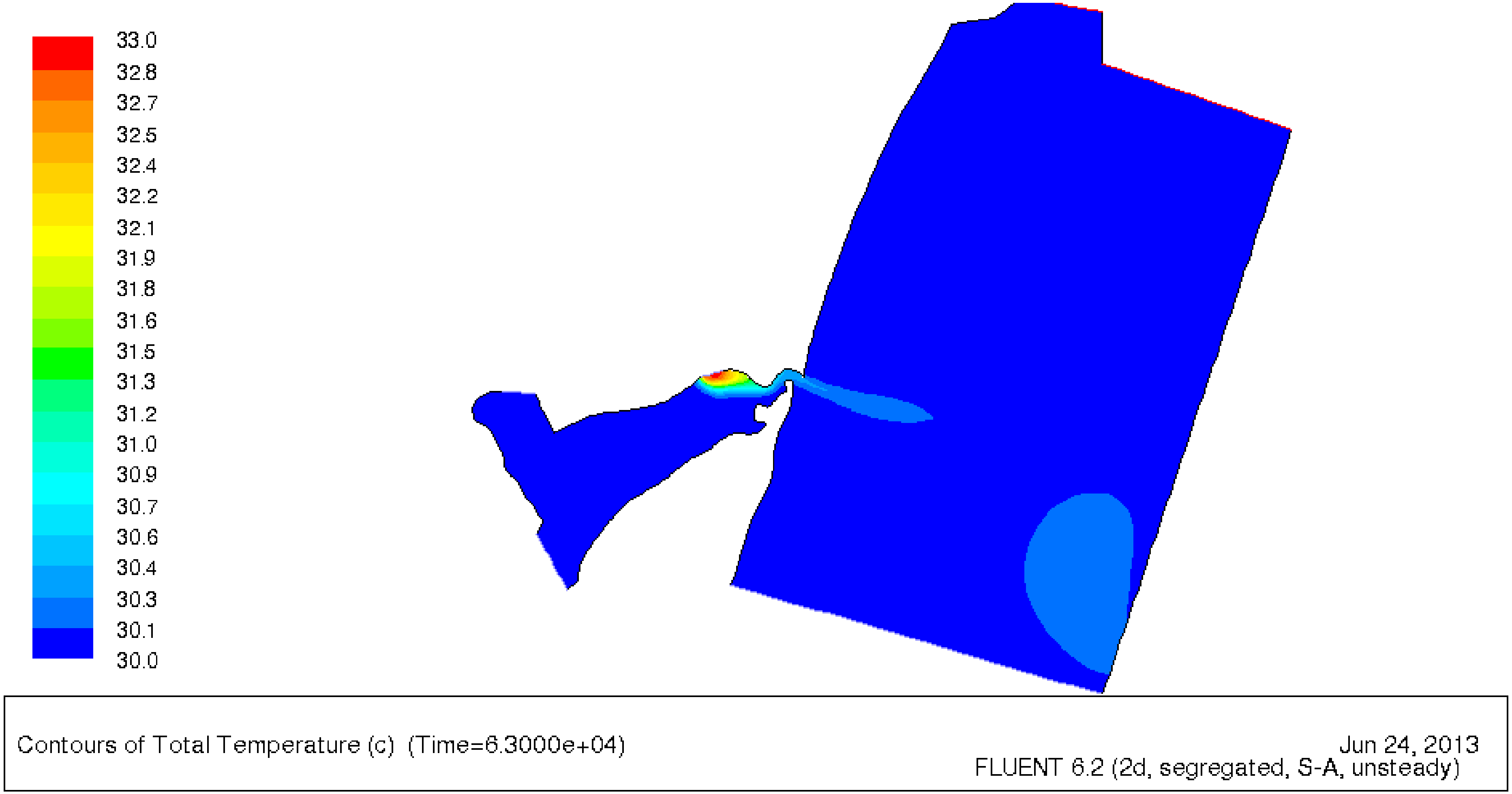


Fig.18. Present creek mouth (140m wide) configuration: Thermal dispersion pattern after low tide.

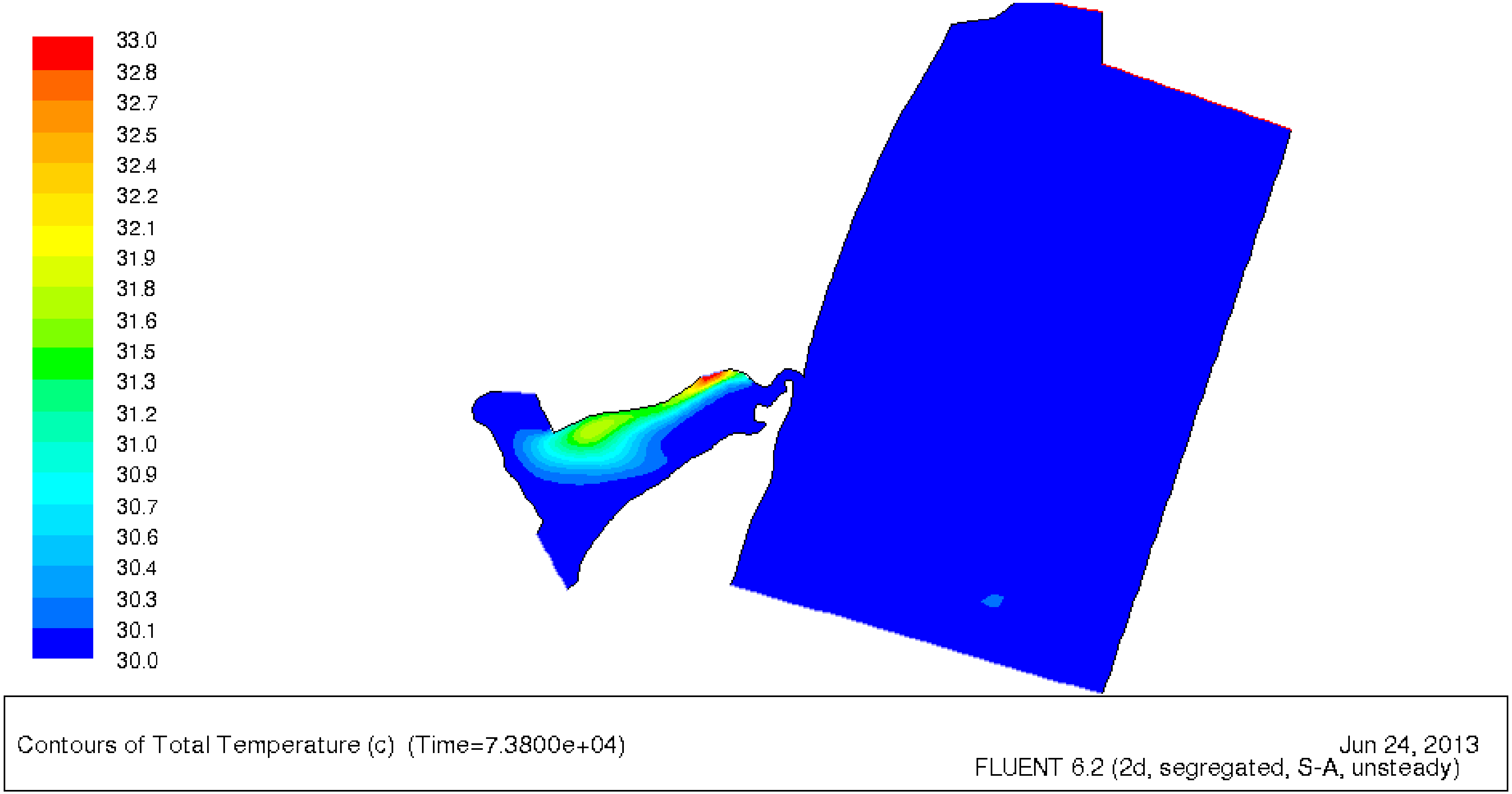


Fig.19. Present creek mouth (140m wide) configuration: Thermal dispersion pattern during flooding tide.

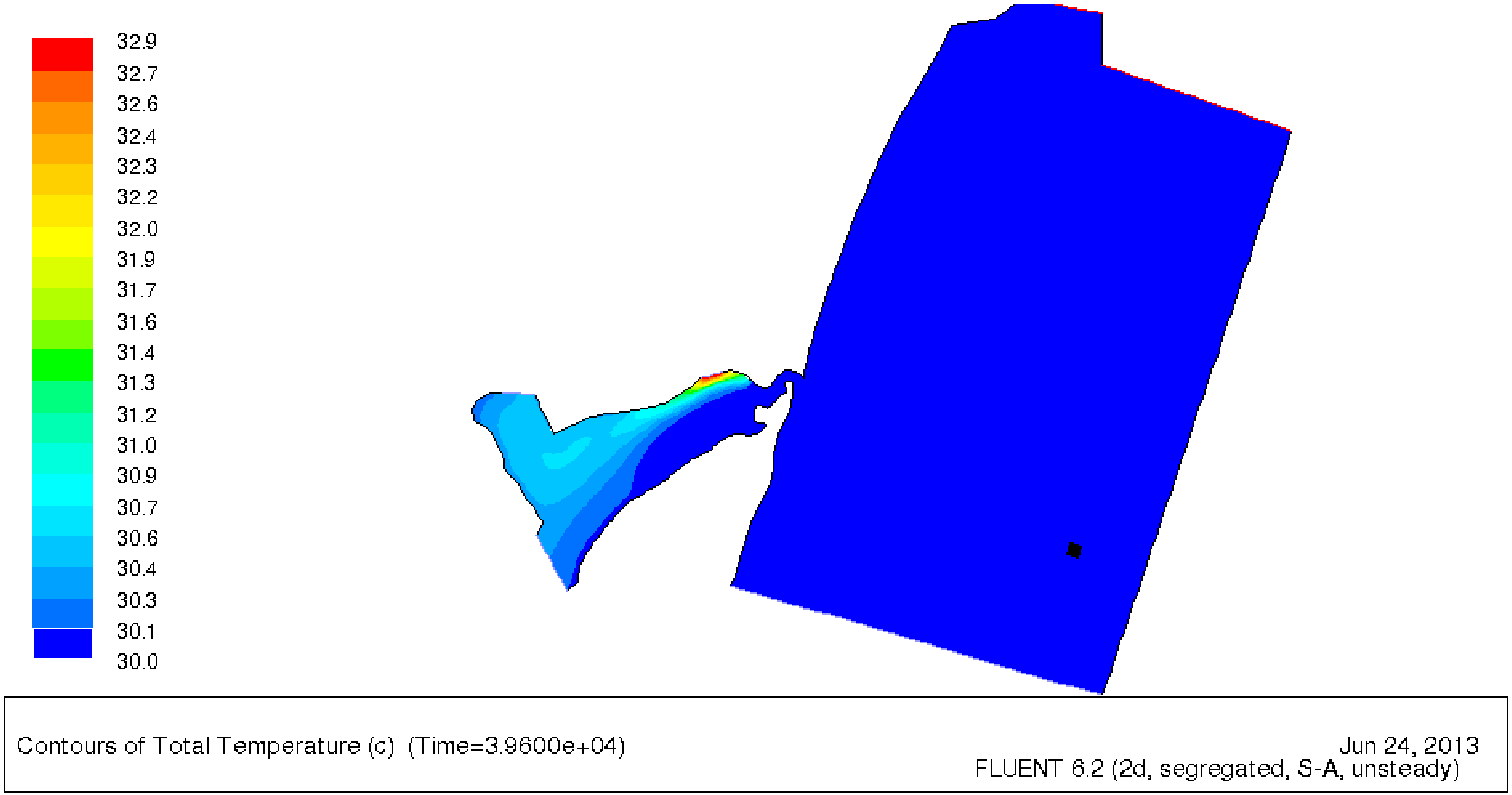


Fig.20. Present creek mouth (140m wide) configuration: Thermal dispersion pattern at high tide.

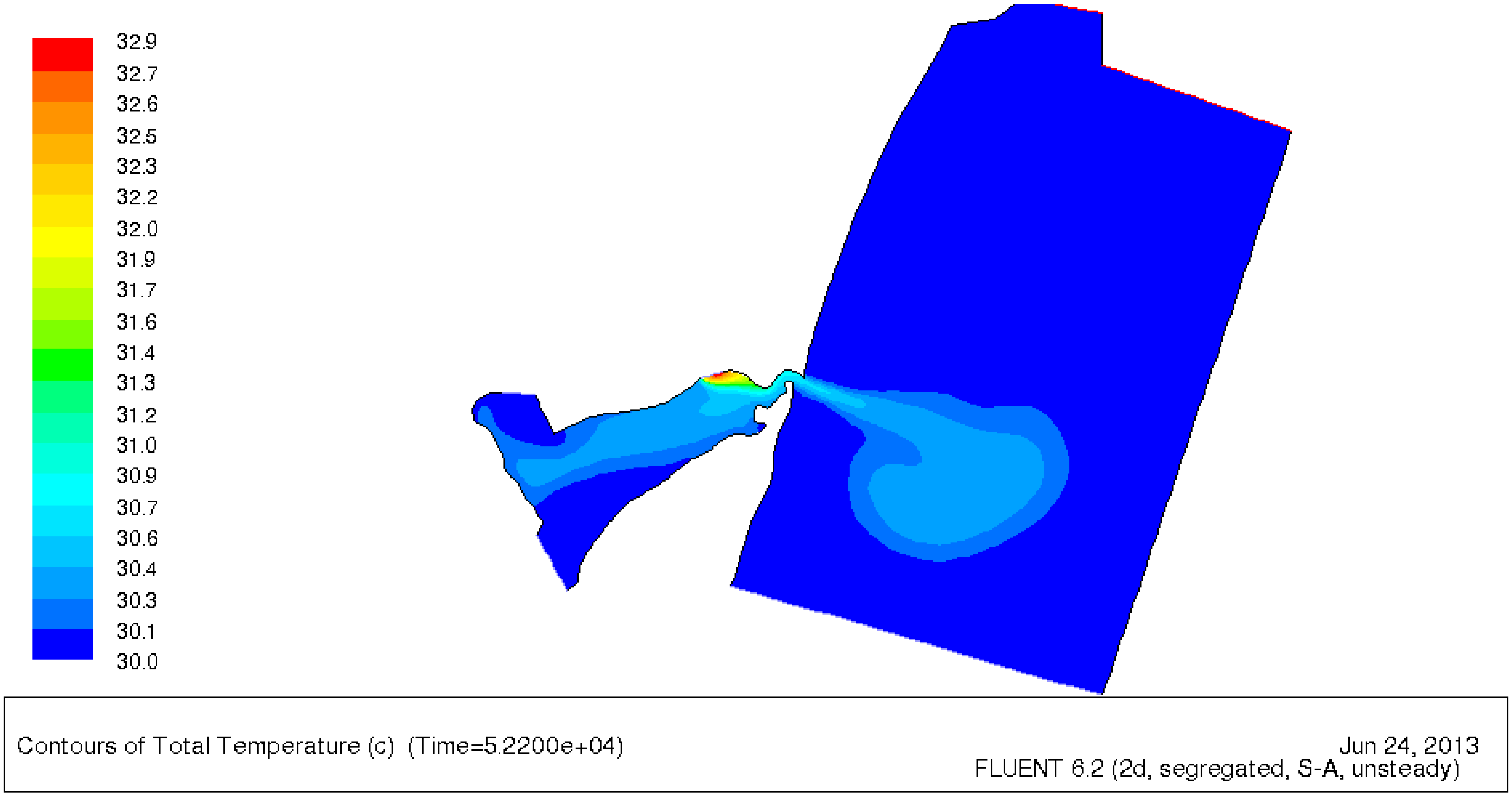


Fig.21. Present creek mouth (140m wide) configuration: Thermal dispersion pattern during ebbing.

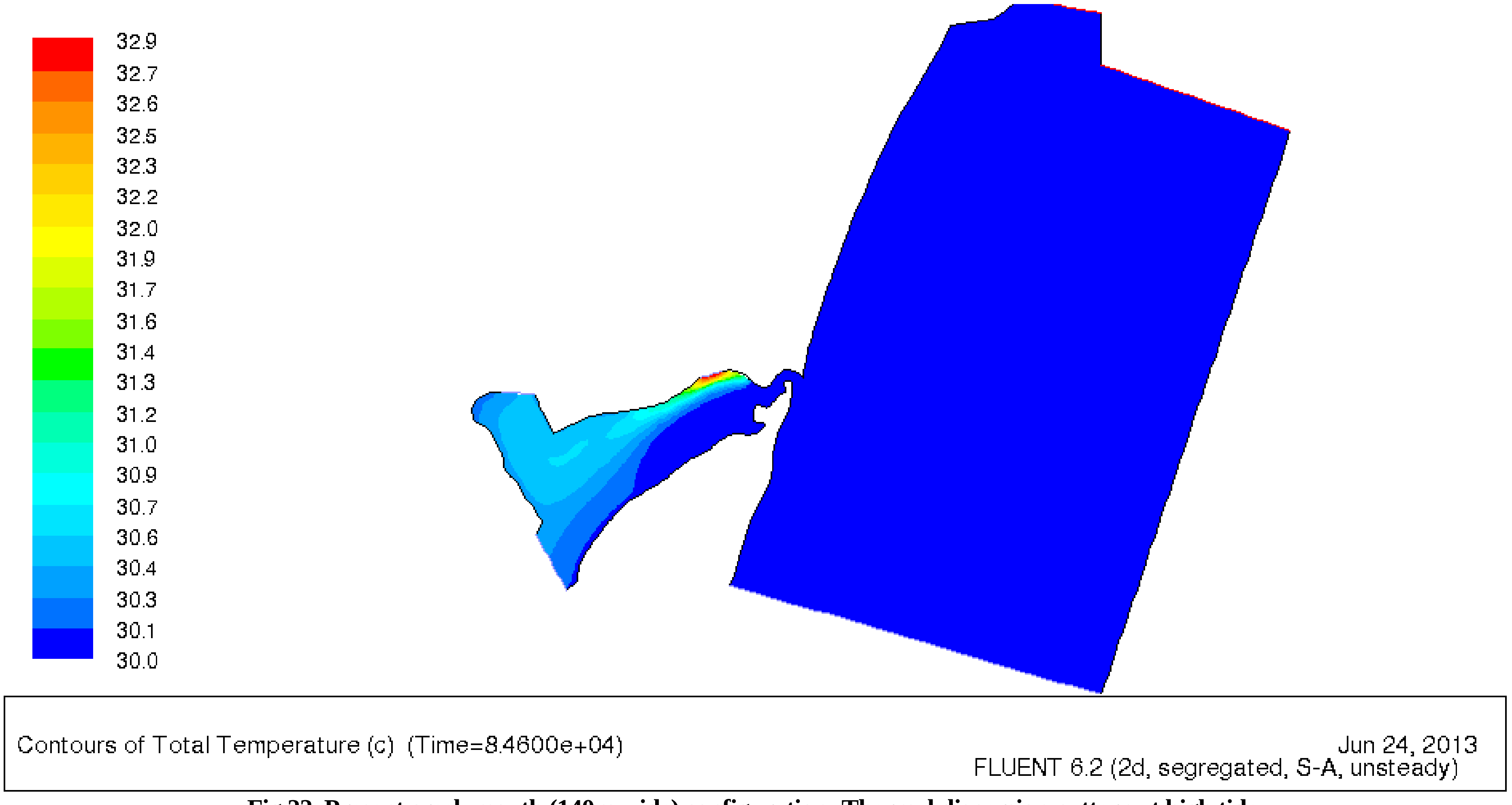


Fig.22. Present creek mouth (140m wide) configuration: Thermal dispersion pattern at high tide.