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VOLUME – III

COMPREHENSIVE MARINE ENVIRONMENTAL IMPACT ASSESSMENT STUDY FOR INTAKE AND OUTFALL

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TANGEDCO

TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LTD

COMPREHENSIVE MARINE ENVIRONMENTAL IMPACT ASSESSMENT STUDY FOR INTAKE AND OUTFALL FOR PROPOSED SUPER CRITICAL COAL BASED THERMAL POWER PROJECT AT UPPUR (2x800 MW) AT THIRUVADANAI TALUK, RAMANATHAPURAM DISTRICT

CENTRE FOR ENVIRONMENT

WAPCOS LIMITED

(A GOVERNMENT OF INDIA UNDERTAKING)

PLOT NO. 76 – C, SECTOR 18, GURGAON – 122 015, HARYANA

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EXECUTIVE SUMMARY

1. INTRODUCTION

M/s Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) is proposing to establish a 2x800 MW Thermal Power Project at Uppur Valamavur and Thiruppalaikudi villages in Thiruvadanai Taluk of Ramanathapuram District.

2. NEED OF THE STUDY

As a part of getting clearance from MoEF under Coastal Regulation Zone (CRZ) Notification (February 1991) and its subsequent amendments upto April 2003 under the Environment Protection Act, (1986) TANGEDCO has appointed WAPCOS Limited (A Government of India Undertaking) under the Ministry fo Water resources to carry out the Marine EIA studies. The EIA studies will incorporate environmental constraints within the project conceptualization, design, construction and its operation phases.

3. ENVIRONMENTAL IMPACTS

During the monitoring program several ecologically sensitive chemical parameters such as Oxygen, BOD, nutrients and heavy metals were analysed. It was found that all the parameters were at the optimal concentration and coincided with the seasonal variation. All the parameters observed as a part of the monitoring program ranged within permissible limits.

In the proposed project, the modeling studies suggest that the outfall temperature shall be increased only by 0.5 -0.75°C from the ambient temperature, which is well below the standard prescribe by the statutory authority. Hence, no specific management measures are suggested. Salinity changes are expected to be within 38 ppt, hence impact of salinity and temperature on the marine biota is expected to be minimal.

Further, in order to mitigate the impacts of the proposed project several monitoring programs have been suggested.

4. CONCLUSIONS

The Comprehensive Marine EIA Study was carried out to identify the impacts of outfall of the proposed Coal Based Thermal Power Project. The following concusions were drawn.

- ✓ The spread of the plume is limited towards south to about 2km. Hence, it is concluded that a dilution of 200 is possible within a distance of about 2.5km from outfall.
- ✓ The temperatures in the sea will rise by only about 0.5-0.75°C within a radius of 2.5km. Beyond this, the plume will have ambient conditions.
- ✓ The rise in temerature is not likely to cause any alteration in the biotic community of the coastal waters of the project area.
- ✓ The pile supported jetty with offshore pump house is recommended since this will cause much lesser disturbance to prevailing marine and seabed environments.
- ✓ The outfall of the proposed Uppur Power Project would not change the quality of existing natural coastal environment.
- ✓ In the project area no endangered, threatend marine speices were recorded during marine survey in all the three seaons.
- ✓ The marine water quality and ecology in and around the proposed outfall area is that of any normal coastal environment during the study period for all the three seaons.

CHAPTER - 1
INTRODUCTION

1.1 Background

M/s Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) is proposing to establish a 2x800 MW Thermal Power Project at Uppur Valamavur and Thiruppalaikudi villages in Thiruvadanai Taluk of Ramanathapuram District. The proposed project will adopt supercritical technology and shall be using either 5.02 MMT of 100% imported coal per annum or blended coal of 5.58 MMT with ratio of 30% Indigenous coal and 70% imported coal per annum shall be used. The consumptive water drawn from the sea, shall be used after treatment in Desalination plant in site as plant water and cooling water. The location map of the project area is shown in Fig 1.1.

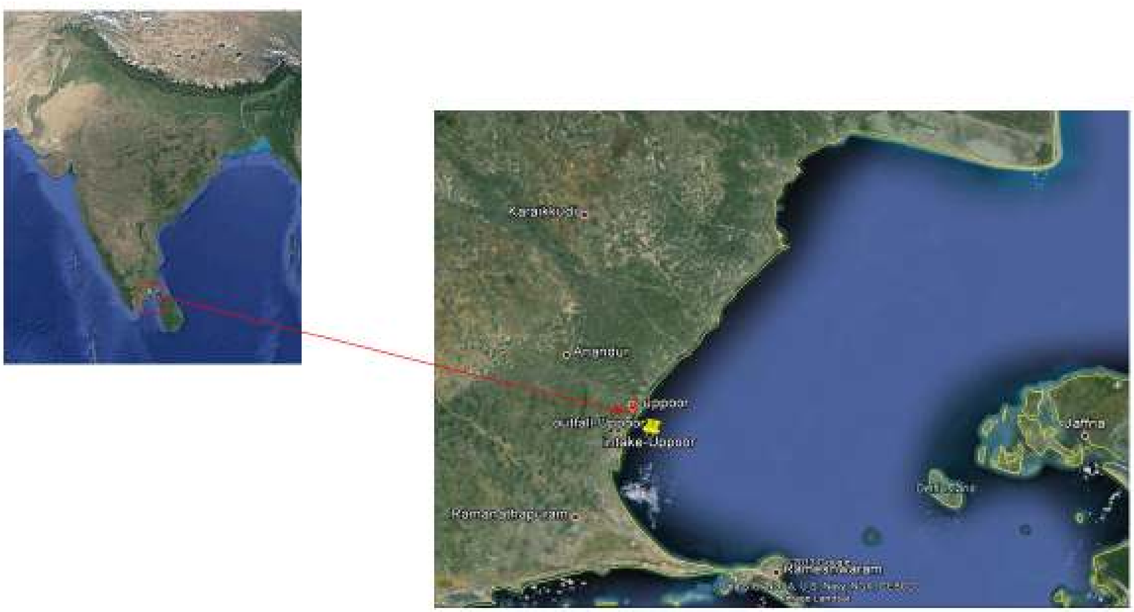


Figure 1.1 Location map of the proposed Uppur Power plant

To carry out the Mathematical Model study of Thermal / Salinity dispersion of the cooling water discharge and impact of the coolant water, TANGEDCO has appointed Indian Institute of Technology (IIT), Madras. In turn 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 to carry out Marine EIA study.

1.2 NEED OF THE STUDY

The proposed Uppur Thermal Power plant would require clearance under Coastal Regulation Zone (CRZ) Notification (February 1991) and its subsequent amendments upto April 2003 under the Environment Protection Act, (1986). Apart from the above-mentioned statutory requirements, Marine EIA is essential because it ensures incorporation of environmental constraints within the project conceptualization, design, construction and its operation phases. Marine EIA inculcates identification of interests and trade-offs, helps to identify management and mitigation measures, brings about consideration and consultation among interested parties, increases technical expertise and experience, and facilitates decision-making. In addition an EIA study also leads to the delineation of long-term environmental monitoring requirements.

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 Power Plant.

Chapter- 2: This chapter describes the project description.

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 GENERAL

TANGEDCO has carried out an extensive study to identify suitable locations for setting-up the proposed Thermal Power Plant of 2 x 800 MW capacity after detailed techno-economic evaluation. For establishing the proposed project, land has been identified in Uppur, Valamavoor and Thiruppalaikudi villages of Thiruvadanai Taluk, Ramanathapuram District.

2.2 PROJECT DESCRIPTION

The proposed Uppur Thermal Power Plant uses a reheat steam cycle with regenerative feed heating arrangement operating at supercritical range has been proposed. The proposed power plant envisages supply of imported coal from Indonesia by ships upto Tuticorin Port. From there it shall be transported by rail to the proposed project site. Raw water supply to the plant is proposed from the Bay of Bengal, which is at a distance of about 1Km on the Eastern side of the project site.

Re-circulating cooling water system with Natural Draft Cooling Towers is proposed for the power plant. The fly ash generated is proposed to be handled pneumatically in dry mode up to fly ash silos and transported through truck for utilization by end users. In case of exigency, ash from the fly ash silos will be conveyed to ash pond in slurry form. The electrical system proposed for the power plant would be equipped with adequately sized equipment and with generous redundancy to ensure uninterrupted operation.

The proposed power plant uses the state-of-the-art Digital Distributed Control & Monitoring Information System (DDCMIS) which will integrate various closed loop sub-systems, open loop sub-systems, monitoring and information sub-system covering the entire plant.

2.3 TECHNICAL FEATURES

Power Generating Unit	Two units of 800 MW turbine generator sets fed by steam from coal fired Pulverised Fuel boilers operating at supercritical range.
Minimum Steam Condition at Steam Turbine Inlet	259.5 bar (a) / 569°C
Cooling System	Recirculating type cooling water system with wet type Natural Draft Cooling Towers using clarified sea water as cooling medium.
Coal Handling System	Imported coal will be transported by Railway BOX-N type wagons to site. Coal storage for 45 days approx. and mill bunker storage for 14 hours is proposed
Ash Disposal System	Dry collection and disposal of Fly Ash and wet disposal of bottom ash is considered. Ash will be primarily disposed by truck to end users as far as possible. Besides provision will be made to transport fly ash (only during emergency) through pipe line to the ash pond (located nearby within the Plant boundary).
Power Evacuation	Power generated in the Power Plant would be available at 400 kV level in the station switchyard bus and would be fed to Tamil Nadu Transmission Corporation Limted (TANTRANSCO) 400KVA Karaikudi substation which is about 40KMs North West of the proposed site and 400KVA Chekkanurani substation which is about 90KMs west of the proposed site.
Power Off-take	Through TANTRANSCO.
Environmental Aspects	• One (1) no of 275 M height twin flue stack is proposed for the 2x800MW units to meet the standard set for dispersion of particulate, SO_X and NO_X. • ESP Multiple field electrostatic precipitators with separation efficiency of around 99.9% is envisaged for steam generator. • The Reject water from RO plant along with Blow down water from Cooling Tower will be pumped back to Bay of Bengal as per Tamil Nadu Pollution Control Board (TNPCB) standards and the Ministry of Environment &

	Forest's (MoE&F) standards. Other Waste water generated will be treated and utilized for horticulture development.
Manpower Requirement	324 personnel during plant operation

2.4 DETAILS OF PROJECT LOCATION

Project Location	The site is located in Uppur, Valamavoor and Thiruppalaikudi Villages of Thiruvadanai Taluka of Ramanathapuram District in Tamil Nadu State Latitude – 9° 36' N Longitude - 78° 55' E
Nearest Major Town/City	Ramanathapuram, which is 28 kms from the proposed site and Madurai city which is at a distance of 140Kms.
Seismic Zone	Zone III as defined in - IS: 1893 –2002
Access by Road	The site is located on the western side of East Coast Road (ECR) connecting Ramanathapuram and Pattukottai
Access by Rail	Ramanathapuram Railway Station, 28 kms from site
Access by Sea	Tuticorin Port - 130 kms from site

The CRZ mapping carried out by Institute of remote sensing is given in figure 2.1.the details of the requirement is given in table 2.1.

TABLE 2.1

LAND REQUIREMENT FOR THE PROPOSED PROJECT

LAND REQUIREMENT	AREA (Acres)
Power Plant Area for 2 units	50
Disposal Area for initial 6 years of ash	138
Other (sea water intake pump house, rail, road, canteen administration building, parking area, pipe corridors etc	449
Green belt	275
Total Land Requirement	**912**

Fig 2.1 Map showing HTL LTL demarcation

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 for three seasons i.e., June 2013, September 2013 and January 2014 for primary data generation on various aspects of marine water quality and ecology.

3.2 METEOROLOGY

The project area has four distinct seasons. The period from March to May comprises the summer season and in subsequent months from June to September, the area comes under the influence of south-west monsoons. The months of October to December, experience the north-east monsoon season, while the area experiences a mild winter season which lasts from January and February.

Temperature

Large scale variations in temperature in various seasons are not observed in the area. The month of May and June is the hottest month of the year with mean monthly maximum temperature being 33.9°C. The month of January, is the coolest month with a monthly minimum temperature of 20.9°C.

Rainfall

The average annual rainfall in the project area district is 801 mm to 1000 mm. Most of the rainfall is received in the months from October to December under the influence of north-east monsoon.

Humidity

The humidity is generally high throughout the year. During monsoon months i.e. November to February, humidity ranges from 80% to 85%. During rest of the year, humidity, varies from 72% to 77%. The average humidity observed over the year is 77%.

The average meteorological conditions of the project area district are outlined in Table-3.1.

TABLE-3.1

Average meteorological conditions in the project area district

S. No.	Month	Temperature (^oC) Max.	Temperature (^oC) Min.	Rainfall (mm)	Relative Humidity (%)
1.	January	28.9	20.9	23.8	81
2.	February	29.7	21.6	0.1	80
3.	March	32.6	24.9	86.5	76
4.	April	33.7	26.8	22.4	77
5.	May	33.9	27.5	10.8	74
6.	June	33.9	26.5	2.3	75
7.	July	33.0	25.3	48.4	75
8.	August	33.7	24.9	12.9	72
9.	September	33.1	24.6	51.7	77
10.	October	30.2	25.3	267.0	77
11.	November	28.7	22.5	254.0	85
12.	December	29.4	24.7	244.2	81

3.3 MARINE ECOLOGY (JUNE, 2013)

Marine Ecological survey was carried out in the Uppur coastal waters in Ramanathapuram District, Tamil Nadu. The marine sampling points for the proposed project are located between Thirupalakudi and Uppur coastal villages. Many water channels were connecting the shore from land side. The Marine Ecological survey at Uppur coastal areas was conducted by a team of experts from the Centre of Advanced Study in Marine Biology of Annamalai University during June 2013.

Fifteen stations were selected in the coastal area and the samples were collected both high and low tide. Among the stations, UTPC 1, 2,3,4,5 and 6 were located in the near shore, UTPC- 7,8,9,10,11 & 12 were located away from the shore stations and UTPC 13, 14 & 15 in the open sea. The sampling locations are shown in Fig 3.1

Fig 3.1 Map showing the sampling stations

The Uppur coastal area covers thick mangrove vegetations along the shore. The Avicennia marina, and Rhizophora apiculata are predominantly available in this area.

The pictorial representation of the sampling station is given below:

 Station 1	 Station 2

Station 3

Station 4 (2 km from the shore)

Station 5 (2 km from the shore)

Station 6 (2 km from the shore)

Station 7

Station 8

Station 9

Station 10

Station 11

Station 12

Station 13

Station 14

Station 15

The geographical locations of the sampling stations are given in the following table:

Table 3.1

SAMPLING LOCATIONS AND ITS GEOGRAPHICAL COORDINATES

S. No.	Station Code	Date	Time	Depth (m)	Latitude	Longitude
1.	UTPC-1	07.06.13	09:40	0.8	9°35'57.55"N	78°56'22.00"E
2.	UTPC-2	07.06.13	10:00	0.8	9°35'27.73"N	78°56'11.42"E
3.	UTPC-3	07.06.13	10:20	0.5	9°34'58.44"N	78°56'1.96"E
4.	UTPC-4	07.06.13	10:35	3.0	9°35'0.66"N	78°56'36.45"E
5.	UTPC-5	07.06.13	10:50	4.0	9°35'28.90"N	78°56'43.98"E
6.	UTPC-6	07.06.13	11:05	4.5	9°35'58.80"N	78°56'54.98"E
7.	UTPC-7	07.06.13	11:20	4.5	9°36'0.43"N	78°57'24.55"E
8.	UTPC-8	07.06.13	11:30	5.0	9°35'29.04"N	78°57'15.40"E
9.	UTPC-9	07.06.13	11:40	5.0	9°35'2.01"N	78°57'9.05"E
10.	UTPC-10	07.06.13	12:00	6.0	9°35'3.57"N	78°57'42.19"E
11.	UTPC- 11	07.06.13	12:20	6.0	9°35'29.44"N	78°57'44.57"E
12.	UTPC- 12	07.06.13	12:40	6.5	9°36'1.87"N	78°57'55.39"E
13.	UTPC- 13	07.06.13	13:05	8.0	9°36'3.05"N	78°58'22.22"E
14.	UTPC- 14	07.06.13	13:20	7.5	9°35'29.69"N	78°58'20.36"E
15.	UTPC- 15	07.06.13	13:50	8.0	9°35'5.02"N	78°58'14.92"E

MATERIALS AND METHODS

Water and Sediment Sampling

Water samples were collected using Universal water sampler below the surface and transferred to the pre-cleaned 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 and he plant 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). Salinity was estimated using a hand refractometer (Erma Company, Japan). Water samples collected for dissolved oxygen estimation were transferred carefully to BOD bottles. The DO was immediately fixed and brought to the laboratory for further analysis.

Preservation and Laboratory Analysis:

After collection, the 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 other nutrients. Unfiltered samples were used for the estimation of total nitrogen and total phosphorus. All the analyses were carried out as per internationally followed standard procedures for samples of aquatic origin. Briefly, the methods of analyses are as follows:

Dissolved Oxygen (DO):

The modified Winkler's method as described by Strickland and Parsons (1972) was adopted for the estimation of dissolved oxygen. The values are 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. The 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 are 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 values are 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 is 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 are 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 soon 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 inoculation 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:

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 detailed methodology is described 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. After collection, the 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 stained with Rose Bengal and sorted to different groups. The number of organisms in each grab sample was expressed as number per meter square. According to size, benthic animals are divided into three groups.

(i) Macrobenthos
(ii) Meiobenthos and
(iii) Microbenthos (Mare, 1942).

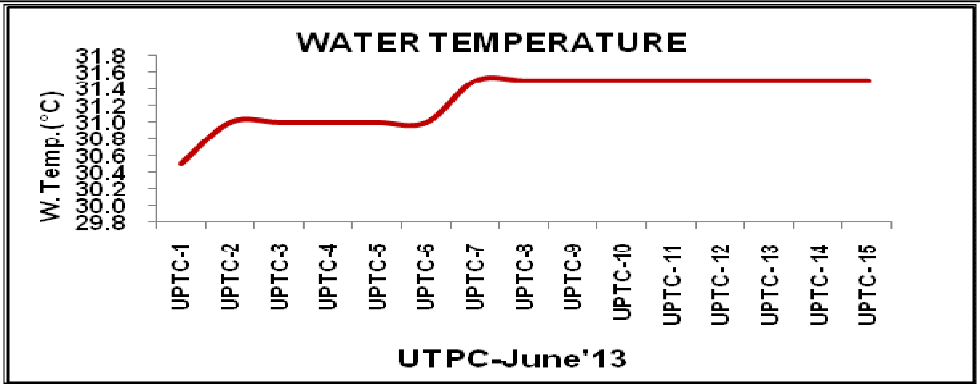
Macrobenthos are organisms which are retained in the sieve having mesh size between 0.5 and 1 mm. For Meiobenthos, the lowest size attributed is 63 μm and the upper limit depends upon the mesh size of the sieve used for separating macrobenthos from meiobenthos.

RESULTS

Water Quality

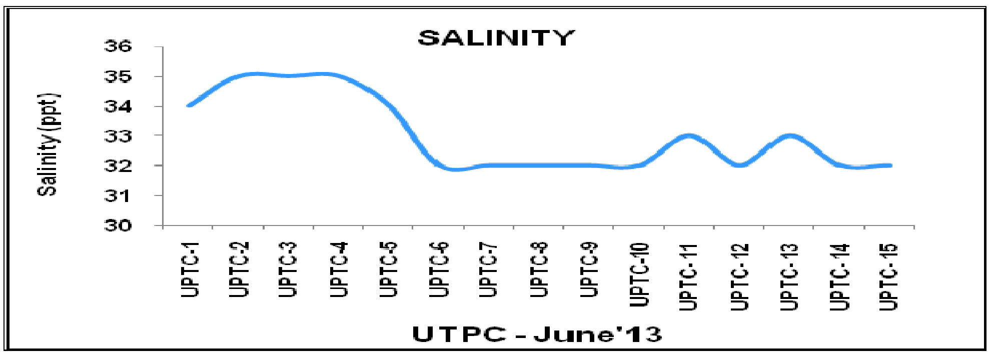
Water Temperature

The water temperature ranged between 30.5 and 31.5°C with maximum at UTPC-7, 8, 9, 10, 11, 12, 13, 14 & 15 and minimum at UTPC-1 (Table-3.2).



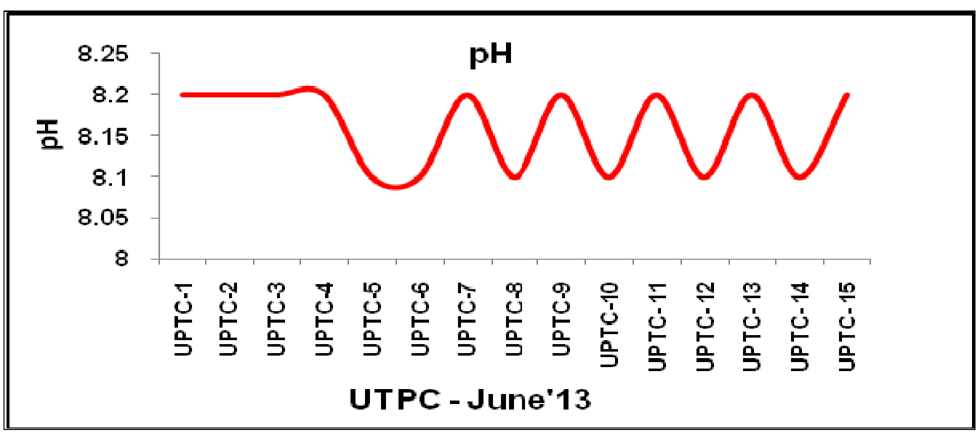
Salinity

The water salinity varied from 32.0 to 35.0 ‰ with maximum at UTPC-2, UTPC-3 and UTPC-4 and the minimum was recorded at UTPC-6, 7, 8, 9, 10, 12, 14 and UTPC-15 respectively (Table-3.2).



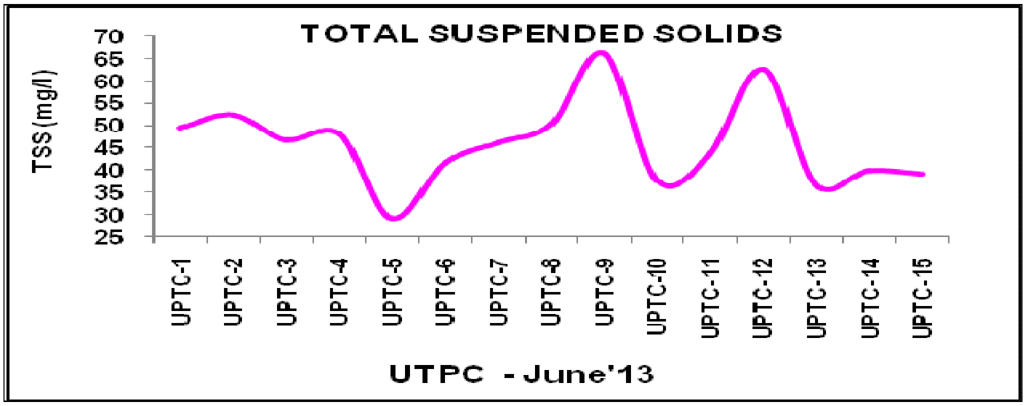
pH

The water pH varied between 8.1 and 8.2 (Table 2) with minimum in UTPC-5, UTPC-6 and the maximum at UTPC-1, 2, 3, 4, 9, 11 and UTPC-15 respectively.



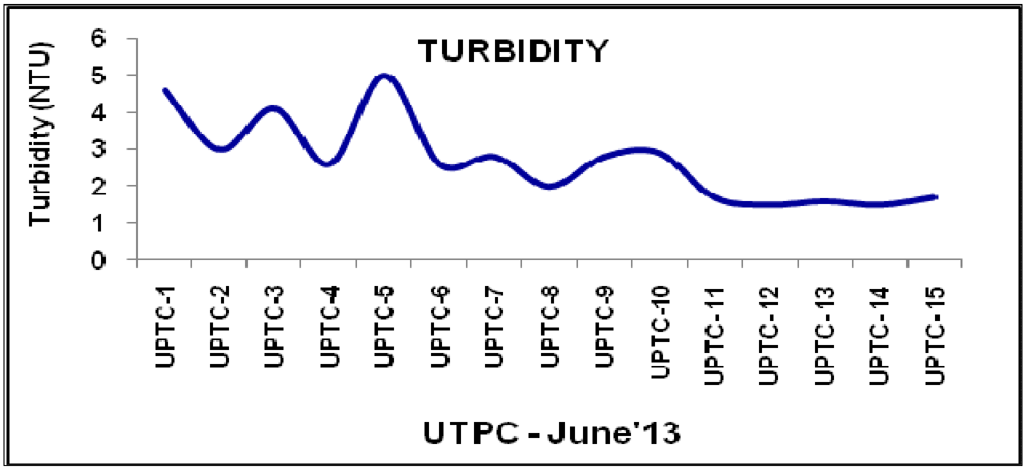
Total Suspended Solids

The TSS values ranged between 29.2 and 66.2 mg/l. The minimum value (29.2 mg/l) was recorded at UTPC-5 and maximum (66.2 mg/l) in UTPC-9 (Table-3.2).



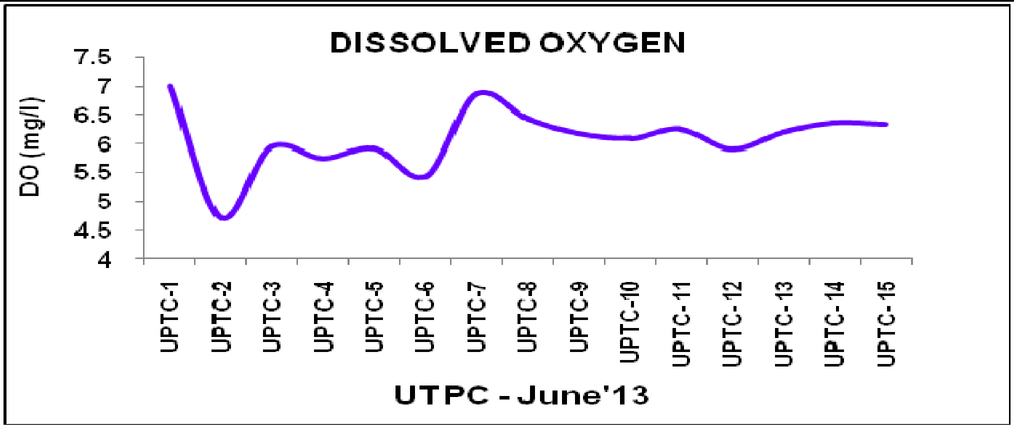
Turbidity

The turbidity values ranged from 1.5 to 5 NTU (Table-3.2) with maximum at UTPC-5 and the minimum was recorded at UTPC-12 & UTPC – 14 respectively.



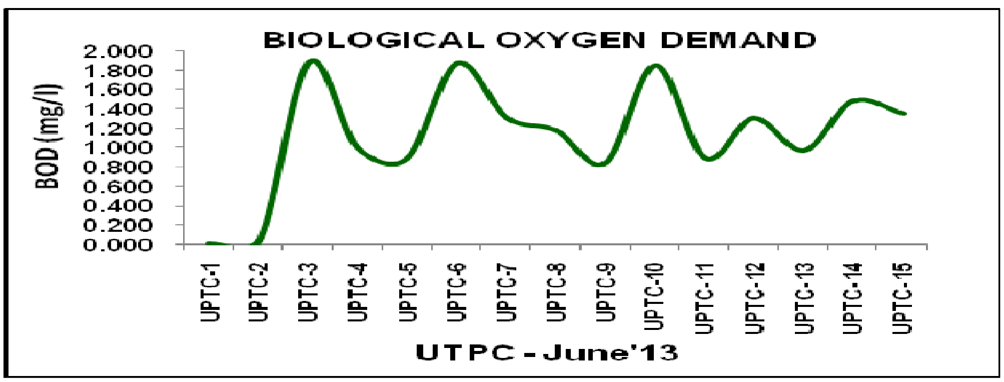
Dissolved Oxygen

The Dissolved Oxygen level in the water varied between 4.719 and 6.997 mg/l. The minimum and maximum values were recorded at UTPC-2 and UTPC-1 (Table-3.2).



Biological Oxygen Demand

The BOD values ranged between 0.016 and 1.888 mg/l with maximum (1.888 mg/l) at UTPC-3 and minimum (0.016 mg/l) in UTPC-1 (Table-3.2).



TABLE– 3.2.

PHYSICO - CHEMICAL PROPERTIES OF MARINE WATER

Sl. No.	Station code	Temp. (°C)	Salinity (‰)	pH	TSS (mg/l)	Turbidity (NTU)	DO (mg/l)	BOD (mg/l)
1.	UTPC-1	30.5	34.0	8.2	49.4	4.6	6.997	0.016
2.	UTPC-2	31.0	35.0	8.2	52.4	3.0	4.719	0.048
3.	UTPC-3	31.0	35.0	8.2	46.8	4.1	5.947	1.888
4.	UTPC-4	31.0	35.0	8.2	48.0	2.6	5.737	1.008
5.	UTPC-5	31.0	34.0	8.1	29.2	5.0	5.915	0.896
6.	UTPC-6	31.0	32.0	8.1	41.8	2.6	5.430	1.872

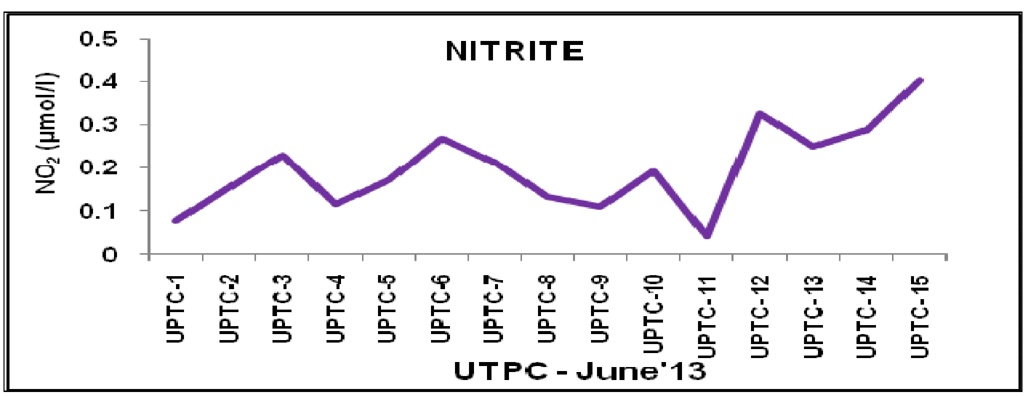
Sl. No.	Station code	Temp. (°C)	Salinity (‰)	pH	TSS (mg/l)	Turbidity (NTU)	DO (mg/l)	BOD (mg/l)
7.	UTPC-7	31.5	32.0	8.2	46.2	2.8	6.852	1.312
8.	UTPC-8	31.5	32.0	8.1	50.4	2.0	6.432	1.184
9.	UTPC-9	31.5	32.0	8.2	66.2	2.8	6.173	0.848
10.	UTPC-10	31.5	32.0	8.1	37.6	2.9	6.092	1.856
11.	UTPC- 11	31.5	33.0	8.2	43.6	1.7	6.254	0.896
12.	UTPC- 12	31.5	32.0	8.1	62.6	1.5	5.898	1.312
13.	UTPC- 13	31.5	33.0	8.2	36.8	1.6	6.205	0.976
14.	UTPC- 14	31.5	32.0	8.1	40.0	1.5	6.367	1.488
15.	UTPC- 15	31.5	32.0	8.2	39.2	1.7	6.335	1.360

Nutrients

The life supporting processes in the sea requires an array of inorganic substances, but the role of nitrogen, phosphorus and silicon are considered vital in marine ecosystem. Among the nitrogenous nutrients, nitrite, nitrate and ammonia are the major constituents, which play key roles in the phytoplankton growth and proliferation.

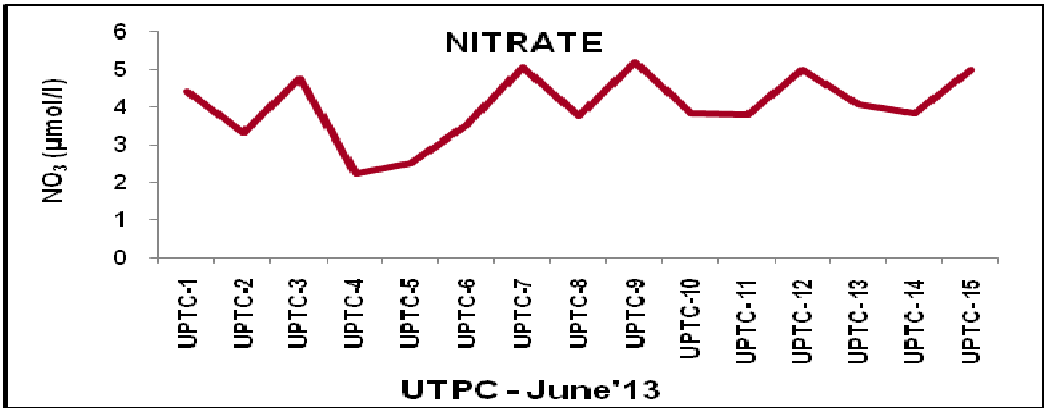
Nitrite

The nitrite concentration varied from 0.042 to 0.402 µmol/l (Table-3.3). The minimum and maximum values were recorded at UTPC-11 and UTPC-15 respectively.



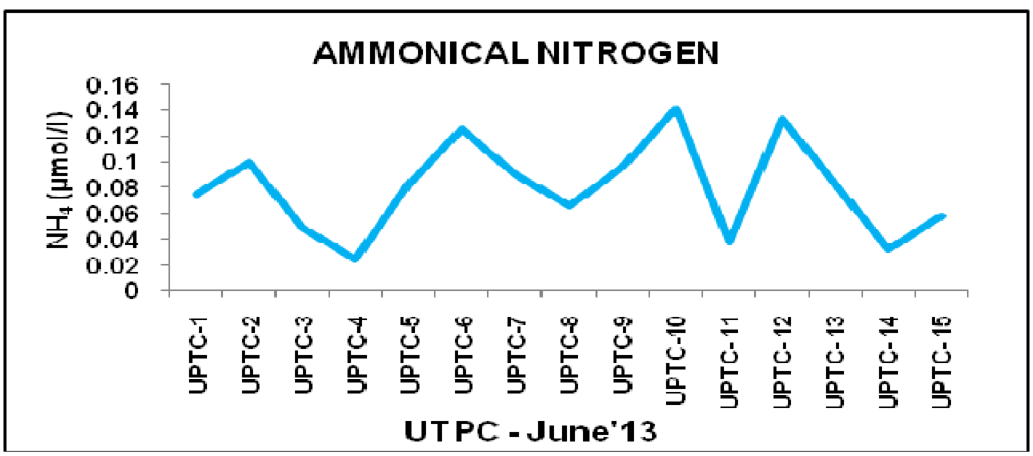
Nitrate

Nitrate content varied from 2.222 to 5.216 µmol/l (Table3.3) with maximum at UTPC-9 and minimum at UTPC-4.



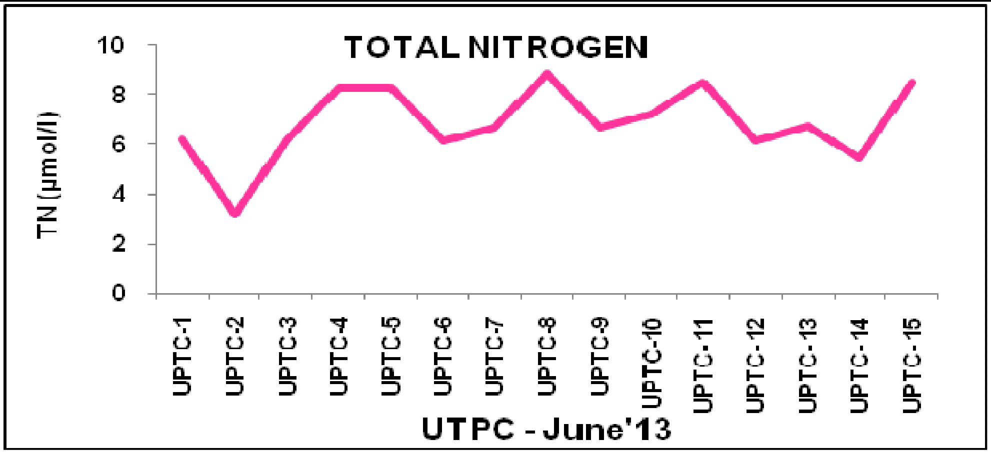
Ammonical Nitrogen

The ammonia concentration fluctuated from 0.025 to 0.141 µmol/l. The maximum level (0.141 µmol/l) was recorded at UTPC-10 and the minimum (0.025 µmol/l) was at UTPC-4 (Table-3.3).



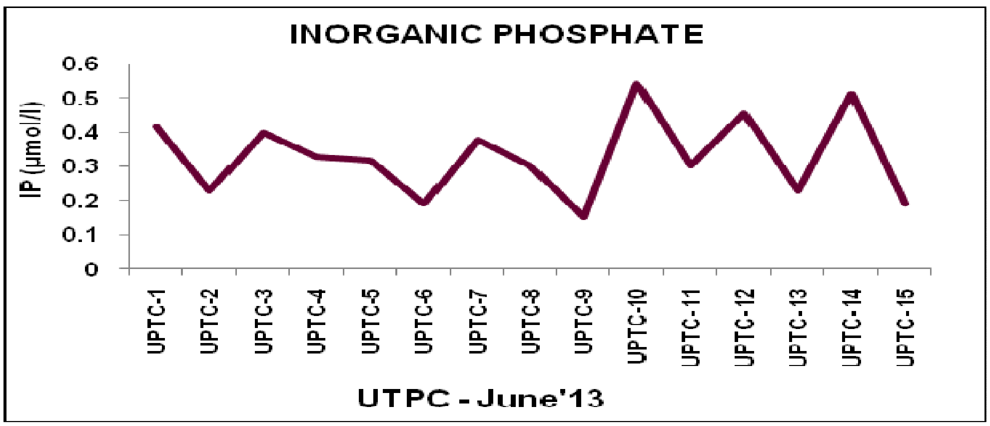
Total Nitrogen

Total nitrogen values showed maximum at UTPC-8 (8.839 µmol/l) and minimum at UTPC-2 (3.178 µmol/l) (Table-3.3).



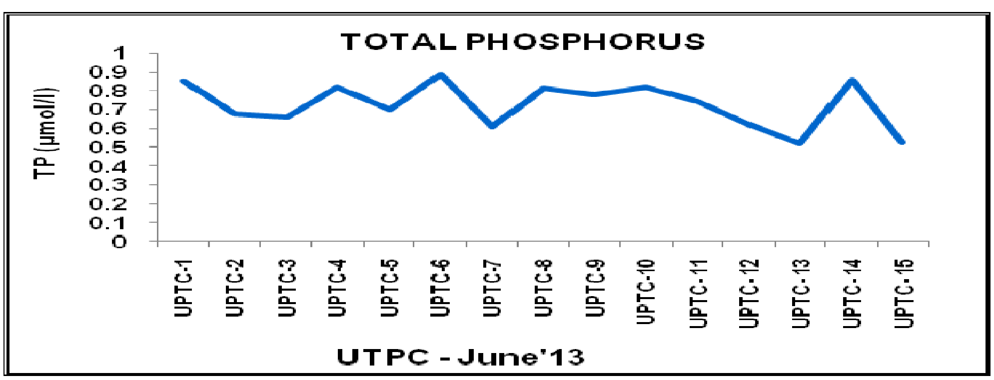
Inorganic Phosphate

Inorganic phosphate level showed maximum (0.543 µmol/l) at UTPC-10 and minimum value (0.151 µmol/l) at UTPC-9 (Table-3.3).



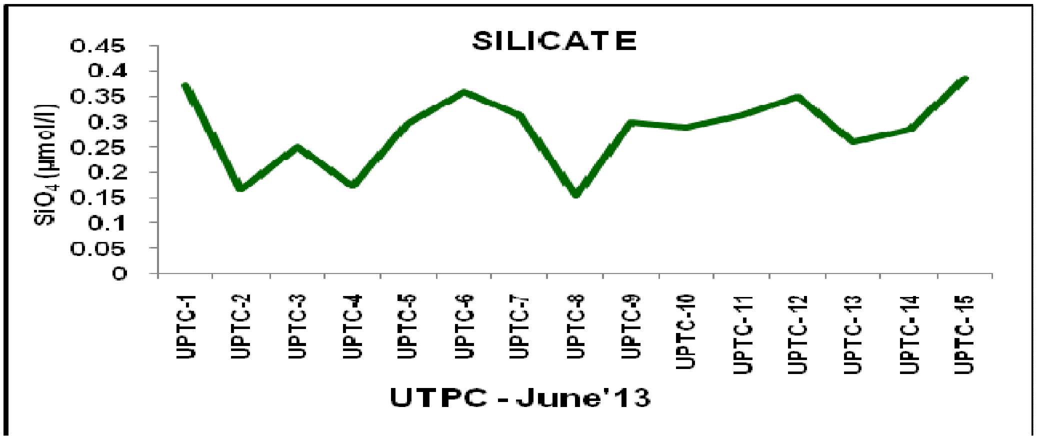
Total Phosphorus

The total phosphorus values ranged from 0.519 to 0.887 µmol/l with maximum (0.887 µmol/l) at UTPC-6 and the minimum (0.519 µmol/l) was recorded at UTPC-13 (Table-3.3).



Reactive Silicate

The silicate values were ranged between 0.155 and 0.385 µmol/l. The maximum (0.385 µmol/l) and minimum (0.155 µmol/l) values were recorded at UTPC-15 and UTPC-8 respectively (Table 3.3).



TABLE– 3.3

NUTRIENTS IN WATER

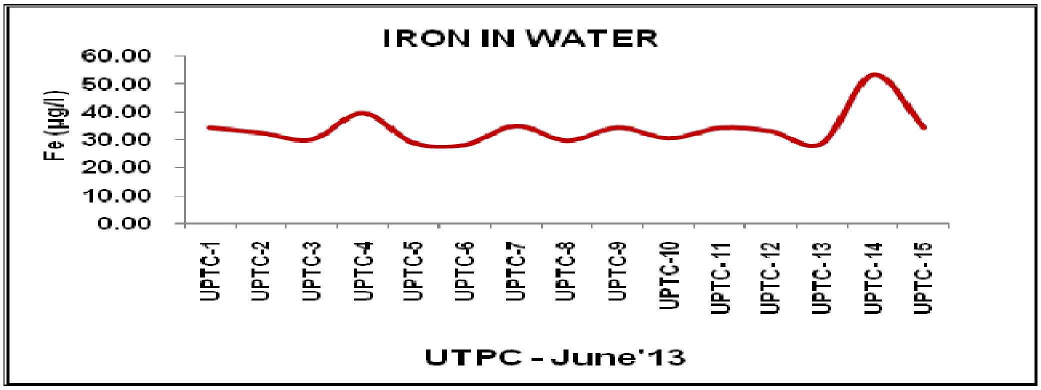
S.No.	Station Code	Parameter (µmol/l)						
		NO_2	NO_3	NH_4	TN	IP	TP	SiO_4
1.	UTPC-1	0.077	4.422	0.075	6.213	0.415	0.852	0.371
2.	UTPC-2	0.153	3.300	0.100	3.178	0.227	0.680	0.168
3.	UTPC-3	0.230	4.753	0.050	6.167	0.398	0.658	0.251
4.	UTPC-4	0.115	2.222	0.025	8.257	0.327	0.821	0.173
5.	UTPC-5	0.172	2.504	0.083	8.259	0.317	0.698	0.297
6.	UTPC-6	0.268	3.493	0.125	6.126	0.189	0.887	0.359
7.	UTPC-7	0.211	5.067	0.091	6.652	0.378	0.607	0.314
8.	UTPC-8	0.134	3.741	0.066	8.839	0.302	0.812	0.155
9.	UTPC-9	0.108	5.216	0.096	6.659	0.151	0.778	0.299
10.	UTPC-10	0.192	3.829	0.141	7.217	0.543	0.819	0.290
11.	UTPC- 11	0.042	3.802	0.038	8.470	0.302	0.745	0.313
12.	UTPC- 12	0.326	5.019	0.133	6.147	0.453	0.621	0.349
13.	UTPC- 13	0.249	4.078	0.083	6.721	0.227	0.519	0.260
14.	UTPC- 14	0.287	3.815	0.033	5.444	0.510	0.856	0.285
15.	UTPC- 15	0.402	5.023	0.058	8.499	0.189	0.527	0.385

Heavy Metals in Water

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

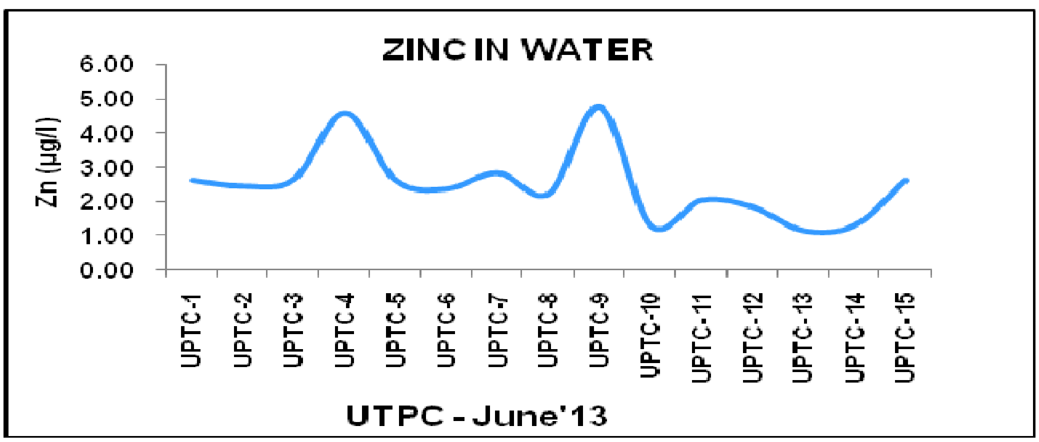
Iron

The iron level varied from 28.28 to 53.33 µg/l. The maximum iron level was recorded at UTPC-14 and the minimum of 28.28 µg/l was recorded at UTPC-6 (Table-3.4).



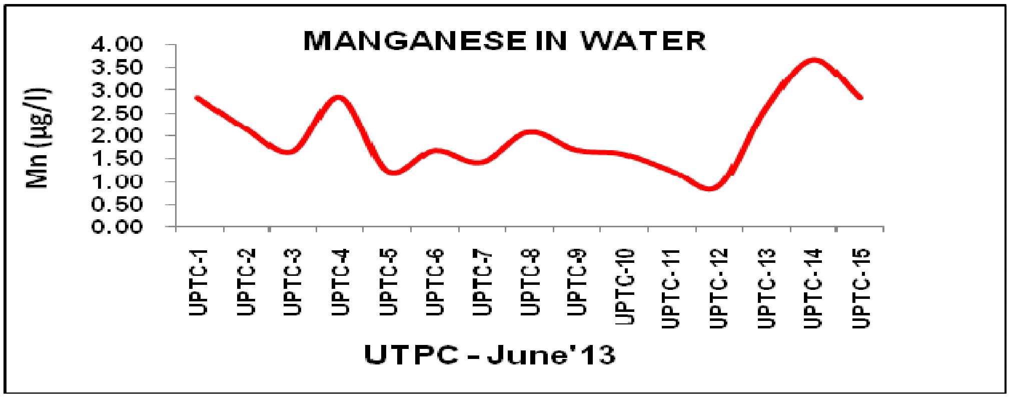
Zinc

The zinc level in the study area varied between 1.15 and 4.78 µg/l. The maximum value was recorded at UTPC-9 and the minimum of 1.15 µg/l was recorded at UTPC-13 (Table-3.4).



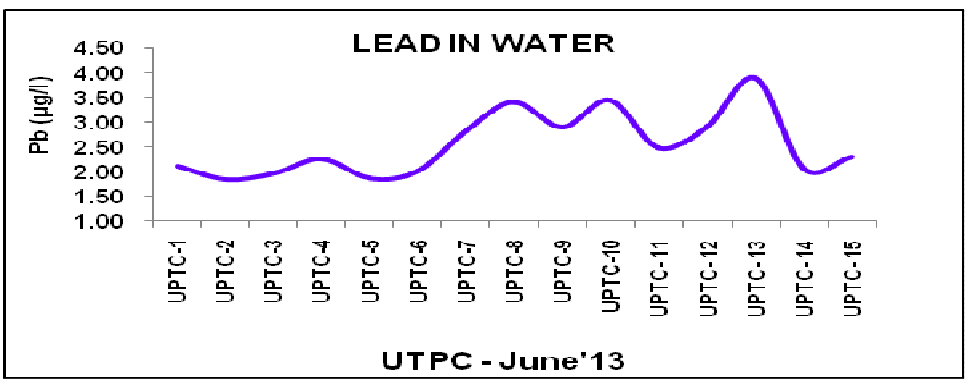
Manganese

The manganese level varied between 0.90 and 3.66 µg/l. The maximum value was recorded at UTPC-14 and the minimum value at UTPC-12 (Table-3.4).



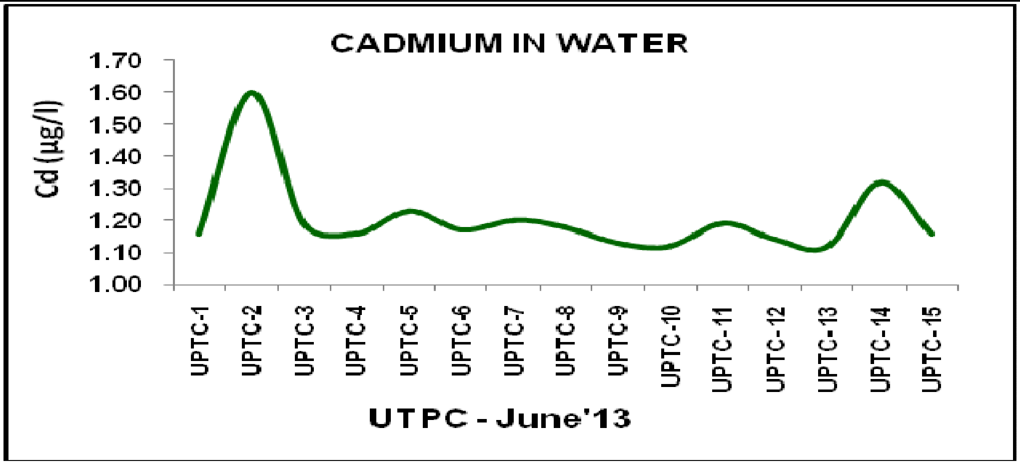
Lead

The lead level in the study area fluctuated between 1.85 and 3.89 µg/l. The maximum of 3.89 µg/l was observed at UTPC-13 and the minimum of 1.85 µg/l was recorded at UTPC-2 during this survey (Table-3.4).



Cadmium

The cadmium level in the study area varied from 1.12 and 1.60 µg/l. The maximum cadmium was recorded at UTPC-2 and the minimum of 1.12 was recorded at UTPC-10 & UTPC-13 respectively during this survey (Table-3.4).



Chromium

The chromium level in the study area varied between 1.37 and 3.22 µg/l. The maximum chromium was recorded at UTPC-13 and the minimum of 1.37 was recorded at UTPC-8 during this survey (Table-3.4).

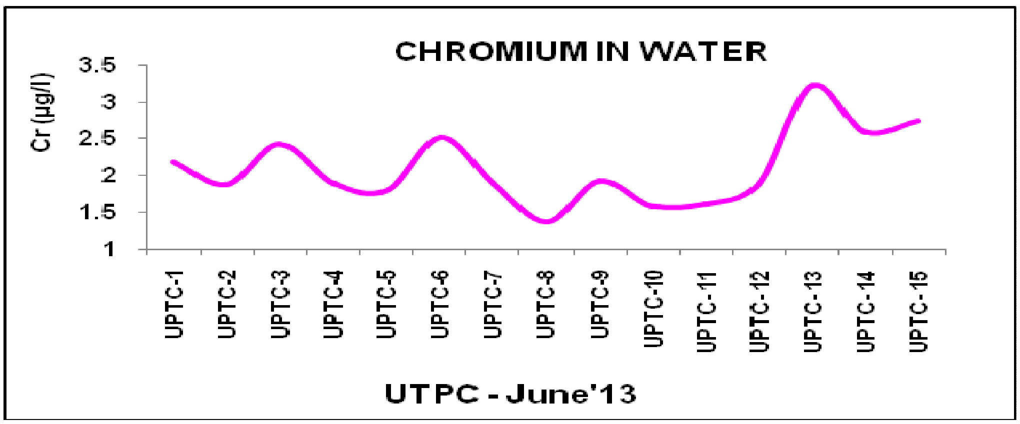


TABLE – 3.4

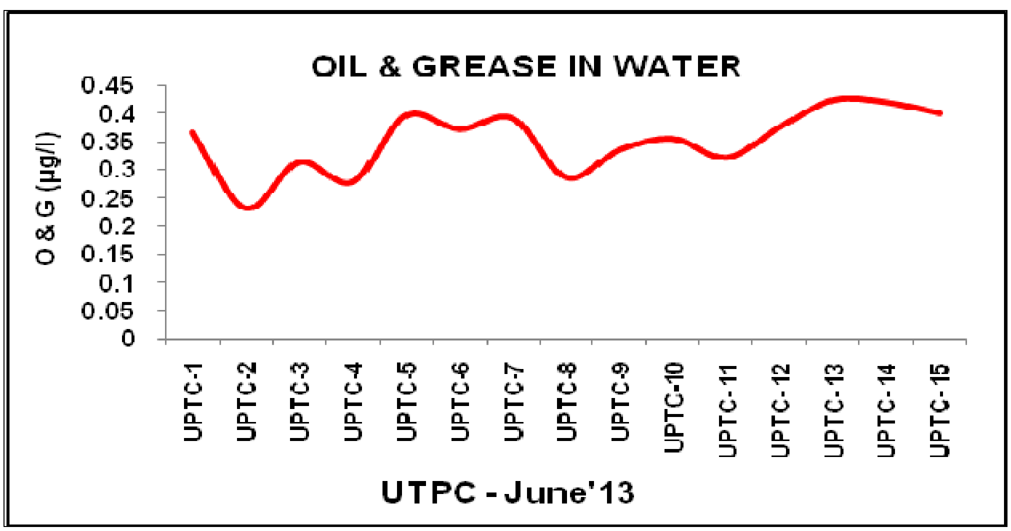
HEAVY METALS IN WATER

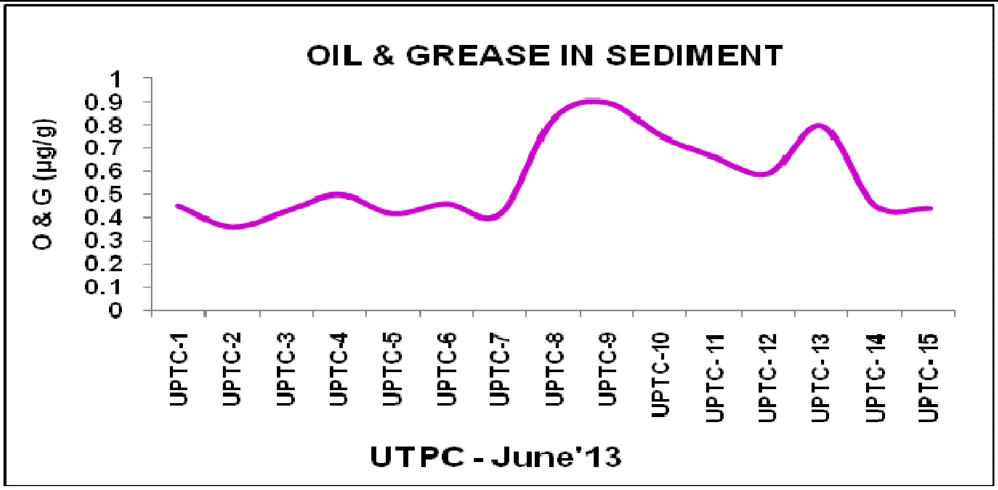
Sl. No.	Station Code	Heavy metals (µg/l)					
		Fe	Zn	Mn	Pb	Cd	Cr
1.	UTPC-1	34.40	2.63	2.83	2.10	1.16	2.17
2.	UTPC-2	32.61	2.46	2.17	1.85	1.60	1.87
3.	UTPC-3	30.17	2.66	1.66	1.96	1.19	2.42
4.	UTPC-4	39.61	4.60	2.84	2.25	1.16	1.89

Sl. No.	Station Code	Heavy metals (µg/l)					
		Fe	Zn	Mn	Pb	Cd	Cr
5.	UTPC-5	28.99	2.62	1.24	1.87	1.23	1.80
6.	UTPC-6	28.28	2.38	1.68	2.01	1.17	2.51
7.	UTPC-7	35.05	2.85	1.43	2.82	1.20	1.89
8.	UTPC-8	29.80	2.24	2.08	3.41	1.18	1.37
9.	UTPC-9	34.42	4.78	1.69	2.89	1.13	1.91
10.	UTPC-10	30.64	1.30	1.60	3.45	1.12	1.58
11.	UTPC- 11	34.29	2.05	1.25	2.49	1.19	1.61
12.	UTPC- 12	33.13	1.85	0.90	2.93	1.14	1.89
13.	UTPC- 13	28.90	1.15	2.59	3.89	1.12	3.22
14.	UTPC- 14	53.33	1.31	3.66	2.07	1.32	2.58
15.	UTPC- 15	34.28	2.36	2.79	2.31	1.16	2.72

OIL & GREASE

In Uppur Thermal Power areas, the Oil & Grease level, in water, fluctuated from 0.232 and 0.422 µg/l. The minimum was recorded at UTPC-2 and the maximum was recorded at UTPC-13 (Table 3.5). In sediment, the Oil & Grease varied between 0.358 and 0.895 µg/g. The minimum and maximum concentrations were recorded at UTPC-2 and UTPC-9 respectively during this survey (Table 3.5).





These values indicate anthropogenic release of petroleum in the system. A part of PHC may also originate from the fishing activities transported by tidal ingress.

TABLE -3.5.

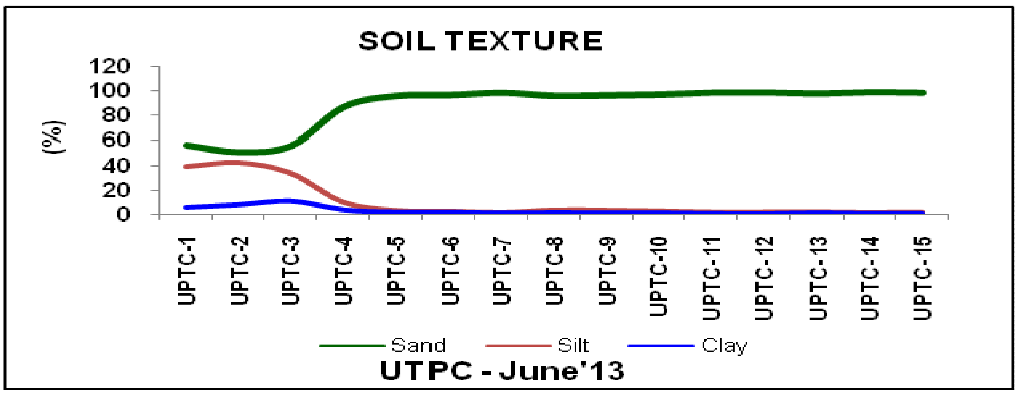
OIL & GREASE IN WATER & SEDIMENT

S. No.	Station Code	Water (µg/l)	Sediment (µg/g)
1.	UTPC-1	0.365	0.450
2.	UTPC-2	0.232	0.358
3.	UTPC-3	0.313	0.424
4.	UTPC-4	0.278	0.498
5.	UTPC-5	0.395	0.415
6.	UTPC-6	0.371	0.458
7.	UTPC-7	0.390	0.415
8.	UTPC-8	0.286	0.825
9.	UTPC-9	0.335	0.895
10.	UTPC-10	0.354	0.751
11.	UTPC- 11	0.321	0.659
12.	UTPC- 12	0.375	0.587
13.	UTPC- 13	0.422	0.794
14.	UTPC- 14	0.418	0.450
15.	UTPC- 15	0.399	0.438

Sediment Characteristics

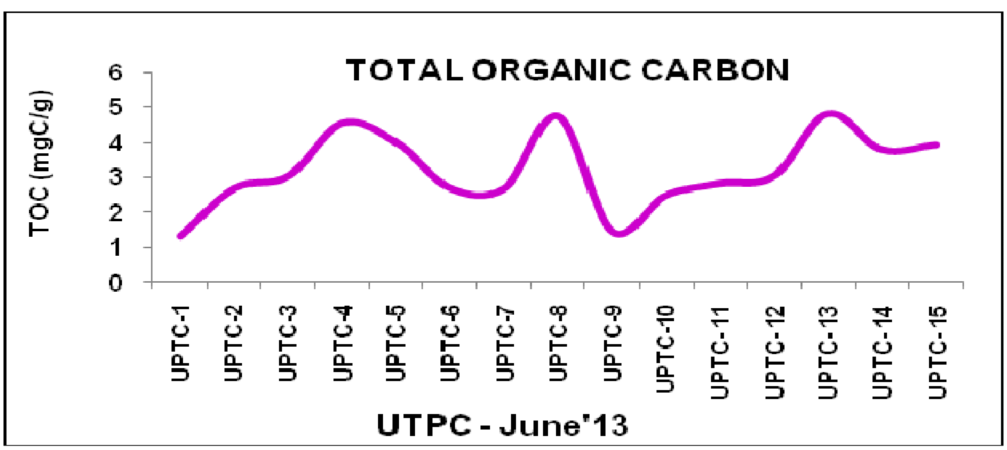
Soil Texture (%)

The sand content varied from 50.24 to 98.16 % with the maximum value at UTPC-14 and the minimum sand content in the station UTPC-2; the silt content showed maximum of 41.96% at UTPC-2 and minimum of 1.42 % at UTPC-14 and the clay was found to be maximum at UTPC-3 (10.98 %) and minimum at UTPC-12 (0.17%) (Table-3.6).



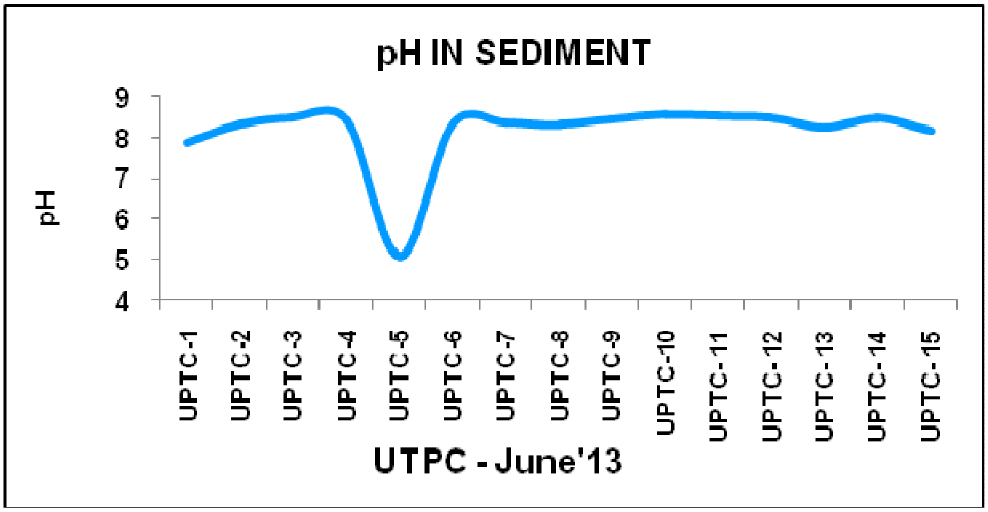
Total Organic Carbon

Total organic carbon values showed maximum (4.83 mgC/g) at UTPC-1 and minimum (1.311 mgC/g) at the station UTPC-1 (Table-3.6).



pH

The pH in the sampling stations varied from 5.09 to 8.57. As evident from the following figure, the minimum level was recorded at UTPC-5 and the maximum level was recorded at UTPC-10 during this survey (Table-3.6).



TABLE– 3.6.

SOIL TEXTURE, TOTAL ORGANIC CARBON & pH OF SEDIMENT

S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	TOC (mgC/g)	pH
1.	UTPC-1	55.86	38.67	5.47	1.311	7.88
2.	UTPC-2	50.24	41.96	7.80	2.691	8.34
3.	UTPC-3	55.56	33.46	10.98	3.036	8.51
4.	UTPC-4	86.33	10.03	3.64	4.554	8.42
5.	UTPC-5	95.16	3.21	1.63	4.002	5.09
6.	UTPC-6	95.88	2.50	1.62	2.691	8.34
7.	UTPC-7	97.7	1.43	0.88	2.691	8.38
8.	UTPC-8	95.18	3.63	1.19	4.761	8.33
9.	UTPC-9	95.59	3.37	1.04	1.449	8.48

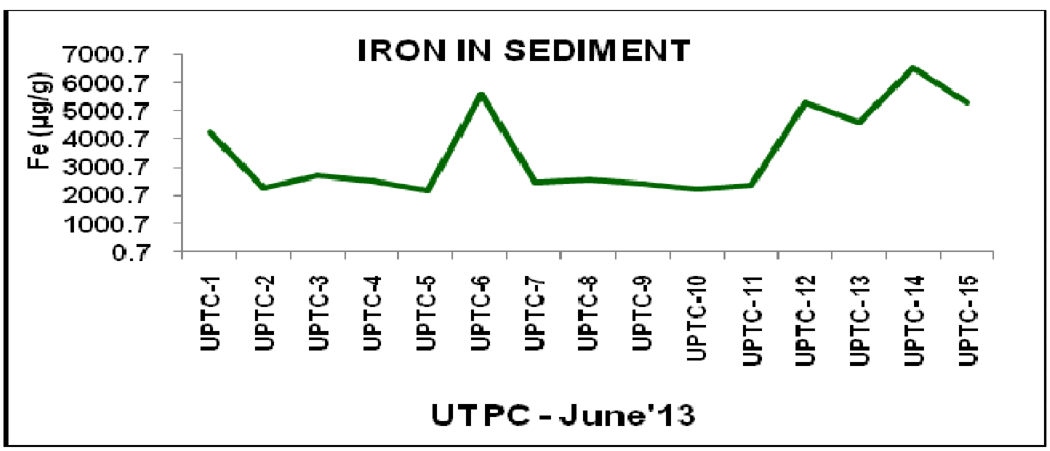
S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	TOC (mgC/g)	pH
10.	UTPC-10	96.27	2.72	1.01	2.484	8.57
11.	UTPC- 11	97.83	1.78	0.39	2.829	8.55
12.	UTPC- 12	98.02	1.81	0.17	3.036	8.51
13.	UTPC- 13	97.04	1.91	1.05	4.830	8.26
14.	UTPC- 14	98.16	1.42	0.42	3.795	8.50
15.	UTPC- 15	97.72	1.76	0.52	3.933	8.17

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.

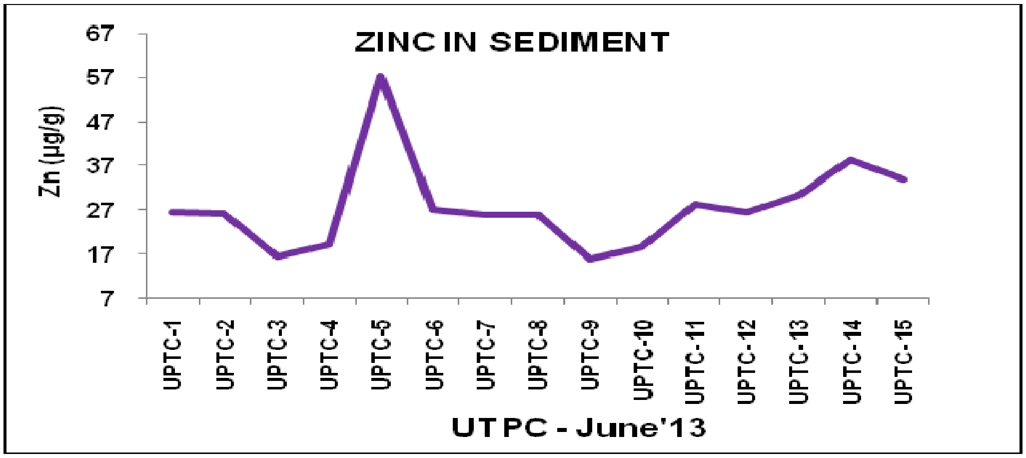
Iron

The cadmium level varied from 2181 to 6545 µg/g. The maximum was recorded at UTPC-14 and the minimum was recorded at UTPC-5 during this survey.



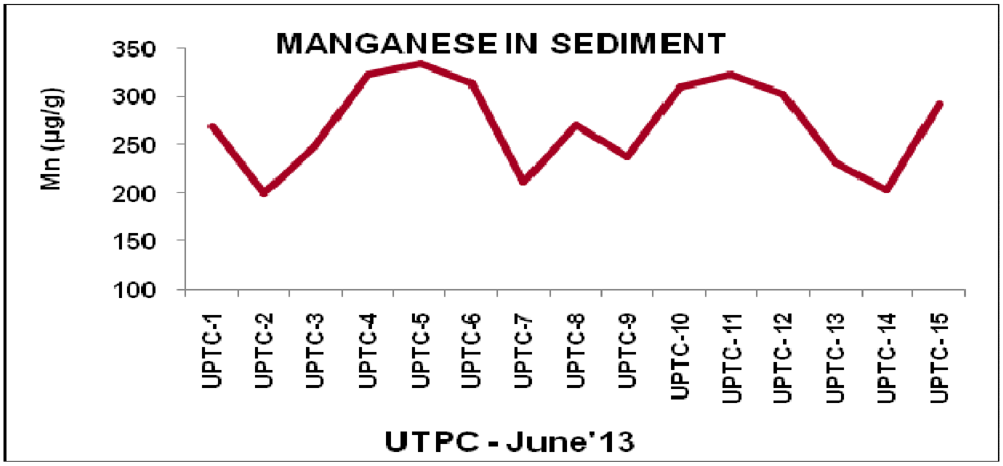
Zinc

The zinc in the sediments fluctuated from 16.07 to 57.18 μg/g with maximum of 57.18 μg/g at UTPC-5 and the minimum of 16.07 at UTPC-9 (Table-3.7).



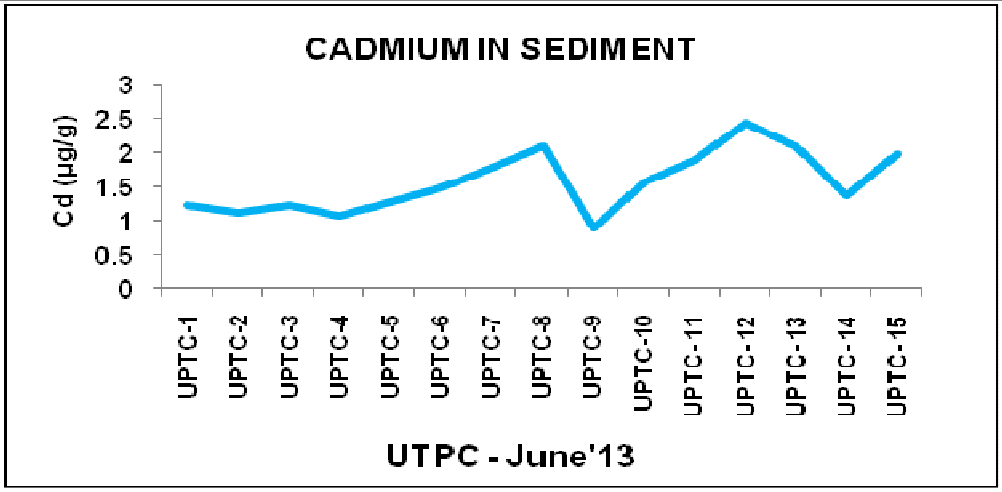
Manganese

The manganese concentration fluctuated between 199.77 and 334.97 μg/g. The maximum manganese concentration of 334.97 μg/g was recorded at UTPC-5 and the minimum of 199.77 μg/g was recorded at UTPC-2 (Table-3.7).



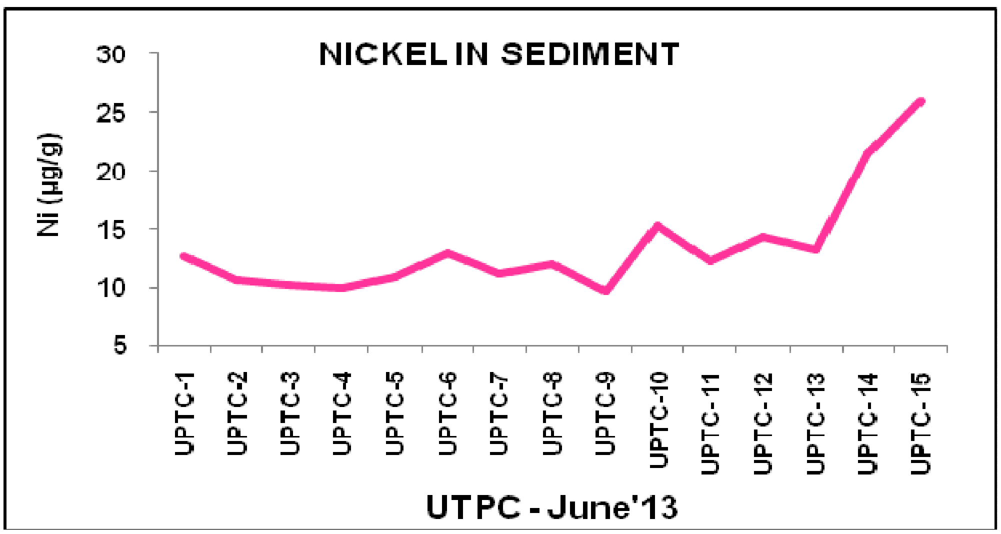
Cadmium

The cadmium level in the sediment ranged from 0.90 to 2.44 μg/g. The maximum cadmium concentration of 2.44 μg/g was recorded at UTPC-12 and minimum of 0.90 μg/g was recorded at UTPC-9 during this survey (Table-3.7).



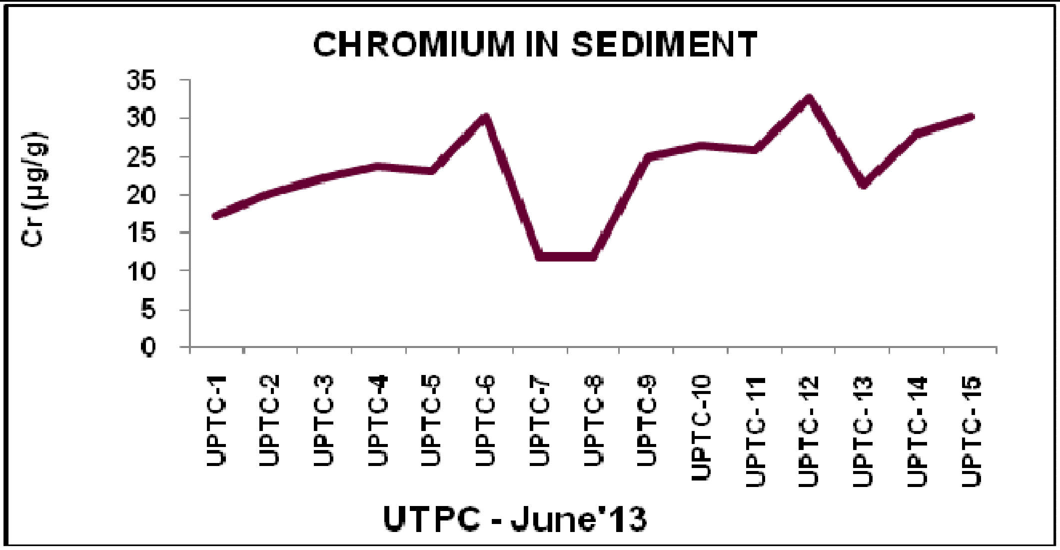
Nickel

The nickel fluctuated from 9.73 to 26.04 µg/g with a maximum of 26.04 µg/g at UTPC-5 and the minimum of 9.73 µg/g at UTPC-9 during this survey (Table-3.7).



Chormium

The chromium level in the sediment varied from 11.76 to 32.75 µg/g. The maximum value was recorded at UTPC-12 and the minimum was recorded at UTPC-8 (Table-3.7).



Lead

The lead level fluctuated from 12.12 to 35.18 µg/g with a maximum of 35.18 µg/g at UTPC-15 and the minimum of 12.12 µg/g at UTPC-10 during this survey (Table-3.7).

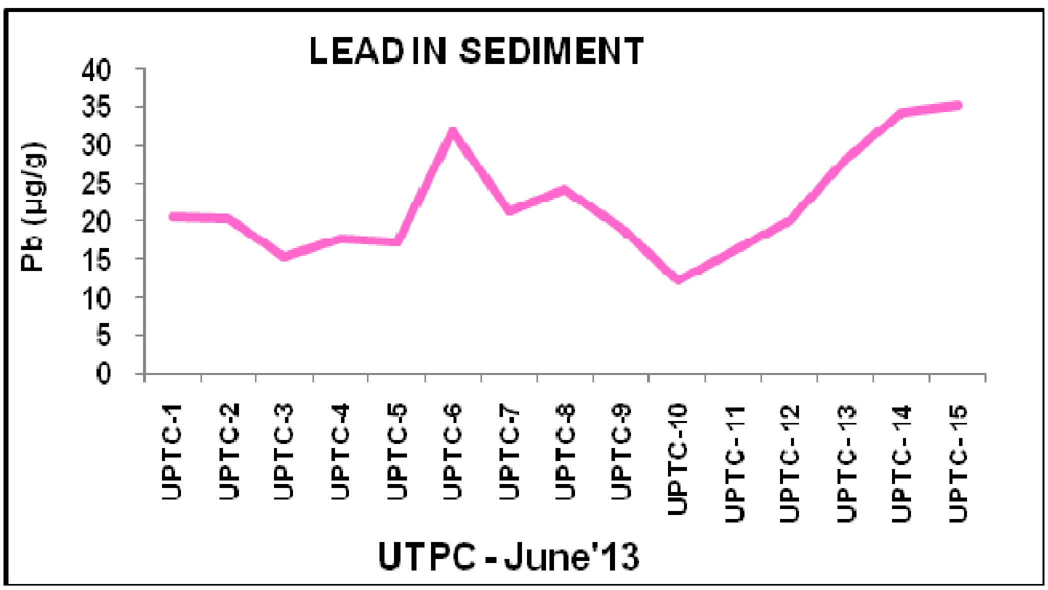


TABLE –3.7.

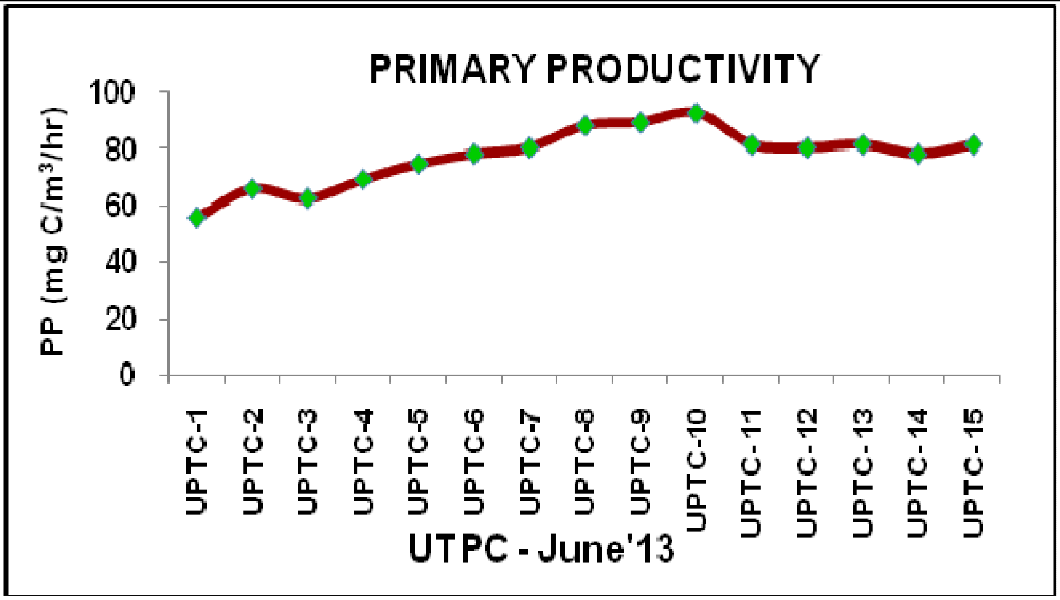
HEAVY METALS IN SEDIMENT

S. No.	Station Code	µg/g						
		Fe	Zn	Mn	Cd	Ni	Cr	Pb
1.	UTPC-1	4276	26.53	269.52	1.23	12.72	17.18	20.51
2.	UTPC-2	2271	26.33	199.77	1.13	10.72	20.17	20.26
3.	UTPC-3	2723	16.56	249.42	1.25	10.34	22.18	15.24
4.	UTPC-4	2518	19.13	322.52	1.08	10.02	23.81	17.76
5.	UTPC-5	2181	57.18	334.97	1.28	10.97	23.06	17.06
6.	UTPC-6	5577	27.03	314.12	1.48	12.97	30.16	31.91
7.	UTPC-7	2481	26.04	211.32	1.78	11.23	11.86	21.35
8.	UTPC-8	2566	25.84	270.63	2.09	12.09	11.76	24.12
9.	UTPC-9	2414	16.07	237.74	0.90	9.73	24.77	19.12
10.	UTPC-10	2209	18.64	310.84	1.59	15.22	26.40	12.12
11.	UTPC- 11	2372	28.42	323.29	1.90	12.34	25.65	15.87
12.	UTPC- 12	5268	26.54	302.44	2.44	14.34	32.75	20.12
13.	UTPC- 13	4590	30.29	232.2	2.09	13.23	21.16	28.12
14.	UTPC- 14	6545	38.35	203.39	1.38	21.54	27.91	34.18
15.	UTPC- 15	5292	34.04	292.14	1.99	26.04	30.26	35.18

Biological Characteristics

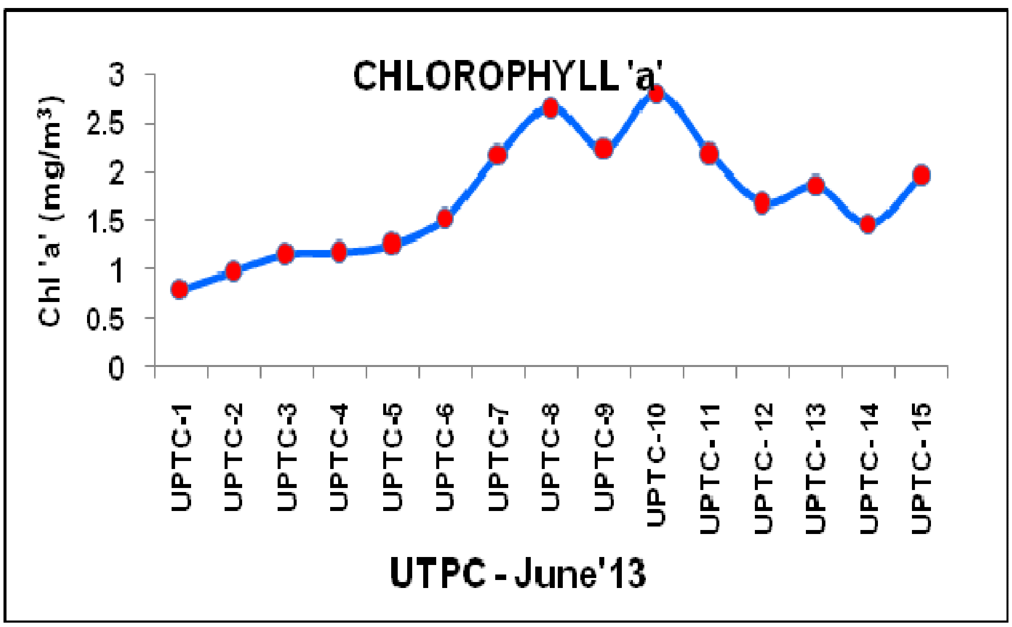
Primary Productivity (mg C/m3/hr)

The primary productivity fluctuated from 55.85 to 92.711 mgC/m3/hr. The maximum PP (92.711 mgC/m3/hr) was recorded at UTPC-10 and the minimum (55.85 mgC/m3hr) was recorded at UTPC-1 during this survey (Table-3.8).



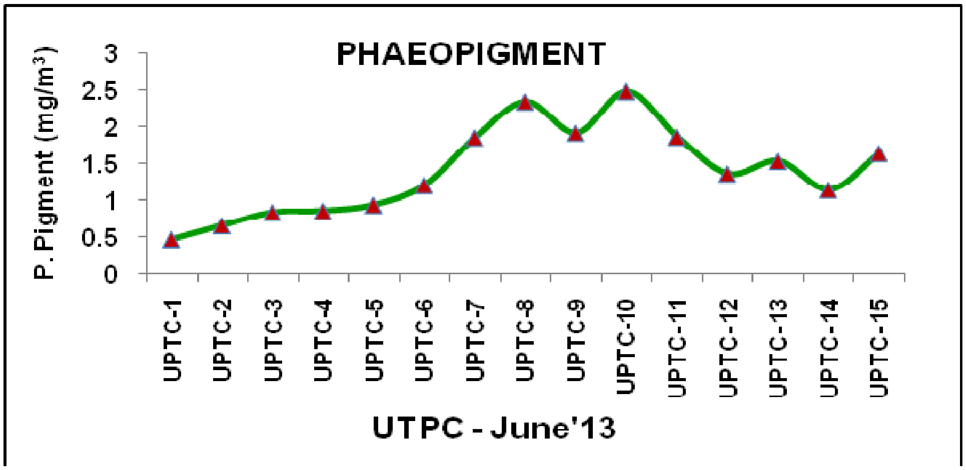
Chlorophyll 'A' (mg/m3)

The chlorophyll 'A' level fluctuated between 0.795 and 2.816 mg/m3. The maximum chlorophyll 'A' (2.816 mg/m3) was observed at UTPC-10 and the minimum (0.795 mg/m3) was recorded at UTPC-1 (Table-3.8).



Phaeopigment (mg/m3)

In the present study, the phaeopigment in water sample varied from 0.467 to 2.488 mg/m3 with maximum in UTPC-10 and minimum at UTPC-1 during this survey (Table-3.8).



Total Biomass (ml/100 m3)

The total biomass in water sample varied between 19.79 and 34.29 (ml/100 m3). The minimum was recorded at UTPC-13 and the maximum was observed at UTPC-4 (Table-3.8).

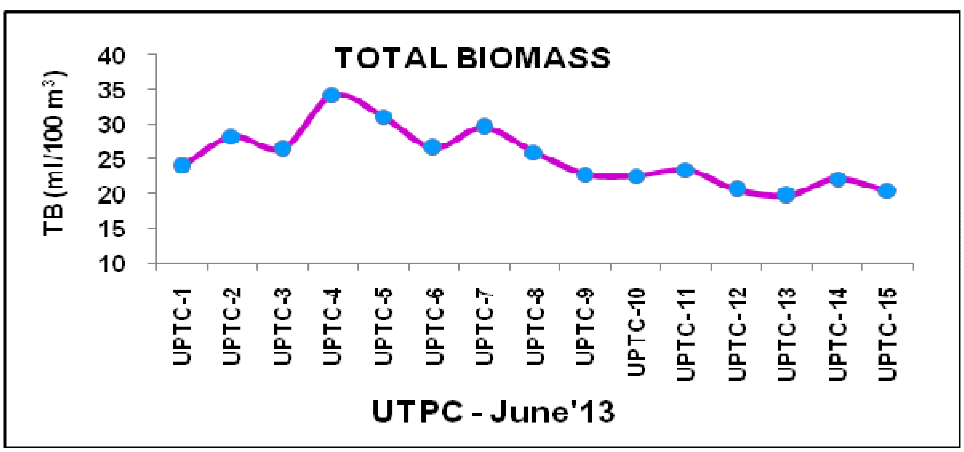


TABLE – 3.8.

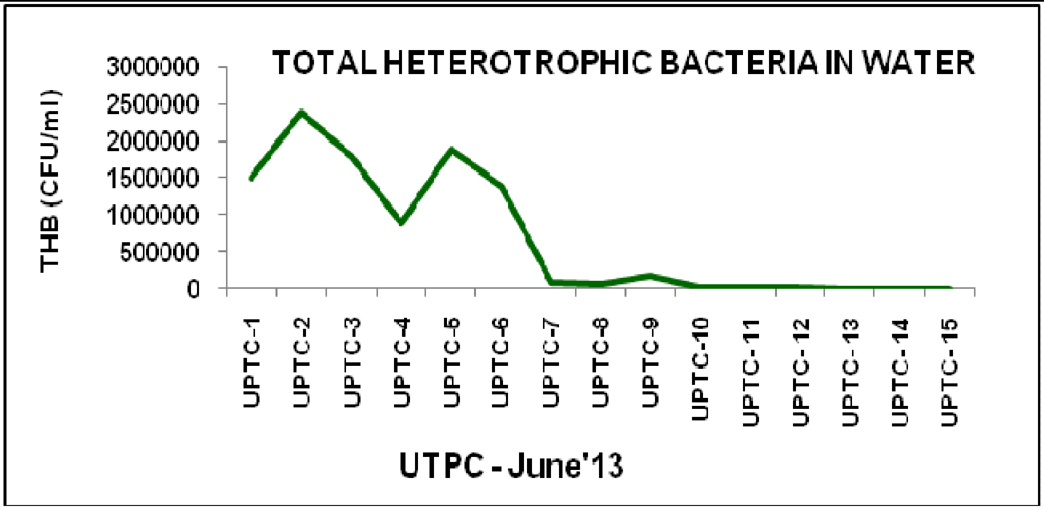
BIOLOGICAL CHARACTERISTICS

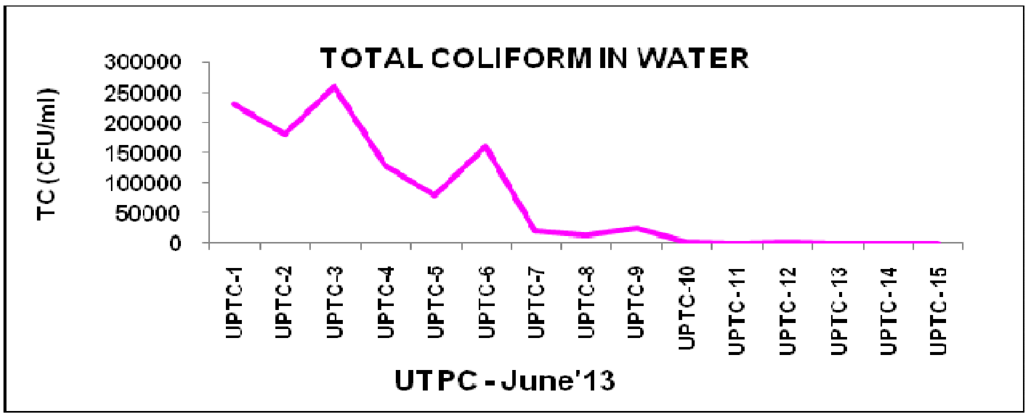
S. No.	Station Code	PP (mg C/m^3/hr)	Chl 'a' (mg/m^3)	Phaeopigment (mg/m^3)	TB (ml/100m^3)
1.	UTPC-1	55.850	0.795	0.467	23.94
2.	UTPC-2	65.903	0.986	0.658	28.26
3.	UTPC-3	62.552	1.163	0.835	26.51
4.	UTPC-4	69.254	1.181	0.853	34.29
5.	UTPC-5	74.839	1.264	0.936	31.12
6.	UTPC-6	78.190	1.537	1.209	26.65
7.	UTPC-7	80.424	2.187	1.859	29.64
8.	UTPC-8	88.243	2.676	2.348	25.95
9.	UTPC-9	89.360	2.249	1.921	22.80
10.	UTPC-10	92.711	2.816	2.488	22.60
11.	UTPC- 11	81.541	2.194	1.866	23.47
12.	UTPC- 12	80.424	1.691	1.363	20.66
13.	UTPC- 13	81.541	1.864	1.536	19.79
14.	UTPC- 14	78.190	1.473	1.145	22.18
15.	UTPC- 15	81.541	1.975	1.647	20.49

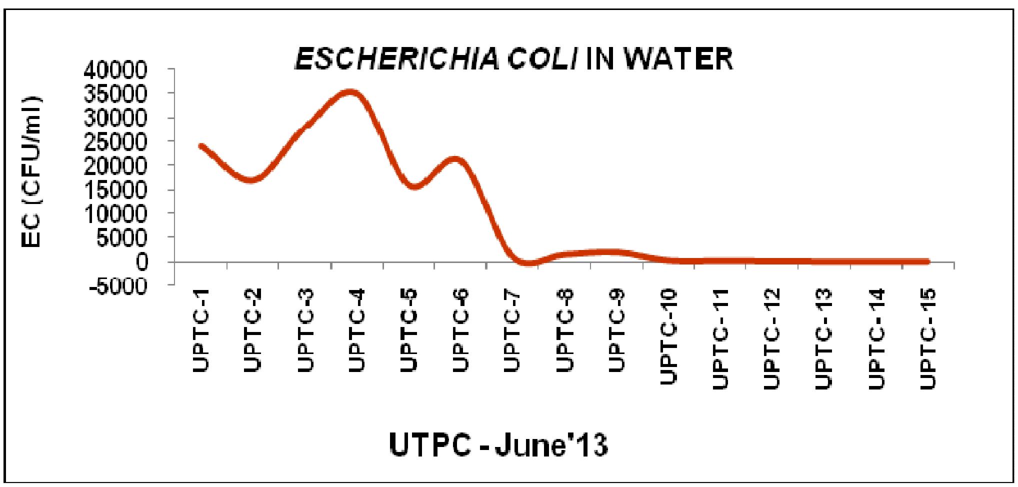
Microbiology

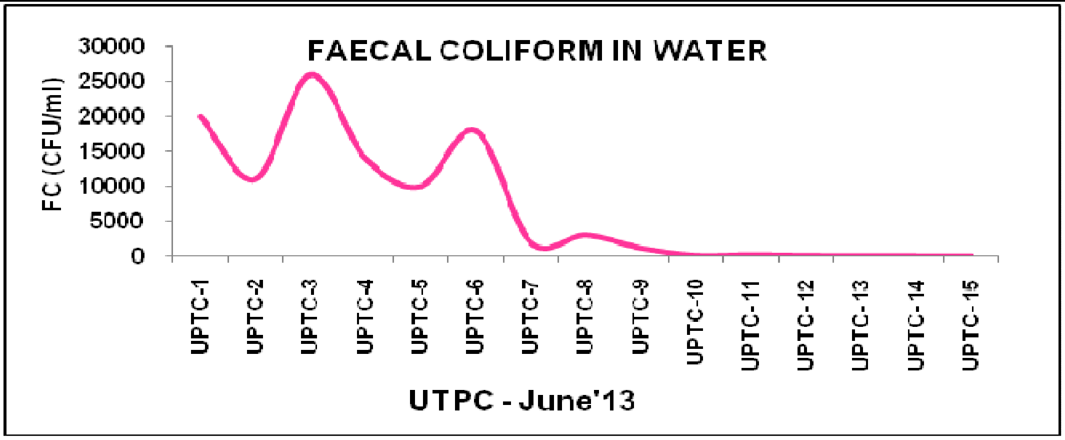
Water sample

The Total Heterotrophic Bacteria (THB) varied from 60x101 to 24x105 with maximum at UTPC-2 and minimum at UTPC-15 of water samples collected in Uppur Thermal Power Corporation areas. The Total Coliform varied between 11x101 and 26x104 with maximum at UTPC-3 and minimum at UTPC-14. The Escherichia coli Bacteria in water sample fluctuated from 15 to 35x103 CFU/ml with maximum at UTPC-4 and minimum at UTPC-4 during the sample collection. Faecal coliform varied between 12 and 26x103 CFU/ml with maximum at UTPC-3 and the minimum was recorded at UTPC-15. The Streptococcus faecalis varied from 8 to 20x102. The minimum and maximum values were observed at UTPC-14 and UTPC-5 during this survey (Table-3.9).


TOTAL HETEROTROPHIC BACTERIA IN WATER
THB (CFU/ml)
3000000
2500000
2000000
1500000
1000000
500000
0
UPTC-1
UPTC-2
UPTC-3
UPTC-4
UPTC-5
UPTC-6
UPTC-7
UPTC-8
UPTC-9
UPTC-10
UPTC-11
UPTC-12
UPTC-13
UPTC-14
UPTC-15
UTPC - June'13


TOTAL COLIFORM IN WATER
TC (CFU/ml)
300000
250000
200000
150000
100000
50000
0
UPTC-1
UPTC-2
UPTC-3
UPTC-4
UPTC-5
UPTC-6
UPTC-7
UPTC-8
UPTC-9
UPTC-10
UPTC-11
UPTC-12
UPTC-13
UPTC-14
UPTC-15
UTPC - June'13


ESCHERICHIA COLI IN WATER
EC (CFU/ml)
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
UPTC-1
UPTC-2
UPTC-3
UPTC-4
UPTC-5
UPTC-6
UPTC-7
UPTC-8
UPTC-9
UPTC-10
UPTC-11
UPTC-12
UPTC-13
UPTC-14
UPTC-15
UTPC - June'13



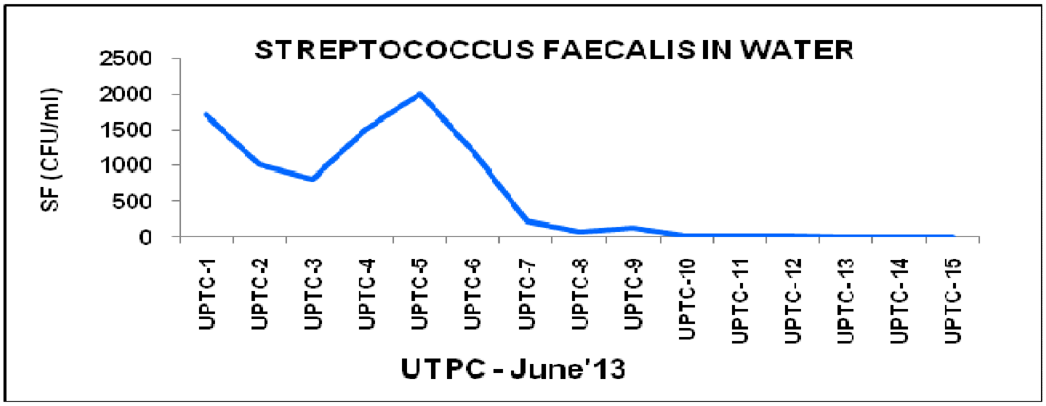


TABLE –3.9.

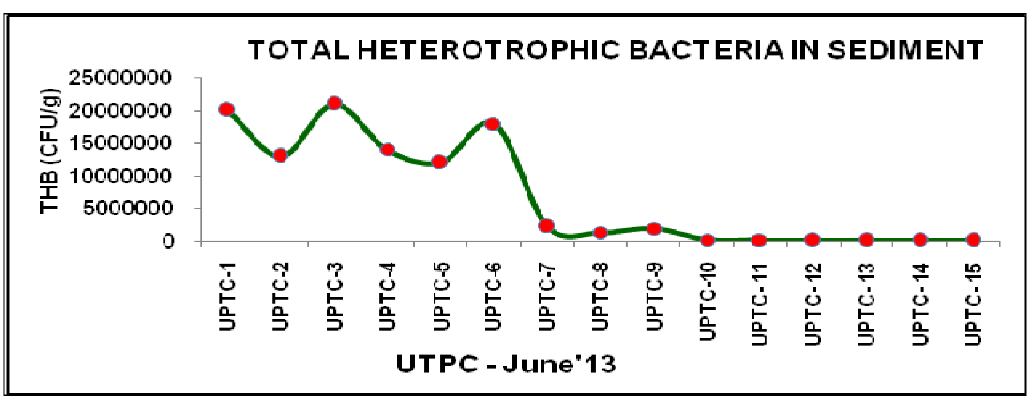
MICROBIAL POPULATIONS IN WATER

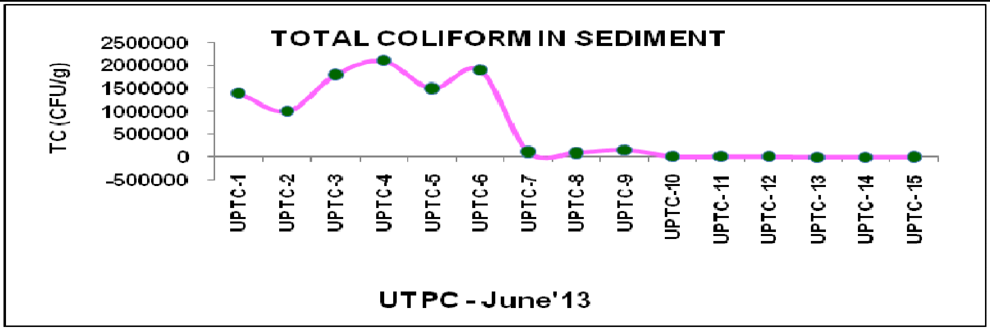
S. No.	Station Code	THB	TC	EC	FC	SF
1.	UTPC-1	$15x10^5$	$23x10^4$	$24x10^3$	$20x10^3$	$17x10^2$
2.	UTPC-2	$24x10^5$	$18x10^4$	$17x10^3$	$11x10^3$	$10x10^2$
3.	UTPC-3	$18x10^5$	$26x10^4$	$28x10^3$	$26x10^3$	$08x10^2$
4.	UTPC-4	$09x10^5$	$13x10^4$	$35x10^3$	$14x10^3$	$15x10^2$
5.	UTPC-5	$19x10^5$	$08x10^4$	$16x10^3$	$10x10^3$	$20x10^2$
6.	UTPC-6	$14x10^5$	$16x10^4$	$21x10^3$	$18x10^3$	$12x10^2$
7.	UTPC-7	$10x10^4$	$20x10^3$	$10x10^2$	$20x10^2$	$22x10^1$
8.	UTPC-8	$08x10^4$	$14x10^3$	$15x10^2$	$31x10^2$	$08x10^1$

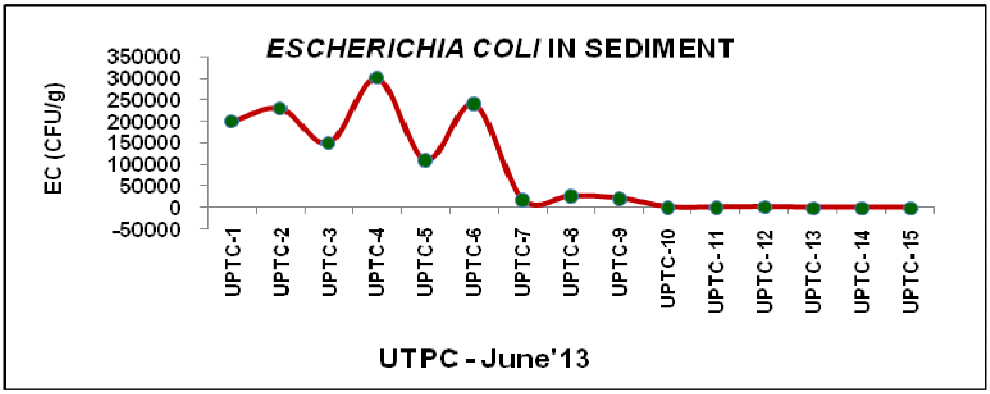
S. No.	Station Code	THB	TC	EC	FC	SF
9.	UTPC-9	$18x10^4$	$25x10^3$	$20x10^2$	$12x10^2$	$13x10^1$
10.	UTPC-10	$22x10^3$	$14x10^2$	$25x10^1$	$10x10^1$	24
11.	UTPC- 11	$19x10^3$	$10x10^2$	$17x10^1$	$21x10^1$	16
12.	UTPC- 12	$15x10^3$	$18x10^2$	$12x10^1$	$08x10^1$	10
13.	UTPC- 13	$09x10^2$	$22x10^1$	24	33	-
14.	UTPC- 14	$15x10^2$	$11x10^1$	15	19	08
15.	UTPC- 15	$06x10^2$	$17x10^1$	20	12	-

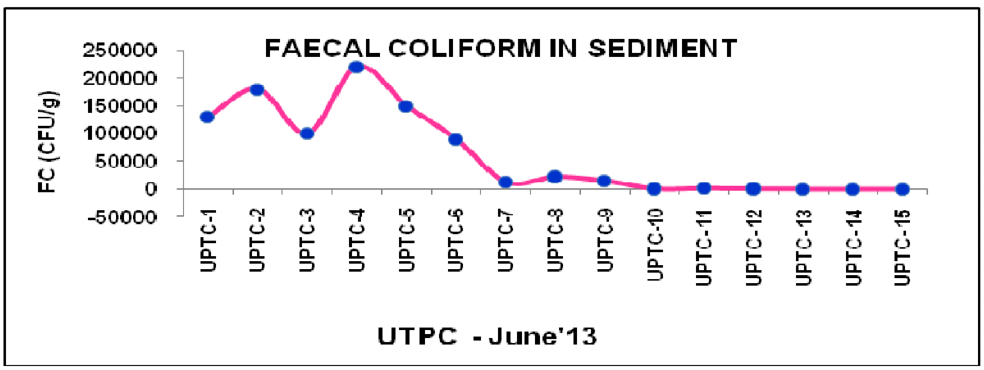
Sediment sample

The Total Heterotrophic Bacteria (THB) varied from $10x10^3$ to $21x10^6$ CFU/g with maximum at UTPC-3 and minimum at UTPC-14 of sediment samples collected in Uppur Thermal Power Corporation areas. The Total Coliform varied between 80x10 and $21x10^5$ CFU/g, the maximum recorded at UTPC-4 and the minimum was recorded at UTPC-14. The Escherichia coli Bacteria in sediment sample varied between 80 and $30x10^4$ CFU/g with maximum at UTPC-4 and minimum at UTPC-14 during the sample collection. Faecal coliform varied from 70 to $22x10^4$ CFU/g with maximum at UTPC-4 and minimum at UTPC-15. The Streptococcus faecalis varied between 10x10 and $21x10^3$w CFU/g. The minimum was recorded at UTPC-15 and the maximum value was recorded at UTPC-4 during this survey (Table-3.10).




TOTAL COLIFORM IN SEDIMENT
TC (CFU/g)
2500000
2000000
1500000
1000000
500000
0
-500000
UPTC-1
UPTC-2
UPTC-3
UPTC-4
UPTC-5
UPTC-6
UPTC-7
UPTC-8
UPTC-9
UPTC-10
UPTC-11
UPTC-12
UPTC-13
UPTC-14
UPTC-15
UTPC - June'13


ESCHERICHIA COLI IN SEDIMENT
EC (CFU/g)
350000
300000
250000
200000
150000
100000
50000
0
-50000
UPTC-1
UPTC-2
UPTC-3
UPTC-4
UPTC-5
UPTC-6
UPTC-7
UPTC-8
UPTC-9
UPTC-10
UPTC-11
UPTC-12
UPTC-13
UPTC-14
UPTC-15
UTPC - June'13


FAECAL COLIFORM IN SEDIMENT
FC (CFU/g)
250000
200000
150000
100000
50000
0
-50000
UPTC-1
UPTC-2
UPTC-3
UPTC-4
UPTC-5
UPTC-6
UPTC-7
UPTC-8
UPTC-9
UPTC-10
UPTC-11
UPTC-12
UPTC-13
UPTC-14
UPTC-15
UTPC - June'13

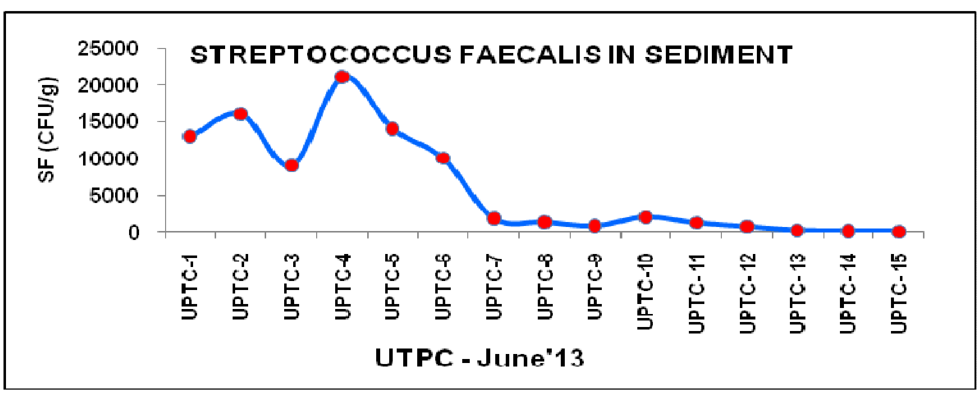

STREPTOCOCCUS FAECALIS IN SEDIMENT
SF (CFU/g)
25000
20000
15000
10000
5000
0
UPTC-1
UPTC-2
UPTC-3
UPTC-4
UPTC-5
UPTC-6
UPTC-7
UPTC-8
UPTC-9
UPTC-10
UPTC-11
UPTC-12
UPTC-13
UPTC-14
UPTC-15
UTPC - June'13

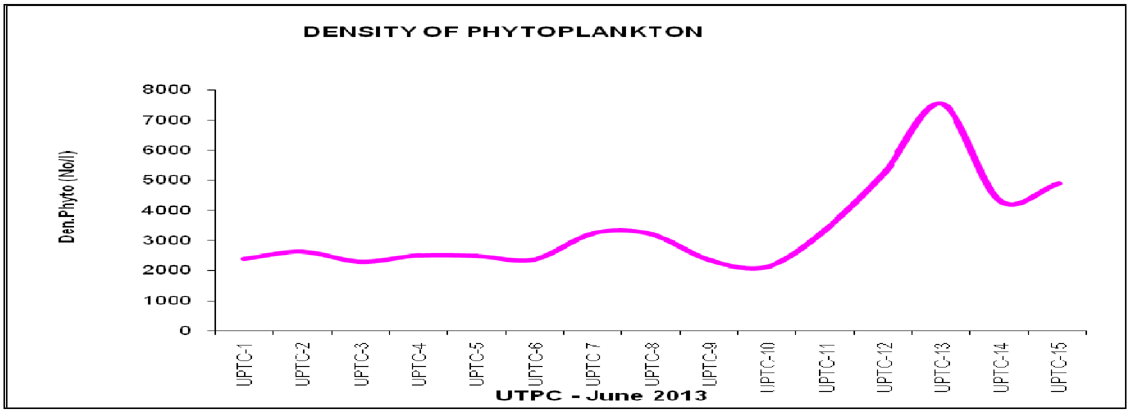
TABLE – 3.10

MICROBIAL POPULATIONS IN SEDIMENT

S. No.	Station Code	THB	TC	EC	FC	SF
1.	UTPC-1	$20x10^6$	$14x10^5$	$20x10^4$	$13x10^4$	$13x10^3$
2.	UTPC-2	$13x10^6$	$10x10^5$	$23x10^4$	$18x10^4$	$16x10^3$
3.	UTPC-3	$21x10^6$	$18x10^5$	$15x10^4$	$10x10^4$	$09x10^3$
4.	UTPC-4	$14x10^6$	$21x10^5$	$30x10^4$	$22x10^4$	$21x10^3$
5.	UTPC-5	$12x10^6$	$15x10^5$	$11x10^4$	$15x10^4$	$14x10^3$
6.	UTPC-6	$18x10^6$	$19x10^5$	$24x10^4$	$09x10^4$	$10x10^3$
7.	UTPC-7	$22x10^5$	$12x10^4$	$19x10^3$	$13x10^3$	$18x10^2$
8.	UTPC-8	$13x10^5$	$10x10^4$	$27x10^3$	$22x10^3$	$13x10^2$
9.	UTPC-9	$19x10^5$	$16x10^4$	$22x10^3$	$15x10^3$	$08x10^2$
10.	UTPC-10	$13x10^4$	$18x10^3$	$14x10^2$	$08x10^2$	$20x10^2$
11.	UTPC- 11	$10x10^4$	$15x10^3$	$10x10^2$	$15x10^2$	$12x10^2$
12.	UTPC- 12	$08x10^4$	$13x10^3$	$18x10^2$	$06x10^2$	$07x10^2$
13.	UTPC- 13	$14x10^3$	$10x10^2$	$13x10^1$	$16x10^1$	$19x10^1$
14.	UTPC- 14	$10x10^3$	$08x10^2$	$08x10^1$	$12x10^1$	$13x10^1$
15.	UTPC- 15	$18x10^3$	$15x10^2$	$16x10^1$	$07x10^1$	$10x10^1$

Phytoplankton

The phytoplankton density ranged from 2302 to 7542 No/l. The maximum density was recorded at UTPC-13 and the minimum was recorded at UTPC-3 during this survey (Table-3.11).



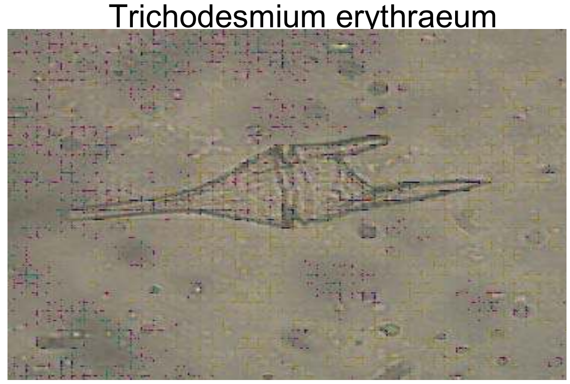
A total of 5 species of phytoplankton were identified from the study area with Rhizosolenia alata dominating (3783/7542 No/l, UTPC-13) the populations. The diatom was the dominant group represented by species such as Ceratium furca, Ceratium macroceros and Rhzizosolenia alata were found in all stations.

COMMON SPECIES OF PHYTOPLANKTON

Rhizosolenia alata

Trichodesmium erythraeum

Ceratium macroceros



Ceratium furca

TABLE-3.11.

PHYTOPLANKTON

	Name of the Species	No/l				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
1.	*Rhizosolenia alata*	2249	3153	3099	2287	2072
2.	*Ceratium macroceros*	126	85	111	64	55
	Total	**2375**	**3238**	**3210**	**2351**	**2127**

*** - Organisms not present**

Sl. No.	Name of the Species	No/l				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
1.	*Biddulphia alternans*	115	142	136	*	*
2.	*Rhizosolenia alata*	2015	2299	1969	2374	2400
3.	*Ceratium macroceros*	175	118	140	130	93
4.	*Ceratium furca*	82	75	57	*	*
	Total	**2387**	**2634**	**2302**	**2504**	**2493**

*** - Organisms not present**

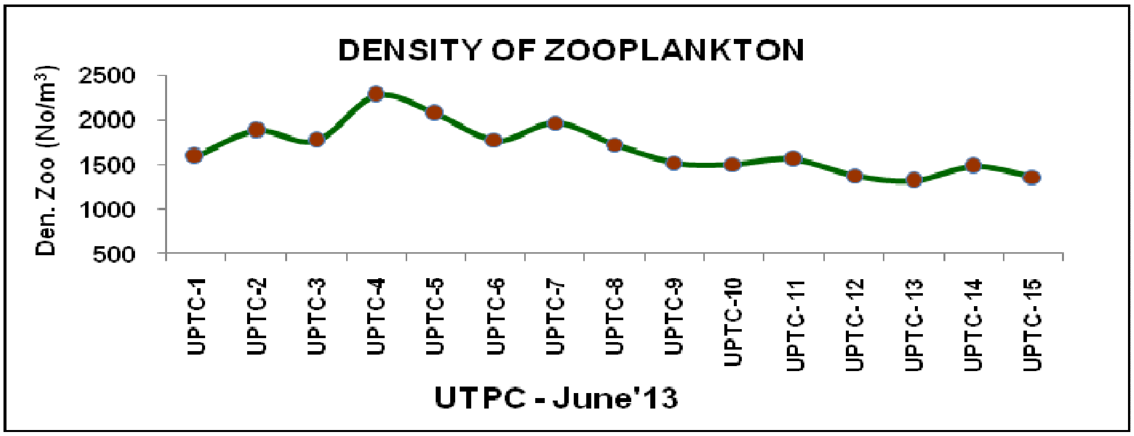
Sl. No.	Name of the Species	No/l				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
1.	*Trichodesmium erythraeum*	*	2758	3717	1896	2826
2.	*Rhizosolenia alata*	3253	2450	3783	2332	1982
3.	*Ceratium macroceros*	95	48	42	68	67
4.	*Ceratium furca*	*	*	*	31	29
	Total	**3348**	**5256**	**7542**	**4327**	**4904**

*** - Organisms not present**

Zooplankton

Zooplankton includes arrays of organisms, varying in size from microscopic protozoans of a few microns to some jelly organisms with tentacles of several metres long. They play an intermediate role between phytoplankton and fish and are considered as the chief index of utilization of aquatic biotope at the secondary trophic level.

The zooplankton density in the study region ranged from 1319 to 2286 No/m3 (Table-3.12). The minimum density was recorded at UTPC-13 and the maximum density was observed at UTPC-4.



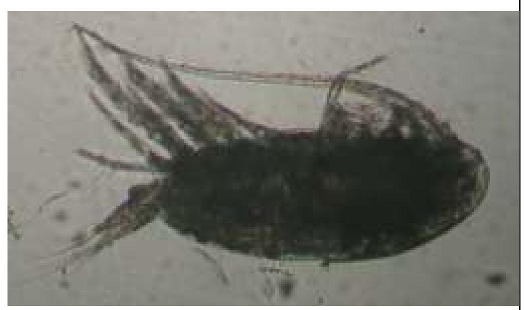
In the present investigation, 12 species of zooplankton were recorded from all the stations monitored. The Gastropod veliger was found to be the dominant forms. The species such as Oithona similis, Euterpina acutifrons, Sagitta enflata, Tintinnopsis tubulosa, Copepod nauplii, and Bivalve veliger were found in all stations.

COMMON SPECIES OF ZOOPLANKTON

Paracalanus parvus

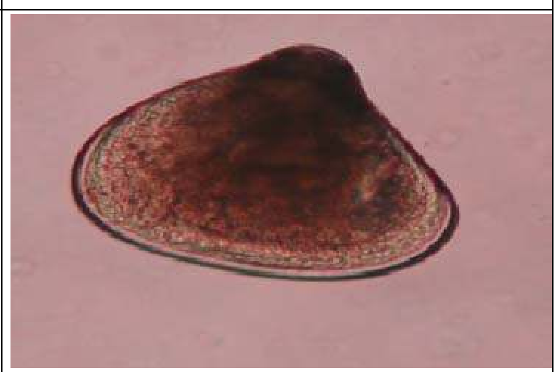
Oithona similis

Euterpina acutifrons



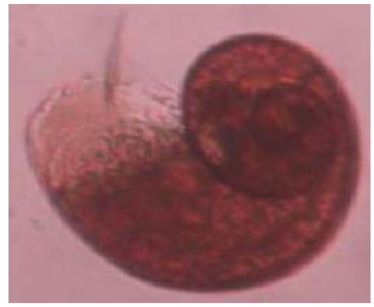
Nannocalanus minor

Sagitta enflata



Bivalve veliger

Copepod nauplii



Gastropod veliger

TABLE-3.12.

ZOOPLANKTON

Sl. No.	Name of the Species	No/m^3				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
1.	*Paracalanus minor*	*	314	161	82	166
2.	*Nannocalanus minor*	228	*	*	*	*
3.	*Oithona similis*	304	157	241	163	249
4.	*Metis jousseaumei*	*	*	*	408	*
5.	*Euterpina acutifrons*	152	157	80	*	332
6.	*Lucifer hanseni*	76	157	161	*	*
7.	*Sagitta enflata*	*	*	*	*	166
8.	*Tintinnopsis tubulosa*	*	79	161	245	166
9.	Bivalve veliger	304	314	321	490	332
10.	Gastropod veliger	152	236	241	571	249
11.	Copepod nauplii	380	471	402	327	415
	Total	**1596**	**1885**	**1768**	**2286**	**2075**

Sl. No.	Name of the Species	No/m^3				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
1.	*Paracalanus minor*	154	*	*	*	79
2.	*Acartia spinicauda*	77	76	*	76	79
3.	*Nannocalanus minor*	*	152	*	152	*
4.	*Oithona similis*	309	304	315	228	238
5.	*Euterpina acutifrons*	232	228	315	304	317
6.	*Sagitta enflata*	77	152	79	76	79
7.	*Tintinnopsis tubulosa*	*	76	157	*	79

8.	Bivalve veliger	386	228	315	228	238
9.	Gastropod veliger	232	304	236	152	79
10.	Copepod nauplii	309	456	315	304	317
	Total	**1776**	**1976**	**1732**	**1520**	**1505**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m³				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
1.	*Paracalanus minor*	*	230	*	156	*
2.	*Nannocalanus minor*	*	*	73	*	*
3.	*Oithona similis*	298	306	220	234	241
4.	*Euterpina acutifrons*	372	306	293	311	321
5.	*Sagitta enflata*	149	77	73	78	80
6.	*Tintinnopsis tubulosa*	74	*	*	*	*
7.	Bivalve veliger	298	153	220	234	161
8.	Gastropod veliger	149	77	147	156	241
9.	Copepod nauplii	223	230	293	311	321
	Total	**1563**	**1379**	**1319**	**1480**	**1365**

*** - Organisms not present**

Finfish Eggs

The finfish eggs density ranged from 6 to 12 No/m3 (Table-3.13). The minimum density was recorded at UTPC-9 & UTPC-12 and the maximum density was observed at UTPC-4 respectively. A total of 12 species of finfish eggs were recorded from all the stations monitored. The Mugil cephalus was found to be the dominant forms.

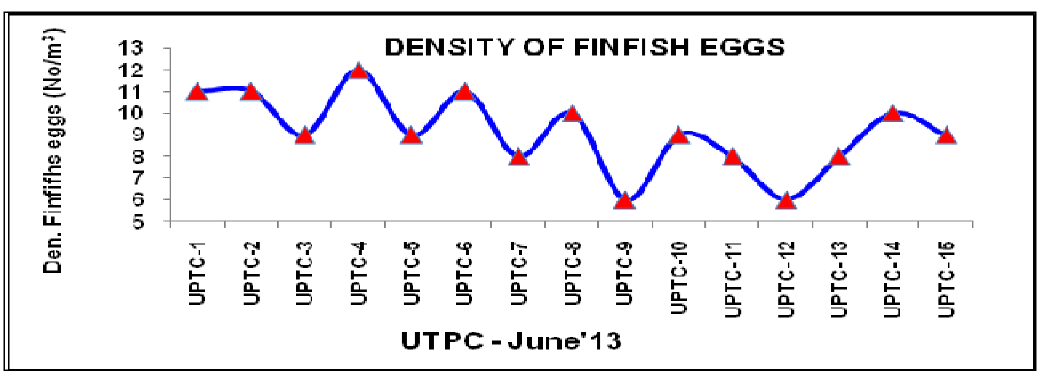


TABLE-3.13.

FINFISH EGGS

Sl. No.	Name of the Species	No/m^3				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
	Enraulidae					
1.	*Stolephora tri*	1	2	2	*	*
2.	*Thryssa dussumieri*	2	2	1	1	2
3.	*Thryssa mystax*	*	*	*	1	1
	Clupeidae					
1.	*Sardinella gibba*	*	*	*	2	1
2.	*Sardinella longiceps*	2	1	2	2	1
	Mugilidae					
1.	*Mugil cephalus*	3	2	2	3	2
	Carangidae					
1.	*Carangoides malabaricus*	1	2	1	*	*
	Teraponidae					
1.	*Terapon jarbua*	2	2	1	2	1
	Siganidae					
1.	*Signaus javus*	*	*	*	1	1
	Total	**11**	**11**	**9**	**12**	**9**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^3				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
	Enraulidae					
1.	*Setipinna taty*	*	1	1	*	*
2.	*Thryssa dussumieri*	2	2	2	1	2
3.	*Thryssa mystax*	1	*	*	*	1
	Clupeidae					
1.	*Sardinella gibbosa*	1	*	*	*	*
2.	*Sardinella longiceps*	2	*	1	1	2
	Mugilidae					
1.	*Mugil cephalus*	2	2	3	2	3
2.	*Liza dusumieri*	*	1	2	1	*
	Teraponidae					
1.	*Terapon jarbua*	2	2	1	1	1
	Siganidae					
1.	*Signaus javus*	1	*	*	*	*
	Scombridae					
1.	*Scomberomorus* sp.	*	*	1	*	*
	Total	**11**	**8**	**10**	**6**	**9**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^3				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
	Enraulidae					
1.	*Stolephora tri*	*	*	1	1	1
2.	*Thryssa dussumieri*	2	1	2	2	2
3.	*Thryssa mystax*	1	*	*	*	*
	Clupeidae					
1.	*Sardinella gibbosa*	*	*	1	2	1
2.	*Sardinella longiceps*	1	2	*	*	*
	Mugilidae					
1.	*Mugil cephalus*	2	1	2	2	1
2.	*Liza dusumieri*	*	*	1	1	2
	Teraponidae					
1.	*Terapon jarbua*	2	2	1	2	2
	Total	**8**	**6**	**8**	**10**	**9**

*** - Organisms not present**

Finfish Larvae

The finfish larvae ranged between 1 and 6 No/m3 (Table-3.14). The maximum number of finfish larvae observed at UTPC-5 and the minimum number of finfish larvae recorded at UTPC-15. A total of 11 species of finfish larvae were identified from all the stations monitored. The Stolephorus tri, Sardinella longiceps, Terapon jurbua, Mugil cephalus and Liza dussumieri were found to be the dominant forms.

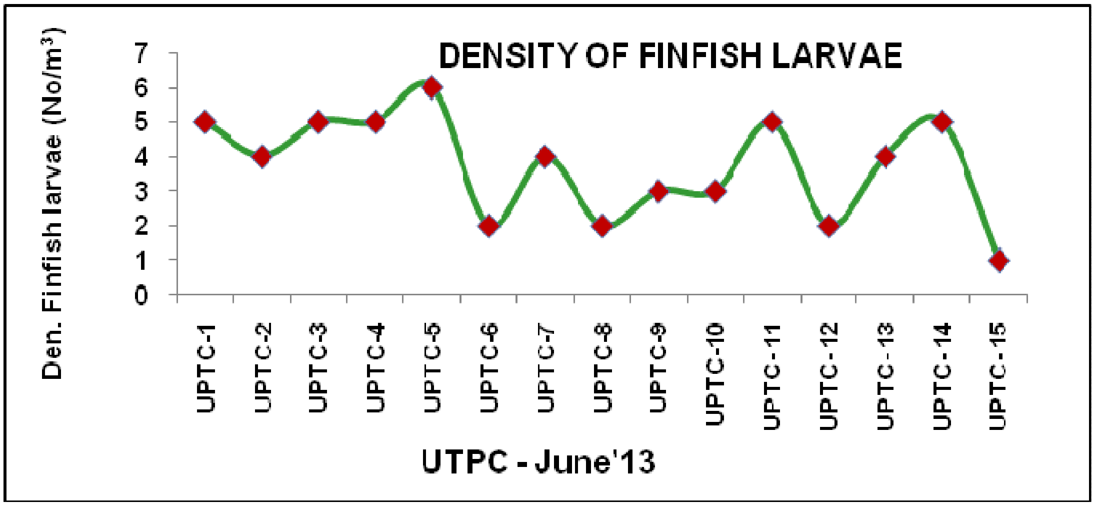


TABLE-3.14.

FINFISH LARVAE

Sl. No.	Name of the Species	No/m^3				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
	Enraulidae					
1.	*Stolephora tri*	1	1	2	*	*
2.	*Thryssa dussumieri*	*	1	*	1	1
3.	*Thryssa mystax*	*	*	*	*	1
	Clupeidae					
1.	*Sardinella gibbosa*	*	*	*	1	1
2.	*Sardinella longiceps*	1	1	1	2	*
	Mugilidae					
1.	*Mugil cephalus*	1	1	*	1	1
	Carangidae					

1.	*Carangoides malabaricus*	*	*	1	*	*
	Teraponidae					
1.	*Terapon jarbua*	2	*	1	*	1
	Siganidae					
1.	*Signaus javus*	*	*	*	*	1
	Total	**5**	**4**	**5**	**5**	**6**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^3				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
	Enraulidae					
1.	*Setipinna taty*	*	*	1	*	*
2.	*Thryssa dussumieri*	*	1	*	1	*
3.	*Thryssa mystax*	1	*	*	*	*
	Clupeidae					
1.	*Sardinella gibbosa*	1	*	*	*	*
2.	*Sardinella longiceps*	*	1	*	1	1
	Mugilidae					
1.	*Mugil cephalus*	*	1	*	*	2
2.	*Liza dusumieri*	*	*	1	*	
	Teraponidae					
1.	*Terapon jarbua*	*	1	*	1	*
	Total	**2**	**4**	**2**	**3**	**3**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^3				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
	Enraulidae					
1.	*Stolephora tri*	*	*	*	1	*
2.	*Thryssa dussumieri*	1	1	1	*	1
3.	*Thryssa mystax*	1	*	*	*	*
	Clupeidae					
1.	*Sardinella gibbosa*	*	*	*	1	*
2.	*Sardinella longiceps*	1	*	*	*	*
	Mugilidae					
1.	*Mugil cephalus*	2	*	2	*	*
2.	*Liza dusumieri*	*	*	*	2	*
	Teraponidae					
1.	*Terapon jarbua*	*	1	1	1	*
	Total	**5**	**2**	**4**	**5**	**1**

*** - Organisms not present**

Benthic Organisms

Benthic animals are divided into three categories, microfauna, meiofauna and macrofauna depending on their size. Macrobenthic organisms are animal species with body size larger than 0.5 mm. Benthic community responses to environmental perturbations are useful in assessing the impact of anthropogenic perturbations on environmental quality.

Macrobenthos:

The macrobenthos density varied from 775 to 2750 No/m2. The minimum was recorded at UTPC-15 and the maximum was observed at UTPC-7. In the present investigation, 77 species of macrobenthos were recorded from the study area and most of the species were found in all the stations. The Capitella capitata (250/1525 No/m2, UTPC-11) and Goniada emeriti (250/2750 No/m2, UTPC-7) were found to be the dominant forms during this survey (Table-3.15).

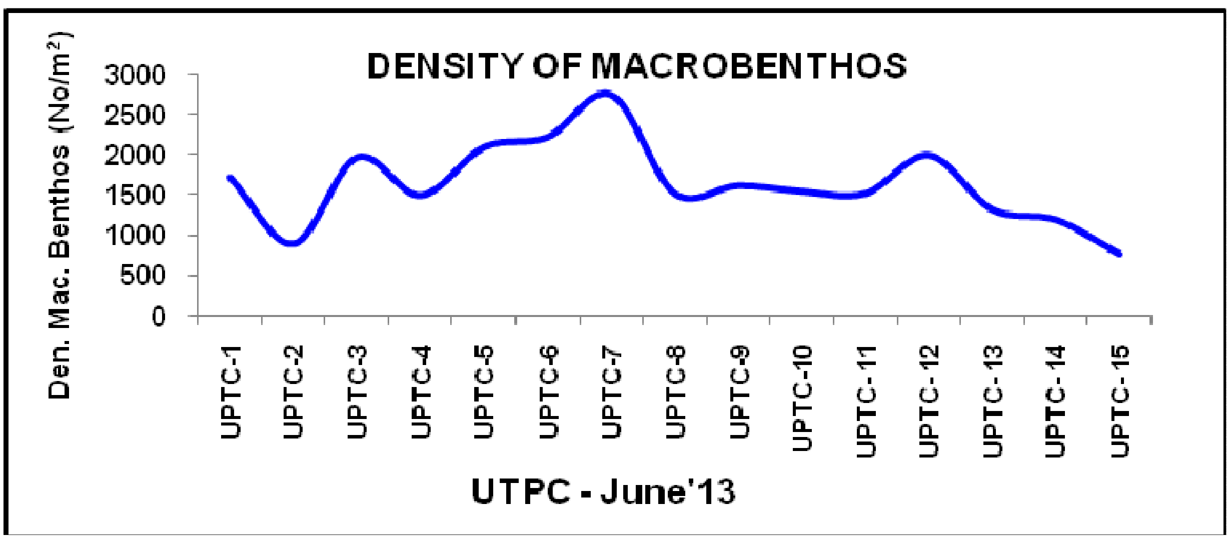


TABLE-3.15.

MACROBENTHOS

Sl. No.	Name of the Species	No/m^2				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
	Polychaetes					
1.	*Autolytus* sp.	*	*	50	*	*
2.	*Ancistrosyllis parva*	50	*	*	*	*
3.	*Ampharete acutifrons*	*	50	*	*	150
4.	*Armandia intermedia*	*	*	150	*	*
5.	*Capitella capitata*	150	*	250	*	*
6.	*Chone* sp.	100	*	*	*	125
7.	*Cirratulus chrysoderma*	*	*	50	*	*
8.	*Cirratulus filiformis*	75	*	*	*	50
9.	*Cirratulus africanus*	*	*	*	75	*
10.	*Cirriformia* sp.	100	*	*	*	*
11.	*Cossura coasta*	*	100	*	75	50
12.	*Drilonereis monroi*	*	50	*	*	*
13.	*Euclymene annandalei*	*	50	*	*	*
14.	*Euclymene* sp.	*	*	50	100	*
15.	*Exogone clavator*	200	*	*	75	150
16.	*Fabricia filamentosa*	*	*	100	*	*
17.	*Glycera alba*	150	*	*	*	*
18.	*Goniada emerita*	*	100	150	*	75
19.	*Leocrates* sp.	*	*	*	*	75
20.	*Lumbrineris* sp.	100	*	*	*	200
21.	*Maldane sarsi*	*	50	*	100	150
22.	*Thelepus* sp.	75	*	50	*	50
23.	*Nephtys dibranchis*	75	*	100	*	50
24.	*Nereis* sp.	*	*	75	*	150
25.	*Onuphis* sp.	*	50	*	100	*
26.	*Pygospio elegans*	50	*	*	100	*
27.	*Tharyx* sp.	*	50	*	*	*
28.	*Perinereis cultrifera*	*	*	75	*	*
29.	*Pisione* sp.	*	*	*	100	*
30.	*Pista* sp.	150	*	50	*	*

31.	*Platynereis* sp.	*	25	*	75	*
32.	*Prionospio pinnata*	*	75	*	*	150
33.	*Prionospio cirrifera*	*	*	100	*	175
34.	*Syllis gracilis*	75	*	100	200	125
35.	*Sphaerosyllis erinaceu*	*	75	*	50	*
	Bivalves					
1.	*Anadara granosa*	*	*	75	*	100
2.	*Anadara* veligers	*	50	*	100	*
3.	*Meretrix meretrix*	50	*	75	*	50
	Gastropods					
1.	*Turris indica*	*	*	50	*	75
2.	*Nassarius variegatus*	25	*	*	*	*
3.	*Cerithedia cingulata*	*	*	*	*	50
4.	*Natica* sp.	*	100	*	50	*
5.	*Turritella attenuata*	50	*	*	*	*
	Crustaceans					
1.	Penaeid shimp larvae	*	*	*	50	*
2.	*Apseudus* sp.	75	*	50	50	*
	Amphipods					
1.	*Ampithoe romondi*	75	*	150	75	*
2.	*Atylus falcatus*	*	*	*	50	*
3.	*Ampithoe rubricata*	50	*	75	*	*
4.	*Harnellia incerta*	*	*	75	*	*
	Isopods					
1.	*Angeliera phreaticola*	*	*	75	*	50
2.	*Jaeropsis beuroisi*	50	*	*	75	*
3.	*Calabozoa pellucida*	*	75	*	*	50
	Total	**1725**	**900**	**1975**	**1500**	**2100**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m²				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
	Polychaetes					
1.	*Autolytus* sp.	*	50	*	100	*
2.	*Ancistrosyllis parva*	*	150	*	75	50
3.	*Armandia longicaudata*	*	200	*	150	*
4.	*Armandia intermedia*	200	*	*	*	100
5.	*Capitella capitata*	*	250	100	225	150
6.	*Chone collaris*	200	100	*	75	*
7.	*Cirratulus filiformis*	150	*	150	*	50
8.	*Cirriformia* sp.	*	100	*	50	*
9.	*Cossura coasta*	150	*	200	*	75
10.	*Euchone*sp.	50	150	*	*	*
11.	*Eunice indica*	100	*	100	*	150
12.	*Exogone clavator*	75	150	*	50	*
13.	*Fabricia filamentosa*	*	*	100	*	200
14.	*Glycera alba*	*	100	*	*	*
15.	*Goniada emerita*	*	250	*	50	*
16.	*Hesionura laubieri*	*	*	*	50	*
17.	*Lumbrineris* sp.	100	75	*	25	50
18.	*Potanilla reniformis*	*	*	75	*	*
19.	*Lanice* sp.	100	100	*	50	*
20.	*Megalomma* sp.	*	*	100	*	*
21.	*Nephtys dibranchis*	50	100	*	75	*
22.	*Ophelia* sp.	75	*	50	*	100
23.	*Ophelina* sp.	*	100	*	50	*
24.	*Tharyx* sp.	75	100	*	*	*
25.	*Pista* sp.	*	*	50	*	75
26.	*Pisionidens indica*	*	75	*	*	*
27.	*Polydora* sp.	*	*	150	*	75
28.	*Prionospio pinnata*	200	200	*	*	*
29.	*Prionospio cirrifera*	*	*	175	*	50
30.	*Syllis gracilis*	50	100	*	200	150
31.	*Sphaerosyllis erinaceu*	*	*	*	*	*
32.	*Scololepis* sp.	150	50	50	*	*
33.	*Streblosoma*sp.	*	*	50	*	*

	Bivalves					
1.	*Anadara granosa*	*	50	*	100	50
2.	*Cardium* veligers	*	*	*	*	50
3.	*Anadara* veligers	*	*	*	*	*
4.	*Donax scortum*	100	*	25	*	*
5.	*Meretrix meretrix*	*	50	*	50	*
	Gastropods					
1.	*Turris indica*	*	50	*	*	75
2.	*Nassarius variegatus*	50	*	*	25	*
	Crustaceans					
1.	*Apseudus* sp.	100	50	*	75	*
	Amphipods					
1.	*Ampithoe rubricata*	100	*	75	*	50
2.	*Urothoe* sp.	*	100	*	75	*
	Isopods					
1.	*Angeliera phreaticola*	*	50	*	75	*
2.	*Jaeropsis beuroisi*	*	*	75	*	50
3.	*Mirocerberus* sp.	150	*	*	*	*
	Total	**2225**	**2750**	**1525**	**1625**	**1550**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^2				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
	Polychaetes					
1.	*Autolytus* sp.	*	100	75	*	*
2.	*Ampharete* sp.	*	100	*	*	75
3.	*Armandia intermedia*	*	*	*	150	*
4.	*Capitella capitata*	250	*	100	*	75
5.	*Chone collaris*	150	200	*	*	50
6.	*Cirratulus filiformis*	*	150	*	200	75
7.	*Cirriformia* sp.	200	*	*	175	*
8.	*Cossura coasta*	*	150	*	*	*
9.	*Drilonereis monroi*	*	*	50	*	*
10.	*Euchone*sp.	*	*	*	*	100
11.	*Exogone clavator*	*	100	*	50	*

12.	*Glycera alba*	100	*	150	*	*
13.	*Hesionura laubieri*	*	75	*	*	*
14.	*Megalomma* sp.	*	*	100	*	*
15.	*Megalomma vesiculasum*	*	100	*	*	*
16.	*Nephtys dibranchis*	175	150	*	*	*
17.	*Nereis* sp.	*	*	75	*	150
18.	*Onuphis* sp.	*	50	*	100	*
19.	*Pygospio elegans*	100	*	75	*	*
20.	*Tharyx* sp.	*	100	*	75	*
21.	*Pisione* sp.	75	*	100	*	*
22.	*Pista* sp.	*	150	*	100	75
23.	*Platynereis* sp.	*	*	150	*	75
24.	*Polydora capensis*	*	125	*	100	*
25.	*Syllis gracilis*	150	200	*	50	*
	Bivalves					
1.	*Anadara granosa*	*	*	100	*	50
2.	*Donax scortum*	*	50	*	*	*
3.	*Meretrix meretrix*	50	*	*	*	*
4.	*Meretrix* veligers	*	*	*	50	*
	Gastropods					
1.	*Turris indica*	25	*	50	*	*
2.	*Natica jucksomiana*	50	50	75	*	*
3.	*Murex trapa*	*	*	*	100	*
	Amphipods					
1.	*Ampithoe romondi*	75	*	100	*	50
2.	*Atylus falcatus*	100	*	75	*	*
3.	*Cheriphotes* sp.	*	50	*	*	*
	Isopods					
1.	*Angeliera phreaticola*	*	100	*	50	*
2.	*Jaeropsis beuroisi*	*	*	50	*	*
3.	*Mirocerberus* sp.	25	*	*	*	*
	Total	**1525**	**2000**	**1325**	**1200**	**775**

*** - Organisms not present**

COMMON SPECIES OF MACROBENTHOS

 Ancistrosyllus parva	 Capitella capitata
 Cirratulus africanus	 Cossura coasta
 Ampithoe rubricata	 Syllis gracilis

Urothoe sp.

Nephtys dibranchis

Meiobenthos:

The meiobenthos in the bottom sediment ranged between 109 and 226 No/10 cm2 (Table -3.16). The minimum density of meiobenthos was recorded at UTPC-2 and the maximum was recorded at UTPC-6. Most of the species were found in all the stations. Totally 45 species of meiobenthos were recorded in the present study period. The Daptonema conicum (12/197 No/10 cm2) was the dominant species found at UTPC-7.

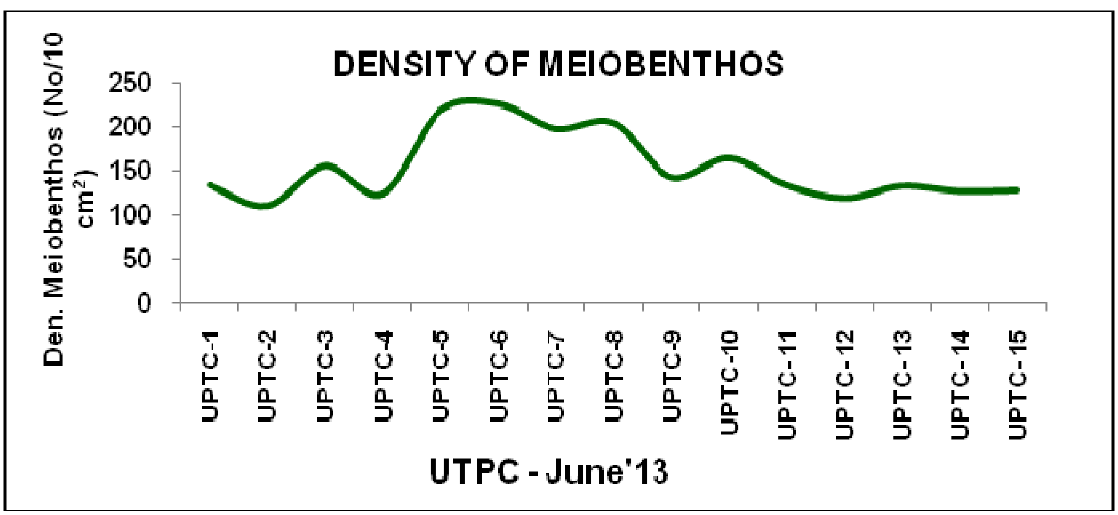


TABLE-3.16.

MEIOBENTHOS

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
	Nematodes					
1.	*Astomonema* sp.	5	6	*	*	5
2.	*Daptonema conicum*	*	5	*	8	*
3.	*Desmodora falcatus*	8	*	5	*	11
4.	*Draconema* sp.	*	6	*	4	*
5.	*Enoploides* sp.	*	9	*	*	5
6.	*Halalaimus filum*	6	*	9	*	10
7.	*Pselionema* sp.	7	*	8	9	10
8.	*Quadricoma* sp.	*	7	10	*	8
9.	*Tricoma* sp.	5	*	6	*	8
10.	*Viscosia* sp.	5	*	9	*	*
	Forminiferans					
1.	*Ammonia beccarii*	*	6	*	5	8
2.	*Cornoboides advena*	5	6	*	10	8
3.	*Cyclammina* sp.	*	*	4	*	5
4.	*Discorbis* sp.	7	*	8	11	10
5.	*Eliphidium* sp.	*	10	*	5	*
6.	*Eponides repandus*	5	*	6	*	*
7.	*Globigerina rubber*	8	*	9	*	9
8.	*Neocnorbina crustata*	5	*	6	*	9
9.	*Nonion depressulum*	*	6	*	7	5
10.	*Quinqueloculina* sp.	4	*	5	8	8
11.	*Rotalia pulchella*	7	*	6	*	5
12.	*Rotalia translucens*	5	*	8	*	10
13.	*Spirillina limbata*	*	5	*	5	6
14.	*Spirolina* sp.	4	*	5	7	*
15.	*Spiroloculina* sp.	*	8	*	*	8

16.	*Triloculina austriaca*	5	*	11	*	8
	Cumacea					
1.	*Gynodiastylis* sp.	8	*	*	8	7
	Harpacticoids					
1.	*Laptastocus* sp.	4	5	6	6	5
2.	*Metis* sp.	*	5	*	6	8
3.	*Microsetella* sp.	8	*	11	*	5
4.	*Stenhelia* sp.	*	6	*	6	7
	Ostrocodes					
1.	*Cyprideis* sp.	5	*	5	*	6
2.	*Cypridina* sp.	*	5	*	5	*
3.	*Leptocythere* sp.	5	*	6	*	5
4.	*Tanella kingmaii*	*	6	*	7	8
5.	*Tanella estuarii*	6	*	7	*	*
	Tanaidacea					
1.	*Heterotanais oerstedi*	6	*	5	*	5
2.	*Apsedues* sp.	*	8	*	6	6
	Total	**133**	**109**	**155**	**123**	**218**

*** - Organisms not present**

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-6	**UTPC-7**	**UTPC-8**	**UTPC-9**	**UTPC-10**
	Nematodes					
1.	*Astomonema* sp.	10	7	*	5	5
2.	*Daptonema conicum*	*	12	6	*	*
3.	*Desmodora falcatus*	9	*	*	10	7
4.	*Draconema* sp.	*	9	4	*	*
5.	*Enoploides* sp.	10	8	7	*	8
6.	*Halalaimus filum*	11	10	*	8	8
7.	*Pselionema* sp.	*	7	4	8	*
8.	*Quadricoma* sp.	7	*	8	*	5
9.	*Tricoma* sp.	8	*	9	*	5
10.	*Viscosia* sp.	*	7	5	6	*

	Forminiferans					
1.	*Ammonia beccarii*	8	7	*	6	*
2.	*Asterotoalia transpinosa*	5	*	5	*	5
3.	*Cornoboides advena*	11	10	*	7	*
4.	*Cyclammina* sp.	5	*	6	*	6
5.	*Discorbis* sp.	10	*	6	*	7
6.	*Eliphidium* sp.	*	5	7	5	5
7.	*Eponides repandus*	6	9	*	8	*
8.	*Globigerina rubber*	*	7	5	*	7
9.	*Globigerina glutinata*	9	5	5	5	6
10.	*Neocnorbina crustata*	10	11	*	7	5
11.	*Quinqueloculina* sp.	*	8	6	*	7
12.	*Rotalia pulchella*	8	*	8	*	8
13.	*Rotalia translucens*	10	*	10	*	8
14.	*Spirillina limbata*	*	10	10	8	*
15.	*Spirolina* sp.	11	*	11	*	8
16.	*Spiroloculina* sp.	*	10	8	8	9
17.	*Textularia agglutinans*	8	*	5	5	6
18.	*Triloculina austriaca*	10	7	9	8	5
	Cumacea					
1.	*Campylaspis* sp.	7	*	8	7	*
	Harpacticoids					
1.	*Canuella*sp.	*	10	7	*	5
2.	*Metis* sp.	7	*	9	6	*
3.	*Microsetella* sp.	*	6	5	*	5
	Ostrocodes					
1.	*Cyprideis* sp.	7	*	8	*	5
2.	*Cypridina* sp.	*	7	*	5	*
3.	*Keijella oertlii*	7	*	6	*	8
4.	*Leptocythere* sp.	8	9	*	8	*
5.	*Tanella indica*	10	11	*	*	6
6.	*Tanella kingmaii*	*	*	7	6	*

	Tanaidacea					
1.	*Heterotanais oerstedi*	8	*	5	6	*
2.	*Apsedues* sp.	6	5	5	*	5
	Total	**226**	**197**	**204**	**142**	**164**

*** - Organisms not present**

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
	Nematodes					
1.	*Astomonema* sp.	6	*	*	7	*
2.	*Daptonema conicum*	*	7	5	*	*
3.	*Desmodora falcatus*	5	*	*	*	6
4.	*Draconema* sp.	*	*	6	*	*
5.	*Enoploides* sp.	*	6	*	5	5
6.	*Halalaimus filum*	8	*	10	*	8
7.	*Pselionema* sp.	8	*	8	*	*
8.	*Quadricoma* sp.	*	7	*	5	6
9.	*Tricoma* sp.	10	*	8	*	10
10.	*Viscosia* sp.	*	8	*	8	*
	Forminiferans					
1.	*Ammonia beccarii*	6	*	8	*	8
2.	*Asterotoalia transpinosa*	*	*	*	*	*
3.	*Cornoboides advena*	5	6	*	7	*
4.	*Cyclammina* sp.	*	5	8	*	8
5.	*Discorbis* sp.	*	10	*	7	6
6.	*Eliphidium* sp.	5	*	5	5	*
7.	*Eponides repandus*	5	6	*	7	*
8.	*Globigerina rubber*	6	*	6	*	7
9.	*Globigerina glutinata*	*	5	*	8	*
10.	*Neocnorbina crustata*	5	5	6	*	5
11.	*Nonion depressulum*	*	*	*	*	*
12.	*Quinqueloculina* sp.	5	5	*	8	*
13.	*Rotalia pulchella*	*	6	7	7	*

14.	*Rotalia translucens*	5	*	6	*	7
15.	*Spirillina limbata*	*	8	*	8	*
16.	*Spirolina* sp.	7	*	5	*	6
17.	*Spiroloculina* sp.	*	*	*	8	*
18.	*Textularia agglutinans*	*	7	7	*	8
19.	*Triloculina austriaca*	5	5	5	8	*
	Cumacea					
1.	*Campylaspis* sp.	8	*	5	*	6
	Harpacticoids					
1.	*Canuella*sp.	4	*	5	*	8
2.	*Metis* sp.	8	*	5	*	5
3.	*Microsetella* sp.	*	6	*	6	*
	Ostrocodes					
1.	*Cyprideis* sp.	6	5	*	6	*
2.	*Cypridina* sp.	*	*	7	*	7
3.	*Keijella oertlii*	5	*	*	5	*
4.	*Leptocythere* sp.	*	7	*	5	*
5.	*Tanella indica*	6	*	5	*	6
6.	*Tanella kingmaii*	*	*	*	*	*
	Tanaidacea					
1.	*Heterotanais oerstedi*	*	4	*	*	5
2.	*Apsedues* sp.	5	*	5	6	*
	Total	**133**	**118**	**132**	**126**	**127**

*** - Organisms not present**

COMMON SPECIES OF MEIOBENTHOS

 Astomonema sp.	 Desmodora falcatus
 Daptonema conicum	 Draconema sp.
 Enoploides sp.	 Halalaimus filum

Pselionema sp.

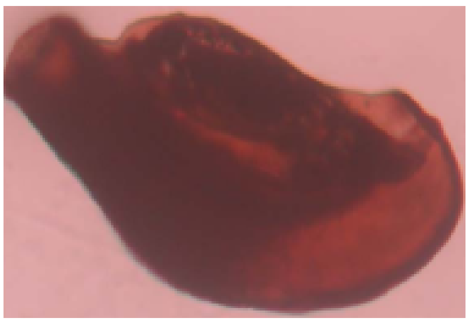
Quadricoma sp.

Tricoma sp.

Viscosia sp.

Ammonia beccarii

Asterorotalia trispinosa

 Eponides repandus	 Textularia agglutinans
 Triloculina austrica	 Rotalia translucens

SUMMARY

The surface water temperature varied from 30.5 to 31.5°C. The variation of temperature noticed at various stations may be as a result of season, geographical location and sampling time. The salinity varied from 32.0 to 35.0 ‰ and the maximum salinity observed was 35.0‰ at UTPC-2, UTPC3 & UTPC-4 during this survey. Hydrogen ion concentration in surface waters remained alkaline and the maximum value of 8.2 at UTPC-1, UTPC-2, UTPC-3, UTPC-4, UTPC-9, UTPC-11 and UTPC-15. The observations made on the prime physical factor TSS and turbidity were within the permissible level. The observed turbidity ranged between 1.5 and 5.0 NTU. The TSS values fluctuated from 29.2 to 66.2 mg/l. The maximum TSS and turbidity values were found to record at UTPC-9 and UTPC-5 respectively.

The ecologically sensitive chemical parameters such as Oxygen, BOD, nutrients and heavy metals were also at the optimal concentration coincided with the seasonal variation. The Dissolved Oxygen and BOD were found to be normal level. The observed oxygen level was fluctuated from 4.719 to 6.997 mg/l, the maximum DO level was recorded at UTPC-1 during this survey and the minimum was recorded at UTPC-2. The present study revealed that the DO concentration remained fairly well prescribed within the range of the values of water quality.

The BOD level was found to be ranged from 0.016 to 1.888 mg/l, the maximum BOD observed was 1.888 mg/l at UTPC-3 during this survey. In the present investigation, the observed ammonia concentration was ranged between 0.025 and 0.141 µmol/l. The concentration of nitrite fluctuated from 0.042 to 0.402 µmol/l. The nitrate values ranged from 2.222 to 5.216 µmol/l and the total nitrogen varied between 3.178 and 8.839 µmol/l. The inorganic phosphate ranged from 0.151 to 0.543 µmol/l. The observed total phosphorus values ranged between 0.579 and 0.887 µmol/l. The silicate concentration ranged from 0.155 to 0.385 µmol/l. The minimum concentration was recorded at UTPC-8 and the maximum concentration was recorded at UTPC-15 during this survey.

In the present survey, Petroleum Hydrocarbons varied between 0.232 and 0.422 µg/l and in sediment it varied between 0.358 and 0.895 µg/g at all locations monitored. The higher concentration of Petroleum Hydrocarbon was recorded at station UTPC-13 and UTPC-9 during this survey.

The concentrations of cadmium in water ranged between 1.12 and 1.60 µg/l. The concentrations of lead varied from 1.85 to 3.89 µg/1. The chromium varied from 1.37 to 3.22 µg/1, iron from 28.28 to 53.33 µg/l and the zinc from 1.15 to 4.78 µg/l. The concentration of manganese varied from 0.90 to 3.66 µg/l.

The sand, silt and clay fractions at each of the stations along with their textural classification indicates that the sand percentage was higher during this survey.

The stations UTPC-1, UTPC-2 & UTPC-3 were found to be record low percentage of sand at Uppur Thermal Power Project area.

The concentrations of cadmium in sediments ranged from 0.90 to 2.44 µg/g. The concentrations of lead varied from 12.12 to 35.18 µg/g. The chromium varied between 11.76 and 32.75 µg/g, iron from 2181 to 6545 µg/g, the zinc from 16.07 to 57.18 µg/g. The concentration of manganese varied from 199.77 to 334.97 µg/g and the nickel level varied from 9.73 to 26.04 µg/g.

The microbial population showed general trend in water and sediment samples during this survey. The observed maximum Total Coliform was 26 x 104 CFU/ml at UTPC-3. However, the higher count was recorded in the sediment samples (21x105 CFU/g) of UTPC-4.

The overall results of bacterial populations in water and sediment of the Uppur Thermal Power Project area was high. This revealed that the area receives significant volume of sewage. Higher numbers of coliforms indicate high level of contamination by faeces associated organisms resulting from sewage entering the coastal area through an estuary.

The primary productivity ranged from 55.85 to 92.711 mg C/m3/hr. The maximum PP 92.711 mg C/m3/hr, Chlorophyll 'a' 2.816 mg/m3 and Phaeopigment 2.488 mg/m3 were noticed at UTPC-10 during this survey. Phytoplankton population density varied from 215606 to 672782 No/l. The higher phytoplankton density was recorded at station UTPC-10 during this survey. The zooplankton density ranged from 1319 to 2286 No/m3. The higher zooplankton density was recorded at station UTPC-4 during this survey. A total of 5 species of phytoplankton and 12 species of zooplankton were found to record during this survey.

The numerical abundance of the macro benthic fauna ranged between 775 and 2750 No/m2 and the meiobenthic form fluctuated from 109 to 226 No/10 cm2. Among, the macrobenthos and meiobenthos, Capitella capitata, Goniada emerita and Daptonema conicum were found to be the dominant species in this survey respectively. A total of 77 species of macrobenthos and 45 species of meiobenthos were found to record during this survey.

The observations made during this survey revealed that the DO content of this coastal water is relatively more than the optimal recorded value of the coastal waters. This would have been due to the beneficial blooming of the phytoplankton viz. Rhizosolenia alata . The observed values were more than 6.7 lakhs. The nutrient levels were found to be below optimal. Interestingly the environment also recorded higher abundance of polychaete Capitella capitata suggesting that the water is receiving considerable quantity of organic discharges presumably from local drainage. However, the levels heavy metals and petroleum hydrocarbon were found to be below permissible level.

The Uppur coastal area covers thick mangrove vegetations along the shore with Avicennia marina, and Rhizophora apiculata.

3.4 MARINE ECOLOGY (SEPTEMBER, 2013)

Marine Ecological survey was carried out in the Uppur coastal area Ramanathapuram District, Tamil Nadu. The Uppur Thermal Power Corporation – (UTPC) sampling points are located between Thirupalakudi and Uppur coastal villages. Many water channels were connecting the shore from land side. The Marine Ecological survey at Uppur coastal areas was made by a team of experts from the Centre of Advanced Study in Marine Biology of Annamalai University during September 2013. The sampling locations are shown in Fig 3.2

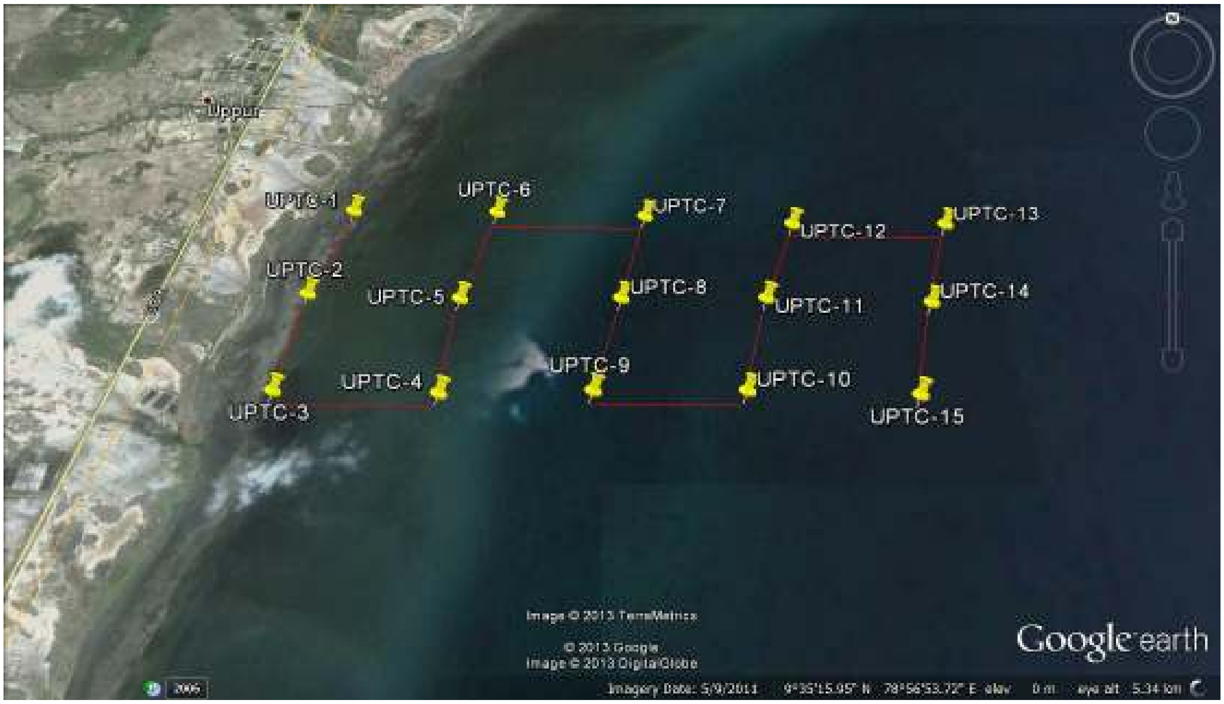


Fig-3.2 Map showing the sampling stations

Fifteen stations were selected in the coastal area and the samples were collected both high and low tide. Among the stations, UTPC 1, 2,3,4,5 and 6 were located in the near shore, UTPC- 7,8,9,10,11 & 12 were located away from the shore stations and UTPC 13, 14 & 15 in the open sea.

The Uppur coastal area covers thick mangrove vegetations along the shore. The Avicennia marina, and Rhizophora apiculata are predominantly available in this area.

The views of some representative sampling locations from where the samples were collected are illustrated below:

SAMPLING STATIONS

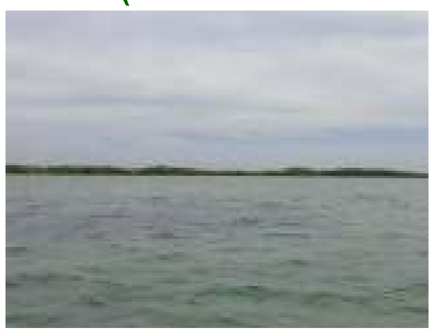
Station 1

Station 2

Station 3

Station 4 (2 km from the shore)

Station 5 (2 km from the shore)



Station 6 (2 km from the shore)

Station 7

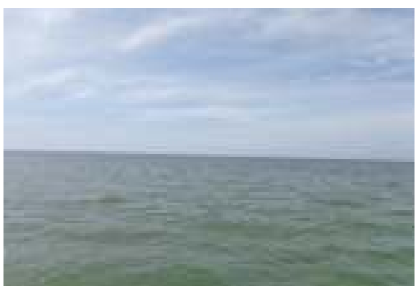
Station 8

Station 9

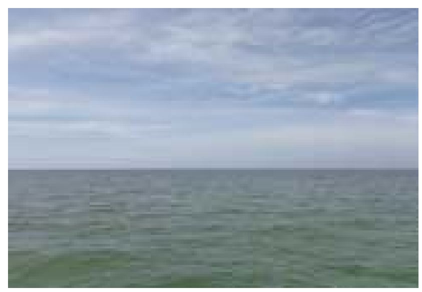
Station 10

Station 11

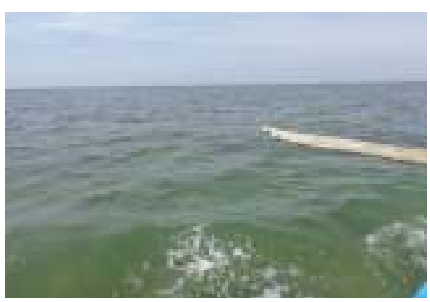
Station 12



Station 13



Station 14



Station 15

The geographical locations of the sampling stations are given in the Table-3.17.

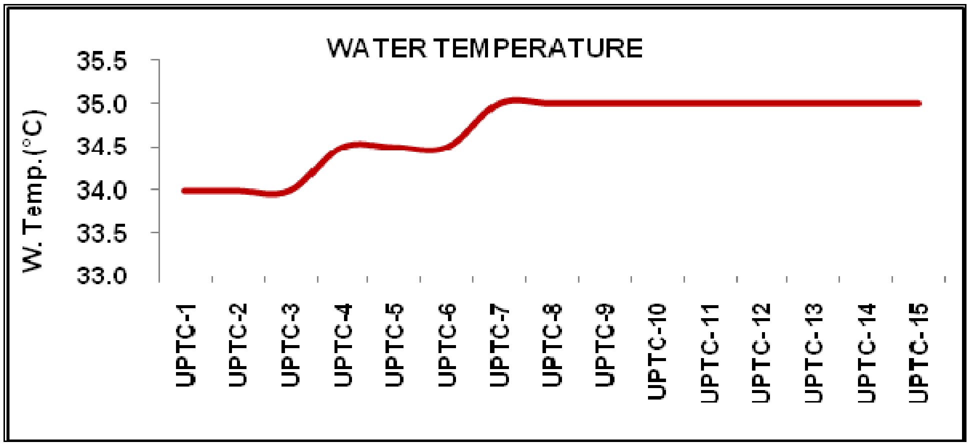
TABLE-3.17

SAMPLING LOCATIONS AND ITS GEOGRAPHICAL COORDINATES

S. No.	St. Code	Date	Time	Depth (m)	Latitude	Longitude
1.	UTPC-1	27.09.13	08:00	0.5	09°56’89” N	78°93’29” E
2.	UTPC-2	27.09.13	08:15	0.5	09°58’60” N	78°92’90” E
3.	UTPC-3	27.09.13	08:35	0.5	09°57’17” N	78°92’52” E
4.	UTPC-4	27.09.13	09:00	1.5	09°56’79” N	78°92’94” E
5.	UTPC-5	27.09.13	09:20	2.0	09°58’26” N	78°94’30” E
6.	UTPC-6	27.09.13	09:35	2.0	09°59’27” N	78°94’56” E
7.	UTPC-7	27.09.13	10:00	4.0	09°59’19” N	78°95’84” E
8.	UTPC-8	27.09.13	10:20	4.5	09°57’90” N	78°95’51” E
9.	UTPC-9	27.09.13	10:45	4.5	09°57’25” N	78°95’92” E
10.	UTPC-10	27.09.13	11:10	6.5	09°57’56” N	78°97’35” E
11.	UTPC- 11	27.09.13	11:35	6.0	09°58’30” N	78°98’09” E
12.	UTPC- 12	27.09.13	12:05	6.5	09°58’42” N	78°98’55” E
13.	UTPC- 13	27.09.13	12:30	10.0	09°57’88” N	78°99’63” E
14.	UTPC- 14	27.09.13	12:50	9.5	09°57’21” N	78°99’06” E
15.	UTPC- 15	27.09.13	13:20	10.0	09°56’56” N	78°98’21” E

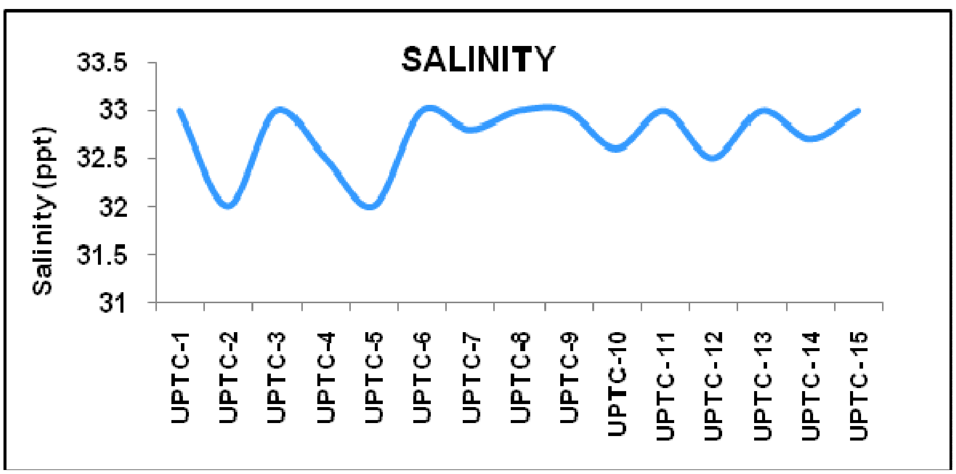
Water Temperature

The water temperature ranged between 34.0 and 35.0°C. The maximum was at UTPC-7, 8, 9, 10, 11, 12, 13, 14 & 15 and minimum at UTPC-1, 2 & 3 (Table-3.18).



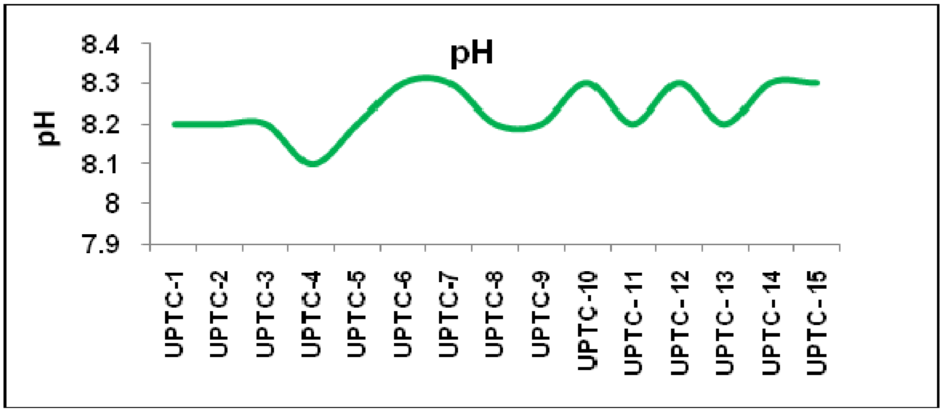
Salinity

The water salinity varied from 32 to 33‰. The maximum salinity was at UTPC-1, 3, 5, 6, 8, 9, 11, 13 and 15 and the minimum was recorded at UTPC-2 (Table 3.18).



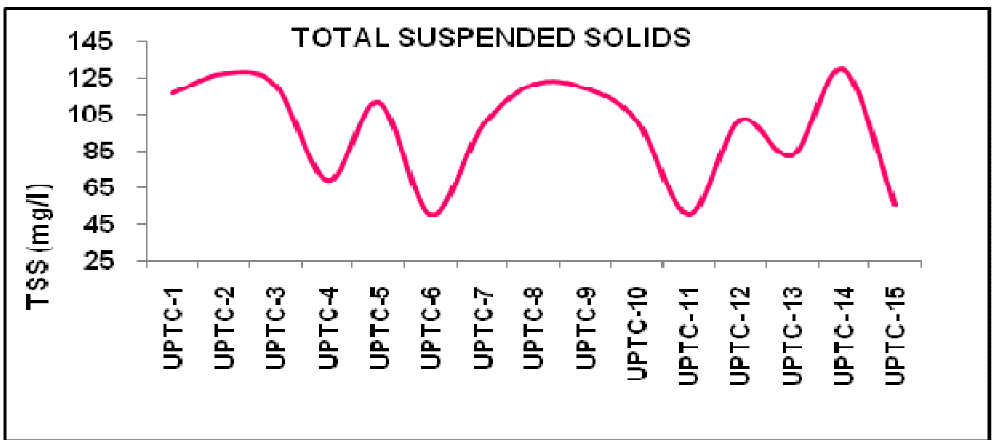
pH

The water pH varied between 8.1 and 8.3 (Table 3.18). The minimum pH was recorded at UTPC-4 and the maximum was at UTPC- 6, 7, 9, 10, 12, 13, 14 and UTPC-15.



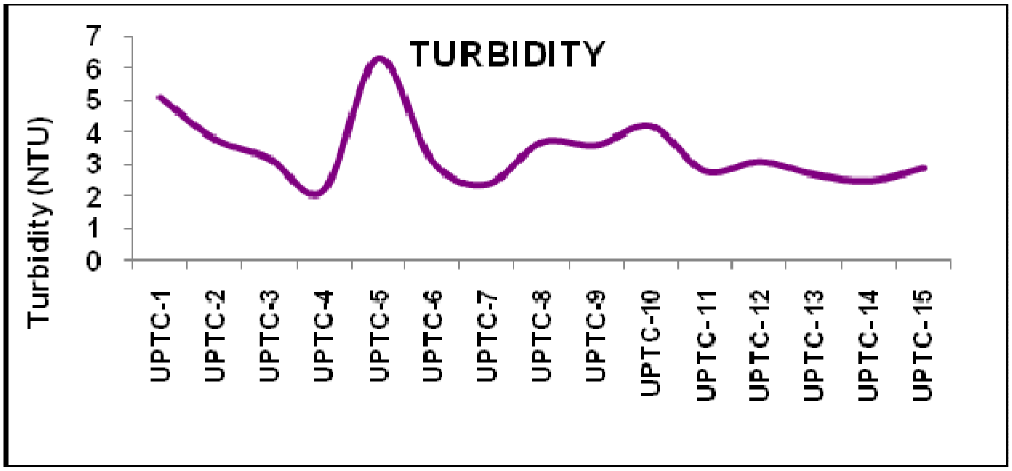
Total Suspended Solids

The TSS values ranged between 50.4 and 130.0 mg/l. The minimum value (50.4 mg/l) was recorded at UTPC-6 and maximum (130 mg/l) was at UTPC-14 (Table 3.18).



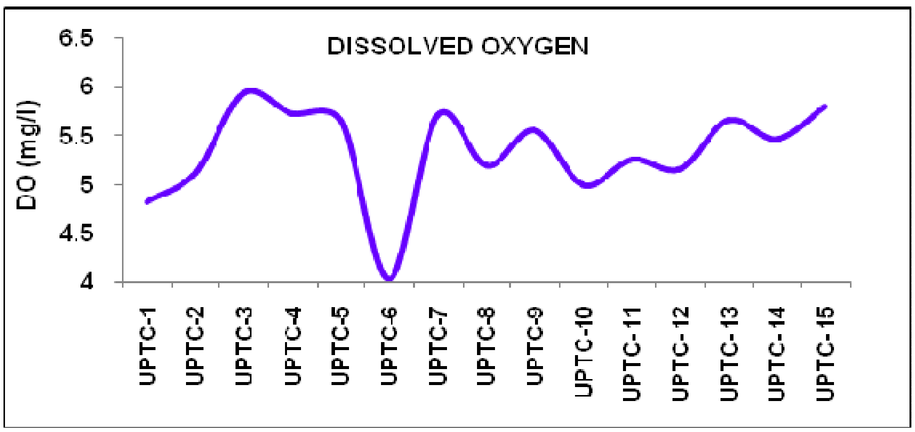
Turbidity

The turbidity values ranged from 2.2 to 6.3 NTU (Table 3.18). The maximum level was at UTPC-5 and the minimum was recorded at UTPC-4.



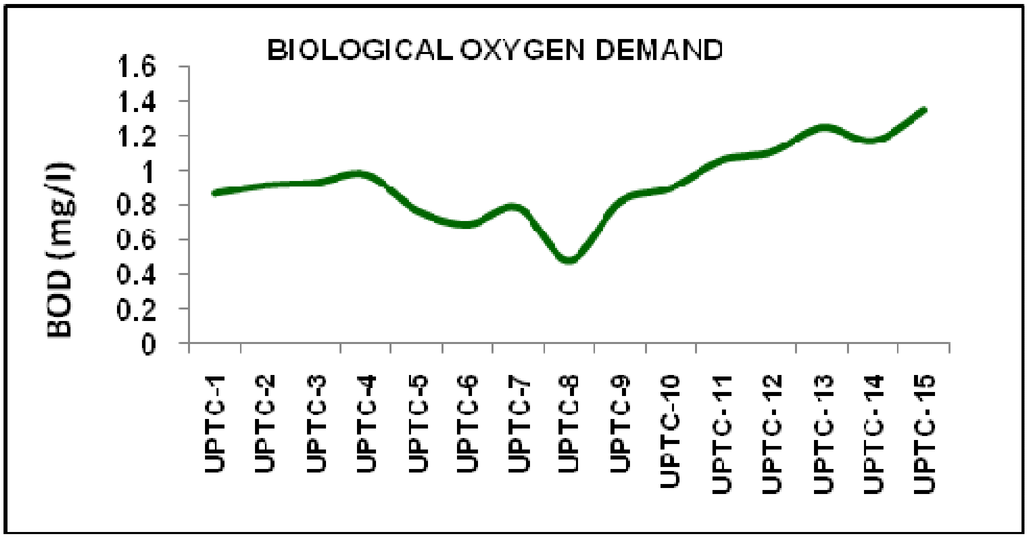
Dissolved Oxygen

The Dissolved Oxygen level in the water varied between 4.024 and 5.931 mg/l. The minimum and maximum levels were recorded at UTPC-6 and UTPC-3 respectively (Table 3.18).



Biological Oxygen Demand

The BOD values ranged between 0.48 and 1.344 mg/l. The maximum value (1.344 mg/l) was at UTPC-15 and minimum (0.48 mg/l) was at UTPC-8 (Table 3.18).



TABLE– 3.18.

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.	UTPC-1	34.0	33.0	8.2	116.8	5.1	4.816	0.864
2.	UTPC-2	34.0	32.0	8.2	127.2	3.8	5.123	0.912
3.	UTPC-3	34.0	33.0	8.2	120.8	3.2	5.931	0.928
4.	UTPC-4	34.5	32.5	8.1	69.2	2.2	5.721	0.976
5.	UTPC-5	34.5	32.0	8.2	111.6	6.3	5.64	0.768
6.	UTPC-6	34.5	33.0	8.3	50.4	3.1	4.024	0.688
7.	UTPC-7	35.0	32.8	8.3	98.8	2.4	5.704	0.784
8.	UTPC-8	35.0	33.0	8.2	121.2	3.7	5.187	0.480
9.	UTPC-9	35.0	33.0	8.2	119.2	3.6	5.559	0.816

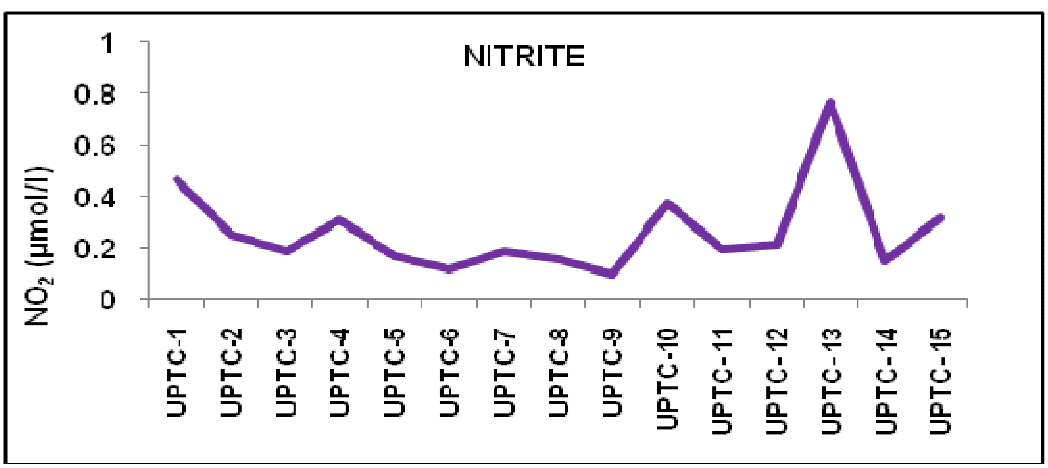
10.	UTPC-10	35.0	32.6	8.3	102.0	4.2	4.993	0.896
11.	UTPC- 11	35.0	33.0	8.2	50.8	2.8	5.252	1.056
12.	UTPC- 12	35.0	32.5	8.3	102.0	3.1	5.155	1.104
13.	UTPC- 13	35.0	33.0	8.2	82.8	2.7	5.656	1.248
14.	UTPC- 14	35.0	32.7	8.3	130.0	2.5	5.462	1.168
15.	UTPC- 15	35.0	33.0	8.3	56.0	2.9	5.801	1.344

Nutrients

The life supporting processes in the sea requires an array of inorganic substances, but the role of nitrogen, phosphorus and silicon are considered vital in marine ecosystem. Among the nitrogenous nutrients, nitrite, nitrate and ammonia are the major constituents, which play key roles in the phytoplankton growth and proliferation.

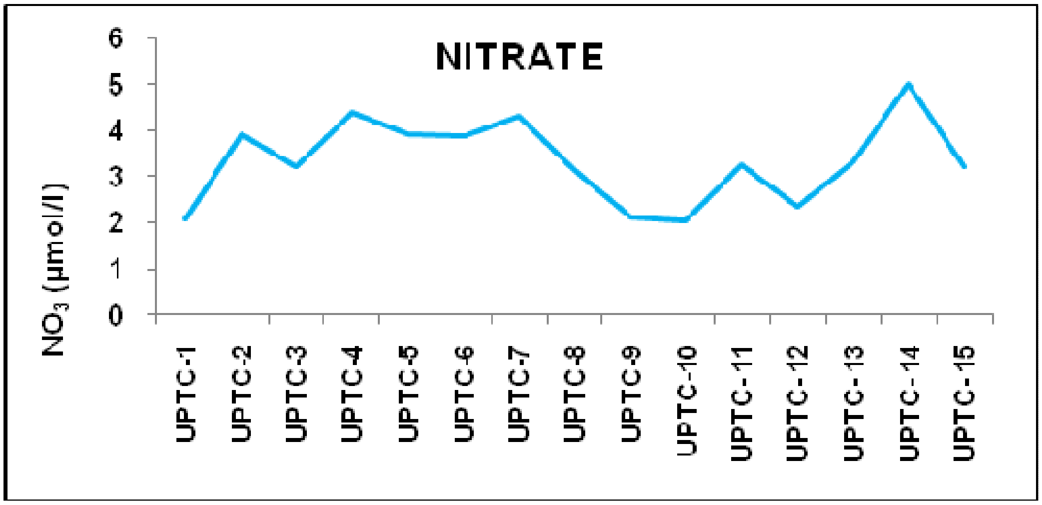
Nitrite

The nitrite concentration varied from 0.096 to 0.766 µmol/l (Table 3.19). The minimum and maximum values were recorded at UTPC-9 and UTPC-13 respectively.



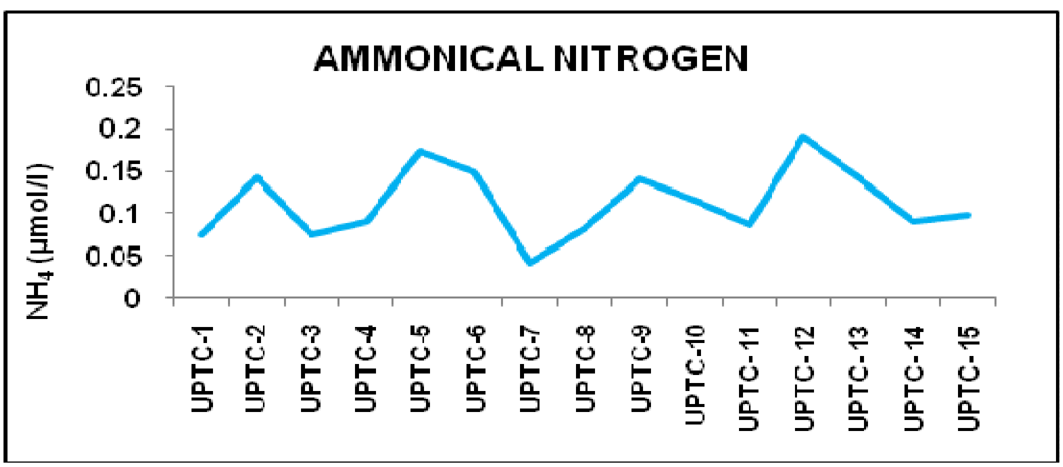
Nitrate

Nitrate concentration varied from 2.039 to 4.990 µmol/l (Table 3.19). The maximum Nitrate concentration was recorded at UTPC-10 and minimum at UTPC-14.



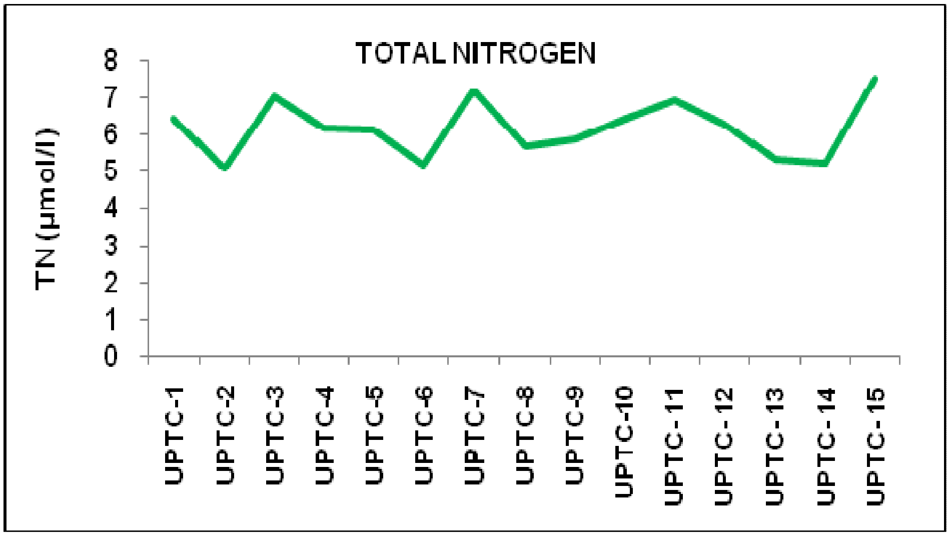
Ammonical Nitrogen

The ammonia concentration fluctuated from 0.042 to 0.191 µmol/l. The maximum concentration (0.191 µmol/l) was recorded at UTPC-12 and the minimum (0.042 µmol/l) was at UTPC-7 (Table 3.19).



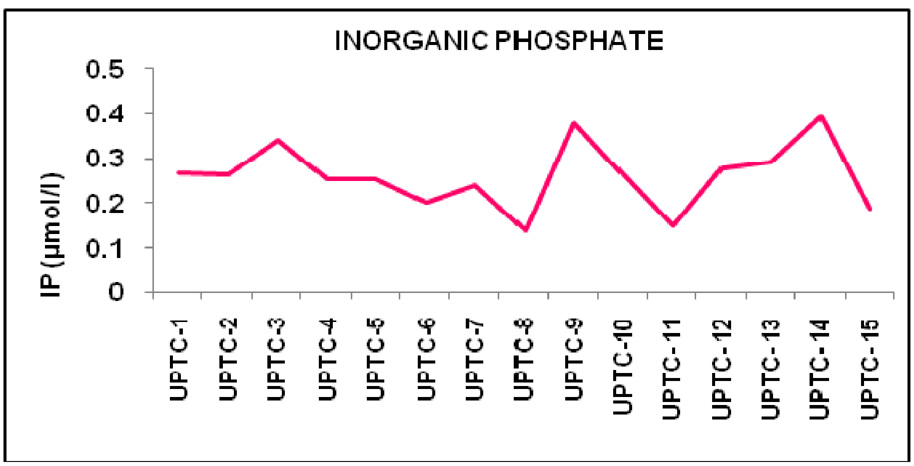
Total Nitrogen

The Total nitrogen values ranged from 5.062 to 7.525 µmol/l. The maximum concentration was recorded at UTPC-15 (7.525 µmol/l) and minimum at UTPC-2 (5.062 µmol/l) (Table 3.19).



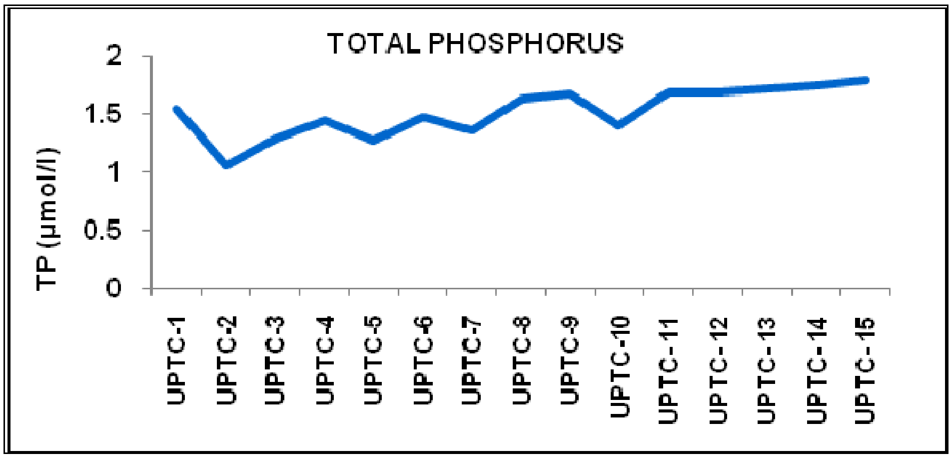
Inorganic Phosphate

The inorganic phosphate values fluctuated between 0.140 and 0.393 µmol/l. The maximum value was recorded at UTPC-14 and the minimum was at UTPC-8 (Table 3.19).



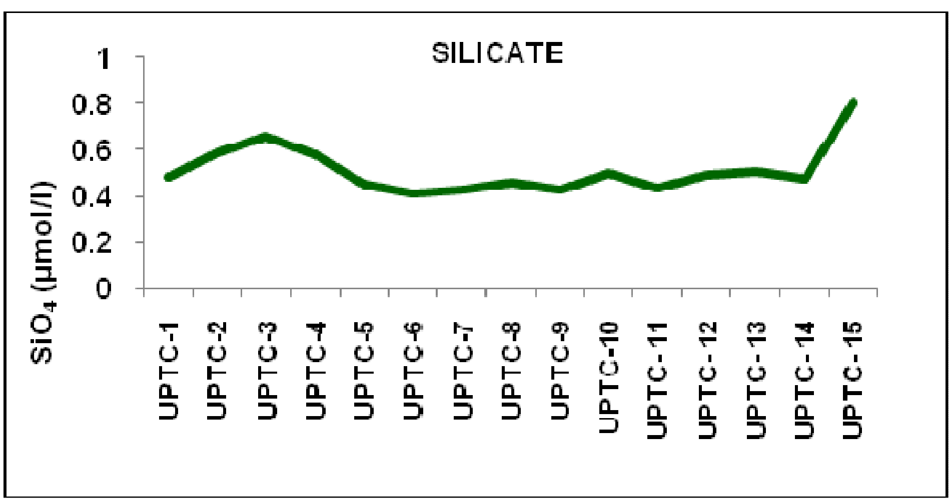
Total Phosphorus

The total phosphorus values ranged from 0.595 to 0.882 µmol/l. The maximum (0.882 µmol/l) value was at UTPC-15 and the minimum (0.595 µmol/l) was recorded at UTPC-10 (Table 3.19).



Reactive Silicate

The silicate values were ranged between 0.412 and 0.802 µmol/l. The maximum (0.802 µmol/l) and minimum (0.412 µmol/l) values were recorded at UTPC-15 and UTPC-6 respectively (Table 3.19).



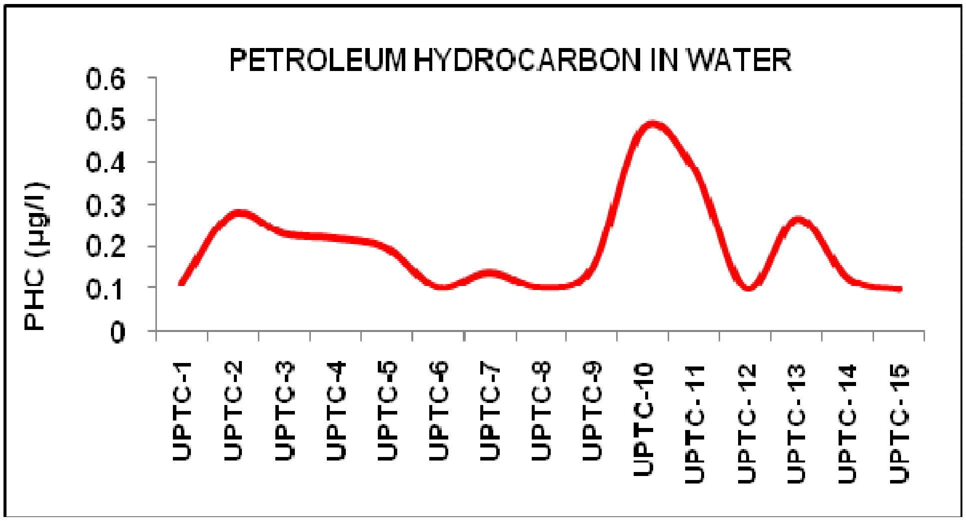
TABLE– 3.19.

NUTRIENTS IN WATER

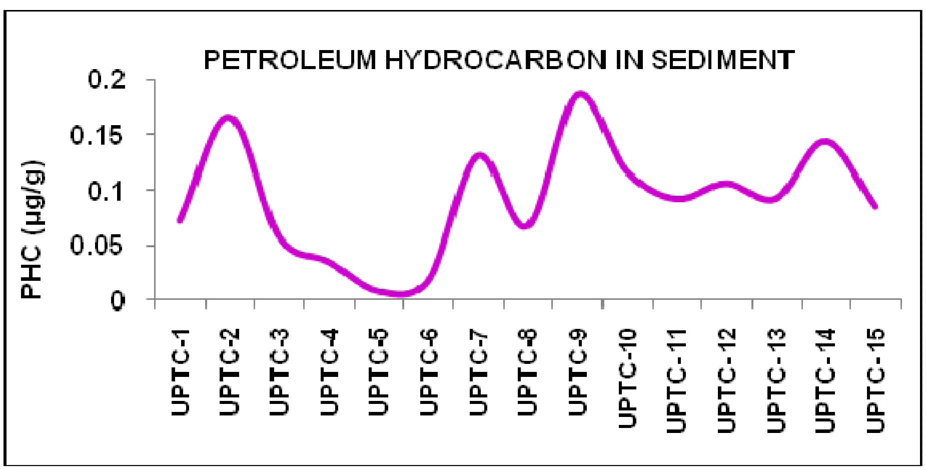
S. No.	Station Code	Parameter (μmol/l)						
		NO_2	NO_3	NH_4	TN	IP	TP	SiO_4
1.	UTPC-1	0.460	2.068	0.075	6.442	0.268	0.843	0.487
2.	UTPC-2	0.249	3.921	0.143	5.062	0.264	0.623	0.590
3.	UTPC-3	0.185	3.212	0.075	7.035	0.342	0.681	0.657
4.	UTPC-4	0.306	4.352	0.090	6.164	0.255	0.738	0.583
5.	UTPC-5	0.164	3.904	0.174	6.138	0.253	0.668	0.455
6.	UTPC-6	0.115	3.858	0.149	5.177	0.204	0.673	0.412
7.	UTPC-7	0.183	4.284	0.042	7.171	0.240	0.662	0.426
8.	UTPC-8	0.153	3.126	0.083	5.655	0.140	0.631	0.461
9.	UTPC-9	0.096	2.104	0.141	5.87	0.378	0.664	0.430
10.	UTPC-10	0.375	2.039	0.116	6.418	0.266	0.595	0.500
11.	UTPC- 11	0.193	3.255	0.087	6.937	0.151	0.675	0.433
12.	UTPC- 12	0.211	2.339	0.191	6.267	0.280	0.623	0.489
13.	UTPC- 13	0.766	3.336	0.143	5.308	0.293	0.632	0.507
14.	UTPC- 14	0.149	4.990	0.091	5.217	0.393	0.734	0.475
15.	UTPC- 15	0.315	3.219	0.098	7.525	0.189	0.882	0.802

PETROLEUM HYDRO CARBON

In Uppur Thermal Power Plant areas, the PHC level in water fluctuated from 0.098 and 0.479 µg/l. The minimum was recorded at UTPC-15 and the maximum was recorded at UTPC-10 (Table 3.20).



In sediment, the PHC varied between 0.008 and 0.186 µg/g. The minimum and maximum concentrations were recorded at UTPC-5 and UTPC-9 respectively during this survey (Table 3.20).



These values indicate anthropogenic release of petroleum in the system. A part of PHC may also originate from the fishing activities transported by tidal ingress.

TABLE -3.20.

PETROLEUM HYDROCARBON IN WATER & SEDIMENT

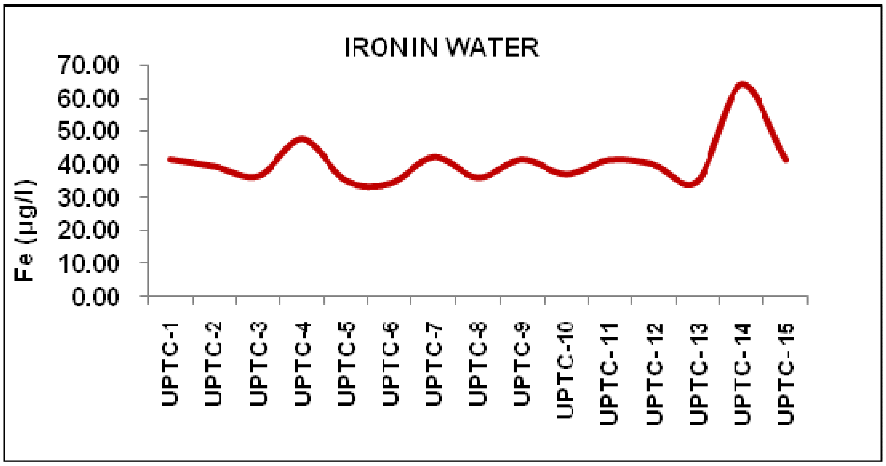
S. No.	Station Code	Water (µg/l)	Sediment (µg/g)
1.	UTPC-1	0.113	0.072
2.	UTPC-2	0.277	0.166
3.	UTPC-3	0.230	0.057
4.	UTPC-4	0.219	0.035
5.	UTPC-5	0.196	0.008
6.	UTPC-6	0.104	0.018
7.	UTPC-7	0.139	0.131
8.	UTPC-8	0.104	0.067
9.	UTPC-9	0.149	0.186
10.	UTPC-10	0.479	0.117
11.	UTPC- 11	0.381	0.092
12.	UTPC- 12	0.101	0.106
13.	UTPC- 13	0.266	0.092
14.	UTPC- 14	0.125	0.144
15.	UTPC- 15	0.098	0.085

Heavy Metals in Water

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

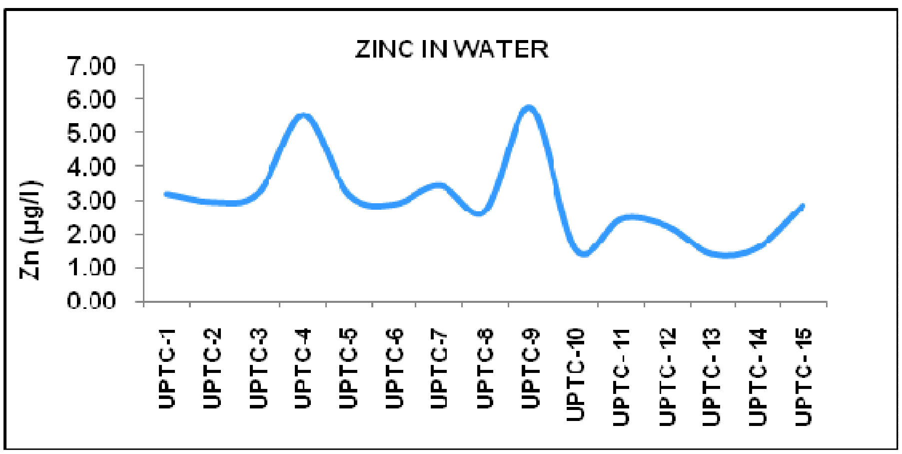
Iron

The iron level varied from 33.94 to 64.0 µg/l. The maximum iron level was recorded at UTPC-14 and the minimum of 33.94 µg/l was recorded at UTPC-6 (Table 3.21).



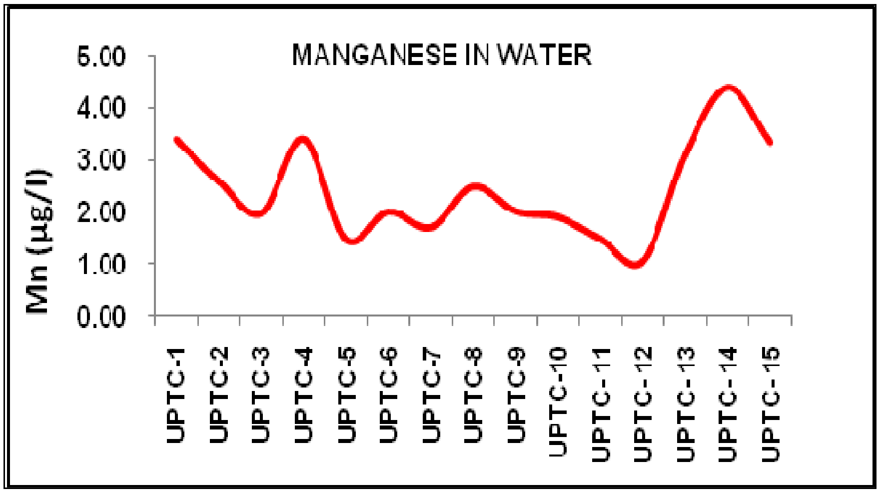
Zinc

The zinc level in the study area varied between 1.38 and 5.74 µg/l. The maximum value was recorded at UTPC-9 and the minimum of 1.38 µg/l was recorded at UTPC-13 (Table 3.21).



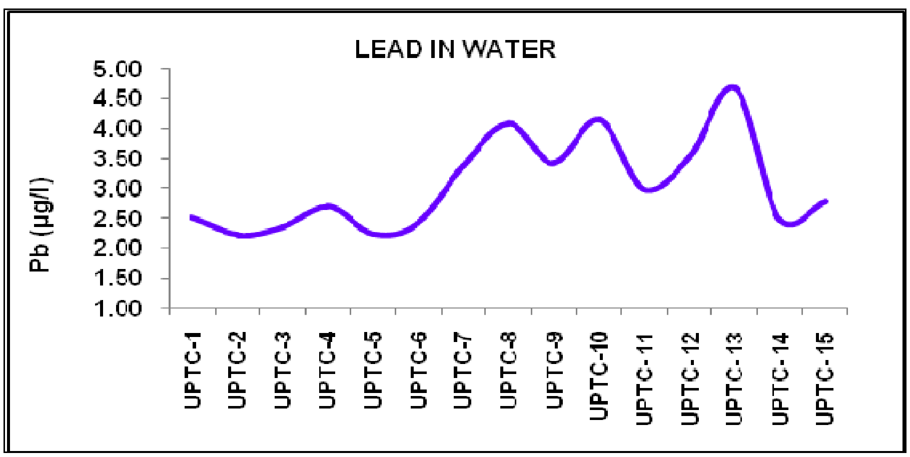
Manganese

The manganese level varied between 1.08 and 4.39 µg/l. The maximum value was recorded at UTPC-14 and the minimum value at UTPC-12 (Table 3.21).



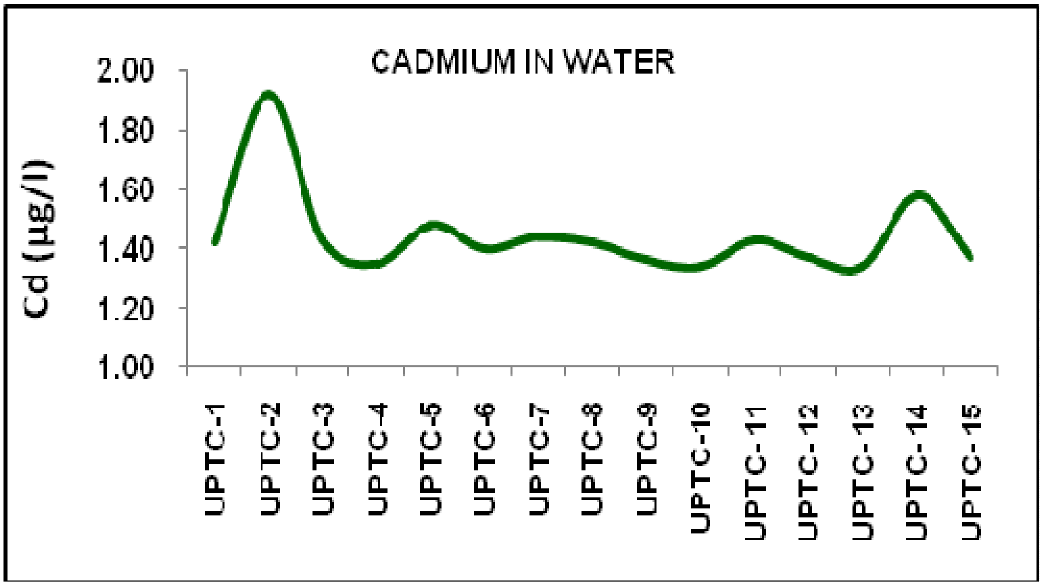
Lead

The lead level in the study area fluctuated between 2.22 and 4.67 µg/l. The maximum of 4.67 µg/l was observed at UTPC-13 and the minimum of 2.22 µg/l was recorded at UTPC-2 during this survey (Table 3.21).



Cadmium

The cadmium level in the study area varied from 1.34 and 1.92 µg/l. The maximum cadmium was recorded at UTPC-2 and the minimum (1.34 µg/l) was recorded at UTPC-10 & UTPC-13 respectively during this survey (Table 3.21).



Chromium

The chromium level in the study area varied between 1.64 and 3.36 µg/l. The minimum and maximum values were recorded at UTPC-8 and UTPC-13 respectively during this survey (Table 3.21).

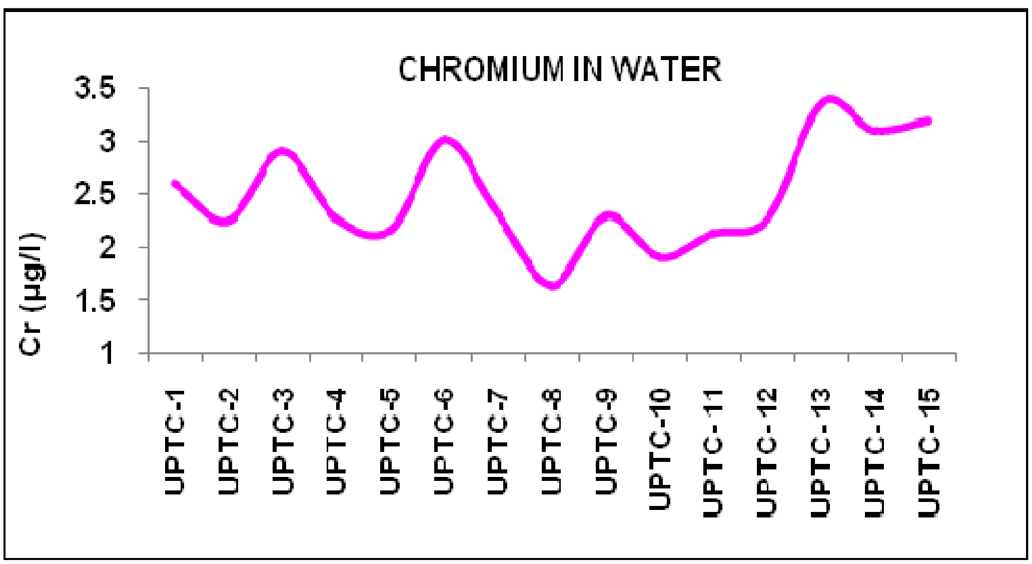


TABLE – 3.21.

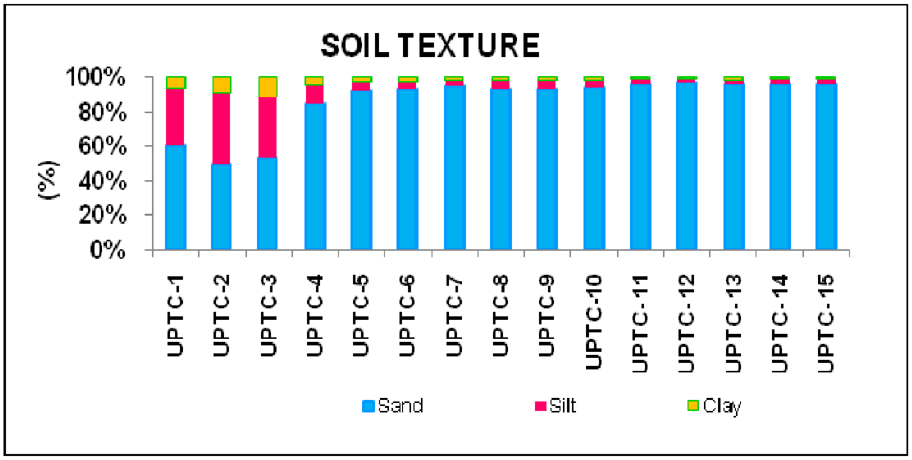
HEAVY METALS IN WATER

Sl. No.	Parameters	Heavy metals (µg/l)					
		Fe	Zn	Mn	Pb	Cd	Cr
1.	UTPC-1	41.28	3.16	3.40	2.52	1.42	2.60
2.	UTPC-2	39.13	2.93	2.60	2.22	1.92	2.24
3.	UTPC-3	36.20	3.19	1.99	2.35	1.43	2.90
4.	UTPC-4	47.53	5.52	3.41	2.70	1.35	2.27
5.	UTPC-5	34.79	3.14	1.49	2.24	1.48	2.16
6.	UTPC-6	33.94	2.86	2.02	2.41	1.40	3.01
7.	UTPC-7	42.06	3.42	1.72	3.38	1.44	2.32
8.	UTPC-8	35.76	2.65	2.50	4.09	1.42	1.64
9.	UTPC-9	41.30	5.74	2.03	3.42	1.36	2.29
10.	UTPC-10	36.77	1.50	1.92	4.14	1.34	1.90
11.	UTPC- 11	41.15	2.43	1.50	2.97	1.43	2.13
12.	UTPC- 12	39.76	2.22	1.08	3.52	1.37	2.27
13.	UTPC- 13	34.68	1.38	3.11	4.67	1.34	3.36
14.	UTPC- 14	64.00	1.57	4.39	2.48	1.58	3.10
15.	UTPC- 15	41.14	2.83	3.35	2.77	1.37	3.19

Sediment Characteristics

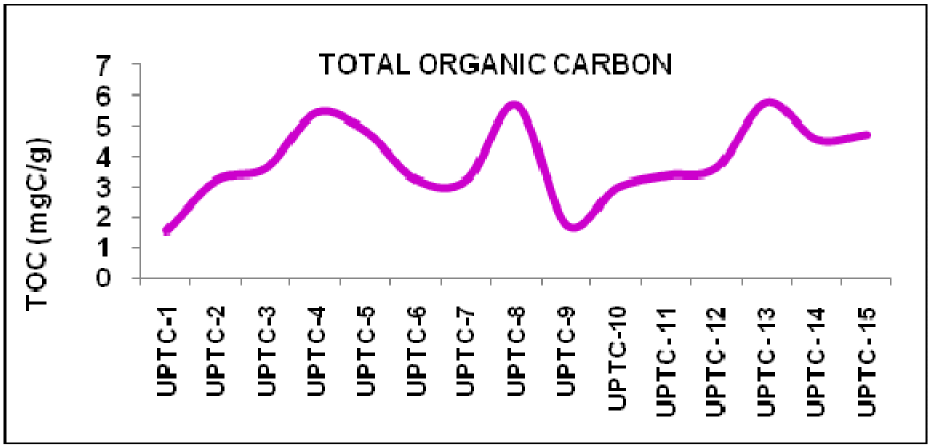
Soil Texture (%)

The sand content varied from 49.51 to 96.12 % with the maximum value at UTPC-12 and the minimum sand content in the station UTPC-2; the silt content showed maximum of 41.84% at UTPC-2 and minimum of 2.75 % at UTPC-12 and the clay was found to be maximum at UTPC-3 (11.83 %) and minimum at UTPC-12 (1.13%) (Table 3.22).



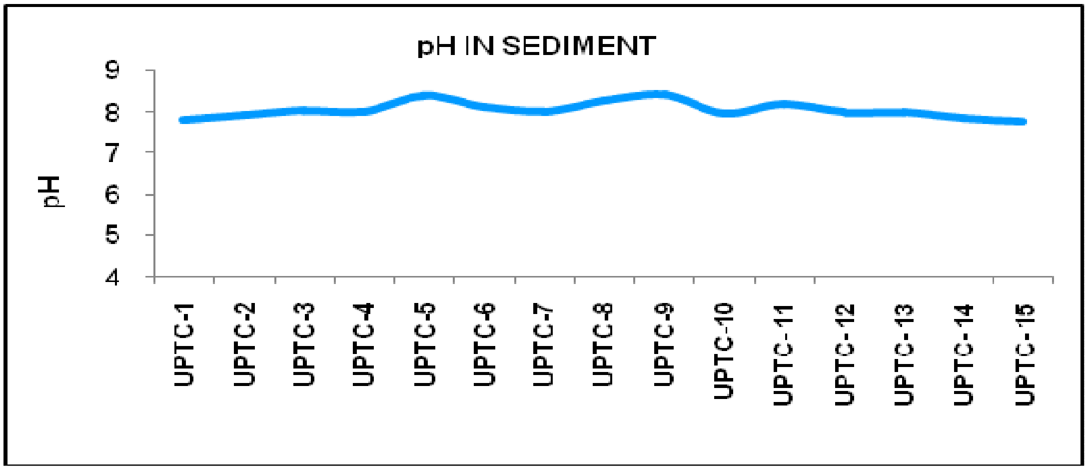
Total Organic Carbon

Total organic carbon level was maximum (5.80 mgC/g) at UTPC-13 and minimum (1.57 mgC/g) at the station UTPC-1 (Table 3.22).



pH

The pH in the sampling stations varied from 7.77 to 8.41. As evident from the following figure, the minimum level was recorded at UTPC-15 and the maximum level was recorded at UTPC-9 during this survey (Table 3.22).



TABLE– 3.22.

SOIL TEXTURE, TOTAL ORGANIC CARBON & pH OF SEDIMENT

S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (mgC/g)	pH
1.	UTPC-1	60.21	33.45	6.34	1.57	7.83
2.	UTPC-2	49.51	41.84	8.65	3.23	7.92
3.	UTPC-3	52.74	35.43	11.83	3.64	8.04
4.	UTPC-4	83.68	11.72	4.6	5.46	8.02
5.	UTPC-5	92.34	5.18	2.48	4.80	8.4
6.	UTPC-6	93.08	4.45	2.47	3.23	8.13
7.	UTPC-7	94.90	3.37	1.73	3.23	8.01

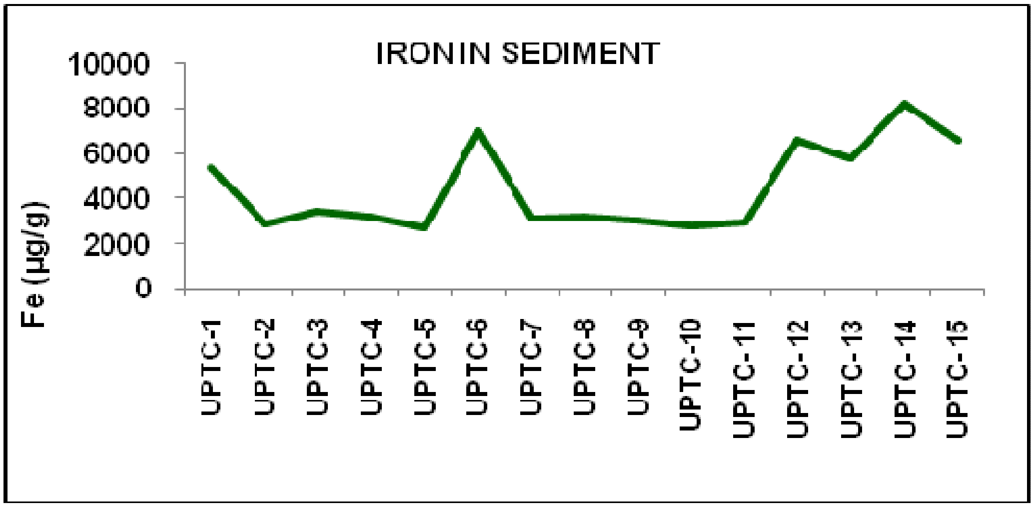
S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (mgC/g)	pH
8.	UTPC-8	92.54	5.42	2.04	5.71	8.25
9.	UTPC-9	93.12	5.26	1.62	1.74	8.41
10.	UTPC-10	93.45	4.69	1.86	2.98	7.97
11.	UTPC- 11	95.16	3.60	1.24	3.39	8.18
12.	UTPC- 12	96.12	2.75	1.13	3.64	7.99
13.	UTPC- 13	95.23	2.87	1.9	5.80	7.99
14.	UTPC- 14	95.37	3.36	1.27	4.55	7.84
15.	UTPC- 15	95.16	3.62	1.22	4.72	7.77

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.

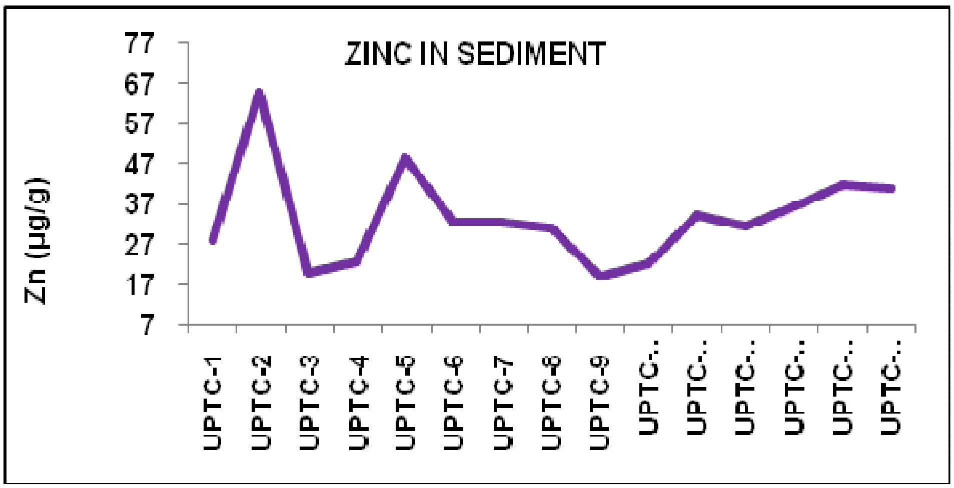
Iron

The cadmium level varied from 2726 to 8181 µg/g (Table 3.23). The maximum was recorded at UTPC-14 and the minimum was recorded at UTPC-9 during this survey.



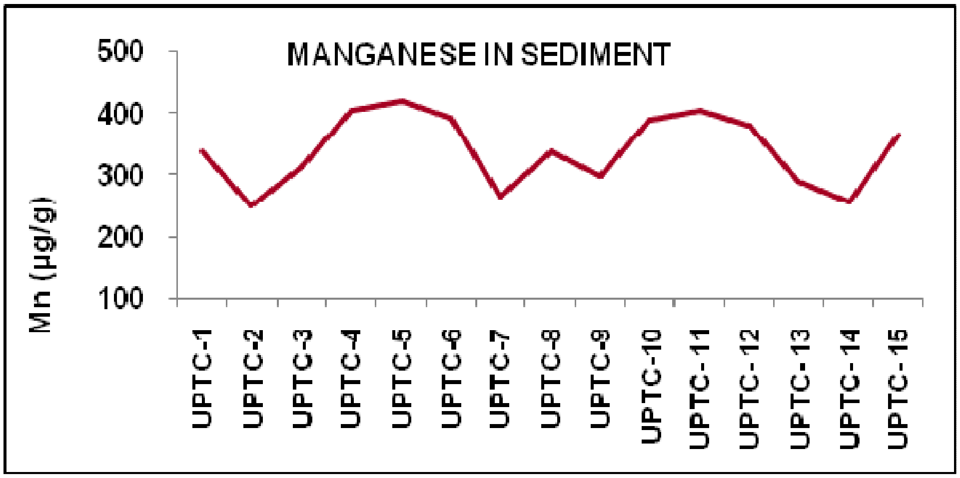
Zinc

The zinc in the sediments fluctuated from 19.28 to 65.0 µg/g with maximum of 65.0 µg/g at UTPC-2 and the minimum of 19.28 µg/g at UTPC-9 (Table 3.23).



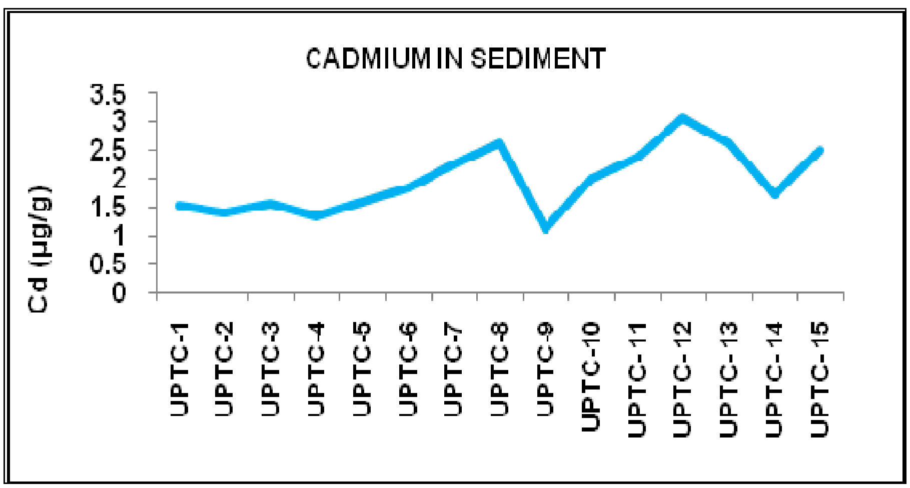
Manganese

The manganese concentration fluctuated between 249.7 and 418.7 µg/g. The maximum manganese concentration (418.7 µg/g) was recorded at UTPC-5 and the minimum (249.7 µg/g) was recorded at UTPC-2 (Table 3.23).



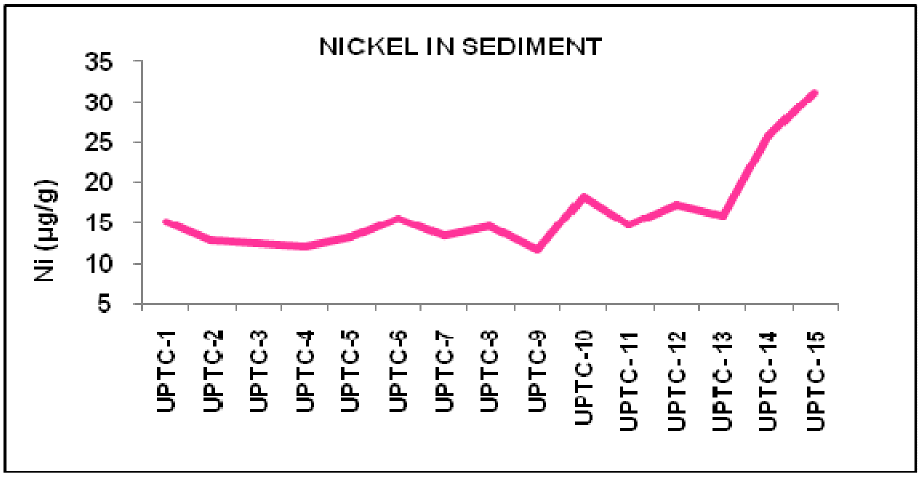
Cadmium

The cadmium level in the sediment ranged from 1.13 to 3.05 µg/g. The maximum cadmium concentration of 3.05 µg/g was recorded at UTPC-12 and minimum of 1.13 µg/g was recorded at UTPC-9 during this survey (Table 3.23).



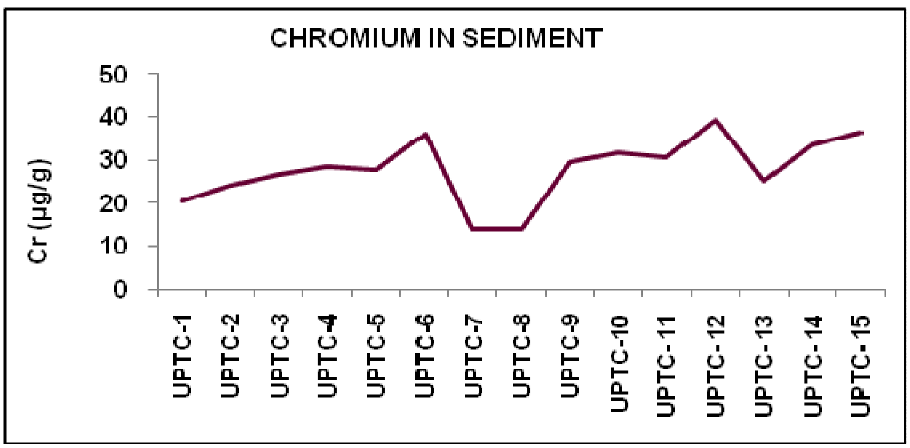
Nickel

The nickel fluctuated from 11.68 to 31.25 µg/g with a maximum of 31.25 µg/g at UTPC-15 and the minimum of 11.68 µg/g at UTPC-9 during this survey (Table 3.23).



Chormium

The chromium level in the sediment varied between 14.11 and 39.30 µg/g. The maximum value was recorded at UTPC-12 and the minimum was recorded at UTPC-8 (Table 3.23).



Lead

The lead level fluctuated from 15.15 to 26.69 µg/g with a maximum of 26.69 µg/g at UTPC-7 and the minimum of 15.15 µg/g at UTPC-10 during this survey (Table 3.23).

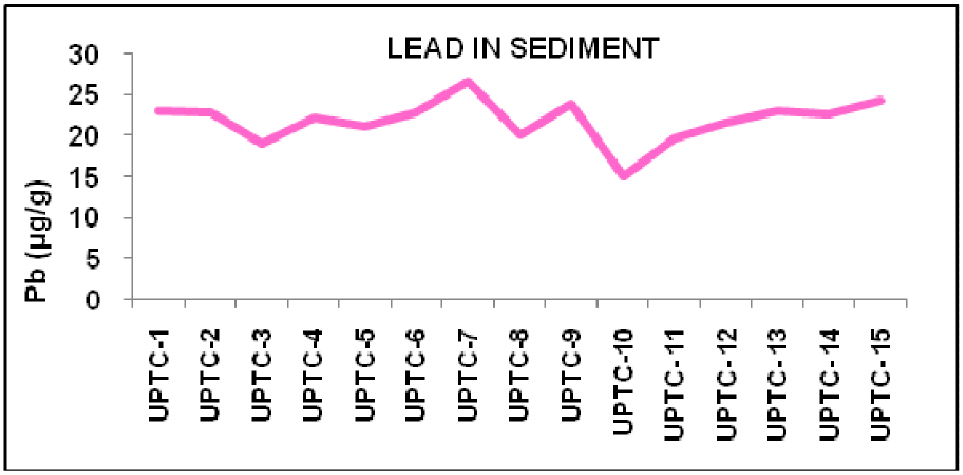


TABLE – 3.23.

HEAVY METALS IN SEDIMENT

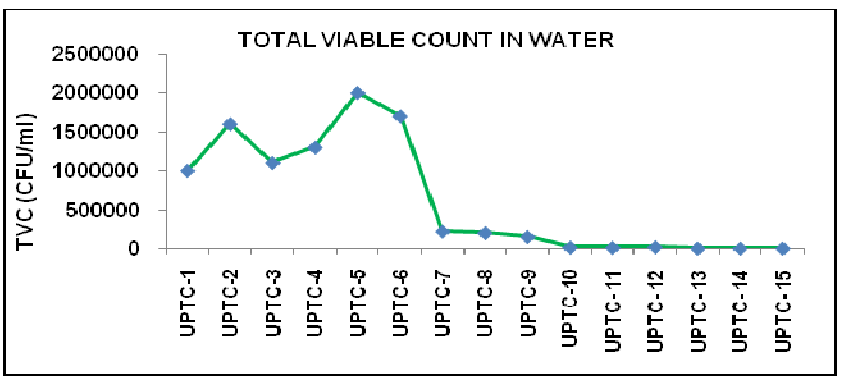
S. No.	Station Code	µg/g						
		Fe	Zn	Mn	Cd	Ni	Cr	Pb
1.	UTPC-1	5345	28.00	336.9	1.54	15.26	20.62	23.14
2.	UTPC-2	2839	65.00	249.7	1.41	12.86	24.20	22.87
3.	UTPC-3	3404	19.87	311.8	1.56	12.41	26.62	19.05
4.	UTPC-4	3148	22.96	403.2	1.35	12.02	28.57	22.20
5.	UTPC-5	2726	48.35	418.7	1.60	13.16	27.67	21.33
6.	UTPC-6	6971	32.44	392.7	1.85	15.56	36.19	22.84
7.	UTPC-7	3101	32.65	264.2	2.23	13.48	14.23	26.69
8.	UTPC-8	3208	31.25	338.3	2.61	14.51	14.11	20.15
9.	UTPC-9	3018	19.28	297.2	1.13	11.68	29.72	23.90
10.	UTPC-10	2761	22.37	388.6	1.99	18.26	31.68	15.15

11.	UTPC- 11	2965	34.10	404.1	2.38	14.81	30.78	19.84
12.	UTPC- 12	6585	31.85	378.1	3.05	17.21	39.30	21.56
13.	UTPC- 13	5738	36.35	290.3	2.61	15.88	25.39	23.14
14.	UTPC- 14	8181	42.06	254.2	1.73	25.85	33.49	22.73
15.	UTPC- 15	6615	40.85	365.2	2.49	31.25	36.31	24.31

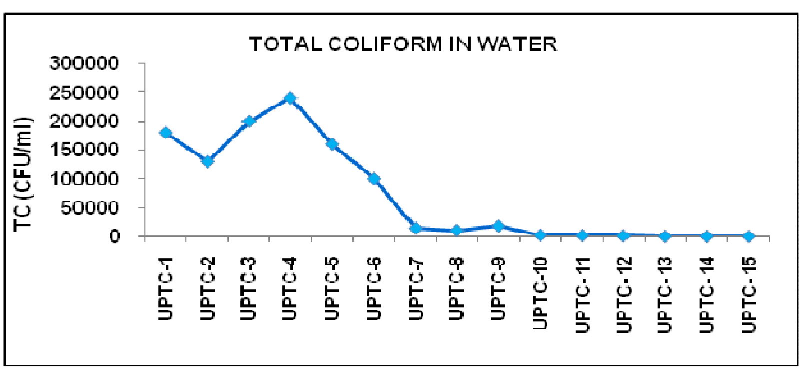
Microbiology

Water sample

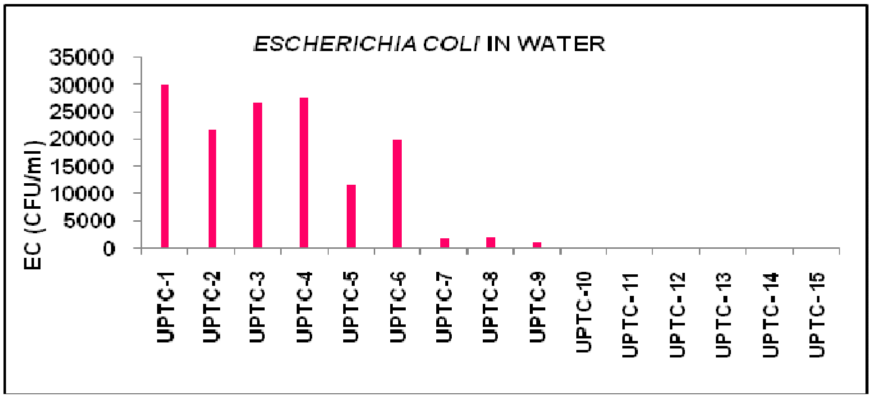
The Total Viable Count (TVC) varied from $10x10^2$ to $20x10^5$ with maximum at UTPC-5 and minimum at UTPC-13.



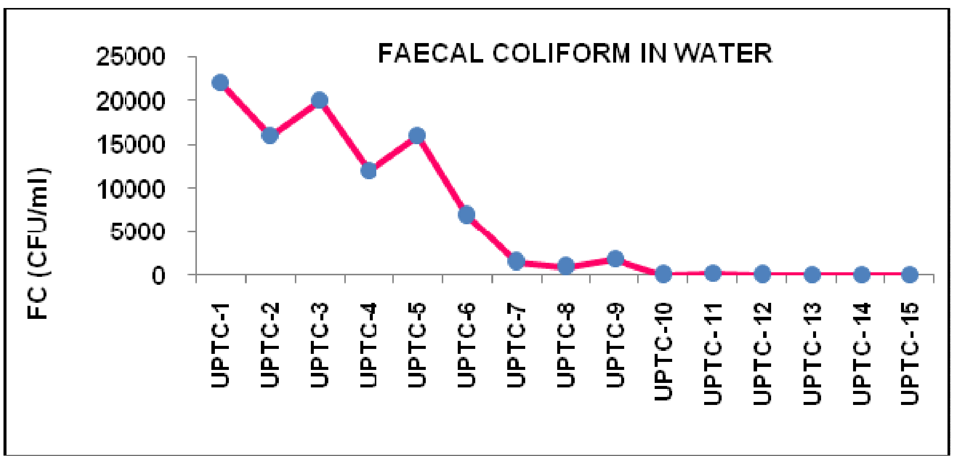
The Total Coliform varied between 90 and $24x10^4$ with maximum at UTPC-4 and minimum at UTPC-14.



The *Escherichia coli* Bacteria in water sample fluctuated from 15 to 30x10^3 CFU/ml with maximum at UTPC-1 and minimum at UTPC-13 during the sample collection.



Faecal coliform varied between 15 and 22x10^3 CFU/ml with maximum at UTPC-1 and the minimum was recorded at UTPC-14.



The *Streptococcus faecalis* varied from 10 to 20x10^2. The minimum and maximum values were observed at UTPC-11 and UTPC-4 respectively during this survey (Table 3.24).

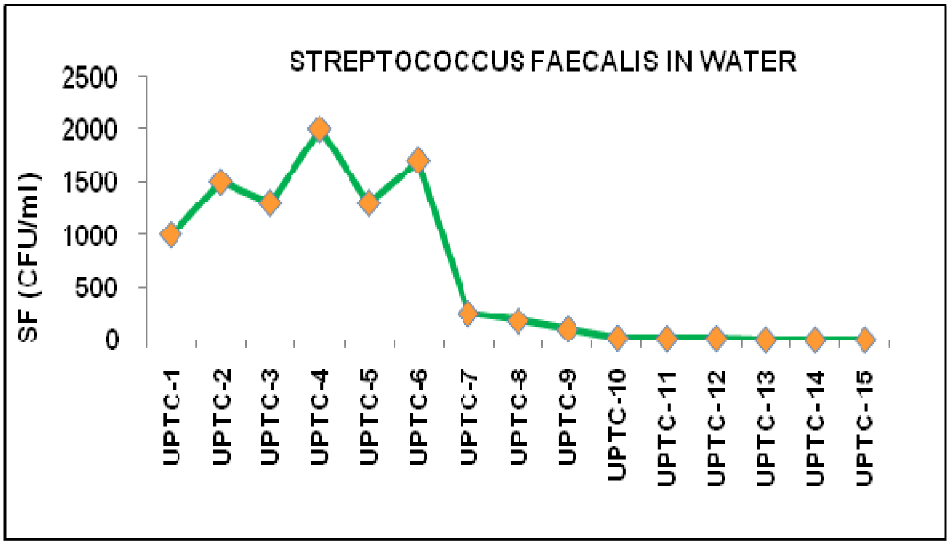


TABLE – 3.24.

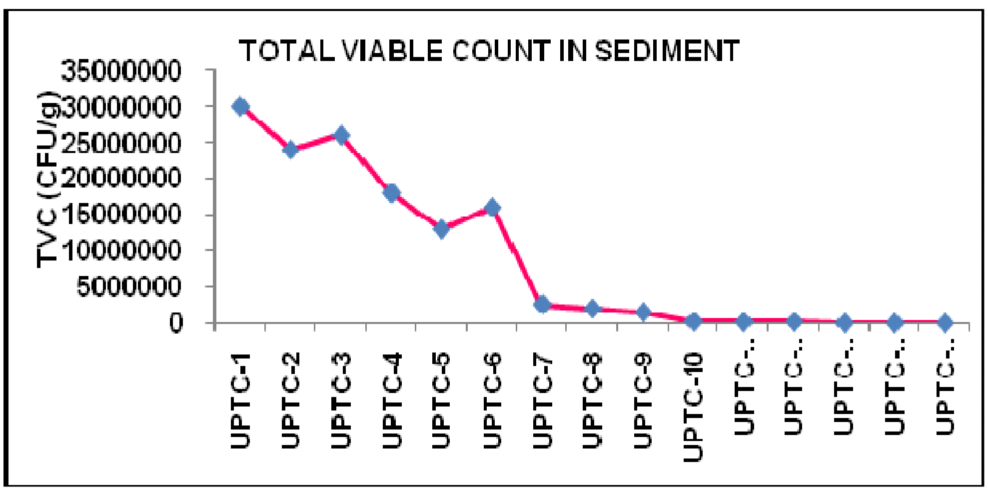
MICROBIAL POPULATIONS IN WATER

S. No.	Station Code	TVC	TC	EC	FC	SF
1.	UTPC-1	$10x10^5$	$18x10^4$	$30x10^3$	$22x10^3$	$10x10^2$
2.	UTPC-2	$16x10^5$	$13x10^4$	$22x10^3$	$16x10^3$	$15x10^2$
3.	UTPC-3	$11x10^5$	$20x10^4$	$27x10^3$	$20x10^3$	$13x10^2$
4.	UTPC-4	$13x10^5$	$24x10^4$	$28x10^3$	$12x10^3$	$20x10^2$
5.	UTPC-5	$20x10^5$	$16x10^4$	$12x10^3$	$16x10^3$	$13x10^2$
6.	UTPC-6	$17x10^5$	$10x10^4$	$20x10^3$	$07x10^3$	$17x10^2$
7.	UTPC-7	$22x10^4$	$14x10^3$	$19x10^2$	$15x10^2$	$25x10^1$
8.	UTPC-8	$20x10^4$	$10x10^3$	$21x10^2$	$10x10^2$	$18x10^1$
9.	UTPC-9	$15x10^4$	$18x10^3$	$16x10^2$	$18x10^2$	$10x10^1$
10.	UTPC-10	$13x10^3$	$23x10^2$	$13x10^1$	$08x10^1$	16

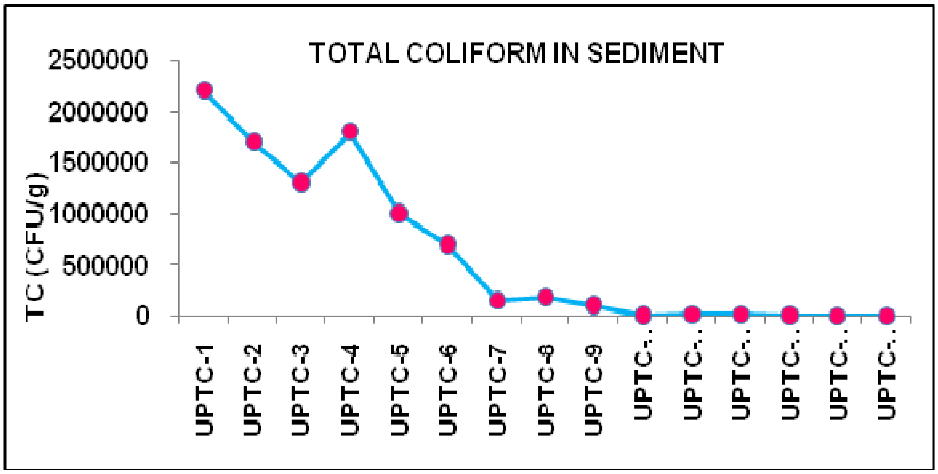
S. No.	Station Code	TVC	TC	EC	FC	SF
11.	UTPC- 11	$10x10^3$	$17x10^2$	$10x10^1$	$14x10^1$	10
12.	UTPC- 12	$19x10^3$	$12x10^2$	$18x10^1$	$06x10^1$	12
13.	UTPC- 13	$10x10^2$	$15x10^1$	15	21	-
14.	UTPC- 14	$16x10^2$	$09x10^1$	18	15	-
15.	UTPC- 15	$11x10^2$	$13x10^1$	23	18	-

Sediment sample

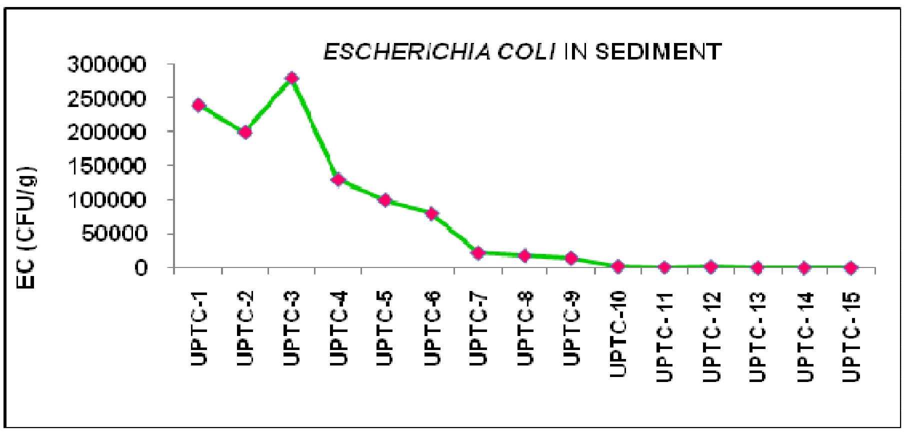
The Total Viable Count (TVC) varied from $80x10^2$ to $30x10^6$ CFU/g with maximum at UTPC-1 and minimum at UTPC-14 of sediment samples collected in Uppur Thermal Power Corporation areas.



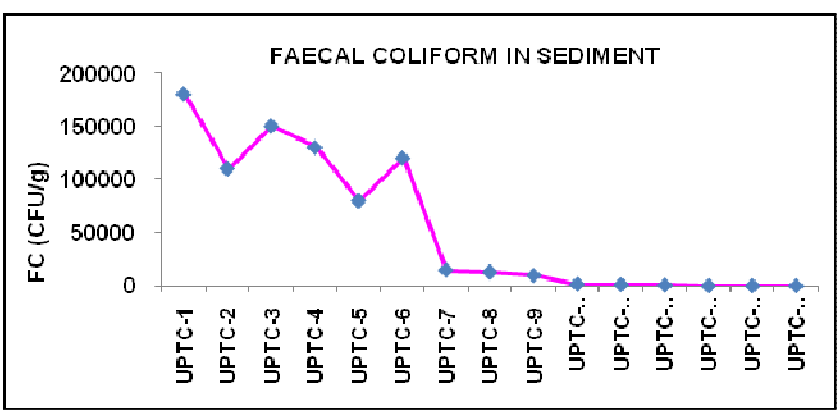
The Total Coliform varied between $13x10^2$ and $22x10^5$ CFU/g, the maximum recorded at UTPC-1 and the minimum was recorded at UTPC-15.



The *Escherichia coli* Bacteria in sediment sample varied between 11×10^1 and 28×10^4 CFU/g with maximum at TPC-3 and minimum at UTPC-15 during this survey.



Faecal coliform varied from 10×10^1 to 18×10^4 CFU/g with maximum at UTPC-1 and minimum at UTPC-14.



The *Streptococcus faecalis* varied between 80 and $14x10^3$ CFU/g. The minimum was recorded at UTPC-13 and the maximum value was recorded at UTPC-2 during this survey (Table 3.25).

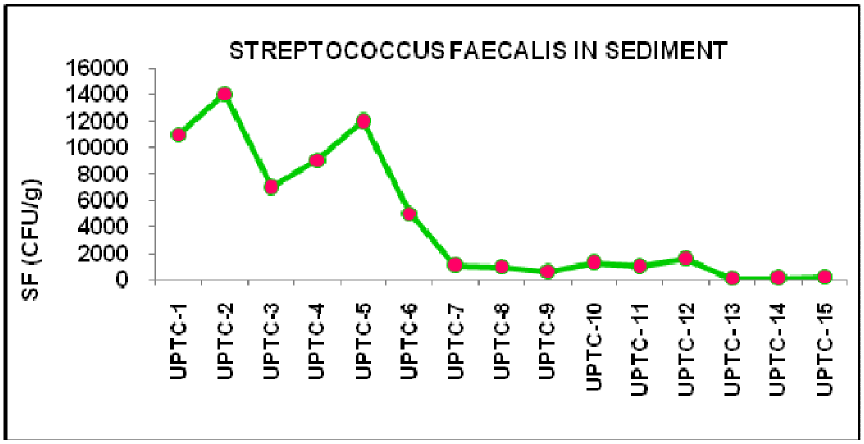


TABLE – 3.25.

MICROBIAL POPULATIONS IN SEDIMENT

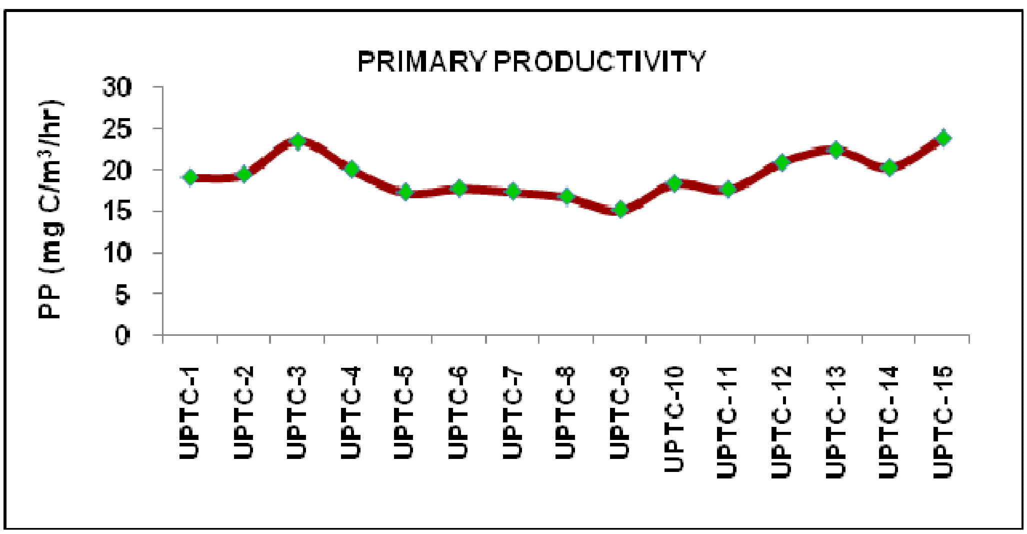
S. No.	Station Code	TVC	TC	EC	FC	SF
1.	UTPC-1	$30x10^6$	$22x10^5$	$24x10^4$	$18x10^4$	$11x10^3$
2.	UTPC-2	$24x10^6$	$17x10^5$	$20x10^4$	$11x10^4$	$14x10^3$
3.	UTPC-3	$26x10^6$	$13x10^5$	$28x10^4$	$15x10^4$	$07x10^3$
4.	UTPC-4	$18x10^6$	$18x10^5$	$13x10^4$	$13x10^4$	$09x10^3$
5.	UTPC-5	$13x10^6$	$10x10^5$	$10x10^4$	$08x10^4$	$12x10^3$
6.	UTPC-6	$16x10^6$	$07x10^5$	$08x10^4$	$12x10^4$	$05x10^3$
7.	UTPC-7	$26x10^5$	$15x10^4$	$22x10^3$	$15x10^3$	$11x10^2$
8.	UTPC-8	$20x10^5$	$18x10^4$	$18x10^3$	$13x10^3$	$09x10^2$
9.	UTPC-9	$15x10^5$	$11x10^4$	$14x10^3$	$10x10^3$	$06x10^2$

S. No.	Station Code	TVC	TC	EC	FC	SF
10.	UTPC-10	$22x10^4$	$08x10^3$	$22x10^2$	$18x10^2$	$13x10^2$
11.	UTPC- 11	$15x10^4$	$11x10^3$	$10x10^2$	$13x10^2$	$10x10^2$
12.	UTPC- 12	$18x10^4$	$16x10^3$	$16x10^2$	$08x10^2$	$16x10^2$
13.	UTPC- 13	$11x10^3$	$21x10^2$	$19x10^1$	$13x10^1$	$08x10^1$
14.	UTPC- 14	$08x10^3$	$18x10^2$	$15x10^1$	$10x10^1$	$12x10^1$
15.	UTPC- 15	$15x10^3$	$13x10^2$	$11x10^1$	$16x10^1$	$14x10^1$

Biological Characteristics

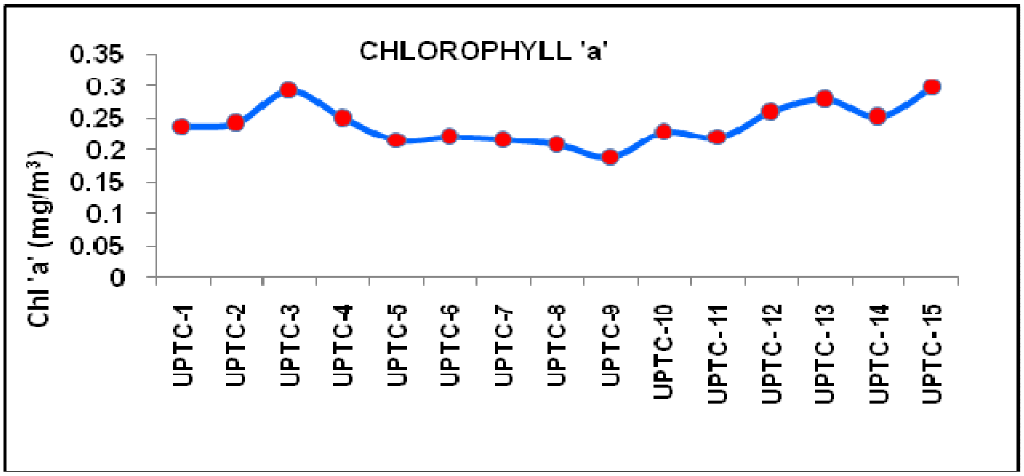
Primary Productivity (mg C/m^3/hr)

The primary productivity fluctuated from 15.13 to 23.811 mgC/m^3/hr. The maximum of primary productivity (23.811 mgC/m^3/hr) was recorded at UTPC-15 and the minimum (15.13 mgC/m^{3}hr) was recorded at UTPC-9 during this survey (Table-3.26).



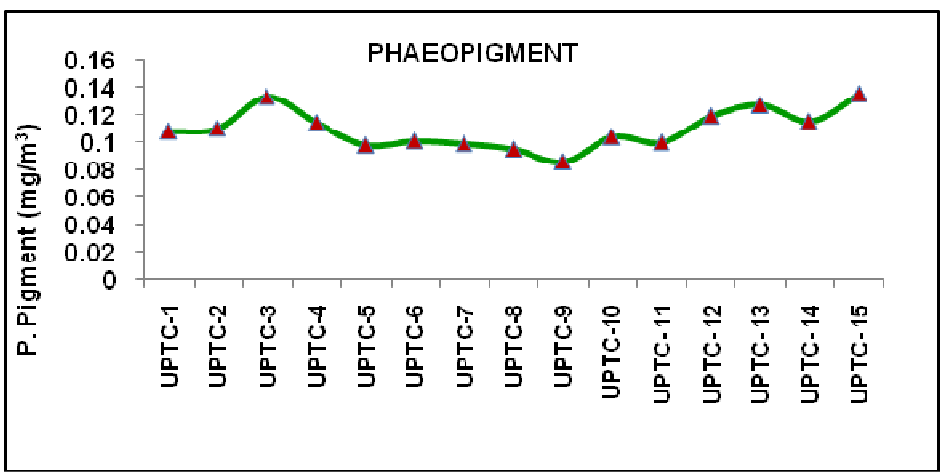
Chlorophyll 'a' (mg/m^3)

The chlorophyll '*a*' level fluctuated between 0.189 and 0.298 mg/m^3. The maximum chlorophyll 'a' (0.298 mg/m^3) was observed at UTPC-15 and the minimum (0.189 mg/m^3) was recorded at UTPC-9(Table-3.26).



Phaeopigment (mg/m^3)

In the present study, the phaeopigment in water sample varied from 0.086 to 0.135 mg/m^3 with maximum in UTPC-15 and minimum at UTPC-9 during this survey (Table 3.26).



Total Biomass (ml/100 m^3)

The total biomass in water sample varied between 20.692 and 28.181 ml/100 m^3. The minimum was recorded at UTPC-10 and the maximum was observed at UTPC-15 (Table 3.26).

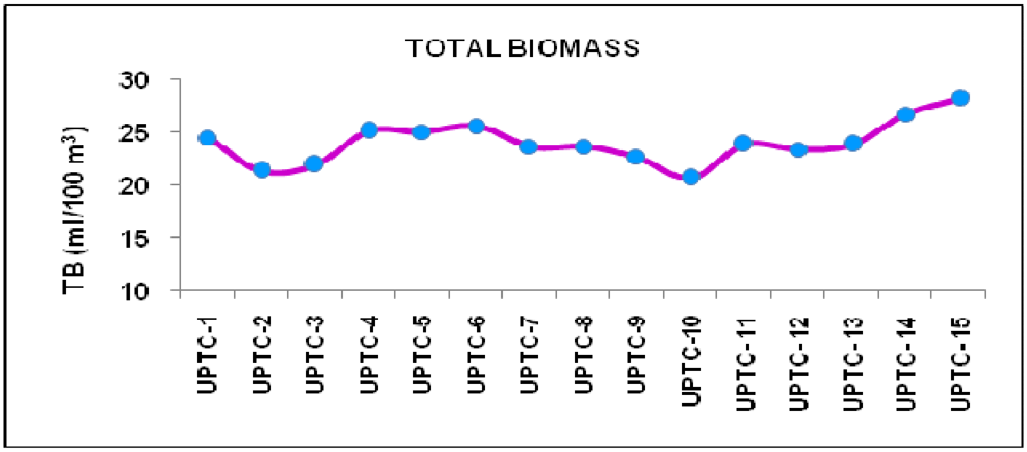


TABLE – 3.26.

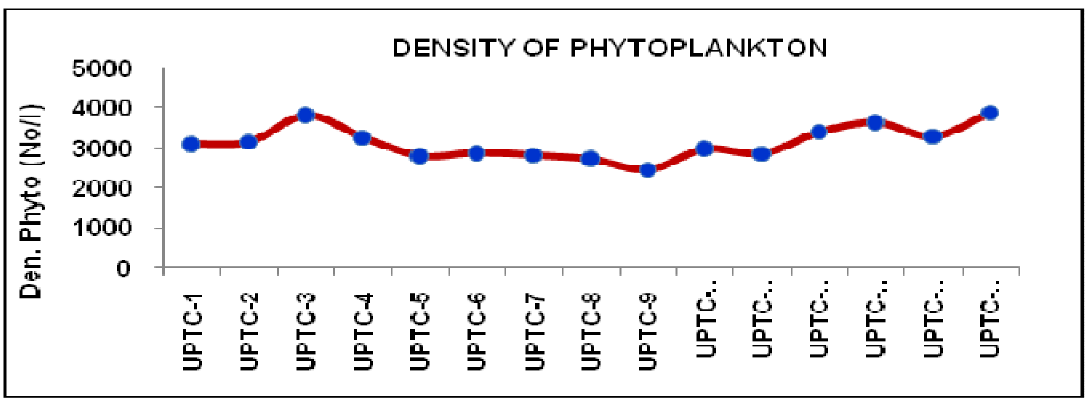
BIOLOGICAL CHARACTERISTICS

S. No.	Station Code	PP (mg C/m^3/hr)	Chl 'a' (mg/m^3)	Phaeopigment (mg/m^3)	TB (ml/100m^3)
1.	UTPC-1	19.059	0.238	0.108	24.537
2.	UTPC-2	19.409	0.243	0.110	21.374
3.	UTPC-3	23.471	0.293	0.133	21.915
4.	UTPC-4	20.057	0.251	0.114	25.155
5.	UTPC-5	17.252	0.216	0.098	25.031
6.	UTPC-6	17.702	0.221	0.101	25.618
7.	UTPC-7	17.343	0.217	0.099	23.648
8.	UTPC-8	16.717	0.209	0.095	23.648

S. No.	Station Code	PP (mg C/m^3/hr)	Chl 'a' (mg/m^3)	Phaeopigment (mg/m^3)	TB (ml/100m^3)
9.	UTPC-9	15.130	0.189	0.086	22.662
10.	UTPC-10	18.328	0.229	0.104	20.692
11.	UTPC- 11	17.591	0.220	0.100	23.882
12.	UTPC- 12	20.863	0.261	0.119	23.404
13.	UTPC- 13	22.380	0.280	0.127	23.882
14.	UTPC- 14	20.232	0.253	0.115	26.748
15.	UTPC- 15	23.811	0.298	0.135	28.181

Phytoplankton

The phytoplankton density ranged from 2,458 to 3,869 No/l. The maximum density was recorded at UTPC-15 and the minimum was recorded at UTPC-9 during this survey (Table 3.27).



A total of 16 species of phytoplankton were identified from the study area with *Climacosphenia* sp. dominating (2,714/3,869 No/l, UTPC-15) the populations. The diatom was the dominant group represented by species such as *Coscinodiscus* *centralis, Skeletonema costatum, Planktoniella sol, Ceratium furca, Ceratium macroceros* and *Pleurosigma normanii* were found in all stations.

TABLE-3.27.

PHYTOPLANKTON

S. No.	Name of the Species	No/l				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
1.	*Coscinodiscus centralis*	*	39	18	20	27
2.	*Skeletonema costatum*	*	194	280	218	199
3.	*Planktoniella sol*	56	38	22	38	30
4.	*Thalassiosira subtilis*	340	605	393	346	273
5.	*Triceratium favus*	*	*	*	14	*
6.	*Chaetoceros affinis*	*	*	157	*	*
7.	*Biddulphia pulchella*	37	43	28	19	42
8.	*Odontella mobiliensis*	28	30	*	29	*
9.	*Pleurosigma normanii*	64	76	55	50	27
10.	*Nitzschia seriata*	133	167	*	58	*
11.	*Navicula vanhoffeni*	*	*	136	155	105
12.	*Dinophysis caudata*	*	*	*	15	*
13.	*Ceratium macroceros*	38	28	37	*	28
14.	*Ceratium longipes*	*	39	33	39	*
15.	*Protoperidinium oceanicum*	*	*	*	*	19
16.	*Climacosphenia* sp.	2401	1896	2656	2259	2055
	Total	**3097**	**3155**	**3815**	**3260**	**2805**

*** - Organisms not present**

Sl. No.	Name of the Species	No/l				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
1.	*Coscinodiscus centralis*	28	20	27	20	*
2.	*Skeletonema costatum*	225	180	154	111	286
3.	*Planktoniella sol*	20	28	36	*	38
4.	*Thalassiosira subtilis*	319	322	247	184	401
5.	*Chaetoceros affinis*	*	140	129	137	167
6.	*Biddulphia pulchella*	50	26	18	*	21
7.	*Odontella mobiliensis*	*	*	37	45	16
8.	*Pleurosigma normanii*	49	65	*	39	59
9.	*Nitzschia seriata*	*	35	136	*	*
10.	*Navicula vanhoffeni*	167	*	*	*	*
11.	*Dinophysis caudata*	20	*	*	*	*
12.	*Ceratium macroceros*	39	*	*	30	*
13.	*Ceratium longipes*	*	28	17	18	28
14.	*Protoperidinium oceanicum*	30	*	*	*	*
15.	*Climacosphenia* sp.	1931	1976	1917	1874	1961
	Total	**2878**	**2820**	**2718**	**2458**	**2977**

*** - Organisms not present**

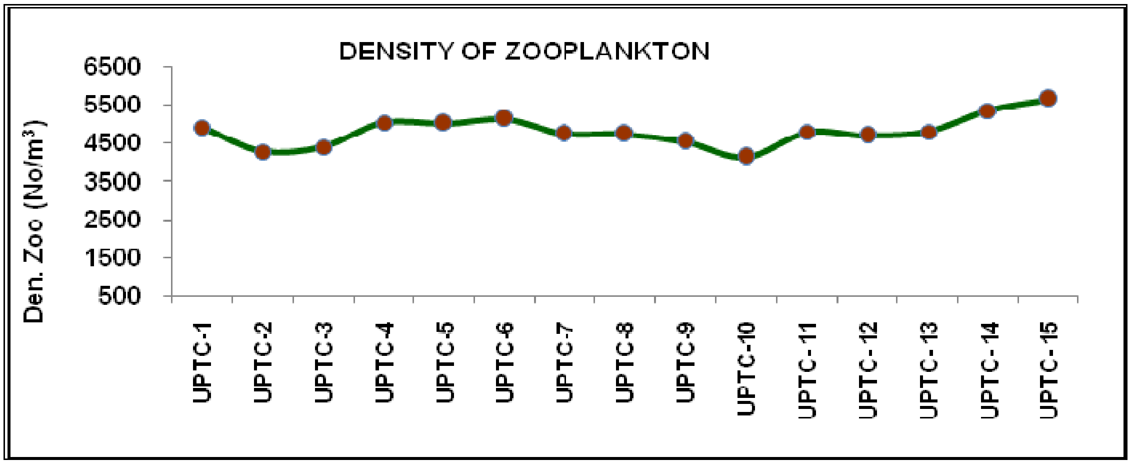
Sl. No.	Name of the Species	No/l				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
1.	*Coscinodiscus centralis*	26	*	18	29	29
2.	*Skeletonema costatum*	285	337	181	288	343
3.	*Planktoniella sol*	20	18	37	18	37
4.	*Thalassiosira subtilis*	337	369	458	391	448
5.	*Triceratium favus*	*	*	*	*	*
6.	*Chaetoceros affinis*	139	119	198	123	166
7.	*Biddulphia pulchella*	19	29	36	29	47
8.	*Odontella mobiliensis*	28	*	18	21	18
9.	*Pleurosigma normanii*	69	29	55	39	46
10.	*Nitzschia seriata*	*	*	*	*	*
11.	*Navicula vanhoffeni*	*	*	*	*	*
12.	*Dinophysis caudata*	*	*	*	*	*
13.	*Ceratium macroceros*	*	*	28	28	*
14.	*Ceratium longipes*	27	15	*	20	21
15.	*Protoperidinium oceanicum*	*	*	*	*	*
16.	*Climacosphenia* sp.	1908	2475	2607	2301	2714
Total		**2858**	**3391**	**3636**	**3287**	**3869**

*** - Organisms not present**

Zooplankton

Zooplankton includes arrays of organisms, varying in size from microscopic protozoans of a few microns to some jelly organisms with tentacles of several metres long. They play an intermediate role between phytoplankton and fish and are considered as the chief index of utilization of aquatic biotope at the secondary trophic level.

The zooplankton density ranged from 4,138 to 5,638 No/m^3 (Table 3.28). The minimum density was recorded at UTPC-10 and the maximum density was observed at UTPC-15.



In the present investigation, 26 species of zooplankton were recorded from all the stations monitored. The Bivalve veliger was found to be the dominant forms. The species such as *Acartia spinicauda, Paracalanus parvus*, *Oithona similis, Euterpina acutifrons, Globigerina bulloides,* Copepod nauplii, and Bivalve veliger were found to be common in all stations monitored during this survey.

TABLE-3.28

ZOOPLANKTON

S. No.	Name of the Species	No/m^3				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
1.	*Paracalanus parvus*	370	*	466	559	687
2.	*Paracalanus* sp.	*	*	*	*	98
3.	*Acrocalanus* sp.	*	186	*	*	*
4.	*Acartia spinicauda*	556	372	93	186	294
5.	*Oithona similis*	463	186	373	466	491
6.	*Corycaeus danae*	185	*	*	93	*
7.	*Longipedia weberi*	185	*	280	373	196
8.	*Microsetella rosea*	463	372	*	93	*
9.	*Microsetella norvegica*	*	*	*	186	294
10.	*Macrosetella oculata*	93	*	*	*	*
11.	*Macrostella gracilis*	*	186	93	280	*
12.	*Euterpina acutifrons*	556	558	653	466	393
13.	*Metis jousseaumei*	370	743	839	839	687
14.	*Sagitta enflata*	93	*	*	93	*
15.	*Oikopleura parva*	*	93	93	186	98
16.	*Globigerina bulloides*	185	279	187	*	294
17.	*Tintinnopsis tubulosa*	*	93	*	*	98
18.	*Favella philipiensis*	93	*	*	*	*
19.	Bivalve veliger	278	279	280	280	196
20.	Gastropod veliger	*	93	93	186	393
21.	Crustacean nauplii	*	*	187	745	*
22.	Copepod nauplii	1019	836	746	*	785
	Total	**4909**	**4276**	**4383**	**5031**	**5004**

*** - Organisms not present**

S. No.	Name of the Species	No/m^3				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
1.	*Paracalanus parvus*	296	296	690	690	591
2.	*Acartia spinicauda*	394	394	99	591	296
3.	*Oithona similis*	394	591	296	296	394
4.	*Corycaeus danae*	*	*	*	*	*
5.	*Longipedia weberi*	394	394	296	197	296
6.	*Microsetella norvegica*	591	*	*	*	*
7.	*Macrostella gracilis*	*	*	*	197	*
8.	*Euterpina acutifrons*	493	493	493	394	493
9.	*Metis jousseaumei*	887	690	985	887	788
10.	*Sagitta enflata*	*	99	*	99	197
11.	*Oikopleura parva*	99	*	99	*	*
12.	Megalopa larvae	*	99	*	*	99
13.	*Globigerina bulloides*	296	296	197	*	*
14.	*Tintinnopsis tubulosa*	*	*	296	99	*
15.	*Tintinnopsis butzschi*	*	99	*	*	99
16.	*Favella philipiensis*	*	*	197	99	*
17.	Bivalve veliger	197	197	296	296	*
18.	Gastropod veliger	296	296	*	*	*
19.	Copepod nauplii	788	788	788	690	887
Total		**5124**	**4730**	**4730**	**4532**	**4138**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^3				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
1.	*Aurelia aurita*	*	*	*	191	382
2.	*Paracalanus parvus*	287	382	382	478	573
3.	*Acrocalanus* sp.	*	*	96	*	96
4.	*Acartia spinicauda*	96	191	96	382	478
5.	*Oithona similis*	191	382	287	287	382
6.	*Corycaeus danae*	*	*	*	96	*
7.	*Corycaeus catus*	*	*	*	191	191
8.	*Longipedia weberi*	382	191	287	382	287
9.	*Microsetella rosea*	*	*	96	96	191
10.	*Macrostella gracilis*	287	*	*	*	*
11.	*Euterpina acutifrons*	573	287	478	573	669
12.	*Metis jousseaumei*	764	669	669	860	669
13.	*Sagitta enflata*	*	*	96	*	96
14.	*Oikopleura parva*	*	*	191	96	*
15.	*Globigerina bulloides*	96	191	*	191	191
16.	*Tintinnopsis tubulosa*	*	96	96	*	*
17.	*Favella philipiensis*	*	96	*	*	*
18.	Bivalve veliger	1051	860	573	382	382
19.	Gastropod veliger	382	669	573	287	287
20.	Copepod nauplii	669	669	860	860	764
	Total	**4778**	**4683**	**4780**	**5352**	**5638**

*** - Organisms not present**

Finfish Eggs

The finfish eggs density ranged from 5 to 18 No/m^3 (Table 3.29). The minimum density was recorded at UTPC-1 and UTPC-2 and the maximum density was observed at UTPC-15. A total of 17 species of finfish eggs were recorded from all the stations monitored. The *Mugil cephalus* was found to be the dominant species.

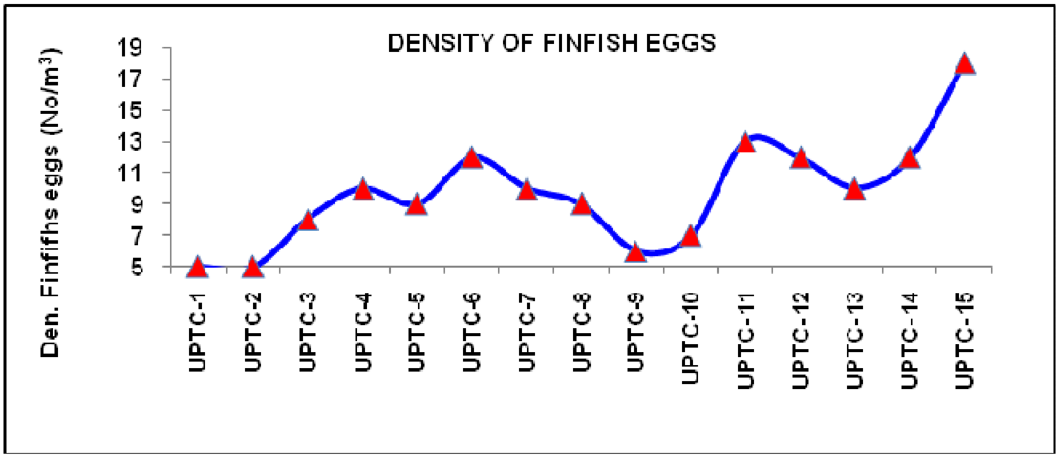


TABLE-3.29.

FINFISH EGGS

Sl. No.	Name of the species	No/m^3			
		UTPC-1	UTPC-2	UTPC-3	UTPC-4
	Enraulidae				
1	*Stolephorus indicus*	2	1	2	2
2	*Thryssa mystax*	1	1	1	2
	Clupeidae				
1	*Sardinella gibbosa*	*	1	1	2
	Synodontidae				
1	*Saurida gracilis*	*	*	1	1
	Mugilidae				
1	*Mugil cephalus*	2	1	*	1
	Teraponidae				
1	*Terapon jarbua*	*	1	2	1
	Cynoglossidae				
1	*Cynoglossus punticeps*	*	*	1	1
	Total	**5**	**5**	**8**	**10**

Sl. No.	Name of the species	No/m^3			
		UTPC-5	UTPC-6	UTPC-7	UTPC-8
	Enraulidae				
1	*Stolephorus tri*	1	2	1	1
2	*Stolephorus indicus*	2	*	1	2
3	*Thryssa mystax*	*	1	*	1
	Clupeidae				
1	*Sardinella gibbosa*	1	*	2	*
2	*Sardinella longiceps*	1	2	*	*
	Mugilidae				
1	*Mugil cephalus*	2	2	1	1
2	*Liza dussumieri*	*	*	1	1
	Carangidae				
1	*Carangoides malabaricus*	1	1	2	1
	Teraponidae				
1	*Terapon jarbua*	1	2	2	1
	Siganidae				
1	*Siganus javus*	*	1	*	1
	Cynoglossidae				
1	*Cynoglossus punticeps*	*	1	*	*
	Total	**9**	**12**	**10**	**9**

*** - Organisms not present**

Sl. No.	Name of the species	No/m^3			
		UTPC-9	UTPC-10	UTPC-11	UTPC-12
	Enraulidae				
1	*Setipinna taty*	1	1	2	1
2	*Stolephorus heterolobus*	1	*	2	1
3	*Thryssa mystax*	*	1	1	2
	Clupeidae				
1	*Sardinella gibbosa*	1	*	1	*
	Mugilidae				
1	*Mugil cephalus*	2	3	2	3
	Carangidae				
1	*Carangoides malabaricus*	*	1	1	2
2	*Carangoides* sp.	*	*	1	*
	Teraponidae				
1	*Terapon jarbua*	1	1	2	1
	Scombridae				
1	*Scomberomorus* sp.	*	*	1	2
	Total	**6**	**7**	**13**	**12**

Sl. No.	Name of the species	No/m^3		
		UTPC-13	UTPC-14	UTPC-15
	Enraulidae			
1	*Setipinna taty*	1	2	1
2	*Stolephorus tri*	1	*	1
3	*Thryssa mystax*	2	2	1
	Chirocentridae			
1	*Chirocentrus dorab*	*	*	2
	Clupeidae			
1	*Sardinella gibbosa*	1	2	2
	Synodontidae			
1	*Saurida gracilis*	*	*	1
	Mugilidae			
1	*Mugil cephalus*	3	3	2
	Carangidae			
1	*Carangoides malabaricus*	*	1	2
	Teraponidae			
1	*Terapon jarbua*	*	2	3
	Scombridae			
1	*Scomberomorus* sp.	2	*	3
	Total	**10**	**12**	**18**

*** - Organisms not present**

Finfish Larvae

The finfish larvae ranged between 1 and 6 No/m^3 (Table 3.30). The maximum number of finfish larvae observed at UTPC-12 and the minimum larvae recorded at UTPC-13. A total of 12 species of finfish larvae were identified from all the stations monitored. The *Mugil cephalus* and *Carangoides malabaricus* were found to be the dominant species.

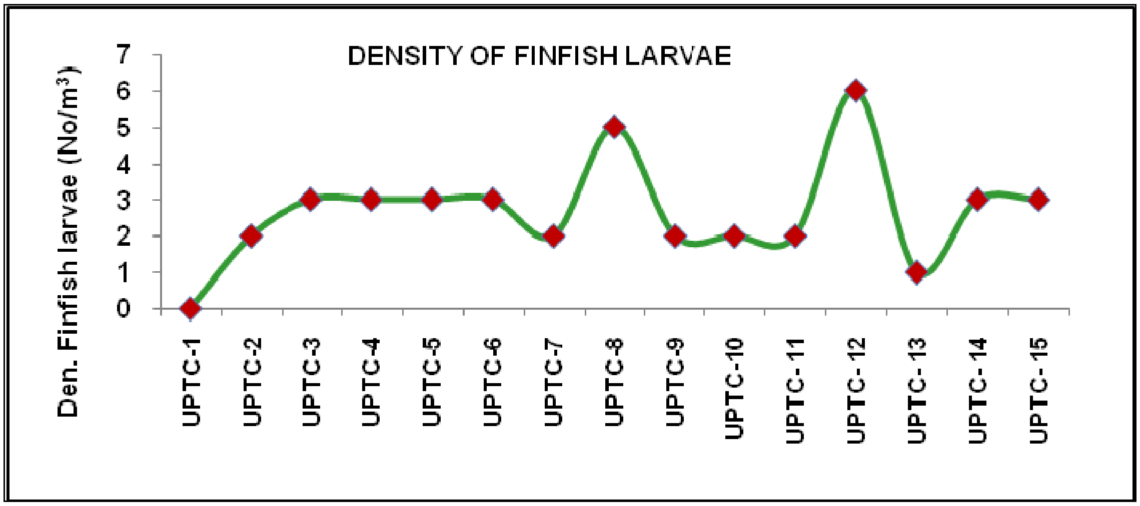


TABLE-3.30.

FINFISH LARVAE

Sl. No.	Name of the species	No/m^3			
		UTPC-1	UTPC-2	UTPC-3	UTPC-4
	Enraulidae				
1	*Stolephorus indicus*	*	1	1	*
2	*Thryssa mystax*	*	1	1	1
	Clupeidae				
1	*Sardinella gibbosa*	*	*	1	1
	Teraponidae				
1	*Terapon jarbua*	*	*	*	1
	Total	*	**2**	**3**	**3**

*** - Organisms not present**

Sl. No.	Name of the species	No/m^3			
		UTPC-5	UTPC-6	UTPC-7	UTPC-8
	Enraulidae				
1	*Stolephorus tri*	*	*	*	1
2	*Thryssa mystax*	*	*	*	1
	Mugilidae				
1	*Mugil cephalus*	*	2	*	1
2	*Liza dussumieri*	*	*	1	*
	Carangidae				
1	*Carangoides malabaricus*	2	*	1	1
	Teraponidae				
1	*Terapon jarbua*	1	1	*	1
	Total	**3**	**3**	**2**	**5**

*** - Organisms not present**

Sl. No.	Name of the species	No/m^3			
		UTPC-9	UTPC-10	UTPC-11	UTPC-12
	Enraulidae				
1	*Setipinna taty*	*	*	*	1
2	*Stolephorus heterolobus*	*	*	1	*
3	*Thryssa mystax*	*	1	*	1
	Clupeidae				
1	*Sardinella gibbosa*	*	*	1	*
	Mugilidae				
1	*Mugil cephalus*	1	1	*	2

	Teraponidae				
1	*Terapon jarbua*	1	*	*	1
	Scombridae				
1	*Scomberomorus* sp.	*	*	*	1
	Total	**2**	**2**	**2**	**6**

*** - Organisms not present**

Sl. No.	**Name of the species**	**No/m^3**		
		UTPC-13	**UTPC-14**	**UTPC-15**
	Enraulidae			
1	*Stolephorus tri*	*	*	1
3	*Thryssa mystax*	1	*	*
	Clupeidae			
1	*Sardinella gibbosa*	*	1	*
	Synodontidae			
1	*Saurida gracilis*	*	*	1
	Mugilidae			
1	*Mugil cephalus*	*	2	1
	Total	**1**	**3**	**3**

*** - Organisms not present**

Benthic Organisms

Benthic animals are divided into three categories, microfauna, meiofauna and macrofauna depending on their size. Macrobenthic organisms are animal species with body size larger than 0.5 mm. Benthic community responses to environmental perturbations are useful in assessing the impact of anthropogenic perturbations on environmental quality.

Macrobenthos:

The macrobenthos density varied from 525 to 1,300 No/m^2. The minimum was recorded at UTPC-1 and the maximum was observed at UTPC-3. In the present investigation, 57 species of macrobenthos were recorded from the study area and most of the species were found in all the stations. The *Cerithedia cingulata* (250/1,050 No/m^2, UTPC-2) was found to be the dominant forms during this survey (Table 3.31).

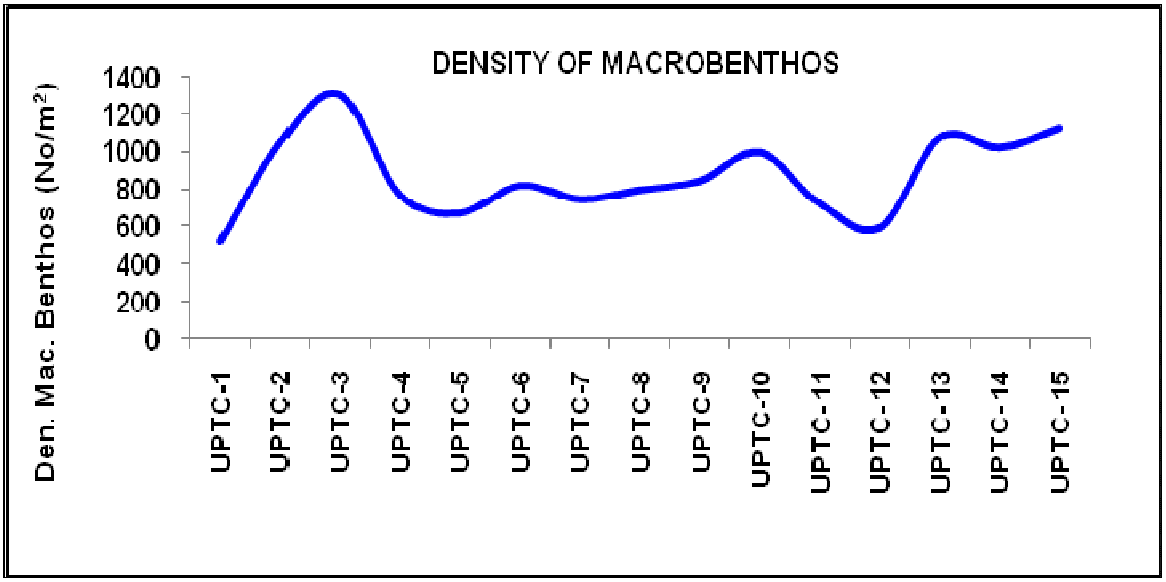


TABLE-3.31.

MACROBENTHOS

Sl. No.	Name of the Species	No/m^2				
		UTPC-1	**UTPC-2**	**UTPC-3**	**UTPC-4**	**UTPC-5**
	Polychaetes					
1.	*Autolytus* sp.	*	*	75	*	*
2.	*Ampharete acutifrons*	*	50	*	*	25
3.	*Armandia intermedia*	*	*	*	125	*
4.	*Capitella capitata*	*	*	100	*	*
5.	*Chone* sp.	*	*	*	*	50
6.	*Cirriformia* sp.	*	*	50	*	*

7.	*Cossura coasta*	*	75	*	*	100
8.	*Euchone* sp.	*	*	*	75	*
9.	*Exogone clavator*	75	*	*	*	50
10.	*Goniada emerita*	*	*	125	*	*
11.	*Lumbrineris* sp.	50	*	*	150	*
12.	*Maldane* sp.	*	75	50	*	*
13.	*Nephtys dibranchis*	*	50	100	*	*
14.	*Nereis* sp.	*	75	*	*	*
15.	*Notomastus aberans*	*	*	100	*	*
16.	*Pygospio elegans*	*	*	*	*	100
17.	*Tharyx* sp.	*	*	*	50	*
18.	*Pettiariid tube*	*	150	100	*	*
19.	*Notomastus* sp.	*	*	*	50	*
20.	*Platynereis* sp.	*	*	*	*	75
21.	*Prionospio pinnata*	*	*	*	125	50
22.	*Prionospio cirrifera*	75	*	150	*	*
23.	*Sabellides* sp.	*	50	*	*	100
24.	*Spionidae* sp.	*	*	*	25	*
25.	*Syllis gracilis*	*	*	125	*	*
	Bivalves					
1.	*Anadara granosa*	75	*	*	50	*
2.	*Meretrix meretrix*	*	*	75	*	50
3.	*Meretrix* veligers	*	50	*	*	*
4.	*Placenta placenta*	*	*	*	50	*
	Gastropods					
1.	*Nassarius stolatus*	*	25	*	*	*
2.	*Bullia tranquebaria*	75	50	125	*	*

Sl. No.	Name of the Species	No/m^2				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
3.	*Cerithedia cingulata*	125	250	75	*	*
4.	*Natica* sp.	*	*	*	25	*
	Crustaceans					
1.	Penaeid shrimp larvae	*	*	*	*	50
	Amphipods					
1.	*Grandidierella* sp.	*	75	*	*	*
2.	*Ampithoe rubricata*	*	*	50	*	*
3.	*Harnella incerta*	50	*	*	*	25
	Isopods					
1.	*Angeliera phreaticola*	*	*	*	50	*
2.	*Jaeropsis beuroisi*	*	75	*	*	*
	Total	**525**	**1050**	**1300**	**775**	**675**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^2				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
	Polychaetes					
1.	*Autolytus* sp.	*	50	100	*	*
2.	*Ampharete acutifrons*	*	*	25	*	75
3.	*Armandia intermedia*	*	*	*	125	*
4.	*Capitella capitata*	75	25	50	*	*
5.	*Chone* sp.	*	*	*	*	125
6.	*Cirratulus africanus*	25	*	*	*	*
7.	*Cirriformia* sp.	*	75	*	100	*
8.	*Cossura coasta*	50	*	125	*	25
9.	*Euchone* sp.	*	25	*	*	*
10.	*Eunice* sp.	*	*	*	50	*

11.	*Exogone clavator*	*	25	*	*	*
12.	*Goniada emerita*	75	75	*	*	100
13.	*Lumbrineris* sp.	*	*	*	75	*
14.	*Maldane* sp.	100	*	75	*	*
15.	*Nephtys dibranchis*	*	75	*	75	*
16.	*Nereis* sp.	50	*	*	*	*
17.	*Notomastus aberans*	*	25	*	*	50
18.	*Pygospio elegans*	*	*	75	*	*
19.	*Tharyx* sp.	*	*	*	*	50
20.	*Owenia futiformis*	*	*	*	25	*
21.	*Nereidae* sp.	*	25	*	*	*
22.	*Platynereis* sp.	*	*	50	*	*
23.	*Prionospio pinnata*	*	*	*	*	150
24.	*Prionospio cirrifera*	*	50	*	125	*
25.	*Prionospio malmgreni*	*	*	100	125	*
26.	*Sabellides* sp.	25	*	*	*	*
27.	*Spionidae* sp.	*	*	25	*	*
28.	*Scololepis* sp.	*	*	*	*	50
29.	*Syllis gracilis*	50	75	75	*	*
	Bivalves					
1.	*Anadara granosa*	*	*	*	100	*
2.	*Meretrix meretrix*	25	*	*	*	*
3.	*Meretrix* veligers	*	25	*	*	50
4.	*Placenta placenta*	*	*	50	*	*

Sl. No.	Name of the Species	No/m²				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
5.	*Paphia textile*	*	*	*	*	25
6.	*Circe scripta*	*	*	*	*	100
	Gastropods					
1.	*Bullia tranquebaria*	75	*	*	*	*
2.	*Cerithedia cingulata*	*	25	*	*	50
3.	*Natica* sp.	50	*	*	*	*
	Amphipods					
1.	*Gammarus* sp.	50	*	*	*	50
2.	*Grandidierella* sp.	*	50	*	*	*
3.	*Atylus minikoi*	25	25	*	*	*
4.	*Ampithoe rubricata*	*	75	*	*	75
5.	*Harnella incerta*	75	*	*	50	*
6.	*Photia digitata*	25	*	*	*	*
	Isopods					
1.	*Angeliera phreaticola*	*	*	*	*	*
2.	*Jaeropsis beuroisi*	*	25	50	*	*
3.	*Mirocerberus* sp.	50	*	*	*	25
	Total	**825**	**750**	**800**	**850**	**1000**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m²				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
	Polychaetes					
1.	*Autolytus* sp.	25	25	*	50	*
2.	*Ampharete acutifrons*	*	*	50	*	*
3.	*Armandia intermedia*	*	100	*	150	75
4.	*Capitella capitata*	225	*	100	75	50
5.	*Chone* sp.	*	*	*	50	*

6.	*Cirriformia* sp.	*	25	*	*	*
7.	*Cossura coasta*	*	*	75	*	100
8.	*Eunice* sp.	*	25	*	50	50
9.	*Exogone clavator*	75	*	25	125	*
10.	*Goniada emerita*	*	50	25	*	*
11.	*Lumbrineris* sp.	*	*	100	25	125
12.	*Maldane* sp.	*	*	100	*	*
13.	*Nephtys dibranchis*	*	100	50	*	25
14.	*Nereis* sp.	*	*	*	*	75
15.	*Notomastus aberans*	*	*	*	25	*
16.	*Pygospio elegans*	*	50	*	*	*
17.	*Tharyx* sp.	*	*	25	*	100
18.	*Owenia futiformis*	50	*	*	*	*
19.	*Notomastus* sp.	75	*	*	*	*
20.	*Pista* sp.	*	*	*	*	50
21.	*Platynereis* sp.	*	25	*	*	*
22.	*Prionospio pinnata*	*	*	100	225	75
23.	*Prionospio cirrifera*	*	50	25	*	*
24.	*Prionospio malmgreni*	*	*	25	*	*
25.	*Sabellides* sp.	75	*	*	*	*
26.	*Spionidae* sp.	*	*	50	50	*
27.	*Scololepis* sp.	*	*	*	*	*
28.	*Syllis gracilis*	*	*	150	100	25
	Bivalves					
1.	*Anadara granosa*	*	50	*	*	75
2.	*Anadara rhombea*	*	*	*	*	50
3.	*Meretrix meretrix*	25	*	*	50	*
4.	*Placenta placenta*	*	*	25	*	*

Sl. No.	Name of the Species	No/m^2				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
	Gastropods					
1.	*Nerita polita*	*	*	*	*	25
2.	*Bullia tranquebaria*	*	*	*	*	75
3.	*Cymatium cingulatum*	*	*	*	*	25
4.	*Natica* sp.	*	50	25	*	25
5.	*Littorina* sp.	*	*	*	*	25
	Crustaceans					
1.	Penaeid shrimp larvae	50	*	*	*	*
	Amphipods					
1.	*Gammarus* sp.	*	*	*	25	*
2.	*Ampithoe rubricata*	*	50	25	*	75
3.	*Harnella incerta*	*	*	*	*	*
4.	*Photia digitata*	*	*	50	25	*
5.	*Harpinia laevis*	50	*	*	*	*
	Isopods					
1.	*Angeliera phreaticola*	75	*	50	*	*
	Total	**725**	**600**	**1075**	**1025**	**1125**

*** - Organisms not present**

Meiobenthos:

The meiobenthos in the bottom sediment ranged between 13 and 60 No/10 cm^2 (Table -3.32). The minimum density of meiobenthos was recorded at UTPC-7 and the maximum was recorded at UTPC-4. Most of the species were found in all the stations. Totally 30 species of meiobenthos were recorded in the present study period. The *Ammonia beccarii* (8/60 No/10 cm^2, UTPC-4) and *Rotalia translucens* (8/41 No/10 cm^2, UTPC-3) were found to be the dominant forms during this survey.

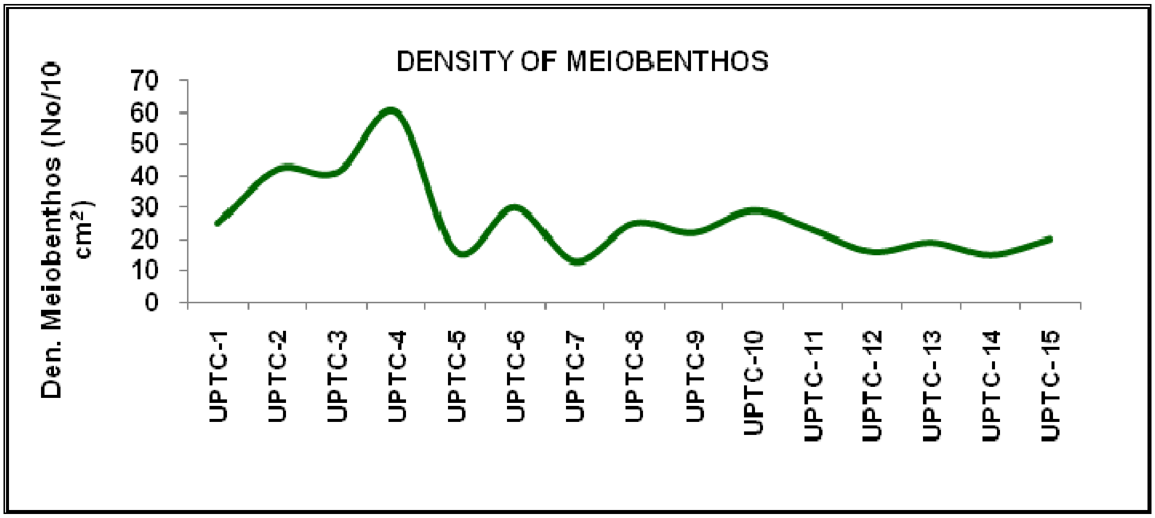


TABLE-3.32.

MEIOBENTHOS

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
	Nematodes					
1.	*Daptonema conicum*	*	*	*	3	1
2.	*Enoploides* sp.	5	*	2	*	*
3.	*Halalaimus filum*	*	1	*	*	*
4.	*Quadricoma* sp.	*	*	*	2	1
5.	*Tricoma* sp.	*	3	*	*	*
6.	*Echinotheristus* sp.	*	*	*	1	*
	Foraminiferans					
1.	*Eponides tuberculata*	*	1	*	*	*
2.	*Ammonia beccarii*	7	6	4	8	2
3.	*Bolivina abbreviata*	1	4	2	5	1
4.	*Cibicides lobatulus*	*	5	*	4	1
5.	*Cornoboides advena*	3	1	3	4	1
6.	*Eliphidium* sp.	1	*	7	5	1
7.	*Globigerinoides glutinata*	3	*	4	2	1

8.	*Quinqueloculina* sp.	*	1	*	*	*
9.	*Rosalina globularis*	2	*	*	*	*
10.	*Rotalia pulchella*	*	1	*	*	*
11.	*Rotalia translucens*	*	7	8	6	2
12.	*Textularia agglutinans*	*	5	*	1	*
13.	*Triloculina* sp.	*	1	*	3	1
	Harpacticoids					
1.	*Asellopes* sp.	*	3	2	4	1
2.	*Euterpina acutifrons*	*	1	*	1	*
3.	*Laptastocus* sp.	*	*	3	*	*
4.	*Microsetella* sp.	*	1	*	*	*
	Ostrocodes					
1.	*Cyprideis* sp.	3	*	1	*	*
2.	*Cypridina* sp.	*	*	3	6	2
3.	*Tanella indica*	*	*	*	*	*
4.	*Tanella estuarii*	*	*	*	5	1
5.	*Cyprideis lengae*	*	1	2	*	*
	Total	**25**	**42**	**41**	**60**	**16**

*** - Organisms not present**

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
	Nematodes					
1.	*Enoploides* sp.	*	*	*	1	*
2.	*Quadricoma* sp.	*	1	*	*	*
3.	*Tricoma* sp.	1	1	*	*	*
	Foraminiferans					
1.	*Eponides tuberculata*	2	*	*	*	*

2.	*Ammonia beccarii*	6	*	2	4	7
3.	*Bolivina abbreviata*	2	1	3	1	3
4.	*Cornoboides advena*	*	*	*	2	*
5.	*Eliphidium* sp.	*	4	3	*	2
6.	*Globigerinoides glutinata*	*	2	7	*	*
7.	*Quinqueloculina* sp.	1	*	*	*	*
8.	*Rotalia pulchella*	*	*	3	2	*
9.	*Rotalia translucens*	3	*	*	*	3
10.	*Textularia agglutinans*	6	4	2	3	4
11.	*Triloculina* sp.	*	*	*	3	*
	Harpacticoids					
1.	*Caneulla* sp.	*	*	2	*	*
2.	*Laptastocus* sp.	2	*	*	*	2
3.	*Microsetella* sp.	*	*	*	1	*
	Ostrocodes					
1.	*Cyprideis* sp.	*	*	3	5	5
2.	*Cypridina* sp.	4	*	*	*	3
3.	*Tanella estuarii*	3	*	*	*	*
	Total	**30**	**13**	**25**	**22**	**29**

*** - Organisms not present**

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
	Nematodes					
1.	*Daptonema conicum*	4	*	2	*	*
2.	*Halalaimus filum*	5	*	*	3	*
3.	*Quadricoma* sp.	2	*	1	*	*
4.	*Tricoma* sp.	*	*	1	2	*
	Foraminiferans					
1.	*Ammonia beccarii*	3	2	5	2	3
2.	*Bolivina abbreviata*	*	*	4	*	*
3.	*Cibicides lobatulus*	2	*	*	*	*
4.	*Cornoboides advena*	*	*	*	2	1
5.	*Eliphidium* sp.	1	*	*	2	2
6.	*Globigerinoides glutinata*	*	5	1	3	3
7.	*Quinqueloculina* sp.	*	*	*	*	1
8.	*Rotalia translucens*	*	2	*	*	1
9.	*Triloculina* sp.	2	1	*	*	*
	Oligochaetes					
1.	*Grania pusilla*	1	*	*	*	*
	Harpacticoids					
1.	*Caneulla* sp.	3	3	*	*	*
2.	*Laptastocus* sp.	*	*	*	1	*
	Ostrocodes					
1.	*Cyprideis* sp.	*	2	*	*	4
2.	*Cypridina* sp.	*	*	5	*	5
	Rotifera sp.	*	1	*	*	*
	Total	**23**	**16**	**19**	**15**	**20**

*** - Organisms not present**

SUMMARY

The surface water temperature varied from 34.0 to 35.0°C. The variation of temperature noticed at various stations may be as a result of season, geographical location and sampling time. The salinity varied from 32.0 to 33.0 ‰. Hydrogen ion concentration in surface waters remained alkaline and the maximum value of 8.3 was recorded at UTPC-6, 7, 10, 12, 14 and UTPC-15. The observations made on the prime physical factor TSS and turbidity were within the permissible level. The observed turbidity ranged between 2.2 and 6.3 NTU. The TSS values fluctuated from 50.4 to 130 mg/l. The maximum TSS and turbidity values were found to record at UTPC-14 and UTPC-5 respectively.

The ecologically sensitive chemical parameters such as Oxygen, BOD, nutrients and heavy metals were also at the optimal concentration coincided with the seasonal variation. The Dissolved Oxygen and BOD were found to be normal level. The observed oxygen level was fluctuated from 4.024 to 5.931 mg/l, the maximum DO level was recorded at UTPC-3 during this survey and the minimum was recorded at UTPC-6. The present study revealed that the DO concentration remained fairly well prescribed within the range of the values of water quality.

The BOD level was found to be ranged from 0.48 to 1.344 mg/l, the maximum BOD observed at UTPC-15 during this survey. In the present investigation, the ammonia concentration was ranged between 0.042 and 0.191 µmol/l. The concentration of nitrite fluctuated from 0.096 to 0.766 µmol/l. The nitrate values ranged from 2.039 to 4.990 µmol/l and the total nitrogen varied between 5.062 and 7.525 µmol/l. The inorganic phosphate ranged from 0.140 to 0.393 µmol/l. The observed total phosphorus values ranged between 0.595 and 0.882 µmol/l. The silicate concentration ranged from 0.412 to 0.802 µmol/l.

In the present survey, Petroleum Hydrocarbon varied between 0.098 and 0.479 µg/l and in sediment it varied from 0.008 to 0.186 µg/g at all locations monitored.

The higher concentration of Petroleum Hydrocarbon was recorded at station UTPC-10 and UTPC-9 during this survey.

The concentrations of cadmium in water ranged between 1.34 and 1.92 µg/l. The concentrations of lead varied from 2.22 to 4.67 µg/1. The chromium varied from 1.64 to 3.36 µg/1, iron from 33.94 to 64.0 µg/l and the zinc from 1.38 to 5.74 µg/l. The concentration of manganese varied from 1.08 to 4.39 µg/l.

The sand, silt and clay fraction at each of the stations along with their textural classification indicates that the sand percentage was higher during this survey. The stations UTPC-2 & UTPC-3 were found to be record low percentage of sand at Uppur Thermal Power Corporation area.

The concentrations of cadmium in sediments ranged from 1.13 to 3.05 µg/g. The concentrations of lead varied from 15.15 to 26.69 µg/g. The chromium varied between 14.11 and 39.30 µg/g, iron from 2726 to 8181 µg/g, the zinc from 19.28 to 65.0 µg/g. The concentration of manganese varied from 249.7 to 418.7 µg/g and the nickel level varied from 11.68 to 31.25 µg/g.

The microbial population showed general trend in water and sediment samples during this survey. The observed maximum Total Coliform was 24x104 CFU/ml at UTPC-4. However, the higher count was recorded in the sediment samples (22x105 CFU/g) of UTPC-1.

The maximum primary productivity 23.811 mgC/m3/hr, Chlorophyll ‘a’ 0.298 mg/m3 and Phaeopigment 0.135 mg/m3 were noticed at UTPC-15 during this survey. Phytoplankton population density varied from 2,458 to 3,869 No/l. The higher phytoplankton density was recorded at UTPC-15 during this survey. The zooplankton density ranged from 4,138 to 5,638 No/m3. The higher zooplankton density was recorded at UTPC-15 during this survey. A total of 16 species of phytoplankton and 26 species of zooplankton were found to record during this survey.

The numerical abundance of the macrobenthic fauna ranged from 525 to 1,300 No/m2 and the meiobenthic fauna fluctuated from 13 to 60 No/10 cm2. Among, the macrobenthos and meiobenthos, Cerithedia cingulata and Ammonia beccarii and Rotalia translucens were found to be the dominant species in this survey respectively. A total of 57 species of macrobenthos and 30 species of meiobenthos were found to record during this survey.

In general the second season survey revealed only marginal variation from the first season. When the nutrient levels were almost similar or appreciably lower, the plankton population also recorded very low density which might be due to lower availability of assailable nutrients. Similarly the benthic population also exhibited low density suggesting the variations in the faunal population might be due to the seasonal changes.

3.5 MARINE ECOLOGY (JANUARY 2014)

Marine Ecological survey was carried out in the Uppur coastal area Ramanathapuram District, Tamil Nadu. The Uppur Thermal Power Corporation – (UTPC) sampling points are located between Thirupalakudi and Uppur coastal villages. Many water channels were connecting the shore from land side. The Marine Ecological survey at Uppur coastal areas was made by a team of experts from the Centre of Advanced Study in Marine Biology of Annamalai University during January 2014.

Fig – 3.3 Map showing the sampling stations

Fifteen stations were selected in the coastal area and the samples were collected both high and low tide. Among the stations, UTPC 1, 2,3,4,5 and 6 were located in the near shore, UTPC- 7,8,9,10,11 & 12 were located away from the shore stations and UTPC 13, 14 & 15 in the open sea.

The Uppur coastal area covers thick mangrove vegetations along the shore with *Avicennia marina,* and *Rhizophora apiculata*.

The views of some representative sampling locations from where the samples were collected are illustrated below:

SAMPLING STATIONS

Station 1

Station 2

Station 3

Station 4 (2 km from the shore)

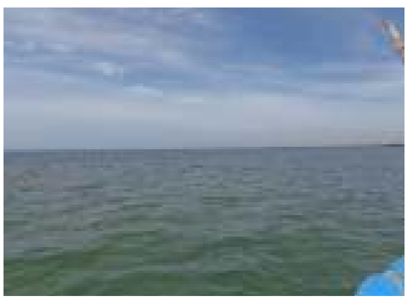
Station 5 (2 km from the shore)

Station 6 (2 km from the shore)

Station 7

Station 8

Station 9



Station 10

Station 11

Station 12

Station 13

Station 14

Station 15

The geographical locations of the sampling stations are given in the following Table-3.33.

TABLE-3.33

SAMPLING LOCATIONS AND ITS GEOGRAPHICAL COORDINATES

S. No.	St. Code	Date	Time	Depth (m)	Latitude	Longitude
1.	UTPC-1	08.01.2014	08:45	0.5	09°56'89" N	78°93'29" E
2.	UTPC-2	08.01.2014	08:55	0.5	09°58'60" N	78°92'90" E
3.	UTPC-3	08.01.2014	09:05	0.5	09°57'17" N	78°92'52" E
4.	UTPC-4	08.01.2014	09:35	2.0	09°56'79" N	78°92'94" E
5.	UTPC-5	08.01.2014	09:50	2.0	09°58'26" N	78°94'30" E
6.	UTPC-6	08.01.2014	10:00	2.0	09°59'27" N	78°94'56" E
7.	UTPC-7	08.01.2014	10:20	4.5	09°59'19" N	78°95'84" E
8.	UTPC-8	08.01.2014	10:35	4.5	09°57'90" N	78°95'51" E
9.	UTPC-9	08.01.2014	10:45	4.5	09°57'25" N	78°95'92" E
10.	UTPC-10	08.01.2014	11:05	6.0	09°57'56" N	78°97'35" E
11.	UTPC- 11	08.01.2014	11:20	6.0	09°58'30" N	78°98'09" E
12.	UTPC- 12	08.01.2014	11:35	6.0	09°58'42" N	78°98'55" E
13.	UTPC- 13	08.01.2014	12:00	10.0	09°57'88" N	78°99'63" E
14.	UTPC- 14	08.01.2014	12:15	9.5	09°57'21" N	78°99'06" E
15.	UTPC- 15	08.01.2014	12:30	10.0	09°56'56" N	78°98'21" E

MATERIALS AND METHODS

Water and Sediment Sampling

Water samples were collected using Universal water sampler below the surface and transferred to the pre-cleaned 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 and he plant 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 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). Salinity was estimated using a hand refractometer (Erma Company, Japan). Water samples collected for dissolved oxygen estimation were transferred carefully to BOD bottles. The DO was immediately fixed and brought to the laboratory for further analysis.

Preservation and Laboratory Analysis:

After collection, the 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 other nutrients. Unfiltered samples were used for the estimation of total nitrogen and total phosphorus. All the analyses were carried out as per internationally followed standard procedures for samples of aquatic origin. Briefly, the methods of analyses are as follows:

Dissolved Oxygen:

The modified Winkler's method as described by Strickland and Parsons (1972) was adopted for the estimation of dissolved oxygen. The values are 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. The 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 are expressed in μmol of Nitrogen/l

Inorganic Phosphate:

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 values are expressed in µmol of Phosphorus/l.

Total Phosphorus:

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 is 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 are 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:

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 soon after collection and bacteriological analyses were done in the laboratory at CAS immediately after arrival, with necessary dilution.

Enumeration of Total Viable Counts:

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 inoculation 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.

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 detailed methodology is described 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. After collection, the 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:

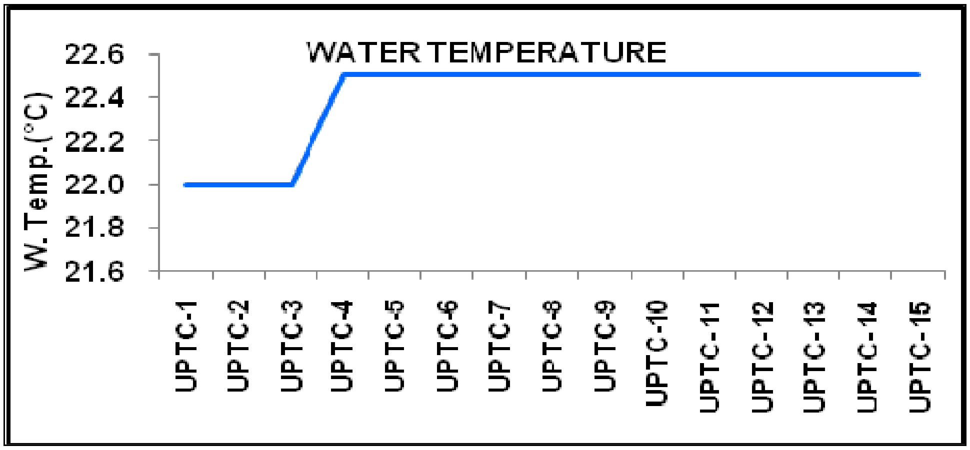
For studying the benthic organisms, sediment samples were collected using a Petersen grab. The wet sediment was sieved with varying mesh sizes for segregating the organisms. The sieved organisms were stained with Rose Bengal and sorted to different groups. The number of organisms in each grab sample was expressed as 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

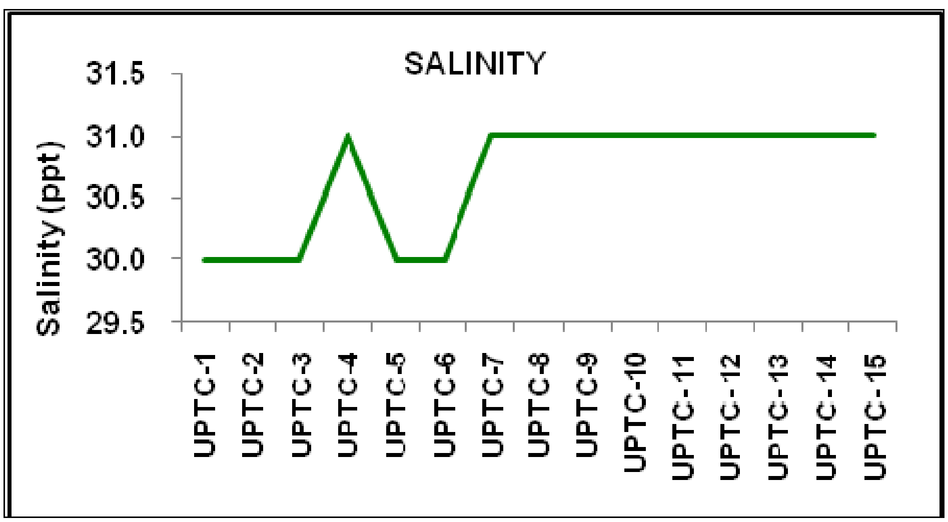
Water Temperature

The water temperature ranged between 22.0 and 22.5°C. The maximum was at UTPC-74 & 15 and minimum at UTPC-1, 2 & 3 (Table-3.34).



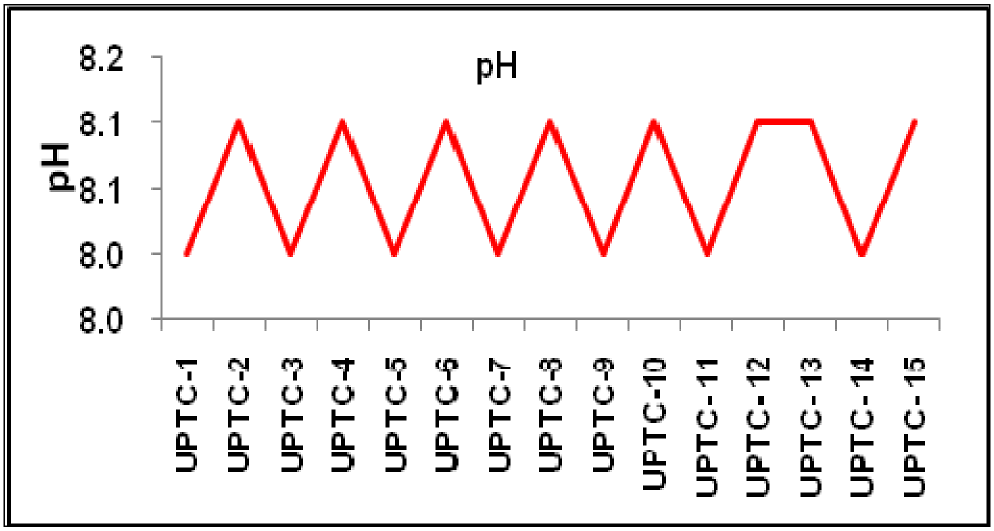
Salinity

The water salinity varied from 30 to 31‰. The maximum salinity was at UTPC-4, 7, 8, 9, 10, 11, 12, 13, 14 and 15 and the minimum was recorded at UTPC-1, 2, 3, 5, 6 (Table 3.34).



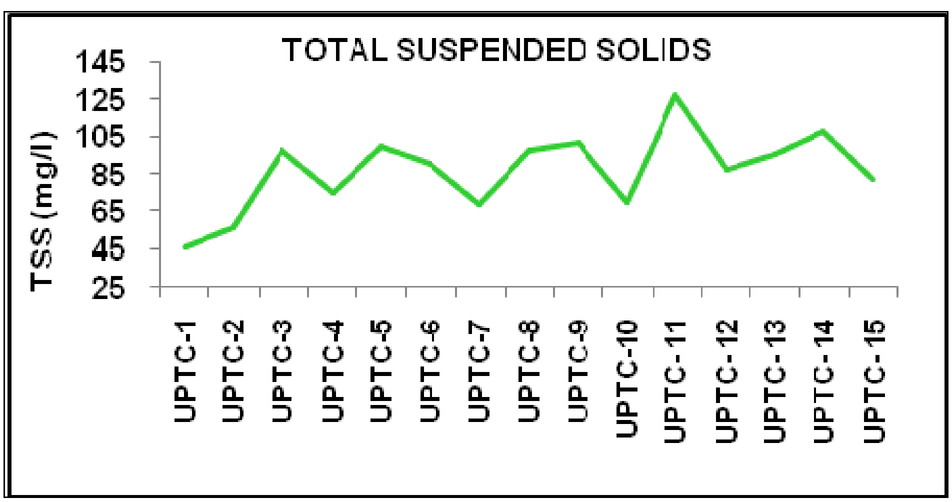
pH

The water pH varied between 8.0 and 8.1 (Table 3.34). The minimum pH was recorded at UTPC-1, 3, 5, 7 & UTPC-9 and the maximum was at UTPC- 2, 4, 6, 8, 10, 12, 13 and UTPC-15.



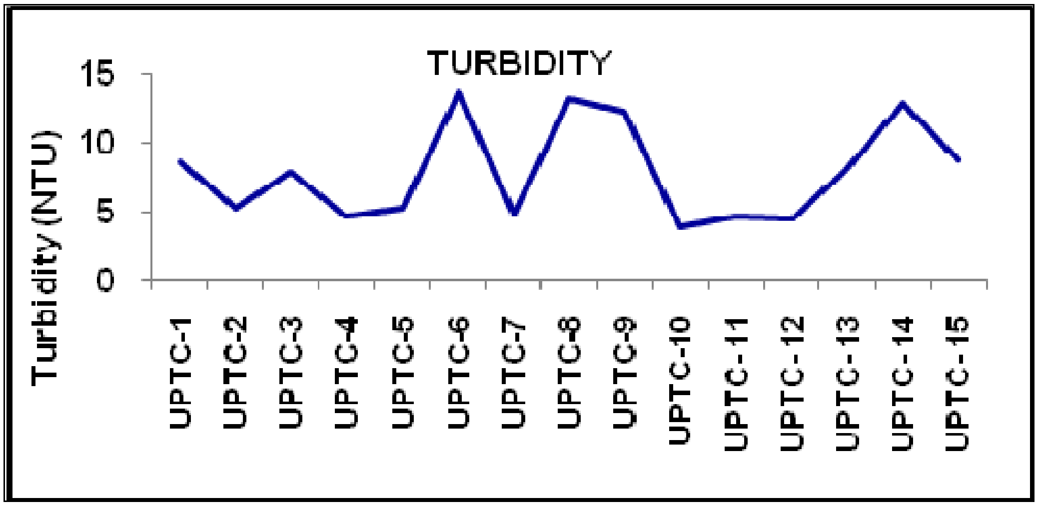
Suspended Solids

The TSS values ranged between 46.4 and 127.2 mg/l. The minimum value (46.4 mg/l) was recorded at UTPC-1 and maximum (127.2 mg/l) was at UTPC-11 (Table 3.34).



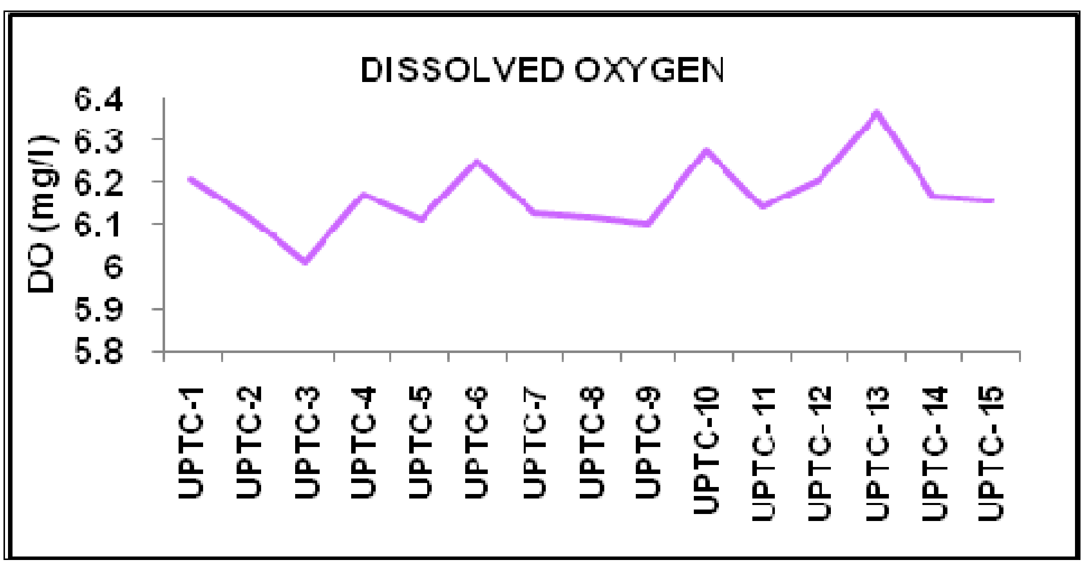
Turbidity

The turbidity values ranged from 3.9 to 13.6 NTU (Table 3.34). The maximum level was at UTPC-6 and the minimum was recorded at UTPC-10.



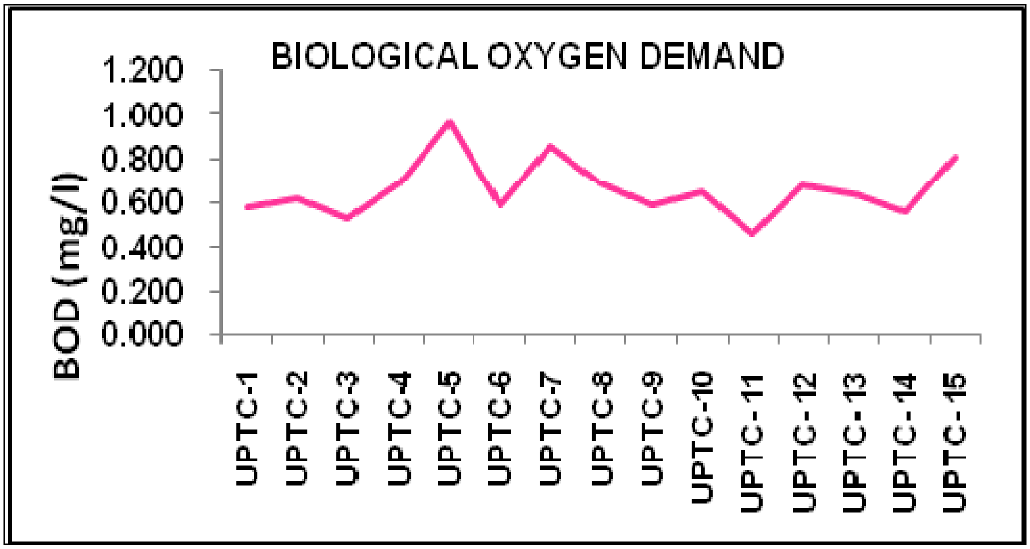
Dissolved Oxygen

The Dissolved Oxygen level in the water varied between 6.012 and 6.367 mg/l. The minimum and maximum levels were recorded at UTPC-3 and UTPC-13 respectively (Table 3.34).



Biological Oxygen Demand

The BOD values ranged between 0.46 and 0.96 mg/l. The maximum value (0.96 mg/l) was at UTPC-5 and minimum of 0.46 mg/l at UTPC-11 (Table 3.34).



TABLE– 3.34

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.	UTPC-1	22.0	30.0	8.0	46.4	8.6	6.205	0.580
2.	UTPC-2	22.0	30.0	8.1	56.4	5.3	6.118	0.620
3.	UTPC-3	22.0	30.0	8.0	97.2	7.9	6.012	0.524
4.	UTPC-4	22.5	31.0	8.1	74.8	4.6	6.173	0.685
5.	UTPC-5	22.5	30.0	8.0	99.6	5.2	6.110	0.960
6.	UTPC-6	22.5	30.0	8.1	90.0	13.6	6.254	0.592
7.	UTPC-7	22.5	31.0	8.0	68.4	4.8	6.125	0.848
8.	UTPC-8	22.5	31.0	8.1	97.6	13.2	6.119	0.685
9.	UTPC-9	22.5	31.0	8.0	101.2	12.3	6.102	0.592

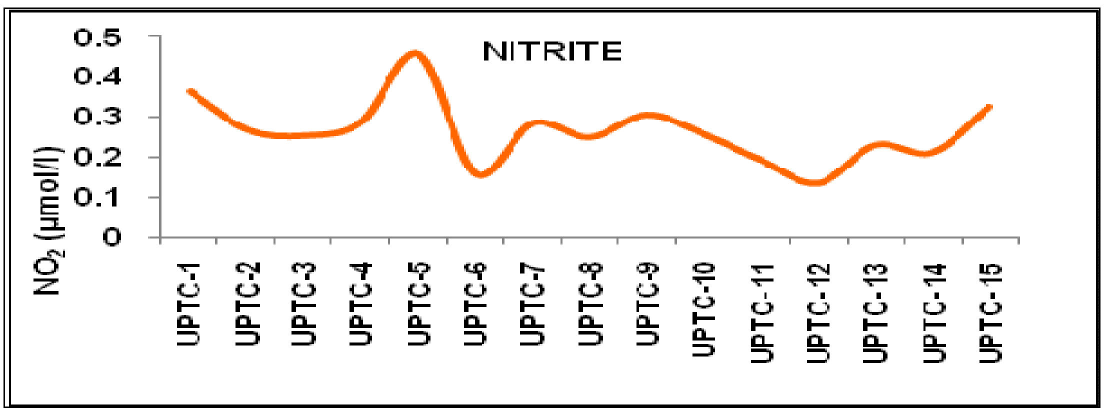
10.	UTPC-10	22.5	31.0	8.1	69.6	3.9	6.277	0.651
11.	UTPC- 11	22.5	31.0	8.0	127.2	4.7	6.141	0.460
12.	UTPC- 12	22.5	31.0	8.1	87.2	4.5	6.209	0.672
13.	UTPC- 13	22.5	31.0	8.1	95.2	8.2	6.367	0.640
14.	UTPC- 14	22.5	31.0	8.0	108.0	12.8	6.165	0.560
15.	UTPC- 15	22.5	31.0	8.1	81.6	8.7	6.158	0.800

Nutrients

The life supporting processes in the sea requires an array of inorganic substances, but the role of nitrogen, phosphorus and silicon are considered vital in marine ecosystem. Among the nitrogenous nutrients, nitrite, nitrate and ammonia are the major constituents, which play key roles in the phytoplankton growth and proliferation.

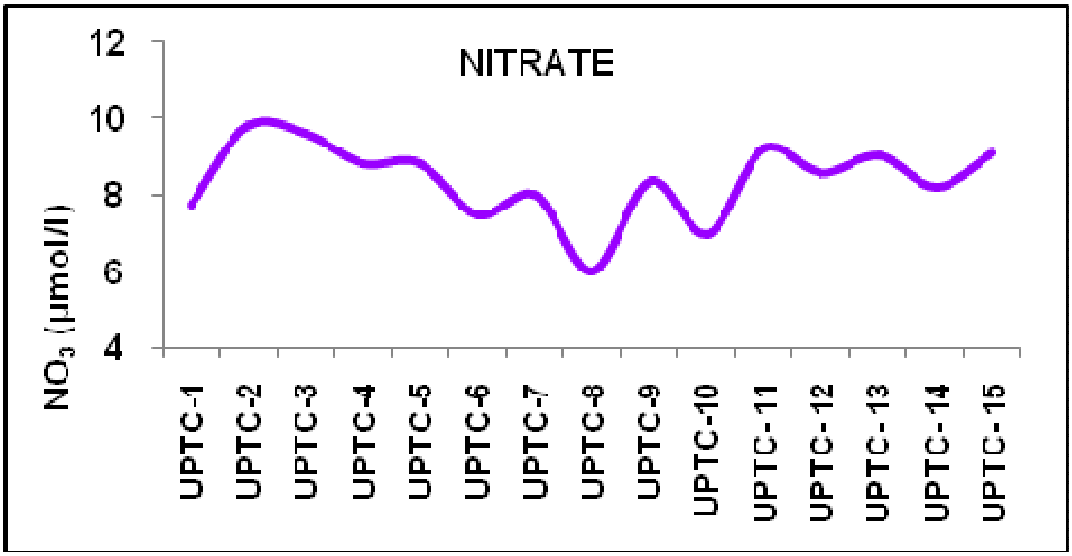
Nitrite

The nitrite concentration varied from 0.134 to 0.458 µmol/l (Table 3.35). The minimum was recorded at UTPC-12 and the maximum recorded at UTPC-5.



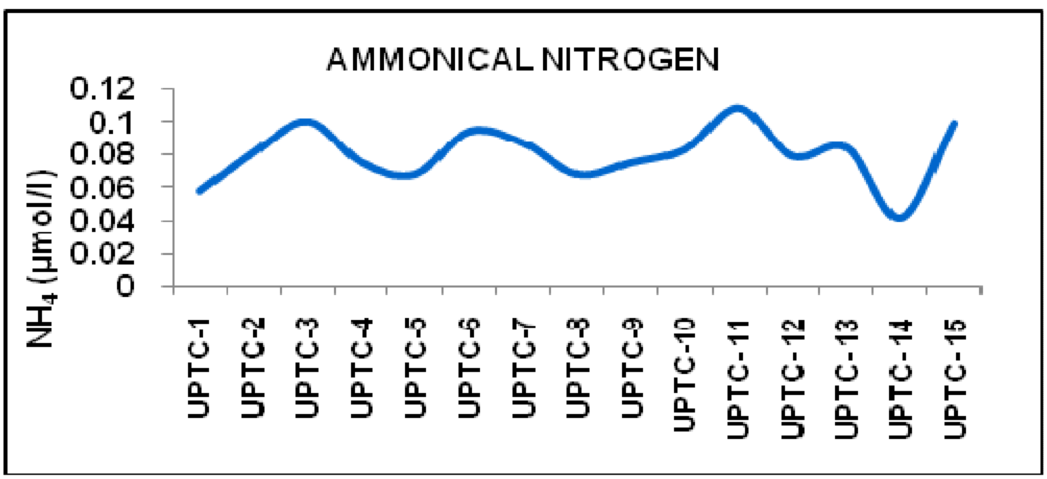
Nitrate

Nitrate concentration varied from 5.965 to 4.990 µmol/l (Table 3.35). The maximum Nitrate concentration was recorded at UTPC-10 and minimum at UTPC-14.



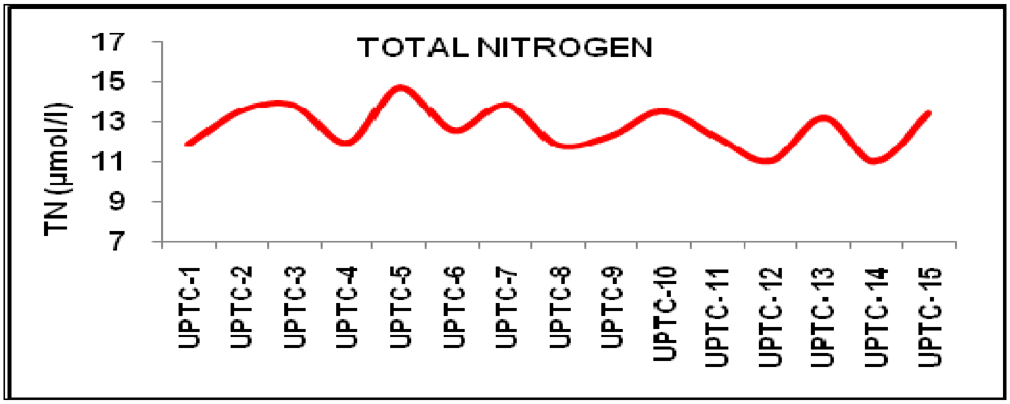
Ammonical Nitrogen

The ammonia concentration fluctuated from 0.042 to 0.191 µmol/l. The maximum concentration (0.191 µmol/l) was recorded at UTPC-12 and the minimum (0.042 µmol/l) was at UTPC-7 (Table 3.35).



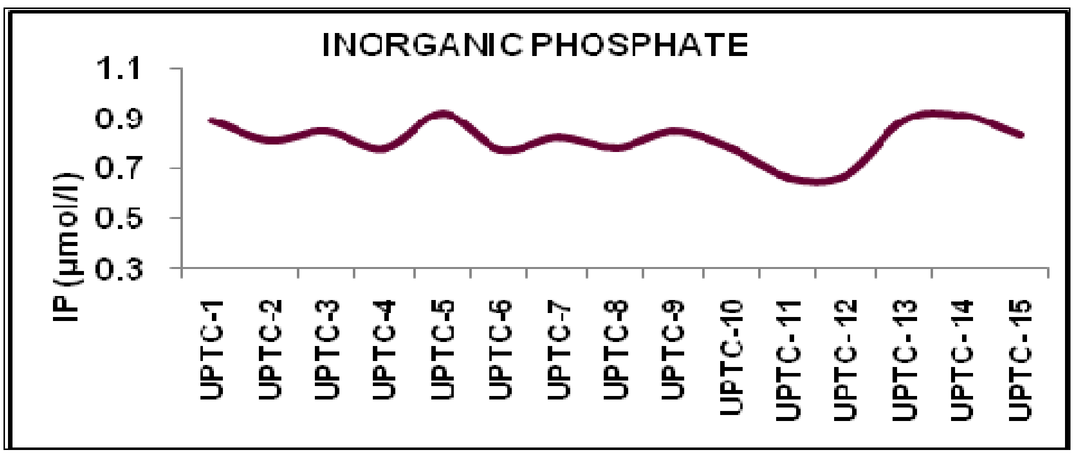
Total Nitrogen

The Total nitrogen values ranged from 5.062 to 7.525 µmol/l. The maximum concentration was recorded at UTPC-15 (7.525 µmol/l) and minimum at UTPC-2 (5.062 µmol/l) (Table 3.35).



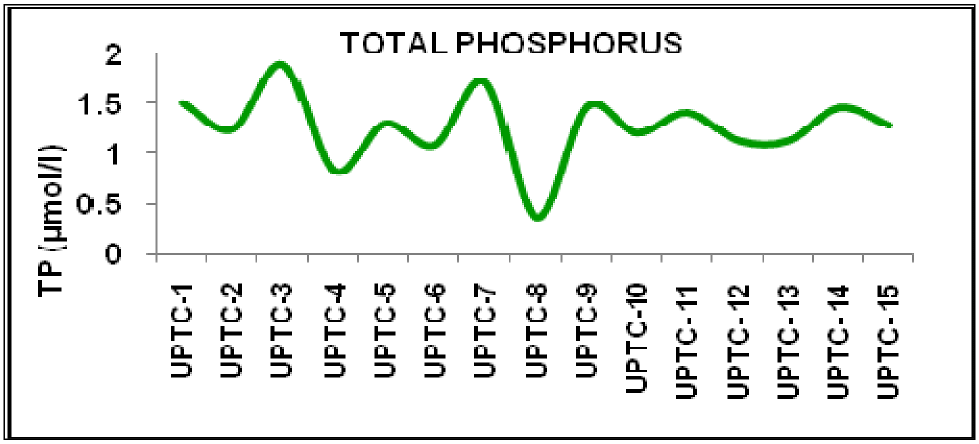
Inorganic Phosphate

The inorganic phosphate values fluctuated between 0.665 and 0.923 µmol/l. The maximum value was recorded at UTPC-5 and the minimum was at UTPC-11 (Table 3.35).



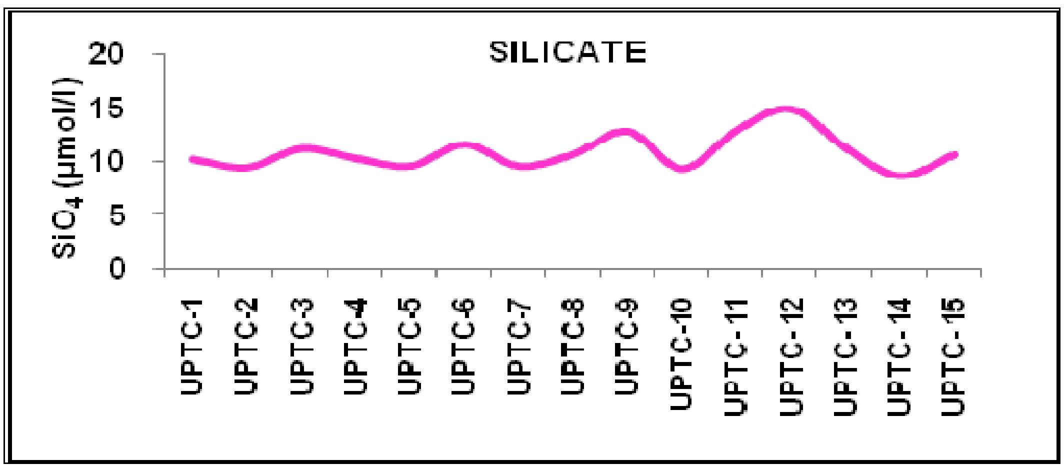
Total Phosphorus

The total phosphorus values ranged from 0.359 to 1.896 µmol/l. The maximum (1.896 µmol/l) value was at UTPC-3 and the minimum (0.359 µmol/l) was recorded at UTPC-8 (Table 3.35).



Reactive Silicate

The silicate values ranged between 8.686 and 14.857 µmol/l. The maximum (14.857 µmol/l) and minimum (8.686 µmol/l) values were recorded at UTPC-12 and UTPC-14 respectively (Table 3.35).



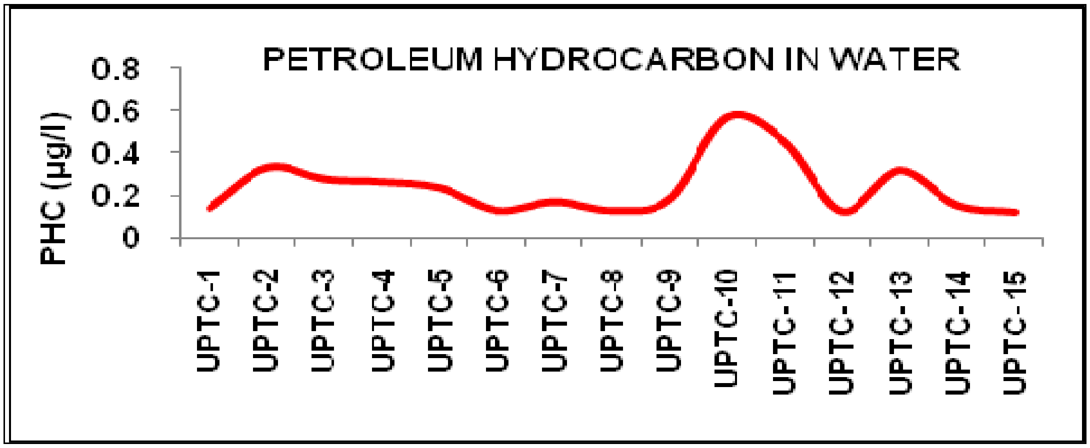
TABLE– 3.35

NUTRIENTS IN WATER

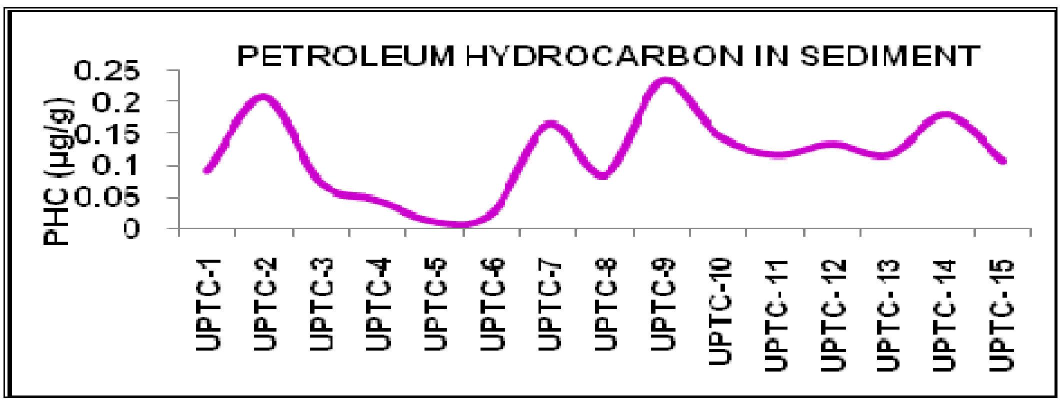
S. No.	Station Code	Parameter (µmol/l)						
		NO_2	NO_3	NH_4	TN	IP	TP	SiO_4
1.	UTPC-1	0.364	7.726	0.058	11.852	0.894	1.511	10.219
2.	UTPC-2	0.268	9.801	0.081	13.555	0.812	1.249	9.472
3.	UTPC-3	0.253	9.603	0.100	13.824	0.847	1.896	11.195
4.	UTPC-4	0.287	8.820	0.075	11.945	0.776	0.827	10.303
5.	UTPC-5	0.458	8.830	0.068	14.729	0.923	1.304	9.601
6.	UTPC-6	0.157	7.458	0.094	12.566	0.770	1.091	11.594
7.	UTPC-7	0.285	8.001	0.087	13.837	0.823	1.723	9.585
8.	UTPC-8	0.249	5.965	0.068	11.797	0.782	0.359	10.690
9.	UTPC-9	0.306	8.360	0.075	12.347	0.845	1.470	12.800
10.	UTPC-10	0.257	6.960	0.083	13.529	0.782	1.212	9.344
11.	UTPC- 11	0.192	9.208	0.108	12.213	0.665	1.413	12.888
12.	UTPC- 12	0.134	8.580	0.079	11.066	0.677	1.133	14.857
13.	UTPC- 13	0.230	9.047	0.084	13.153	0.894	1.134	11.274
14.	UTPC- 14	0.211	8.203	0.042	11.005	0.910	1.462	8.686
15.	UTPC- 15	0.326	9.107	0.099	13.421	0.829	1.288	10.644

PETROLEUM HYDRO CARBON

In Uppur Thermal Power Plant areas, the PHC level in water fluctuated from 0.118 and 0.575 µg/l. The minimum was recorded at UTPC-15 and the maximum was recorded at UTPC-10 (Table 3.36).



In sediment, the PHC varied between 0.010 and 0.233 µg/g. The minimum and maximum concentrations were recorded at UTPC-5 and UTPC-9 respectively during this survey (Table 3.36).



These values indicate anthropogenic release of petroleum in the system. A part of PHC may also originate from the fishing activities transported by tidal ingress.

TABLE -3.36.

PETROLEUM HYDROCARBON IN WATER & SEDIMENT

S. No.	Station Code	Water (µg/l)	Sediment (µg/g)
1.	UTPC-1	0.136	0.090
2.	UTPC-2	0.332	0.208

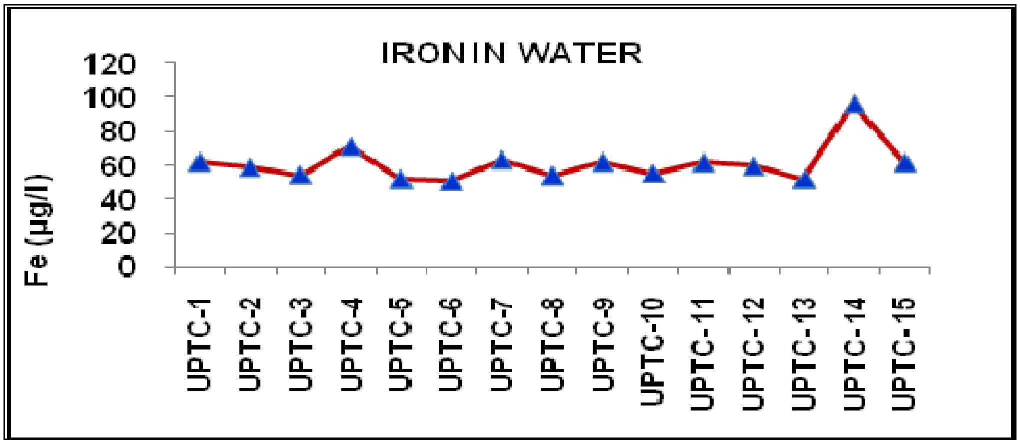
S. No.	Station Code	Water (µg/l)	Sediment (µg/g)
3.	UTPC-3	0.276	0.071
4.	UTPC-4	0.263	0.044
5.	UTPC-5	0.235	0.010
6.	UTPC-6	0.125	0.023
7.	UTPC-7	0.167	0.164
8.	UTPC-8	0.125	0.084
9.	UTPC-9	0.179	0.233
10.	UTPC-10	0.575	0.146
11.	UTPC- 11	0.457	0.115
12.	UTPC- 12	0.121	0.133
13.	UTPC- 13	0.319	0.115
14.	UTPC- 14	0.150	0.180
15.	UTPC- 15	0.118	0.106

Heavy Metals in Water

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

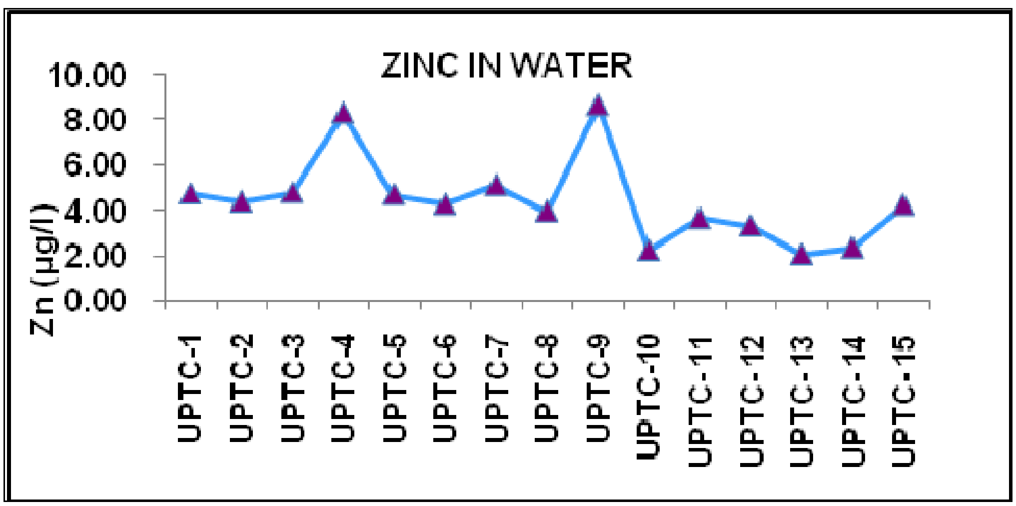
Iron

The iron level varied from 50.91 to 96.0 µg/l. The maximum iron level was recorded at UTPC-14 and the minimum of 50.91 µg/l was recorded at UTPC-6 (Table 3.37).



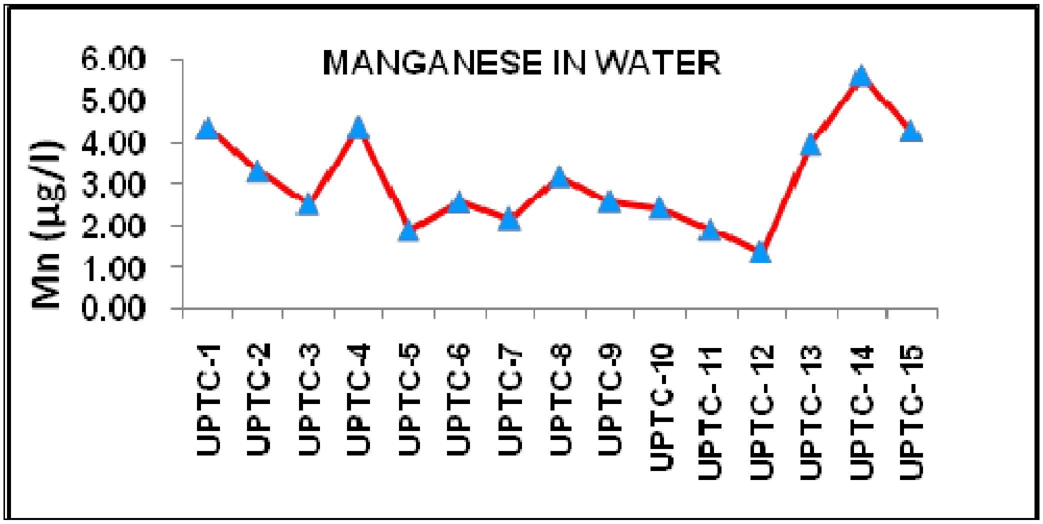
Zinc

The zinc level in the study area varied between 2.07 and 8.61 µg/l. The maximum value was recorded at UTPC-9 and the minimum of 2.07 µg/l was recorded at UTPC-13 (Table 3.37).



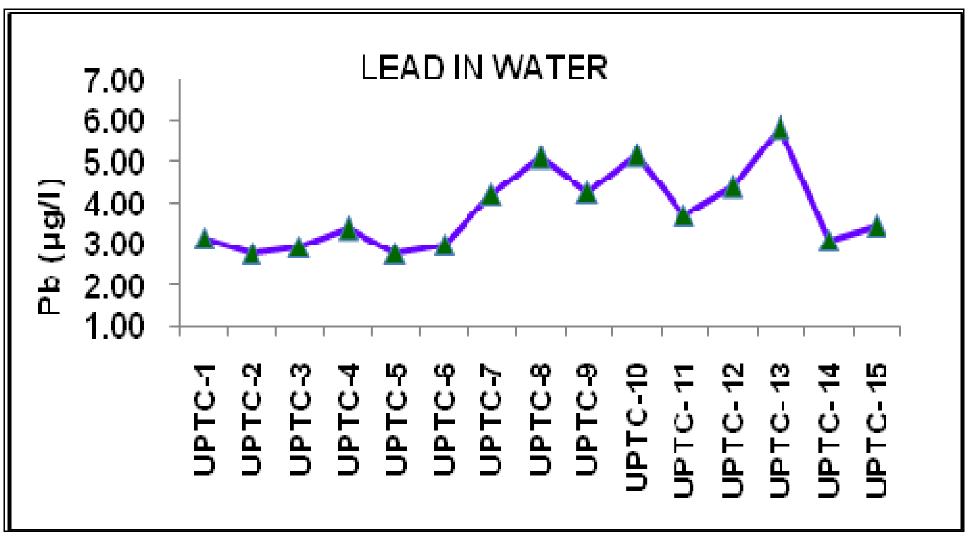
Manganese

The manganese level varied between 1.38 and 5.62 µg/l. The maximum value was recorded at UTPC-14 and the minimum value at UTPC-12 (Table 3.37).



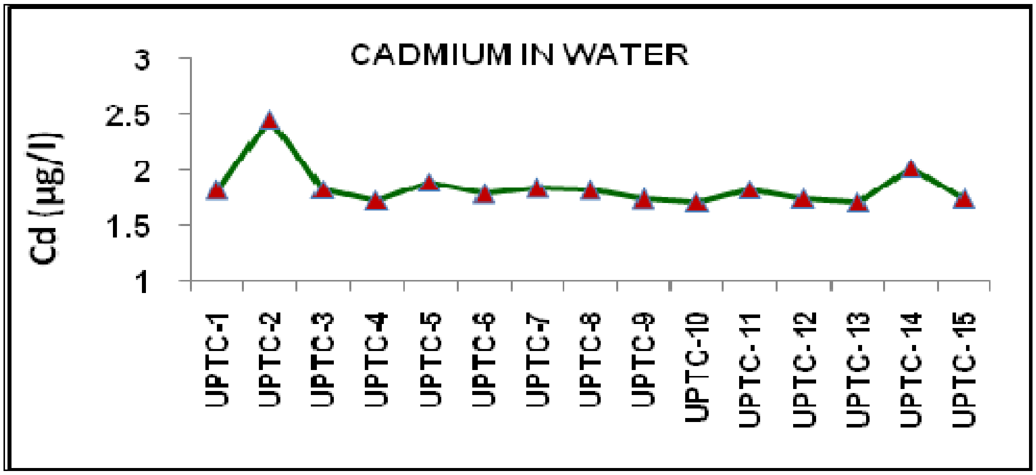
Lead

The lead level in the study area fluctuated between 2.78 and 5.84 µg/l. The maximum of 5.84 µg/l was observed at UTPC-13 and the minimum of 2.78 µg/l was recorded at UTPC-2 during this survey (Table 3.37).



Cadmium

The cadmium level in the study area varied from 1.72 and 2.46 µg/l. The maximum cadmium was recorded at UTPC-2 and the minimum (1.72 µg/l) was recorded at UTPC-10 & UTPC-13 respectively during this survey (Table 3.37).



Chromium

The chromium level in the study area varied between 2.10 and 4.30 µg/l. The minimum and maximum values were recorded at UTPC-8 and UTPC-13 respectively during this survey (Table 3.37).

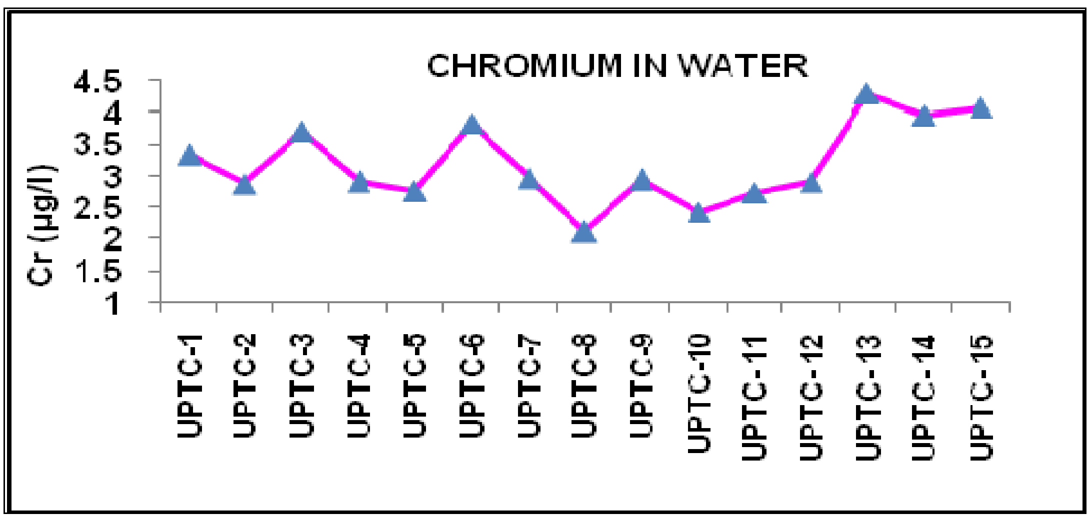


TABLE – 3.37

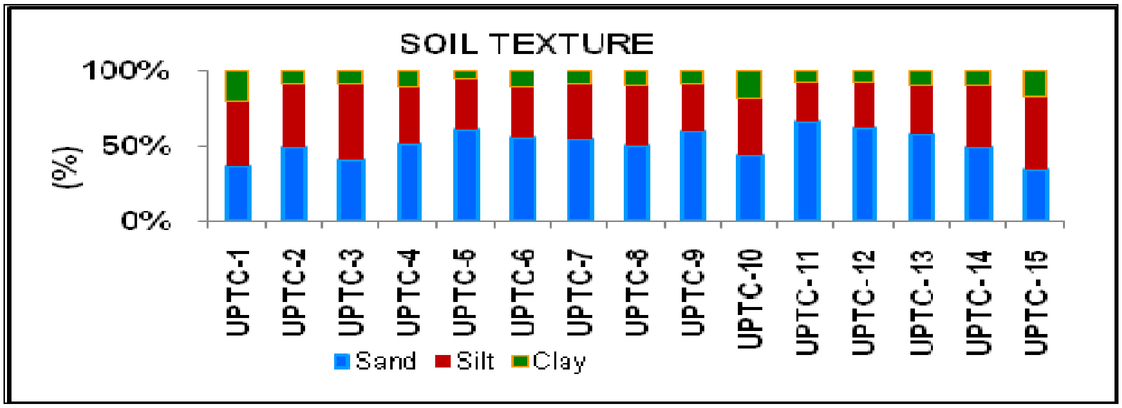
HEAVY METALS IN WATER

Sl. No.	Parameters	(µg/l)					
		Fe	Zn	Mn	Pb	Cd	Cr
1.	UTPC-1	61.92	4.74	4.35	3.15	1.82	3.33
2.	UTPC-2	58.70	4.40	3.33	2.78	2.46	2.87
3.	UTPC-3	54.30	4.79	2.55	2.94	1.83	3.71
4.	UTPC-4	71.30	8.28	4.36	3.38	1.73	2.91
5.	UTPC-5	52.19	4.71	1.91	2.80	1.89	2.76
6.	UTPC-6	50.91	4.29	2.59	3.01	1.79	3.85
7.	UTPC-7	63.09	5.13	2.20	4.23	1.84	2.97
8.	UTPC-8	53.64	3.98	3.20	5.11	1.82	2.10
9.	UTPC-9	61.95	8.61	2.60	4.28	1.74	2.93
10.	UTPC-10	55.16	2.25	2.46	5.18	1.72	2.43
11.	UTPC- 11	61.73	3.65	1.92	3.71	1.83	2.73
12.	UTPC- 12	59.64	3.33	1.38	4.40	1.75	2.91
13.	UTPC- 13	52.02	2.07	3.98	5.84	1.72	4.30
14.	UTPC- 14	96.00	2.36	5.62	3.10	2.02	3.97
15.	UTPC- 15	61.71	4.25	4.29	3.46	1.75	4.08

Sediment Characteristics

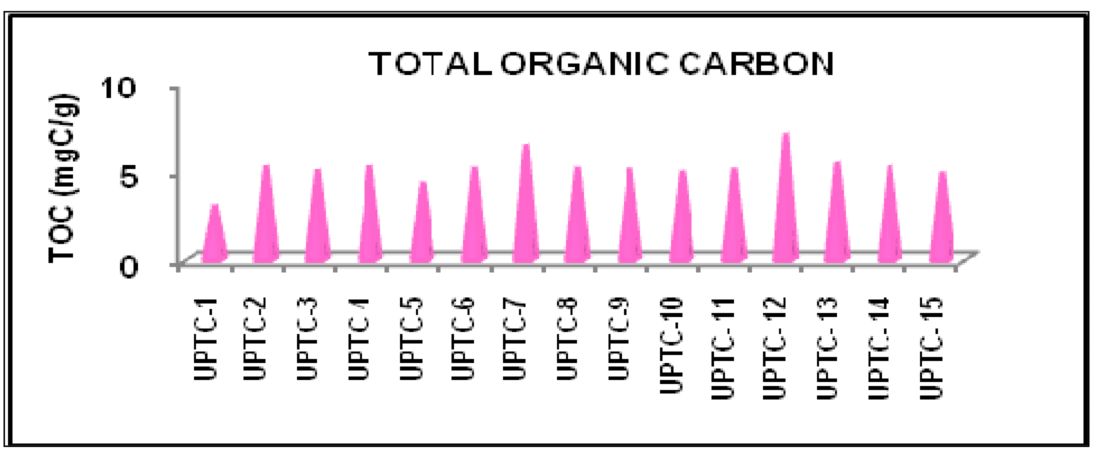
Soil Texture (%)

The sand content varied from 33.35 to 65.92 % with the maximum value at UTPC-11 and the minimum sand content in the station UTPC-15; the silt content showed maximum of 50.53% at UTPC-3 and minimum of 26.23 % at UTPC-11 and the clay was found to be maximum at UTPC-1 (20.24 %) and minimum at UTPC-5 (1.13%) (Table 3.38).



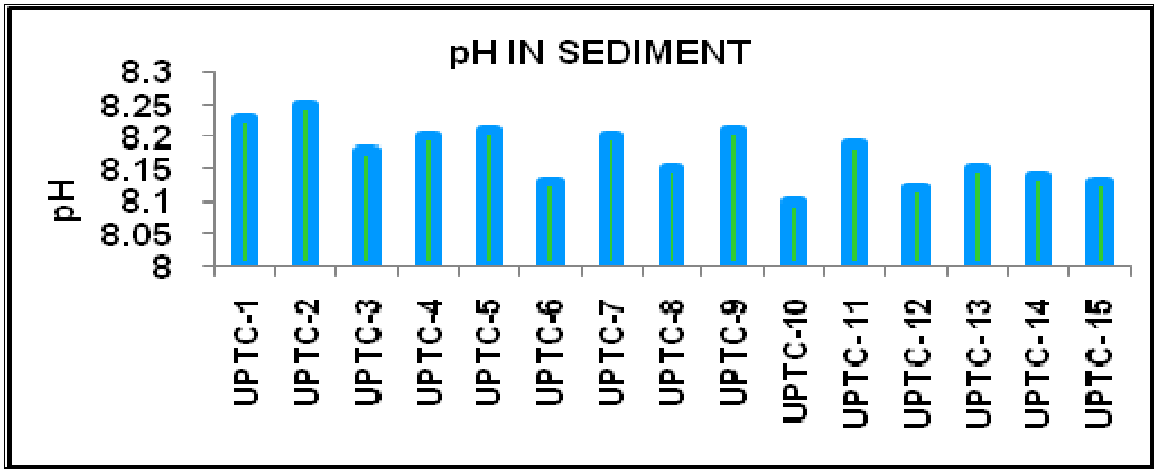
Total Organic Carbon

Total organic carbon level was maximum (7.09 mgC/g) at UTPC-12 and minimum (3.08 mgC/g) at the station UTPC-1 (Table 3.38).



pH

The pH in the sampling stations varied from 7.77 to 8.41. As evident from the following figure, the minimum level was recorded at UTPC-15 and the maximum level was recorded at UTPC-9 during this survey (Table 3.38).



TABLE– 3.38.

SOIL TEXTURE, TOTAL ORGANIC CARBON & pH OF SEDIMENT

S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (mgC/g)	pH
1.	UTPC-1	36.06	43.70	20.24	3.08	8.23
2.	UTPC-2	49.12	42.07	8.81	5.22	8.25
3.	UTPC-3	40.66	50.53	8.81	5.02	8.18
4.	UTPC-4	51.49	37.11	11.40	5.22	8.20
5.	UTPC-5	60.98	33.08	5.93	4.33	8.21
6.	UTPC-6	55.21	34.18	10.62	5.15	8.13
7.	UTPC-7	54.77	36.58	8.65	6.47	8.20

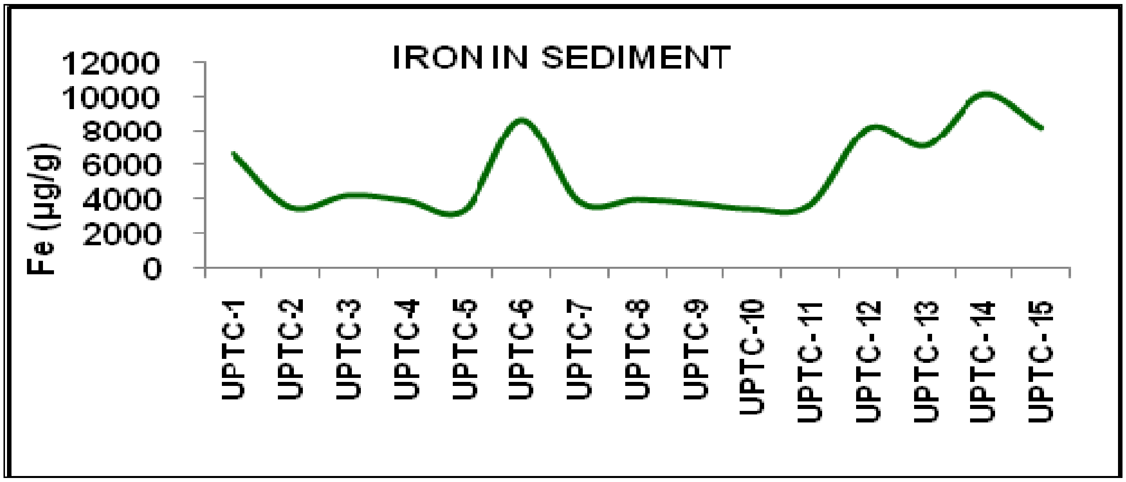
S. No.	Station Code	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (mgC/g)	pH
8.	UTPC-8	49.77	40.88	9.34	5.15	8.15
9.	UTPC-9	59.44	31.47	9.09	5.09	8.21
10.	UTPC-10	43.23	38.40	18.37	4.95	8.10
11.	UTPC- 11	65.92	26.23	7.85	5.09	8.19
12.	UTPC- 12	61.75	31.01	7.24	7.09	8.12
13.	UTPC- 13	57.44	32.98	9.58	5.43	8.15
14.	UTPC- 14	48.75	41.03	10.22	5.22	8.14
15.	UTPC- 15	33.35	49.15	17.50	4.88	8.13

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.

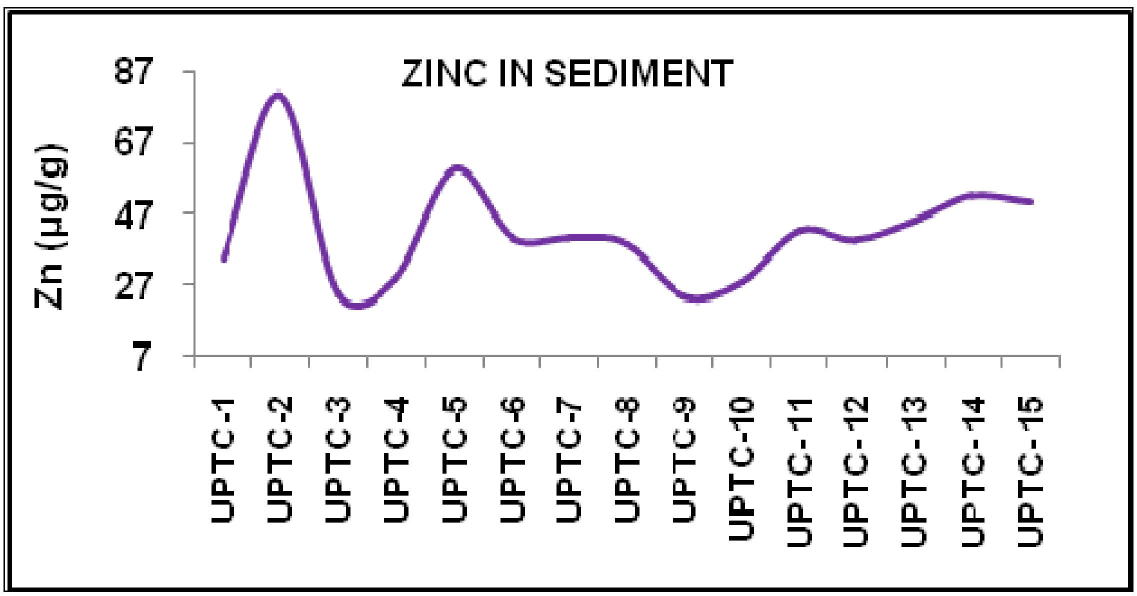
Iron

The cadmium level varied from 3380 to 10144 µg/g (Table 3.39). The maximum was recorded at UTPC-14 and the minimum was recorded at UTPC-5 during this survey.



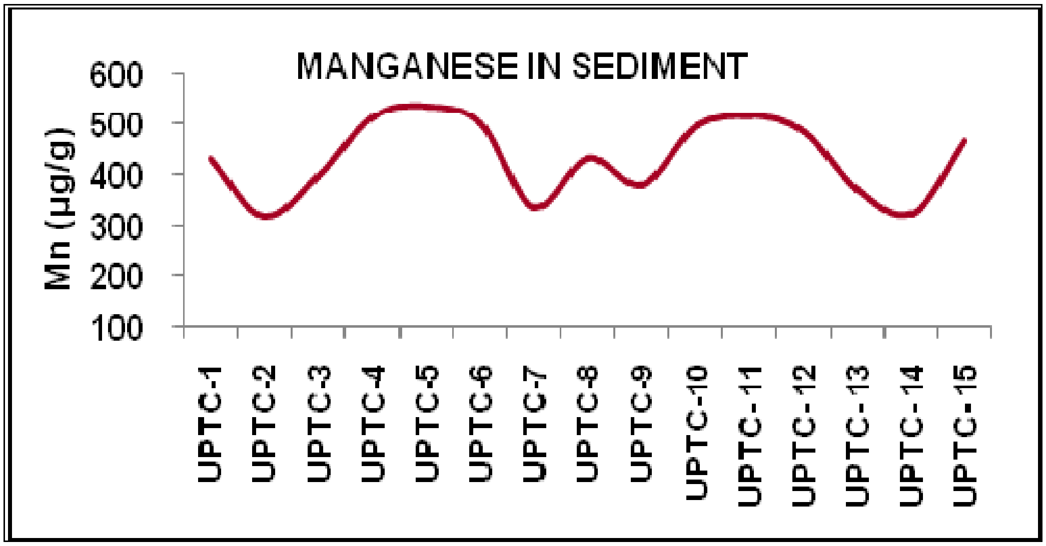
Zinc

The zinc in the sediments fluctuated from 23.91 to 80.60 µg/g with maximum of 80.6 µg/g at UTPC-2 and the minimum of 23.91 µg/g at UTPC-9 (Table 3.39).



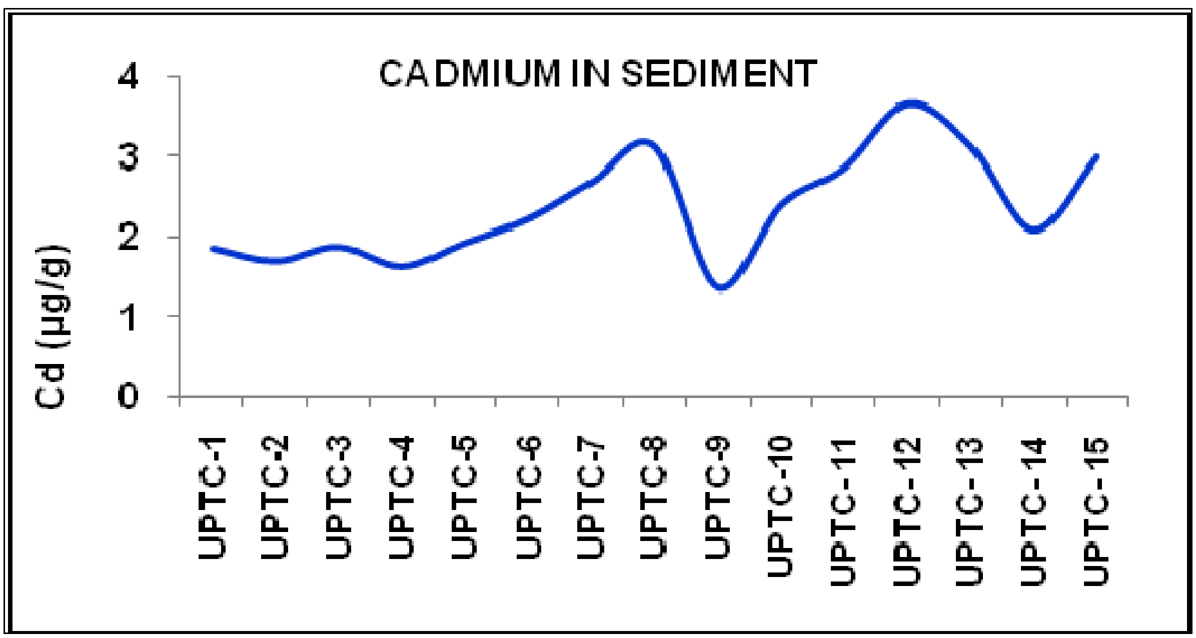
Manganese

The manganese concentration fluctuated between 319.6 and 535.9 µg/g. The minimum and maximum values were recorded at UTPC-2 and UTPC-5 respectively during this survey (Table 3.39).



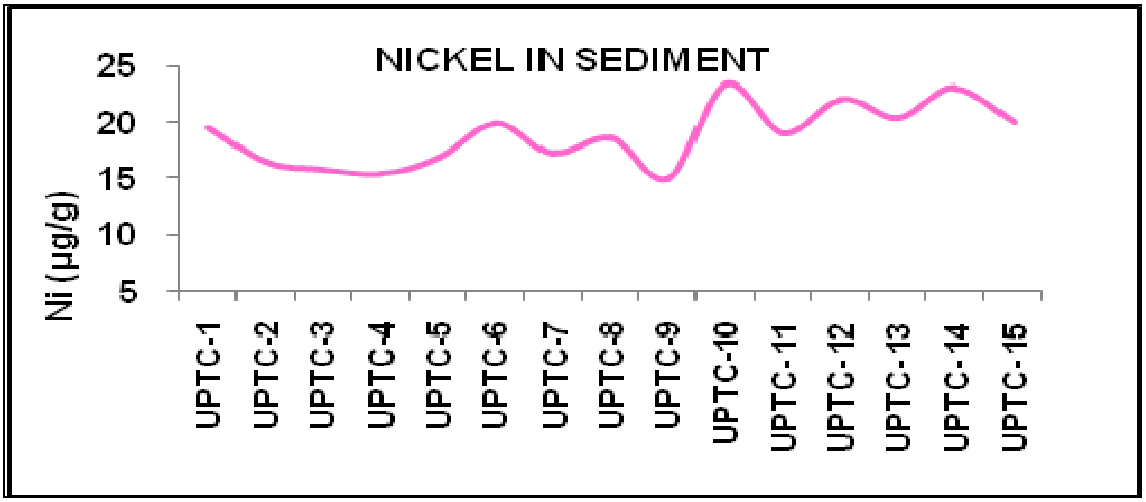
Cadmium

The cadmium level in the sediment ranged from 1.36 to 3.66 µg/g. The maximum cadmium concentration of 3.66 µg/g was recorded at UTPC-12 and minimum of 1.36 µg/g was recorded at UTPC-9 (Table 3.39).



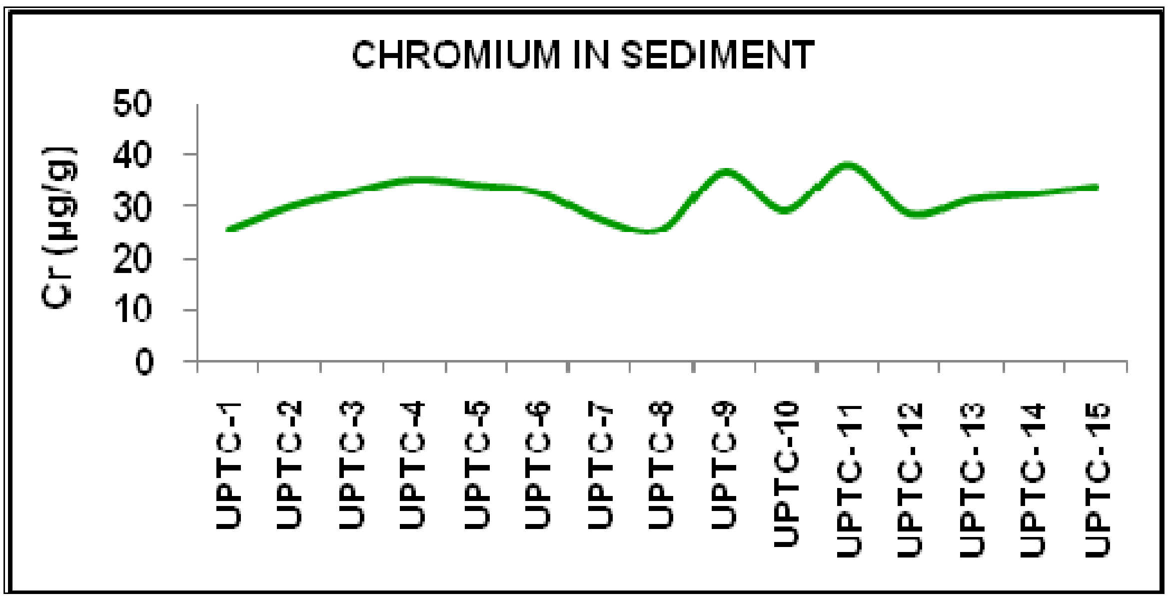
Nickel

The nickel fluctuated from 14.95 to 23.37 µg/g with a maximum of 23.37 µg/g at UTPC-10 and the minimum of 14.95 µg/g at UTPC-9 during this survey (Table 3.39).



Chormium

The chromium level in the sediment varied between 25.50 and 38.17 µg/g. The maximum value was recorded at UTPC-11 and the minimum was recorded at UTPC-8 (Table 3.39).



Lead

The lead level fluctuated from 17.42 to 30.69 µg/g with a maximum of 30.69 µg/g at UTPC-7 and the minimum of 17.42 µg/g at UTPC-10 during this survey (Table 3.39).

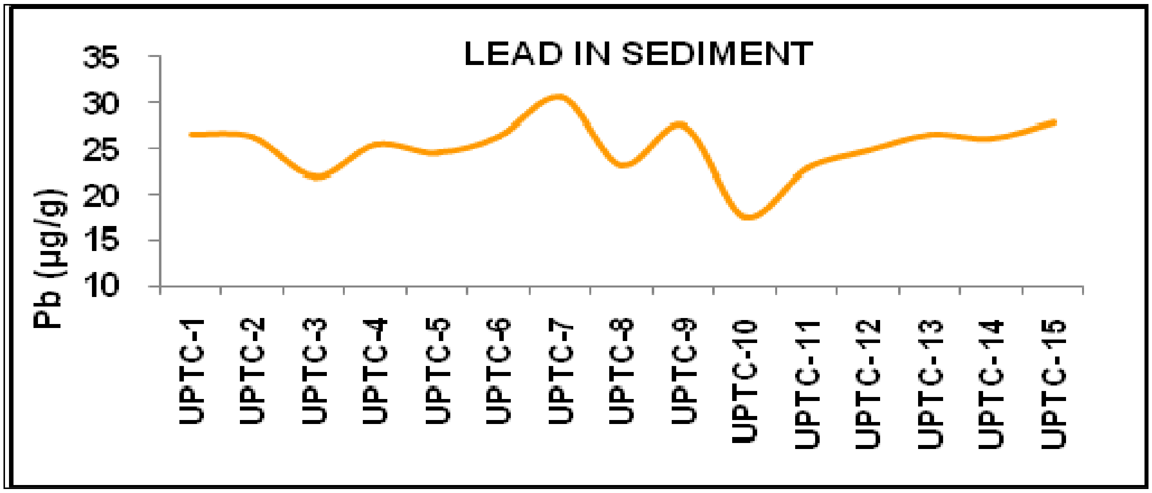


TABLE – 3.39.

HEAVY METALS IN SEDIMENT

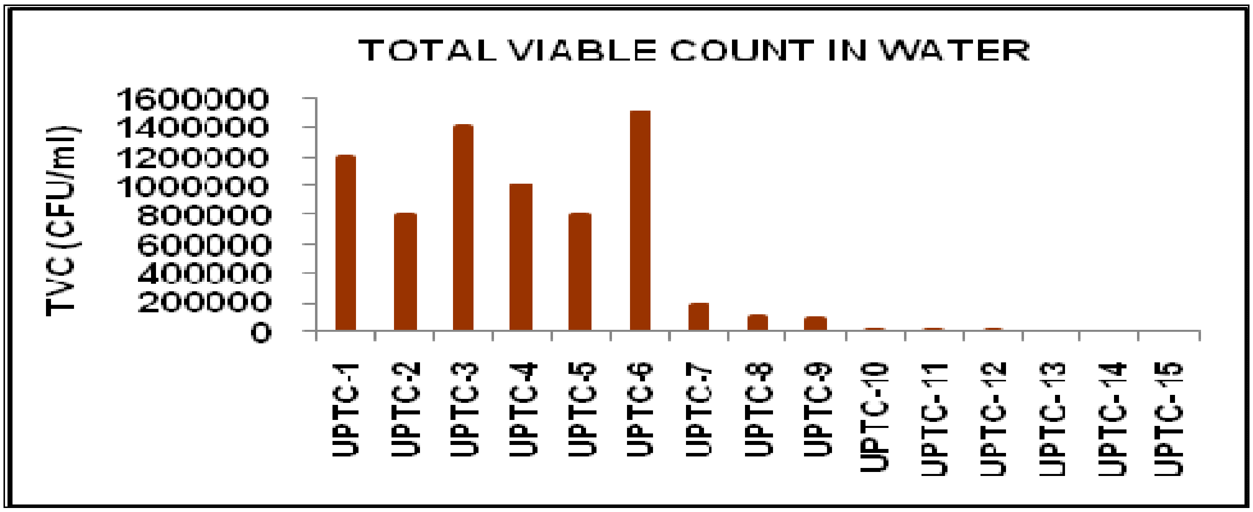
S. No.	Station Code	µg/g						
		Fe	Zn	Mn	Cd	Ni	Cr	Pb
1.	UTPC-1	6628	34.72	431.2	1.85	19.53	25.57	26.61
2.	UTPC-2	3520	80.60	319.6	1.69	16.46	30.01	26.30
3.	UTPC-3	4221	24.64	399.1	1.87	15.88	33.01	21.91
4.	UTPC-4	3904	28.47	516.1	1.62	15.39	35.43	25.53
5.	UTPC-5	3380	59.95	535.9	1.92	16.84	34.31	24.53
6.	UTPC-6	8644	40.23	502.7	2.22	19.92	32.88	26.27
7.	UTPC-7	3845	40.49	338.2	2.68	17.25	27.65	30.69
8.	UTPC-8	3978	38.75	433.0	3.13	18.57	25.50	23.17
9.	UTPC-9	3742	23.91	380.4	1.36	14.95	36.85	27.49
10.	UTPC-10	3424	27.74	497.4	2.39	23.37	29.28	17.42

11.	UTPC- 11	3677	42.28	517.2	2.86	18.96	38.17	22.82
12.	UTPC- 12	8165	39.49	484.0	3.66	22.03	28.73	24.79
13.	UTPC- 13	7115	45.07	371.6	3.13	20.33	31.48	26.61
14.	UTPC- 14	10144	52.15	325.4	2.08	23.09	32.53	26.14
15.	UTPC- 15	8203	50.65	467.5	2.99	20.00	34.02	27.96

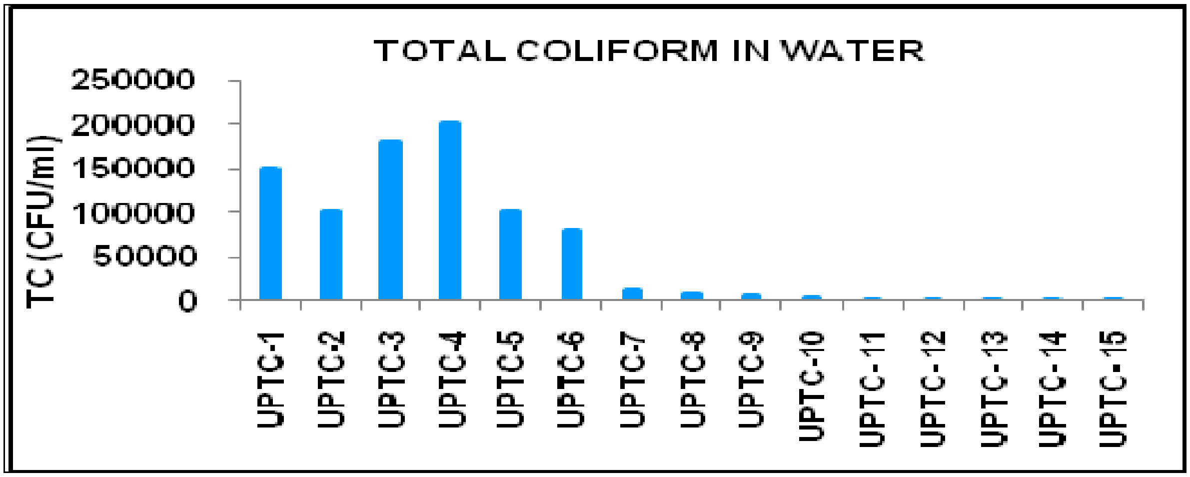
Microbiology

Water sample

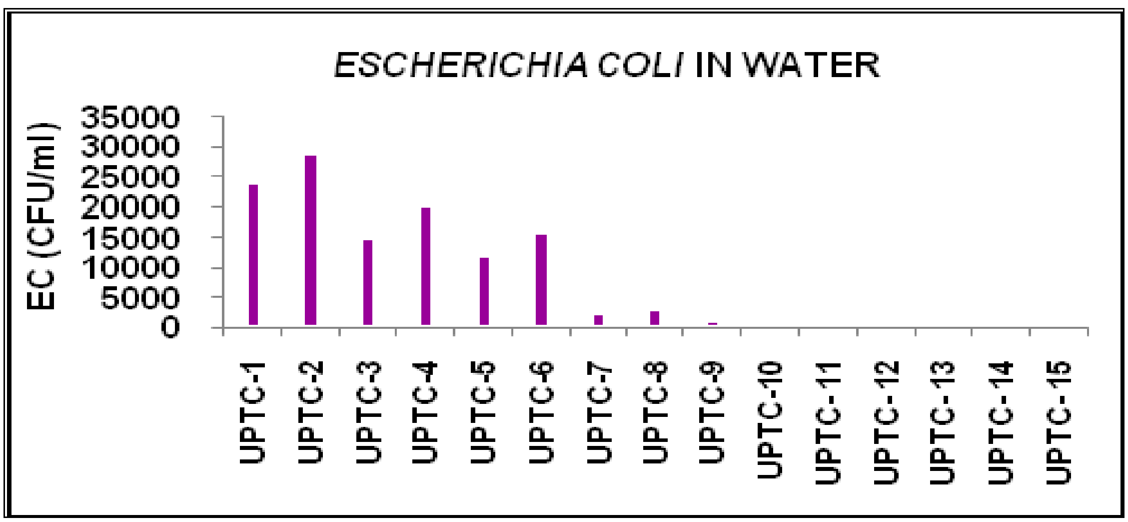
The Total Viable Count (TVC) varied from 60×10^1 to 15×10^5 with maximum at UTPC-6 and minimum at UTPC-13.



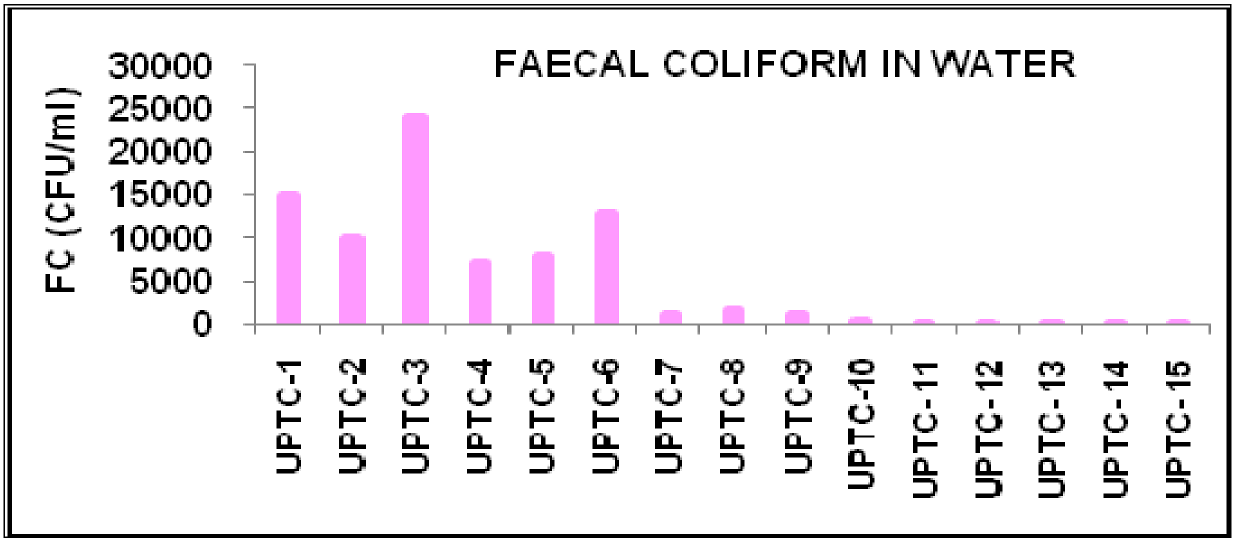
The Total Coliform varied between 80 and 20×10^4 with maximum at UTPC-4 and minimum at UTPC-14.



The *Escherichia coli* Bacteria in water sample fluctuated between 18 and 29x10^3 CFU/ml with maximum at UTPC-2 and minimum at UTPC-14 during the sample collection.



Faecal coliform varied from 10 to 24x10^3 CFU/ml with maximum at UTPC-3 and the minimum was recorded at UTPC-14.



The *Streptococcus faecalis* varied from 5 to 17x10^2. The minimum and maximum values were observed at UTPC-12&14 and UTPC-1 respectively during this survey (Table 3.40).

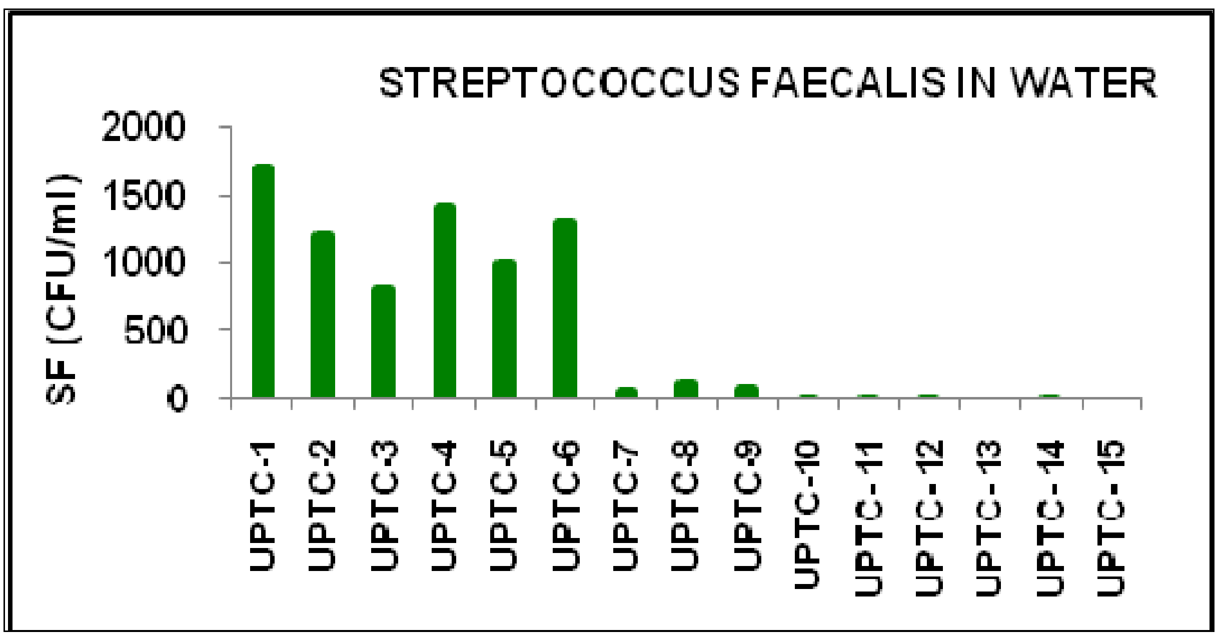


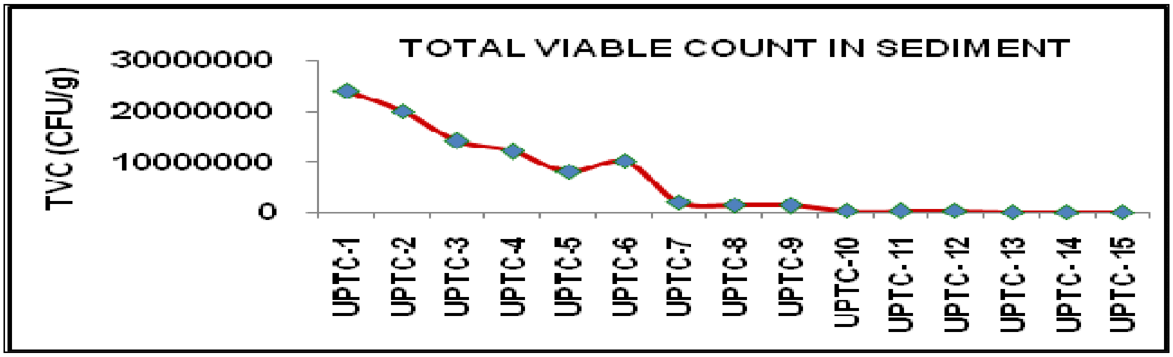
TABLE – 3.40.

MICROBIAL POPULATIONS IN WATER

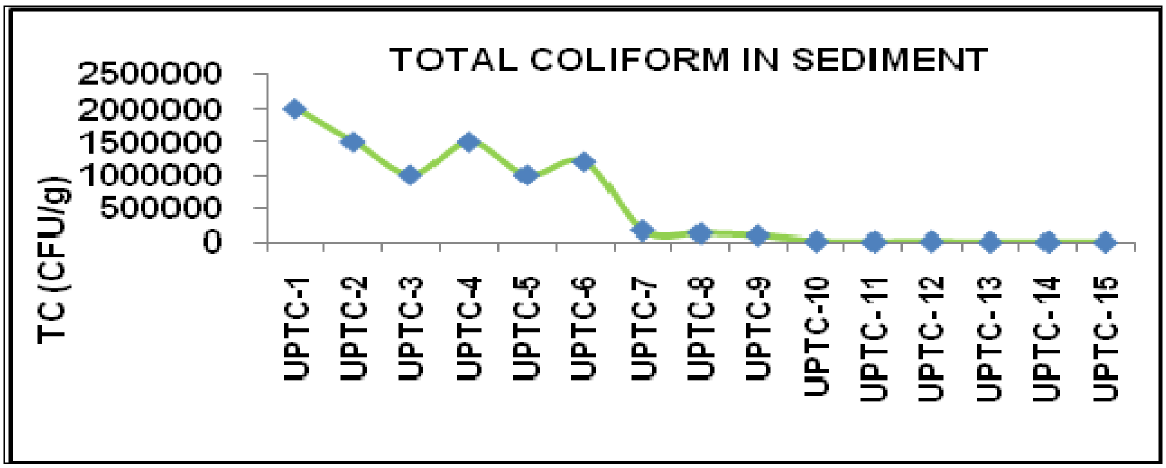
S. No.	Station Code	TVC	TC	EC	FC	SF
1.	UTPC-1	$12x10^5$	$15x10^4$	$24x10^3$	$15x10^3$	$17x10^2$
2.	UTPC-2	$08x10^5$	$10x10^4$	$29x10^3$	$10x10^3$	$12x10^2$
3.	UTPC-3	$14x10^5$	$18x10^4$	$15x10^3$	$24x10^3$	$08x10^2$
4.	UTPC-4	$10x10^5$	$20x10^4$	$20x10^3$	$07x10^3$	$14x10^2$
5.	UTPC-5	$08x10^5$	$10x10^4$	$12x10^3$	$08x10^3$	$10x10^2$
6.	UTPC-6	$15x10^5$	$08x10^4$	$16x10^3$	$13x10^3$	$13x10^2$
7.	UTPC-7	$18x10^4$	$12x10^3$	$22x10^2$	$10x10^2$	$06x10^1$
8.	UTPC-8	$10x10^4$	$07x10^3$	$28x10^2$	$16x10^2$	$12x10^1$
9.	UTPC-9	$08x10^4$	$05x10^3$	$10x10^2$	$11x10^2$	$08x10^1$
10.	UTPC-10	$18x10^3$	$15x10^2$	$07x10^1$	$15x10^1$	10
11.	UTPC- 11	$16x10^3$	$10x10^2$	$14x10^1$	$10x10^1$	07
12.	UTPC- 12	$10x10^3$	$08x10^2$	$21x10^1$	$04x10^1$	05
13.	UTPC- 13	$06x10^2$	$13x10^1$	24	13	-
14.	UTPC- 14	$11x10^2$	$08x10^1$	18	10	05
15.	UTPC- 15	$08x10^2$	$16x10^1$	20	22	-

Sediment sample

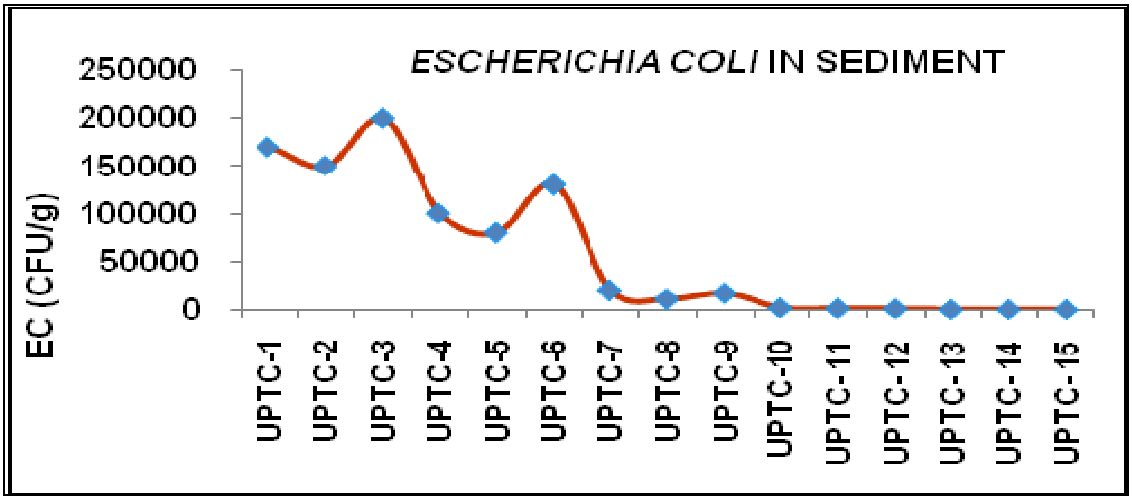
The Total Viable Count (TVC) varied from $80x10^2$ to $24x10^6$ CFU/g with maximum at UTPC-1 and minimum at UTPC-13 of sediment samples collected in Uppur Thermal Power Corporation areas.



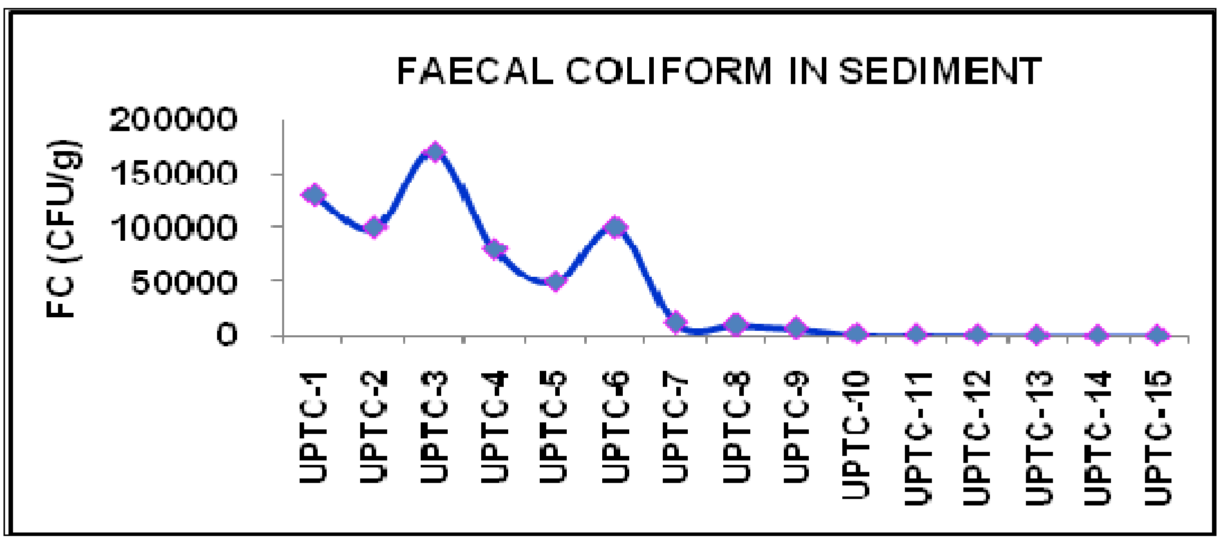
The Total Coliform varied between 80×10^1 and 20×10^5 CFU/g, the maximum was recorded at UTPC-1 and the minimum was recorded at UTPC-15.



The *Escherichia coli* Bacteria in sediment sample varied between 70 and 20×10^4 CFU/g with maximum at UTPC-3 and minimum at UTPC-15 during this survey.



Faecal coliform varied from 70 to 17×10^4 CFU/g with maximum at UTPC-3 and minimum at UTPC-14.



The *Streptococcus faecalis* varied between 50 and 13×10^3 CFU/g. The minimum was recorded at UTPC-3 and the maximum value was recorded at UTPC-1 during this survey (Table 3.41).

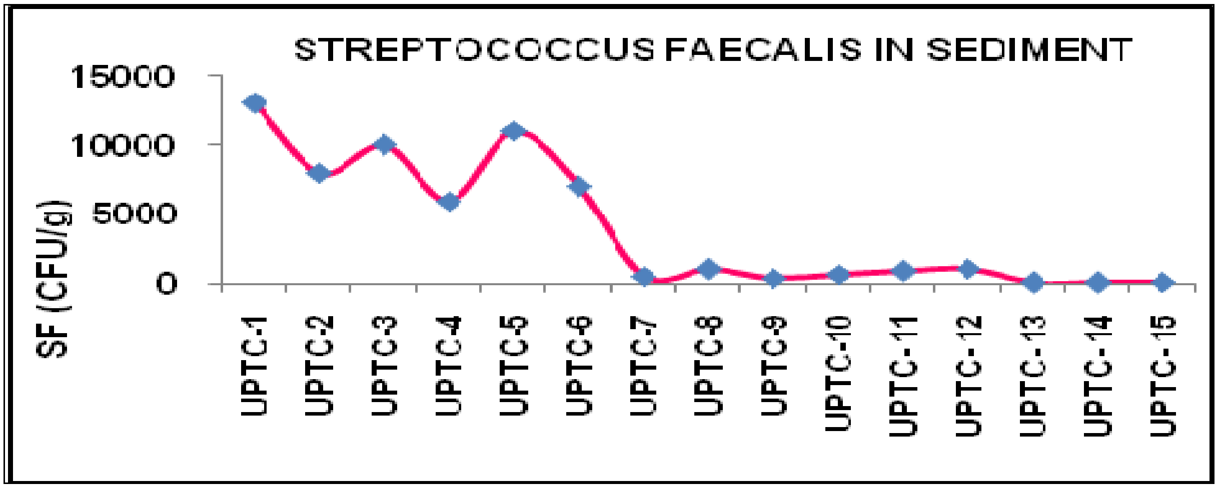


TABLE – 3.41.

MICROBIAL POPULATIONS IN SEDIMENT

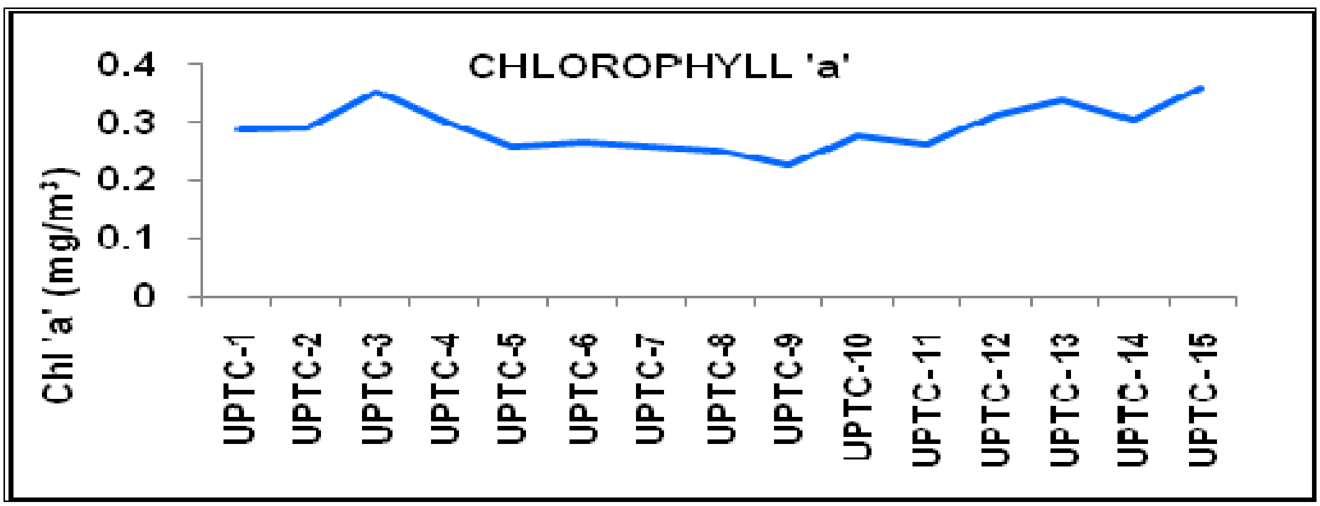
S. No.	Station Code	TVC	TC	EC	FC	SF
1.	UTPC-1	$24x10^6$	$20x10^5$	$17x10^4$	$13x10^4$	$13x10^3$
2.	UTPC-2	$20x10^6$	$15x10^5$	$15x10^4$	$10x10^4$	$08x10^3$
3.	UTPC-3	$14x10^6$	$10x10^5$	$20x10^4$	$17x10^4$	$10x10^3$
4.	UTPC-4	$12x10^6$	$15x10^5$	$10x10^4$	$08x10^4$	$06x10^3$
5.	UTPC-5	$08x10^6$	$10x10^5$	$08x10^4$	$05x10^4$	$11x10^3$
6.	UTPC-6	$10x10^6$	$12x10^5$	$13x10^4$	$10x10^4$	$07x10^3$
7.	UTPC-7	$20x10^5$	$17x10^4$	$20x10^3$	$12x10^3$	$05x10^2$
8.	UTPC-8	$14x10^5$	$13x10^4$	$11x10^3$	$10x10^3$	$10x10^2$
9.	UTPC-9	$12x10^5$	$10x10^4$	$17x10^3$	$07x10^3$	$04x10^2$
10.	UTPC-10	$20x10^4$	$13x10^3$	$20x10^2$	$13x10^2$	$07x10^2$
11.	UTPC- 11	$13x10^4$	$06x10^3$	$13x10^2$	$10x10^2$	$09x10^2$
12.	UTPC- 12	$16x10^4$	$10x10^3$	$10x10^2$	$06x10^2$	$11x10^2$

13.	UTPC- 13	$08x10^3$	$13x10^2$	$14x10^1$	$11x10^1$	$05x10^1$
14.	UTPC- 14	$14x10^3$	$11x10^2$	$09x10^1$	$07x10^1$	$08x10^1$
15.	UTPC- 15	$10x10^3$	$08x10^2$	$07x10^1$	$13x10^1$	$10x10^1$

Biological Characteristics

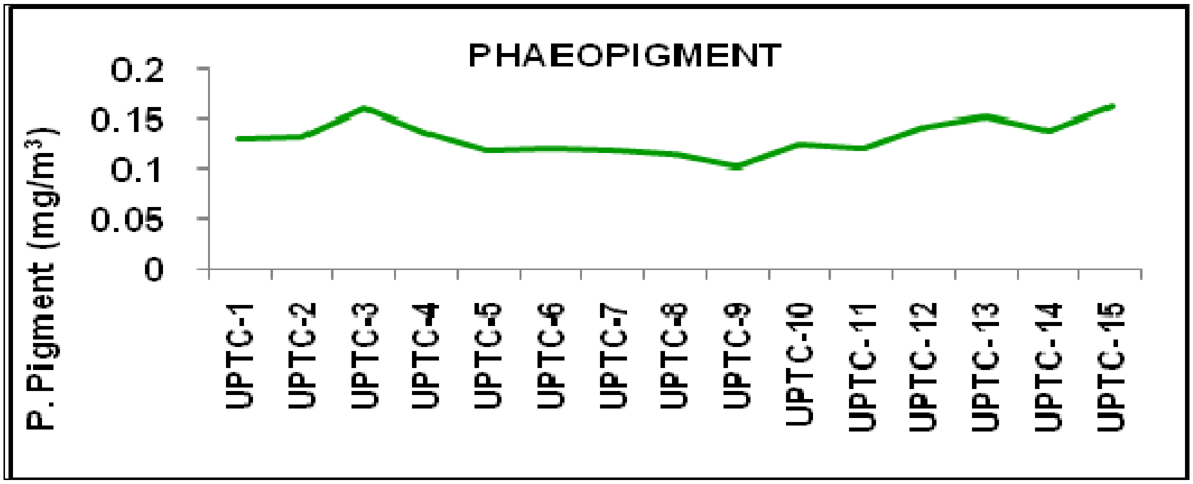
Chlorophyll ‘a’ (mg/m^3)

The chlorophyll ‘*a*’ level fluctuated between 0.227 and 0.358 mg/m^3. The maximum chlorophyll ‘a’ (0.358 mg/m^3) was observed at UTPC-15 and the minimum (0.227 mg/m^3) was recorded at UTPC-9 (Table-3.42).



Phaeopigment (mg/m^3)

In the present study, the phaeopigment in water sample varied from 0.103 to 0.162 mg/m^3 with maximum in UTPC-15 and minimum at UTPC-9 during this survey (Table 3.42).



Total Biomass (ml/100 m^3)

The total biomass in water sample varied between 20.692 and 28.181 ml/100 m^3. The minimum was recorded at UTPC-10 and the maximum was observed at UTPC-15 (Table 3.42).

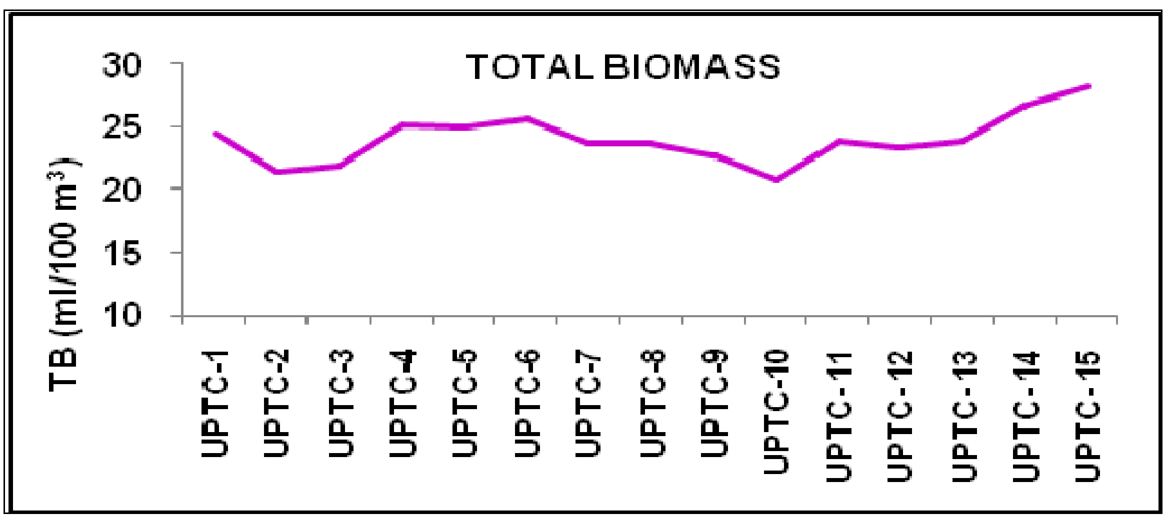


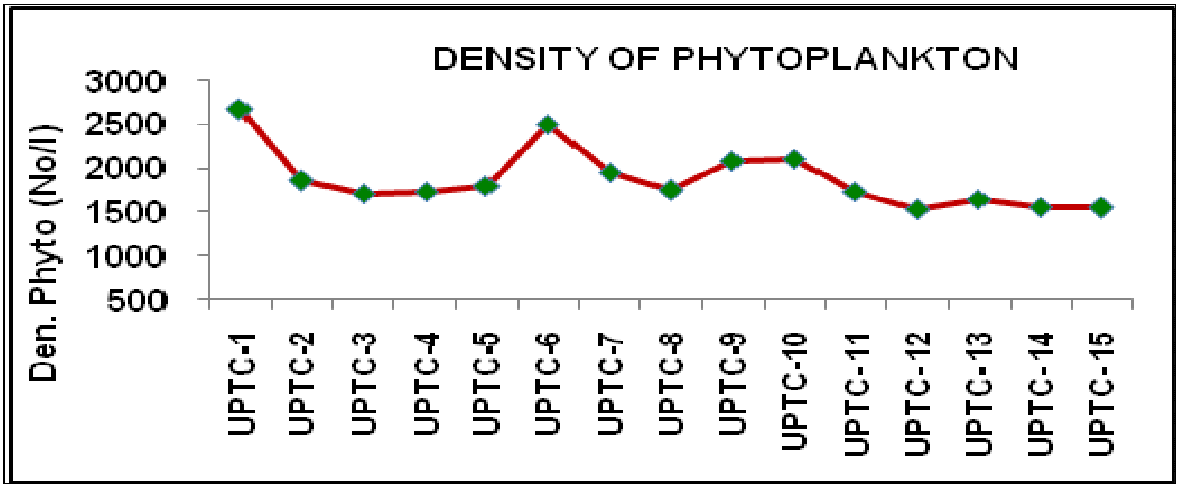
TABLE – 3.42.

BIOLOGICAL CHARACTERISTICS

S. No.	Station Code	PP (mg C/m^3/hr)	Chl 'a' (mg/m^3)	Phaeopigment (mg/m^3)	TB (ml/100m^3)
1.	UTPC-1	Unable to measure due to rain	0.286	0.130	24.537
2.	UTPC-2		0.292	0.132	21.374
3.	UTPC-3		0.352	0.160	21.915
4.	UTPC-4		0.301	0.137	25.155
5.	UTPC-5		0.259	0.118	25.031
6.	UTPC-6		0.265	0.121	25.618
7.	UTPC-7		0.260	0.119	23.648
8.	UTPC-8		0.251	0.114	23.648
9.	UTPC-9		0.227	0.103	22.662
10.	UTPC-10		0.275	0.125	20.692
11.	UTPC- 11		0.264	0.120	23.882
12.	UTPC- 12		0.313	0.143	23.404
13.	UTPC- 13		0.336	0.152	23.882
14.	UTPC- 14		0.304	0.138	26.748
15.	UTPC- 15		0.358	0.162	28.181

Phytoplankton

The phytoplankton density ranged from 1,537 to 2,672 No/l. The maximum density was recorded at UTPC-1 and the minimum was recorded at UTPC-12 during this survey (Table 3.43).



A total of 27 species of phytoplankton were identified from the study area with *Thalassiosira subtilis* dominating (702/2,672 No/l, UTPC-1) the populations. The diatom was the dominant group represented by species such as *Coscinodiscus gigas, Coscinodiscus centralis, Skeletonema costatum, Thalassiosira subtilis, Biddulphia pulchella, Odontella mobiliensis, Rhizosolenia styliformis, Ceratium macroceros* and *Pleurosigma normanii* were found in all stations.

TABLE-3.43.
PHYTOPLANKTON

S. No.	Name of the Species	No/l				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
1.	*Coscinodiscus granii*	*	38	*	*	*
2.	*Coscinodiscus gigas*	14	19	15	28	20
3.	*Coscinodiscus centralis*	28	29	*	*	41
4.	*Coscinodiscus radiatus*	19	*	*	*	*
5.	*Skeletonema costatum*	322	273	206	399	283
6.	*Cyclotella* sp.	*	*	*	*	112

7.	*Planktoniella sol*	75	39	55	*	*
8.	*Thalassisira subtilis*	702	398	378	508	325
9.	*Ditylum brightwelli*	*	*	13	*	*
10.	*Chaetoceros currvisetus*	460	213	334	*	372
11.	*Biddulphia pulchella*	168	75	152	172	128
12.	*Odontella mobiliensis*	48	*	18	24	18
13.	*Rhizosolenia styliformis*	*	*	21	22	38
14.	*Rhizosolenia alata*	28	38	29	16	30
15.	*Pleurosigma normanii*	*	60	29	*	31
16.	*Pleurosigma directum*	129	*	*	67	45
17.	*Gyrosigma* sp.	*	*	37	*	70
18.	*Nitzschia closterium*	*	*	80	116	*
19.	*Nitzschia lonigissima*	171	*	*	*	*
20.	*Dinophysis caudata*	20	24	28	29	19
21.	*Ceratium macroceros*	37	19	23	13	36
22.	*Ceratium furca*	68	31	18	*	*
23.	*Ceratium longipes*	*	13	49	19	54
24.	*Protoperidinium oceanicum*	*	21	28	*	*
25.	*Climacosphenia* sp.	383	567	206	321	181
	Total	**2672**	**1857**	**1719**	**1734**	**1803**

*** - Organisms not present**

Sl. No.	Name of the Species	No/l				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
1.	*Coscinodiscus granii*	43	*	*	*	*
2.	*Coscinodiscus thori*	*	*	42	*	*
3.	*Coscinodiscus gigas*	22	18	22	19	28
4.	*Coscinodiscus centralis*	69	56	81	55	68
5.	*Skeletonema costatum*	435	262	315	383	374
6.	*Cyclotella* sp.	136	*	*	*	*
7.	*Planktoniella sol*	*	28	50	51	47
8.	*Thalassisira subtilis*	338	445	369	261	407

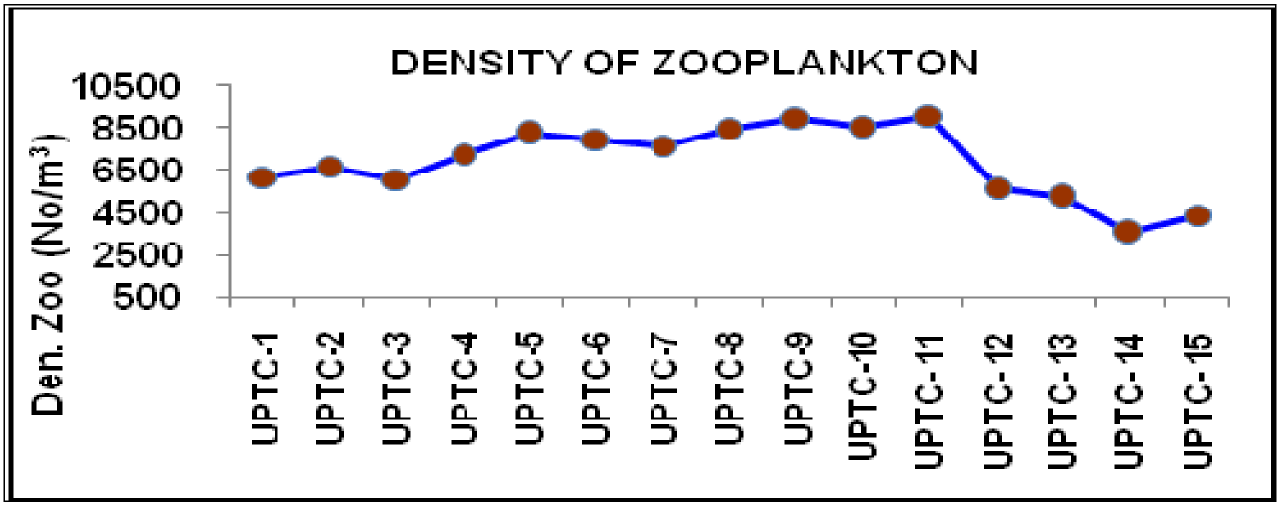
9.	*Triceratium favus*	28	37	18	47	28
10.	*Ditylum brightwelli*	*	*	11	*	*
11.	*Chaetoceros currvisetus*	436	292	270	457	320
12.	*Biddulphia pulchella*	219	183	288	282	368
13.	*Odontella mobiliensis*	40	24	*	*	*
14.	*Rhizosolenia styliformis*	33	37	*	28	21
15.	*Rhizosolenia alata*	20	*	*	*	*
16.	*Pleurosigma normanii*	69	62	36	38	38
17.	*Gyrosigma* sp.	122	79	27	76	*
18.	*Dinophysis caudata*	23	47	14	18	26
19.	*Ceratium macroceros*	46	34	14	*	*
20.	*Ceratium furca*	*	*	*	28	38
21.	*Ceratium longipes*	22	*	18	*	*
22.	*Protoperidinium oceanicum*	*	17	*	*	19
23.	*Climacosphenia* sp.	408	337	176	347	332
	Total	**2509**	**1958**	**1751**	**2090**	**2114**

*** - Organisms not present**

Zooplankton

Zooplankton includes arrays of organisms, varying in size from microscopic protozoans of a few microns to some jelly organisms with tentacles of several metres long. They play an intermediate role between phytoplankton and fish and are considered as the chief index of utilization of aquatic biotope at the secondary trophic level.

The zooplankton density ranged from 3,563 to 9,079 No/m^3 (Table 3.34). The minimum density was recorded at UTPC-14 and the maximum density was observed at UTPC-11.



In the present investigation, 32 species of zooplankton were recorded from all the stations monitored. The Copepod nauplii was found to be the dominant forms. The species such as *Acartia spinicauda, Pontella danae, Corycaeus catus, Paracalanus parvus*, *Oithona similis, Euterpina acutifrons, Globigerina bulloides,* Copepod nauplii, Gastropod veliger and Bivalve veliger were found to be common in all stations monitored during this survey.

TABLE-3.44.
ZOOPLANKTON

S. No.	Name of the Species	No/m³				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
1.	*Brachionus rubens*	*	*	187	186	196
2.	*Paracalanus* sp.	*	*	*	*	294
3.	*Paracalanus parvus*	370	465	373	373	393
4.	*Pontella danae*	*	93	93	186	196
5.	*Acrocalanus gibber*	*	*	187	*	*
6.	*Acrocalanus gracilis*	185	651	466	559	491
7.	*Nannocalanus minor*	*	*	*	186	*
8.	*Labidocera pavo*	*	186	187	93	196
9.	*Acartia spinicauda*	556	651	560	466	687
10.	*Oithona rigida*	*	*	*	93	*
11.	*Oithona brevicornis*	463	651	373	466	294
12.	*Oithona similis*	926	743	839	745	1080
13.	*Corycaeus catus*	556	93	93	186	*
14.	*Longipedia weberi*	*	93	187	373	491
15.	*Microsetella rosea*	370	558	466	559	393
16.	*Microsetella norvegica*	*	*	280	*	*
17.	*Euterpina acutifrons*	556	465	653	652	785
18.	*Metis jousseaumei*	*	*	280	*	393
19.	*Oikopleura parva*	185	186	93	186	294
20.	*Tintinnopsis tubulosa*	*	*	280	280	*
21.	*Tintinnopsis beroidea*	185	*	*	*	*
22.	*Tintinnopsis butzschi*	*	93	*	*	98
23.	*Favella philipiensis*	278	279	*	186	196
24.	*Favella brevis*	93	*	187	*	*
25.	Bivalve veliger	93	372	280	186	98
26.	Gastropod veliger	185	186	*	93	294
27.	Copepod nauplii	1204	929	*	1211	1374
	Total	**6205**	**6694**	**6064**	**7265**	**8243**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^3				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
1.	*Brachionus rubens*	296	197	*	99	*
2.	*Evadne* sp.	99	99	99	*	*
3.	*Paracalanus* sp.	296	296	394	296	197
4.	*Paracalanus parvus*	493	493	690	394	591
5.	*Pontella danae*	197	197	296	197	394
6.	*Acrocalanus gibber*	*	*	*	394	*
7.	*Acrocalanus gracilis*	591	493	394	296	493
8.	*Nannocalanus minor*	*	*	*	*	197
9.	*Tortannus barbatus*	197	296	197	99	296
10.	*Labidocera pavo*	99	197	99	*	99
11.	*Acartia spinicauda*	493	394	690	493	394
12.	*Oithona brevicornis*	394	394	394	394	394
13.	*Oithona similis*	887	788	985	887	985
14.	*Corycaeus catus*	*	*	*	197	*
15.	*Longipedia weberi*	197	296	99	493	296
16.	*Microsetella rosea*	394	296	394	394	493
17.	*Macrosetella gracilis*	*	*	296	*	197
18.	*Euterpina acutifrons*	887	591	690	887	690
19.	*Metis jousseaumei*	296	*	296	394	394
20.	*Oikopleura* sp.	*	*	99	*	*
21.	*Oikopleura parva*	296	197	296	296	99
22.	*Tintinnopsis tubulosa*	197	296	197	394	197
23.	*Tintinnopsis beroidea*	*	394	*	296	296
24.	*Tintinnopsis butzschi*	*	*	99	*	*
25.	*Favella brevis*	296	296	296	591	394
26.	Bivalve veliger	99	99	197	197	99
27.	Gastropod veliger	*	99	99	99	197
28.	Copepod nauplii	1281	1281	1182	1182	1182
	Total	**7985**	**7689**	**8478**	**8969**	**8574**

*** - Organisms not present**

Finfish Eggs

The finfish eggs density ranged between 7 and 20 No/m^3 (Table 3.45). The minimum density was recorded at UTPC-7 and the maximum density was observed at UTPC-15. A total of 17 species of finfish eggs were recorded from all the stations monitored. The *Mugil cephalus, Sardinella longipes* and *Terapon jarbua* were found to be the dominant species.

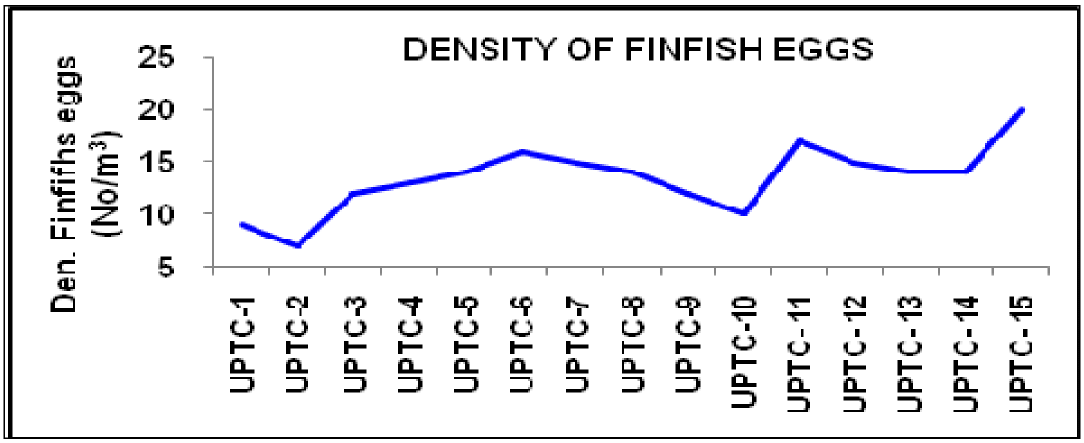


TABLE-3.45

FINFISH EGGS

Sl. No.	Name of the species	No/m^3			
		UTPC-1	UTPC-2	UTPC-3	UTPC-4
	Enraulidae				
1	*Stolephorus indicus*	2	1	3	3
2	*Thryssa mystax*	2	1	1	1
	Clupeidae				
1	*Sardinella gibbosa*	1	2	2	1
	Synodontidae				
1	*Saurida gracilis*	*	*	1	2
	Mugilidae				
1	*Mugil cephalus*	3	1	1	2
	Teraponidae				
1	*Terapon jarbua*	*	2	3	3
	Cynoglossidae				
1	*Cynoglossus punticeps*	1	*	1	1
	Total	**9**	**7**	**12**	**13**

Sl. No.	Name of the species	No/m^3			
		UTPC-5	UTPC-6	UTPC-7	UTPC-8
	Enraulidae				
1	*Stolephorus tri*	1	2	2	2
2	*Stolephorus indicus*	2	1	2	1
3	*Thryssa mystax*	0	1	1	2
	Clupeidae				
1	*Sardinella gibbosa*	2	2	2	*
2	*Sardinella longiceps*	3	3	2	*
	Mugilidae				
1	*Mugil cephalus*	3	2	1	2
2	*Liza dussumieri*	*	1	2	1
	Carangidae				
1	*Carangoides malabaricus*	1	1	1	2
	Teraponidae				
1	*Terapon jarbua*	2	1	1	1
	Siganidae				
1	*Siganus javus*	*	1	1	2
	Cynoglossidae				
1	*Cynoglossus punticeps*	*	1	*	1
	Total	**14**	**16**	**15**	**14**

*** - Organisms not present**

Sl. No.	Name of the species	No/m^3			
		UTPC-9	UTPC-10	UTPC-11	UTPC-12
	Enraulidae				
1	*Setipinna taty*	2	1	2	1
2	*Stolephorus heterolobus*	1	1	1	2
3	*Thryssa mystax*	1	1	2	2
	Clupeidae				
1	*Sardinella gibbosa*	2	2	2	2
	Mugilidae				
1	*Mugil cephalus*	3	2	3	3
	Carangidae				
1	*Carangoides malabaricus*	1	1	2	1
2	*Carangoides* sp.	*	*	1	*
	Teraponidae				
1	*Terapon jarbua*	2	2	3	2
	Scombridae				
1	*Scomberomorus* sp.	*	*	1	2
	Total	**12**	**10**	**17**	**15**

Sl. No.	Name of the species	No/m^3		
		UTPC-13	UTPC-14	UTPC-15
	Enraulidae			
1	*Setipinna taty*	2	1	2
2	*Stolephorus tri*	1	*	1
3	*Thryssa mystax*	2	2	2
	Chirocentridae			
1	*Chirocentrus dorab*	*	*	2
	Clupeidae			
1	*Sardinella gibbosa*	2	3	2
	Synodontidae			
1	*Saurida gracilis*	1	1	2
	Mugilidae			
1	*Mugil cephalus*	3	3	3
	Carangidae			
1	*Carangoides malabaricus*	*	1	2
	Teraponidae			
1	*Terapon jarbua*	2	2	3
	Scombridae			
1	*Scomberomorus* sp.	1	1	1
	Total	**14**	**14**	**20**

*** - Organisms not present**

Finfish Larvae

The finfish larvae ranged from 2 to 7 No/m^3 (Table 3.46). The maximum number of finfish larvae observed at UTPC-12 & 15 and the minimum number of finfish larvae recorded at UTPC-1. A total of 12 species of finfish larvae were identified from all the stations monitored. The *Liza dussumieri, Mugil cephalus, Stolephorus indicus, Saurida gracilis* and *Thryssa mystax* were found to be the dominant species.

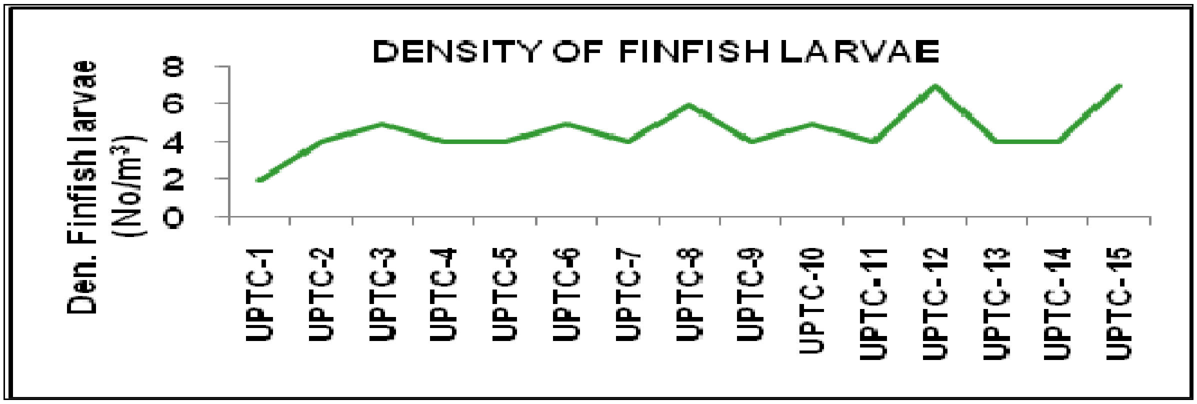


TABLE-3.46.

FINFISH LARVAE

Sl. No.	Name of the species	No/m^3			
		UTPC-1	UTPC-2	UTPC-3	UTPC-4
	Enraulidae				
1	*Stolephorus indicus*	*	2	1	*
2	*Thryssa mystax*	*	1	2	2
	Clupeidae				
1	*Sardinella gibbosa*	1	*	2	1
	Teraponidae				
1	*Terapon jarbua*	1	1	*	1
	Total	**2**	**4**	**5**	**4**

Sl. No.	Name of the species	No/m^3			
		UTPC-5	UTPC-6	UTPC-7	UTPC-8
	Enraulidae				
1	*Stolephorus tri*	*	1	*	1
2	*Thryssa mystax*	*	*	*	1
	Mugilidae				
1	*Mugil cephalus*	1	2	1	1
2	*Liza dussumieri*	1	1	1	2
	Carangidae				
1	*Carangoides malabaricus*	1	*	1	*
	Teraponidae				
1	*Terapon jarbua*	1	1	1	1
	Total	**4**	**5**	**4**	**6**

Sl. No.	Name of the species	No/m^3			
		UTPC-9	UTPC-10	UTPC-11	UTPC-12
	Enraulidae				
1	*Setipinna taty*	*	*	*	1
2	*Stolephorus heterolobus*	*	*	1	*
3	*Thryssa mystax*	*	1	*	1
	Clupeidae				
1	*Sardinella gibbosa*	1	1	1	1
	Mugilidae				
1	*Mugil cephalus*	2	2	1	2
	Teraponidae				

1	*Terapon jarbua*	1	1	1	1
	Scombridae				
1	*Scomberomorus* sp.	*	*	*	1
	Total	**4**	**5**	**4**	**7**

*** - Organisms not present**

Sl. No.	Name of the species	No/m^3		
		UTPC-13	UTPC-14	UTPC-15
	Enraulidae			
1	*Stolephorus tri*	*	*	1
3	*Thryssa mystax*	1	*	*
	Clupeidae			
1	*Sardinella gibbosa*	1	2	2
	Synodontidae			
1	*Saurida gracilis*	1	1	2
	Mugilidae			
1	*Mugil cephalus*	1	1	2
	Total	**4**	**4**	**7**

*** - Organisms not present**

Benthic Organisms

Benthic animals are divided into three categories, microfauna, meiofauna and macrofauna depending on their size. Macrobenthic organisms are animal species with body size larger than 0.5 mm. Benthic community responses to environmental perturbations are useful in assessing the impact of anthropogenic perturbations on environmental quality.

Macrobenthos:

The macrobenthos density varied from 325 to 1,050 No/m^2. The minimum was recorded at UTPC-1 and the maximum was observed at UTPC-5. In the present investigation, 60 species of macrobenthos were recorded from the study area and most of the species were found in all the stations. The *Cerithedia cingulata* (200/1,000 No/m^2, UTPC-6) was found to be the dominant forms during this survey (Table 3.47).

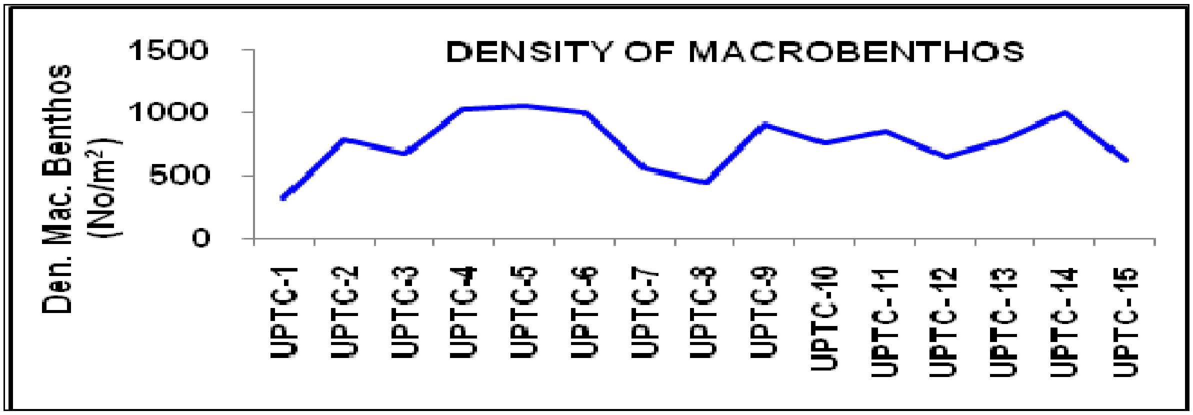


TABLE-3.47.

MACROBENTHOS

Sl. No.	Name of the Species	No/m^2				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
	Polychaetes					
1.	*Autolytus charcoti*	*	*	25	*	25
2.	*Ampharete acutifrons*	50	*	*	50	*
3.	*Armandia intermedia*	*	*	*	75	*
4.	*Capitella capitata*	*	125	*	*	*
5.	*Chone* sp.	*	*	25	*	50
6.	*Cirratulus africanus*	*	*	*	25	*
7.	*Cossura coasta*	50	*	*	125	75
8.	*Euchone* sp.	*	*	*	*	50
9.	*Exogone clavator*	25	*	*	75	*
10.	*Goniada emerita*	*	75	*	100	50

11.	*Lumbrineris* sp.	*	*	25	*	*
12.	*Maldane* sp.	*	*	25	*	100
13.	*Nephtys dibranchis*	*	75	*	25	*
14.	*Nereis capensis*	*	*	50	*	*
15.	*Notomastus aberrans*	*	*	*	*	75
16.	*Pygospio elegans*	*	*	*	50	25
17.	*Tharyx* sp.	*	*	25	*	*
18.	*Pista* sp.	*	*	*	75	*
19.	*Spionidae* sp.	*	*	50	*	25
20.	*Notomastus* sp.	*	75	25	*	*
21.	*Pysidice natalensis*	*	*	*	*	25
22.	*Cirratulus chrysomderma*	*	25	*	25	*
23.	*Platynereis* sp.	*	*	50	*	*
24.	*Prionospio pinnata*	*	25	*	*	100
25.	*Prionospio cirrifera*	*	50	*	*	75
26.	*Sabellides* sp.	25	*	*	75	*
27.	*Syllis gracilis*	*	*	100	*	75
28.	*Syllidia armata*	25	*	*	50	*
	Bivalves					
1.	*Anadara granosa*	*	25	*	*	75
2.	*Donax* veligers	50	*	*	*	*
3.	*Meretrix meretrix*	*	*	50	*	25
4.	*Placenta placenta*	*	*	*	75	*
	Gastropods					
1.	*Nassarius stolatus*	25	75	*	*	*
2.	*Bullia tranquebaria*	*	*	75	25	125
3.	*Umbonium vestiarium*	75	175	50	*	*
4.	*Oliva nebulosa*	*	*	*	50	*
	Crustaceans					
1.	Penaeid shrimp larvae	*	*	*	*	25
	Amphipods					
1.	*Grandidierella* sp.	*	*	50	*	*

2.	*Ampithoe rubricata*	*	*	25	50	*
3.	*Urothoe* sp.	*	25	*	*	*
4.	*Phaxocephalus holbolli*	*	*	*	25	50
	Isopods					
1.	*Angeliera phreaticola*	*	*	25	*	*
2.	*Jaeropsis beuroisi*	*	25	*	*	*
3.	*Mirocerberus* sp.	*	*	*	50	*
	Total	**325**	**775**	**675**	**1025**	**1050**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^2				
		UTPC-6	UTPC-7	UTPC-8	UTPC-9	UTPC-10
	Polychaetes					
1.	*Autolytus charcoti*	*	50	*	125	*
2.	*Ampharete acutifrons*	*	*	*	75	*
3.	*Armandia intermedia*	25	*	*	*	100
4.	*Capitella capitata*	50	25	125	175	*
5.	*Chone* sp.	*	*	*	50	*
6.	*Cirriformia* sp.	75	*	*	*	75
7.	*Cossura coasta*	*	25	50	*	*
8.	*Eunice* sp.	*	*	*	25	50
9.	*Eunice antennata*	25	25	*	*	*
10.	*Exogone clavator*	50	*	25	*	*
11.	*Goniada emerita*	*	*	*	100	*
12.	*Lumbrineris heteropoda*	*	*	*	*	50
13.	*Lumbrineris* sp.	125	*	*	*	*
14.	*Maldane* sp.	*	50	*	*	*
15.	*Nephtys dibranchis*	50	*	*	*	100
16.	*Nereis capensis*	25	50	*	75	*
17.	*Owenia fusiformis*	*	*	*	25	25
18.	*Pista* sp.	50	25	*	*	*
19.	*Notomastus* sp.	25	*	*	50	*
20.	*Platynereis* sp.	*	*	25	*	*

21.	*Prionospio pinnata*	*	50	*	75	*
22.	*Prionospio cirrifera*	150	*	50	*	25
23.	*Prionospsio malmgreni*	*	*	50	*	*
24.	*Diopatra neapolitana*	*	*	25	*	*
25.	*Sabellides* sp.	*	25	*	*	*
26.	*Spiophanes bombyx*	*	*	*	*	25
27.	*Syllis gracilis*	*	25	*	25	*
	Bivalves					
1.	*Anadara granosa*	*	25	*	*	75
2.	*Meretrix meretrix*	*	50	*	50	*
3.	*Placenta placenta*	*	*	25	*	*
	Gastropods					
1.	*Bullia tranquebaria*	*	50	*	*	*
2.	*Cerithedia cingulata*	200	*	50	*	*
3.	*Oliva nebulosa*	*	25	*	*	*
4.	*Natica* sp.	*	*	25	25	*
	Amphipods					
1.	*Gammarus* sp.	25	25	*	25	75
2.	*Grandidierella* sp.	50	*	*	*	*
3.	*Ampithoe rubricata*	25	*	*	*	100
4.	*Phaxocephalus holbolli*	*	25	*	*	*
5.	*Harnellia incerta*	*	*	*	*	50
	Isopods					
1.	*Angeliera phreaticola*	50	*	*	*	*
	Total	**1000**	**550**	**450**	**900**	**750**

*** - Organisms not present**

Sl. No.	Name of the Species	No/m^2				
		UTPC-11	UTPC-12	UTPC-13	UTPC-14	UTPC-15
	Polychaetes					
1.	*Autolytus charcoti*	*	50	*	25	100
2.	*Ampharete acutifrons*	50	25	*	25	*
3.	*Armandia intermedia*	*	50	50	*	*
4.	*Capitella capitata*	75	*	*	*	50
5.	*Chone* sp.	*	25	25	*	*
6.	*Cirriformia* sp.	*	*	50	25	25
7.	*Cossura coasta*	100	*	*	25	*
8.	*Eunice* sp.	*	*	25	*	50
9.	*Euclymene* sp.	*	*	*	*	25
10.	*Exogone clavator*	25	*	75	50	*
11.	*Goniada emerita*	50	*	125	*	*
12.	*Lumbrineris heteropoda*	25	*	*	50	*
13.	*Maldane* sp.	*	*	75	*	*
14.	*Nephtys dibranchis*	*	75	*	125	*
15.	*Nereis capensis*	25	*	*	50	50
16.	*Pygospio elegans*	*	50	*	25	*
17.	*Pista* sp.	*	*	*	*	25
18.	*Spionidae* sp.	50	*	25	25	*
19.	*Notomastus* sp.	25	*	*	25	*
20.	*Platynereis* sp.	50	*	*	25	*
21.	*Prionospio pinnata*	*	125	*	175	50
22.	*Prionospio cirrifera*	*	*	75	*	*
23.	*Prionospsio malmgreni*	25	*	*	50	*
24.	*Diopatra neapolitana*	25	*	*	*	*
25.	*Sabellides* sp.	50	25	*	50	25
26.	*Syllis gracilis*	*	75	125	50	25
	Bivalves					

1.	*Anadara granosa*	*	*	25	25	50
2.	*Meretrix meretrix*	25	*	*	*	*
3.	*Pecten* sp.	*	75	*	25	*
4.	*Placenta placenta*	50	*	*	*	*
5.	*Circe scripta*	50	*	*	25	*
	Gastropods					
1.	*Cerithedia cingulata*	75	*	*	25	75
2.	*Natica* sp.	*	*	*	*	25
3.	*Cymatium lingulatum*	*	*	*	*	25
	Crustaceans					
1.	Penaeid shrimp larvae	*	50	*	25	*
	Amphipods					
1.	*Ampithoe rubricata*	*	*	25	50	*
2.	*Urothoe* sp.	25	*	*	*	*
3.	*Harnellia incerta*	*	25	75	*	25
	Isopods					
1.	*Angeliera phreaticola*	50	*	*	25	*
	Total	**850**	**650**	**775**	**1000**	**625**

*** - Organisms not present**

Meiobenthos:

The meiobenthos in the bottom sediment ranged between 3 and 52 No/10 cm^2 (Table -3.48). The minimum density of meiobenthos was recorded at UTPC-6 and the maximum was recorded at UTPC-8. Most of the species were found in all the stations. Totally 33 species of meiobenthos were recorded in the present study period. The *Cibicides lobatus, Cyprideis* sp., *Rosalina globularis, Rotalia translucens* and *Triloculina austriaca* were found to be the dominant forms during this survey.

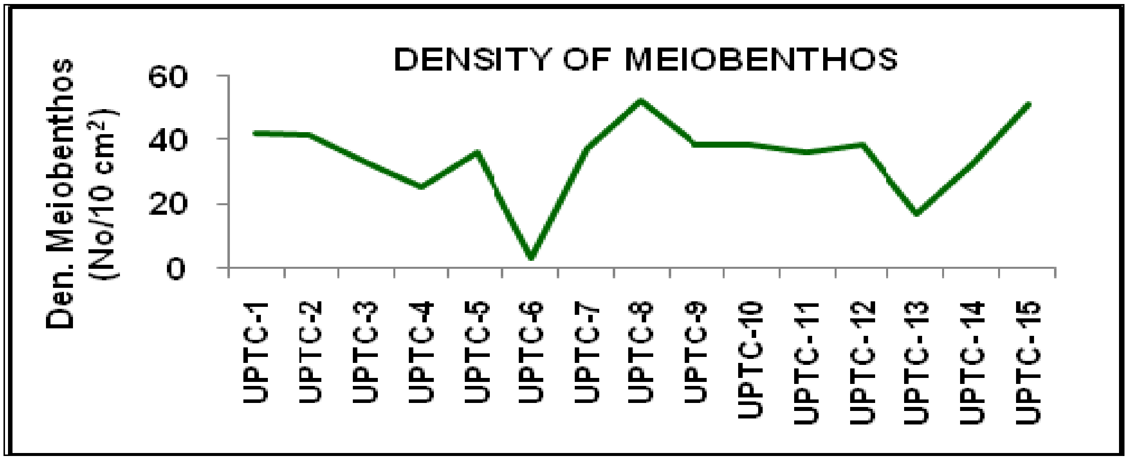


TABLE-3.48.

MEIOBENTHOS

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-1	UTPC-2	UTPC-3	UTPC-4	UTPC-5
	Nematodes					
1.	*Astonema* sp.	2	3	1	*	*
2.	*Enoploides* sp.	3	*	*	2	*
3.	*Pselionema* sp.	1	*	*	*	*
4.	*Quadricoma* sp.	4	*	*	1	3
	Foraminiferans					
1.	*Ammonia beccarii*	3	4	*	4	*
2.	*Cibicides lobatulus*	*	3	4	*	7
3.	*Cornoboides advena*	5	6	*	4	3
4.	*Eliphidium* sp.	*	*	2	*	*
5.	*Globigerina ruber*	6	4	3	*	5
6.	*Hauerina miocenica*	*	3	3	*	*
7.	*Neoconorbina crustata*	*	1	*	*	*
8.	*Quinqueloculina* sp.	*	3	*	4	3
9.	*Rosalina bradyi*	3	1	3	*	1
10.	*Rotalia pulchella*	*	*	*	2	*
11.	*Ammonia pauciloculata*	*	1	*	*	1
12.	*Cyprideis langae*	1	1	*	2	*

13.	*Eponides tuberculata*	2	1	*	*	1
14.	*Globigerinita glutinata*	3	2	*	*	2
15.	*Spiroloculina* sp.	*	*	1	*	1
16.	*Triloculina austriaca*	1	*	4	2	5
	Harpacticoids					
1.	*Euterpina acutifrons*	*	*	1	*	*
	Ostrocodes					
1.	*Cyprideis* sp.	5	7	7	3	4
2.	*Cypridina* sp.	2	1	3	*	*
3.	*Tanella indica*	*	*	1	*	*
4.	*Phlycieno phoraaff*	1	*	*	1	*
	Total	**42**	**41**	**33**	**25**	**36**

*** - Organisms not present**

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-6	**UTPC-7**	**UTPC-8**	**UTPC-9**	**UTPC-10**
	Nematodes					
1.	*Astonema* sp.	*	2	*	3	*
2.	*Enoploides* sp.	*	*	3	4	3
3.	*Quadricoma* sp.	*	1	*	*	6
	Foraminiferans					
1.	*Ammonia beccarii*	*	2	3	*	2
2.	*Cornoboides advena*	1	4	3	5	5
3.	*Eliphidium* sp.	*	4	*	3	*
4.	*Globigerina ruber*	*	4	1	3	*
5.	*Hauerina miocenica*	*	5	*	*	*
6.	*Quinqueloculina* sp.	*	1	1	*	2
7.	*Rosalina bradyi*	*	3	*	*	*
8.	*Rosalina globularis*	*	*	7	5	5
9.	*Ammonia pauciloculata*	*	2	*	*	*
10.	*Cyprideis langae*	*	*	5	*	*

11.	*Eponides tuberculata*	*	*	*	*	1
12.	*Rotalia translucens*	*	*	7	5	4
13.	*Triloculina austriaca*	1	3	7	4	3
	Harpacticoids					
1.	*Canuella* sp.	*	*	1	*	*
	Ostrocodes					
1.	*Cyprideis* sp.	*	3	5	5	3
2.	*Cypridina* sp.	*	1	*	*	*
3.	*Tanella indica*	1	*	6	1	4
4.	*Phlycieno phoraaff*	*	2	*	*	*
5.	*Sderochilus* sp.	*	*	3	*	*
	Total	**3**	**37**	**52**	**38**	**38**

*** - Organisms not present**

Sl. No.	Name of the Species	No/10 cm^2				
		UTPC-11	**UTPC-12**	**UTPC-13**	**UTPC-14**	**UTPC-15**
	Nematodes					
1.	*Astonema* sp.	4	3	*	*	2
2.	*Desmodora falcatus*	*	*	*	*	1
3.	*Enoploides* sp.	*	6	*	4	*
4.	*Quadricoma* sp.	3	*	*	*	*
	Foraminiferans					
1.	*Ammonia beccarii*	*	*	*	*	4
2.	*Cornoboides advena*	2	5	1	3	7
3.	*Eliphidium* sp.	1	*	1	2	4
4.	*Eponides repandus*	*	*	*	*	4
5.	*Globigerina ruber*	2	*	1	*	3
6.	*Hauerina miocenica*	1	*	*	1	4
7.	*Rosalina globularis*	3	2	1	7	*
8.	*Cyprideis langae*	2	*	1	*	2
9.	*Eponides tuberculata*	*	*	*	1	*

10.	*Rotalia translucens*	5	7	3	2	1
11.	*Textularia agglutinans*	*	*	*	*	2
12.	*Triloculina austriaca*	4	6	4	5	3
	Harpacticoids					
1.	*Euterpina acutifrons*	*	1	*	*	1
2.	*Canuella* sp.	1	*	1	*	*
3.	*Stenhelia* sp.	*	*	*	*	3
	Ostrocodes					
1.	*Cyprideis* sp.	6	4	2	3	3
2.	*Cypridina* sp.	*	*	*	*	4
3.	*Tanella indica*	2	4	*	4	3
4.	*Sderochilus* sp.	*	*	2	*	*
	Total	**36**	**38**	**17**	**32**	**51**

*** - Organisms not present**

SEAGRASS AND ASSOCIATED FAUNAL ASSEMBLAGES IN UPPUR COAST

Seagrass

In the 10 km radius of the proposed project area eight species of seagrasses namely *S. isoetifolium, C. serrulata, C. rotundata, H. ovalis, H. pinifolia, H. uninervis, T. hemprichii* and *E. acoroides* were identified. The region from Thondi to Devipattinam has seagrass beds along the shore from 0.5 km to 2 km perpendicular to the shore and is occupied by sparse to dense seagrass beds depending on the local geomorphological features.

During all the three seasons of survey carried out during June 2013, September 2013 and January 2014 there were no sightings of any mammals or rare or endangered species that inhabit the seagrass ecosystem including Dugong dugon in the study area. Sivakumar and Nair,2013 have also confirmed the same that there had been no reports by scientists or researchesrs for the presence of Dugong in the proposed project area. Currently the largest population of dugongs in India is believed to be in the Gulf of Mannar followed by the Andaman and

Nicobar Islands, although the population size in each of these regions is presumed to be very small (Sivakumar 2006; Choudhury and Sivakumar 2007).

Fishery resources

The project area falls in Tuticorin coast of Gulf of Mannar, which is endowed with rocky bottom, coral reefs and sea grass beds with characteristic flora and fauna. Fishery resources of this region were exploited by a variety of gears during 2000-2005 with the average annual catch 36,851 tonnes. Major gears used and their contribution to the fishery are trawls (67.2%), mini-trawls (4.0%), gillnets (22.8%), hooks and line (3.3%) and shore seines (2.7%). Among the catches, bony fishes belonging 73 families under 14 orders forms the major catch (91.7%). Other constituents of the catch are elasmobranchs (3.66%), crustaceans (1.93%), mollusks (1.8%), seacucumber (0.01%) and other non-edible biota (0.09%).The average annual catch of teleosts during the period 2008-2010 was 33808.1 tonnes. Order Perciformes contribute major teloest catches with 64.2% (23, 658.34 tonnes) and 63.06% (23, 341.02 tonnes). The perciformes fishery distinguishes with 41 families such as Carangidae (13.98%), Lethrinidae (5.565%), Leiognathidae (8.29%), Nemipteridae (5.33%), Scombridae (6.56%) and Sphyraenidae (5.25%). *Selar crumenophthalmus*, *Lethrinus nebulosus*, *Leiognathus dussumieri*, *Nemipterus delagoae*, *Rastrelliger kanagurta* and *Sphyraena jello* contributed dominantly in perciformes fishery. The Major exploited marine resources, average annual catch and percentage contribution by weight in the project area along the Tuticorin coast during 2000-2005 are given in Table-3.49.

Table-3.49

Average annual catch and percentage contribution by weight of marine resources of Tuticorin coast - 2000-2005.

Sl. No.	Major groups	Catch (kg)	% of total catch
1.	Teleosts	33792749	91.70
2.	Elasmobranchs	1347426	3.66
3.	Crustaceans	710426	1.93
4.	Molluscs	664245	1.80
5.	Sea cucumber	4699	0.01
6.	Other groups	331841	0.90
Total		36851387	100.00

Major orders representing the exploited bony fish resources of Tuticorin region, number of suborders and families under different order and their relative abundance during 2000-2005 are given in Table-3.50.

. **TABLE-3.50**

Major orders, suborders and families of bony fish and their relative abundance of Tuticorin coast, 2000-2005

Sl. No.	Order	Sub-orders (No)	Families (No)	% in total fish catch	% in bony fish catch
1.	Elopiformes	-	2	0.78	0.85
2.	Clupeiformes	-	3	20.35	22.20
3.	Anguiliformes	-	3	0.06	0.07
4.	Siluriforrmes	-	2	1.04	1.14
5	Gonorhynchiformes	-	1	0.03	0.03
6	Myctophiformes	-	2	1.62	1.77
7	Atherineformes	-	1	0.08	0.09
8	Beloniformes	-	3	1.88	2.05

9	Beryciformes	-	1	0.18	0.20
10	Syngnathiformes	-	2	0.05	0.06
11	Scorpioniformes	-	1	0.20	0.22
12	Perciformes	9	41	58.50	63.80
13	Pleuronectiformes	-	4	0.23	0.25
14	Tetraodontiformes	-	7	6.52	7.11
15	Other bonyfishes	-	-	0.17	0.18
	Total	9	73	91.70	100.00

The Composition of the families of fishes contributing to the exploited marine bonyfish fishery resource of Tuticorin during 2000-2005 are given in Table-3.51

Table 3.51

Composition of the families of bonyfish of the exploited marine fishery resource of Tuticorin -2000-2005

Order	Sub-order	Family	% in total
Elopiformes		Elopidae	0.16
		Megalopidae	0.69
Clupeiformes		Clupeidae Engraulidae Chirocentridae	15.92 5.20 1.08
Anguilliformes		Anguilidae Muraenidae Muraenesocidae	0.04 0.02 0.01
Siluriformes		Aridae Plotosidae	0.97 0.17
Gonorhynchiformes		Chanidae	0.03
Myctophiformes		Myctophidae Synodontidae	0.01 1.76
Atheriniformes		Atherinidae	0.09
Beloniformes		Hemiramphidae Exocoetidae Belonidae	0.24 0.54 1.27
Beryciformes		Holocentridae	0.20
Syngnathiformes		Syngnathidae	0.01

Order	Sub-order	Family	% in total
		Fistularidae	0.05
Scorpioniformes		Platycephalidae	0.22
Perciformes	Percoidei	Serranidae	2.30
		Centropomidae	0.28
		Lutjanidae	1.68
		Lethrinidae	5.49
		Ambassidae	0.00
		Pomadasydae	0.61
		Rachycentridae	0.47
		Carangidae	14.08
		Nemipteridae	5.43
		Sciaeneidae	1.83
		Mullidae	3.50
		Priacanthidae	0.45
		Teraponidae	0.30
		Coryphaenidae	0.09
		Lactaridae	0.54
		Gerridae	0.26
		Apogonidae	0.07
		Sillaginidae	1.26
		Echeinidae	0.02
		Leognathidae	8.23
		Lobotidae	0.03
		Emmelichthydae	0.21
		Drepanidae	0.31
		Platacidae	0.04
		Scatophagidae	0.09
		Chaetodontidae	0.05
		Pomacanthidae	0.38
		Menidae	0.11
	Mugilloidei	Mugilidae	0.16
	Sphyraenoidei	Sphyraenidae	5.20
	Polynemoidei	Polynemidae	0.17
	Labrodei	Scaridae	1.05
	Acanthuroidei	Acanthuridae	0.37
		Siganidae	0.79
	Scombroidei	Scombridae	6.59

Order	Sub-order	Family	% in total
		Trichiuridae Gemphylidae	0.75 0.07
	Xiphioidei	Xiphidae Istiophoridae	0.001 0.20
	Stromateoidei	Stromatidae Ariommidae	0.15 0.10
Pleuronectifirmes		Psettodidae Bothidae Soleidae Cynoglossidae	0.07 0.02 0.09 0.07
Tetraodontiformes		Triodontidae Tetraodontidae Triacanthidae Ballistidae Diodontidae Ostracidae Molidae	0.11 0.16 0.001 6.71 0.07 0.05 0.01
Other bony fishes			0.25

Miscellaneous biota

Other non-edible components like Squilla, echinoderms, molluscan shells etc are grouped as miscellaneous. They form about 0.9% of the total catch of the region.

SUMMARY AND CONCLUSION:

The surface water temperature varied from 22.0 to 22.5°C. The variation of temperature noticed at various stations may be as a result of season, geographical location and sampling time. The salinity varied from 30.0 to 31.0 ‰. Hydrogen ion concentration in surface waters remained alkaline and the maximum value of 8.1 was recorded at UTPC-2, 4, 6, 8, 10, 12, 13 and UTPC-15. The observations made on the prime physical factor TSS and turbidity were within the permissible level. The observed turbidity ranged between 3.9 and 13.63 NTU. The TSS values fluctuated from 46.4 to 127.2 mg/l. The maximum

TSS and turbidity values were found to record at UTPC-11 and UTPC-6 respectively.

The ecologically sensitive chemical parameters such as Oxygen, BOD, nutrients and heavy metals were also at the optimal concentration coincided with the seasonal variation. The Dissolved Oxygen and BOD were found to be normal level. The observed oxygen level was fluctuated from 6.012 to 6.367 mg/l, the maximum DO level was recorded at UTPC-13 during this survey and the minimum was recorded at UTPC-3. The present study revealed that the DO concentration remained fairly well prescribed within the range of the values of water quality.

The BOD level was found to be ranged from 0.46 to 0.96 mg/l, the maximum BOD observed at UTPC-5 during this survey. In the present investigation, the ammonia concentration was ranged between 0.042 and 0.108 µmol/l. The concentration of nitrite fluctuated from 0.134 to 0.458 µmol/l. The nitrate values ranged from 5.965 to 9.801 µmol/l and the total nitrogen varied between 11.005 and 14.729 µmol/l. The inorganic phosphate ranged from 0.665 to 0.923 µmol/l. The observed total phosphorus values ranged between 0.359 and 1.896 µmol/l. The silicate concentration ranged from 8.686 to 14.857 µmol/l.

In the present survey, Petroleum Hydrocarbon varied between 0.118 and 0.575 µg/l and in sediment it varied from 0.010 to 0.233 µg/g at all locations monitored. The higher concentration of Petroleum Hydrocarbon was recorded at station UTPC-10 and UTPC-9 during this survey.

The concentrations of cadmium in water ranged between 1.72 and 2.46 µg/l. The concentrations of lead varied from 2.78 to 5.84 µg/1. The chromium varied from 2.10 to 4.30 µg/1, iron from 50.91 to 96.0 µg/l and the zinc from 2.07to 8.61 µg/l. The concentration of manganese varied from 1.38 to 5.62 µg/l.

The sand, silt and clay fraction at each of the stations along with their textural classification indicates that the sand and silt percentage was higher during this survey.

The concentrations of cadmium in sediments ranged from 1.36 to 3.66 µg/g. The concentrations of lead varied from 17.42 to 30.69 µg/g. The chromium varied between 25.50 and 38.72 µg/g, iron from 3380 to 10144 µg/g, the zinc from 23.91 to 80.60 µg/g. The concentration of manganese varied from 319.6 to 535.9 µg/g and the nickel level varied from 14.95 to 23.37 µg/g.

The microbial population showed general trend in water and sediment samples during this survey. The observed maximum Total Coliform 24x104 CFU/ml was found to record in water at UTPC-4. However, the higher count was recorded in the sediment samples (20x105 CFU/g) of UTPC-1.

The maximum Chlorophyll 'a' 0. 358 mg/m3 and Phaeopigment 0.162 mg/m3 were noticed at UTPC-15 during this survey. Phytoplankton population density varied from 2,458 to 3,869 No/l. The higher phytoplankton density 2672 No/l was recorded at UTPC-1 during this survey. The zooplankton density ranged from 3563 to 9079 No/m3. The higher zooplankton density was recorded at UTPC-11 during this survey. A total of 27 species of phytoplankton and 32 species of zooplankton were found to record during this survey.

The numerical abundance of the macrobenthic fauna ranged from 325 to 1,050 No/m2 and the meiobenthic fauna fluctuated from 3 to 52 No/10 cm2. Among, the macrobenthos and meiobenthos, Cerithedia cingulata and Rosalina globularis and Rotalia translucens and Triloculina austrica were found to be the dominant species in this survey respectively. A total of 60 species of macrobenthos and 33 species of meiobenthos were found to record during this survey.

The observations made during this survey revealed that the DO content of this coastal water is relatively more than the optimal recorded value of the coastal waters.

In the marine survey during the different season Rhizosolena alata, Climacosphenia sp. and Thalassiosira subtilis dominated the phytoplankton populations.

Phytoplankton population density reduced from 7542 No/l (June 2013), followed by 3815 (September 2013) which was reduced to 2672 No/l (January 2014). The zooplankton density ranged from 1319 to 8969 No/m3.

The diversity of Phytoplankton increased from 5 to 27 and zooplankton increased from 12 to 32 during this survey.

The results of the survey made during the three seasons namely June 2013, September 2013 and January 2014 suggests that the physical, chemical and biological parameters exhibited only marginal variation which can be ascribed to the seasonal variations. The results of different seasons indicate that the water is well oxygenated and nutrients are adequate supporting good plankton population, the base in the food chain. Similarly, the levels of heavy metals and petroleum hydrocarbon were found to be below permissible level in all the seasons.

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 proposed 2x800 MW Super Critical Coal Based Thermal Power Plant at Uppur, Valamavoor and Thiruppalaikudi villages in Thiruvadanai Taluk, in Ramanathapuram District.

ADVECTION - DISPERSION MODELLING STUDIES

IIT, Madras has carried out the thermal dispersion characteristics of the proposed Uppur thermal power plant for assessing the Marine Environmental impact due to the cooling water discharge for Thermal Power station. The report of the same is enclosed as Annexure-II.

The quantum of seawater required for the proposed power project is 25,000 m^3/hr and about 16,650 m3/hr of this will be discharged into the sea. The outfall will be discharging at 5°C and 16 ppt higher than ambient conditions.

During the studies, the ambient temperature is taken to be corresponding to summer months as 31.5 deg. C (corresponding to highest summer temperature). The ambient water salinity is 33 ppt. The outfall is located at a water depth of 5.0m off the site near Uppur.

In the outfall area the discharge is about 6.11 m3/s at a maximum temperature of about (31+5)°C (5° more than intake). Overall the temperatures in the sea will rise by about 0.5-0.75° C within a radius of 2.5km. Beyond this, the plume will have ambient conditions.

Hence, it can be concluded that as the outfall temperature increase is only about 0.5°C to 0.75°C above ambient temperature, which is below the stipulated limit of 50C. Hence, there shall be negligible / insignificant impact on the marine organism.

The salinity observed in the project area ranges between 31 ppt to 33 ppt. Salinity will rise by about 4 ppt within 1.5km distance from outfall. Beyond this, ambient conditions will be preserved.

Intake and Outfall structures are proposed to be located in the offshore. The structures will be laid over pile supported jetties. A common jetty is provided for both intake and outfall for about 5 km and separate jetties shall be laid beyond this point. The details are discussed in the Annexure II.

4.2 IMPACTS ON MARINE ENVIRONMENT AND MITIGATION MEASURES DURING CONSTRUCTION PHASE

The jetty for intake and outfall pipelines will be constructed over piles. The piles will be constructed over both subtidal and intertidal habitats. Piles and other in-water structures can alter the substrate below and adjacent to the structures by providing a surface for encrusting communities of mussels and other sessile organisms, which can create shell deposits and shift the biota normally associated with sand, gravel, mud, and eelgrass substrates to those communities associated with shell as substrates (Penttila and Doty 1990; Nightingale and Simenstad 2001).

Impact on mangroves

The corridor for the proposed structure has been selected so as to have minimum impact. The total area of mangroves within the 10km buffer zone of the project area is 129.15 Ha, which is about 0.22% of the total land use.

It is worthwhile to mention that it may not be possible to avoid all direct impacts on mangroves, hence impacts have been minimised as far as possible by optimising the design of the infrastructure corridor, so that the area of mangroves that will be affected is minimal.

Cumulative Mangrove Vegetation Loss

Direct Habitat Loss

The proposed development may impact on 100m X 50m which is 0.5 ha of mangrove vegetation associations (i.e. not including the open canopy Avicennia marina scattered vegetation) currently spreadout over an area of 129.15 Ha. This represents a loss of approximately 0.004%, which is considered to be a negligible impact on this vegetation association. The mangrove area affected due to the proposed project is less than an acre and also it has been observed that there is only sporadic growth of mangroves.

It is unlikely that this project will detrimentally impact upon the conservation status of any species of mangrove, marine fauna or avifauna, as there are no known species endemic to present project location. Those species that inhabit these mangrove areas are known to occur more widely along the East Coast of India. Although species impacts are not expected, the loss of mangrove vegetation may impact upon the fisheries and ecosystem services provided by the mangroves temporarily during the construction period. Although such impacts are important, due to the low level of loss of both closed canopy and sparse mangrove vegetation associations, relative to the surrounding habitats (approximately 0.5ha out of 129.15ha currently present in the area), it is considered that this impact will be very minimal.

Management

The primary mechanism for management of mangrove loss will be to confine to the areas of direct loss to the proposed infrastructure corridor footprint and the disturbance during the construction of the piers. The area of disturbance will be surveyed and delineated using coloured flagging where practicable. Construction machinery will remain within the infrastructure footprint without impinging on the disturbance envelope, to minimise any unplanned loss or damage of adjacent areas of mangrove.

Following precaution will be taken during execution so that there is minimal impact on the mangroves.

- Where practical, cleared material that is lost will be collected;
- The disturbance area will be surveyed and delineated using coloured flagging (where practical); and
- Clear briefings and instructions to relevant contractors regarding the clearance procedures will be undertaken to minimise the area disturbed.

Benthos, Foraminifera and larvae

In the study area, it was observed that out of the 45 total meiobenthos species found around 19 foraminiferal assemblages was present. Change in the seawater salinity is the major factor that controls the benthic foraminiferal population and species diversity in the coastal near-shore regions. One of the most important physical parameter having potential to influence the benthic foraminiferal population in the marginal marine areas is seawater salinity (De Rijk, 1995).

Laboratory culture studies have also been carried out to understand the changes in benthic foraminiferal characteristics under different salinity conditions. Further it has been proved that the salinity tolerance limit of benthic foraminifera is wider than the thermal tolerance limit (Arnold, 1954).

Fishes

Very heavy noise have serious effects on fishes that includes damage to body tissues which can result in death or impacts on behavior that could cause fishes to leave sites of biological importance (e.g., feeding, spawning)

The main concern in pile driving and associated activities during construction of a jetty is noise. Pile driving is believed to be having a lesser impact on the other biota compared to other types of construction activities.

High intensity sound that can be generated during pile driving is found to be above 187 dB SEL re 1μPa (where dB = decibels, a measure of sound pressure; SEL= sound exposure level, a constant sound level over one second; and μPa = micro Pascals a measure of pressure fluctuation, with 1 μPa as the water pressure reference level) can result in physical injury to fish. These can include change in hearing capability or actual damage to the inner ear, damage or destruction of the swim bladder, other cellular and molecular effects, and possible adverse effects on eggs and larvae.

Behavioral effects such as fish leaving or avoiding an area have been observed. Cumulative stress induced impacts related to sound level and duration causing fish to be more susceptible to things like infection, predation, and slower growth rate may also result.

4.2.2. Mangrove Insects, Invertebrates and Other Fauna

Insects and invertebrates that are associated with mangrove habitats will be impacted by the direct loss of habitat that these fauna rely on for food and shelter. There will also be some direct mortality of insects and invertebrates during the clearing of mangrove vegetation during construction works and although important this is considered a relatively minor impact since the area to be cleared shall be very small, relative to the mangrove habitat in the adjoining areas.

Generally, it is expected that mobile species and individuals will move away from the project area during construction, particularly in the case of some species of mangrove crabs and mudskippers. For non or less mobile species, it is considered that any direct mortality will be localised and restricted to the project footprint. Furthermore, surrounding mangrove habitat that shall not be disturbed is expected to support sustainable populations of all species such that there will be no long-term impacts on populations or species in region. It is unlikely that the piling and the laying of the pipeline in the proposed power plant would result in regional or sub-regional effects to the conservation status of the faunal assemblages.

4.2.3 Dust

Accumulation of dust on mangrove leaves adjacent to the proposed development may impact on insects inhabiting mangrove canopies. Dust impacts on mangrove canopy insects are not well documented, although it is expected that insects will avoid leaves with dust accumulation if it interferes with their foraging, breeding or habitat provision, and will utilise nearby areas that are unaffected by dust accumulation. It is also likely that different species will have different tolerance levels to cement or other dust on leaves, which in turn may result in compositional changes to the assemblage of canopy insects in mangroves adjacent to the proposed development. While it is expected that accumulation of dust during construction phase will be transient and will tend to be washed away by heavy rainfall. Hence, any impact on insect population will be temporary. Further, it should also be noted that heavy rainfall tends to washoff the dust on the surface of the leaves and hence the dust due to construction activities may be restricted to that season only.

4.3 IMPACTS ON MARINE ENVIRONMENT AND MITIGATION MEASURES DURING OPERATION PHASE

4.3.1 Impact of Temperature and salinity on Marine Biota

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. The proposed outfall from the Thermal Power plant will be 4 ppt higher than the ambient salinity conditions. As per the modeling study, the salinity will get diluted to the ambient conditions within a radius of 1.5 km.

The impact on the receptors is mainly categorized into Plankton, Intertidal habitats, Fish and Fish larvae etc. the long-term average temperature increase assessed from modeling studies is 0.5° to 0.75° C above the ambient temperature at the outfall.

Effect on plankton

Plankton species have limited or less motility and their occurrence and distribution within a sea area is thus governed by external factors such as hydrodynamic regime, vertical mixing within the water column etc. As they do not have a selective avoidance mechanism of unfavorable conditions, they are susceptible to environmental changes both natural and anthropogenic, including the direct influence of thermal discharges.

There is a range of potential effects on planktonic communities that can result from increases in water temperature. Changes to the temperature regime of the water column in the receiving environment can have direct effects on planktonic species, as metabolic rates are dependent upon temperature. All species have upper thermal tolerance which when exceeded results in adverse impacts ranging from reduced productivity to mortality. Such changes also leads to change in community structure lowering the abundance of benthos and fish population (Langford et al, 1998).

Exposure to higher temperature in the order of 2° C usually leads to changes in the community structure. In the proposed project the temperature rise is 0.5 ° C to 0.75°C in a radius of 2 KM. so the effects resulting due to the temperature difference will be minimal. Further the modeling studies shows that the temperature gradient declines as it moves towards the seaward side. Hence no adverse impact is anticipated.

Effect on planktonic Crustacea and Fish larvae.

A number of studies has been conducted on the effect of temperature difference on the crustaceans and fish population. It has been observed that the elevation of ambient temperature upto 8°C can cause significant effect on the organisms (Bamber & Seaby 2004) and result in the abnormality in the developing embryos. Studies conducted elsewere have established that most eggs can tolerate a temperature difference of + 6° C. (Bunn et al 2000). Eggs that develop beyond the upper limit of their optimum temperature may still be fertile but tend to develop abnormally due to the damage to critical enzymes (Laurence & Rogers 1976).

The spawning period for the fishes is during the months of April to May where the average diurnal temperature difference is more than 1°C, hence the rise in temperature fluctuation due to the proposed project area is not likely to cause any adverse impact.

Impact on Intertidal species and communities.

The marine intertidal organisms are exposed to relatively extreme environment and are subject to a wide range of temperatures naturally. At low tide intertidal organisms are exposed to direct sunlight. Usually a fluctuation of 10° C during summer and 5° C during winter and monsoons is experienced. Hence, the fauna associated with these sediment are a adjusted to regular temperature variations. Further the impact of temperature changes on the water column above the intertidal zone is minimal hence the fluctuation in the sediment shall be very minimal.

Overall, in the proposed project the temperature fluctuation is not bound to be beyond 0.5 – 0.75 °C. The change in temperature is not considered severe in case of the marine biota. Based on previous studies and the adaptability of the marine biota the adverse impact due to temperature rise is found to be minimal.

4.3.2 Impact due to Salinity Changes

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.

A variety of published literatures and readings disclose the effect of brine on the salinity of the seawater and the resultant impact on marine environment. The centre of attention of these studies is the concentration and expansion of brine plumes on the receiving water (Roberts, Johnston & Knott 2010). It is now widely recognized that extensive brine discharge, as it constitutes a hypersaline layer that sinks towards the seabed due to its greater density, has the potential to heavily affect local marine biota (Medeazza 2005). Changes of salinity influence the propagation activity of the marine species and that consequentially affect their development and growth rate.

Larval stages are very crucial transition periods for marine species and increasing salinity disrupts that period significantly (Neuparth, Costa & Costa 2002). Although marine species of the saline water are familiar to this fluctuation of salinity concentrations but they may not survive on this sudden augmentation of salinity because of brine disposal (Haurwitz et al. 2008). As discharged brine is much denser than the seawater so brine plumes have the affinity to extend further along the seafloor than the surface which contributes to greater exposure of benthic organisms to brine discharges, than pelagic and planktonic organisms in deep waters (Roberts, Johnston & Knott 2010).

In the proposed project brine will be delivered in the cooling tower blowdown. Further, there shall be a dilution in the same. The average salinity is 33ppt and with a 200 dilution the outfall will have 37 ppt that shall dilute to ambient conditions at a radius of 1.5 kms.

In the case of fresh water biota an increase in the salinity in the surrounding water can have a detrimental impact. Whereas in the marine environment biota are capable of surviving fluctuations in salinity. The rise in salinity due to the proposed project is expected to be 38 ppt near the outfall and the same is expected to dilute within a radius of 2.5 kms. Hence impact of salinity fluctuation on the marine community as a whole shall be insignificant.

4.4 IMPACT DUE TO PIPELINE

Chlorination - Antifouling agent

There are potential operational issues caused by the growth or encrustation of marine organisms in pipes and inlet wells. Operationally, the colonization of marine organisms such as algae, bryozoans, molluscs and cirripedes within cooled water circuits could result in losses in thermal efficiency and reduced reliability of the system (including total shutdown). To counteract settling and growth of marine organisms, cooled water circuits are typically dosed with chemicals (usually sodium hypochlorite). Such chemicals are known as antifoulants and they inhibit the growth of organisms within the circuit by creating unsuitable living conditions. A secondary consequence of this form of treatment is associated with the discharge of the treated seawater into the marine environment.

The concentration of chlorine in the inlet is 1ppm which is similar to that found in the cooling waters of power stations operating worldwide and is below the proposed power plant discharge limits.

Concentrations of residual chlorine have been shown to diminish rapidly with time and distance from the discharge point (Mattice & Zittel, 1976). The concentration in the outfall shall not exceed 0.5mg L-1 which is acceptable as per EPA guidelines.

Consequentially, significant impacts to fisheries resources as a result of the discharge of chlorinated water are not expected to occur. As per literature review, it is observed that residual chlorine at a concentration of 0.5mg/L on the hatching of fish larvae was found to have no significant impact.

Socio-Economic Impacts

The coastal area of the project area district is occupied by scattered villages and dominated by fishermen community. The Demographic profile of fishing villages in the study area are given in Table 4.1.

The members of the fishermen community are engaged in fishing activity, marketing of fish net repairing etc. on day to day basis. Thus the economy of the population of this area is sustained by the coastal marine fishery activities as it provides food employment, food and income to the fisherman community. As per the data available with the fisheries department Directorate of Fisheries, Tamil Nadu suggest that good fishery resources is available in the area. The important socio economic factor is the availability of commercially important species of fish and prawns supporting good fishery in the area. The intake of sea water for the project will not have any adverse impact on the marine fishery resource of the region since the intake of water will be through intake screens and trash bars.

Table 4.1

Demographic profile of fishing villages in the study area

S. no	Name of the village	Children	Adults (18 yrs & above)			Total population			Total families	Family size/ persons per house
			Male	Female	Total	Male	Female	Total		
1.	Pudhupattinam	297	300	265	565	452	410	862	195	4
2.	Mullimunai	856	825	780	1605	1257	1204	2461	504	4
3.	Karangadu	497	629	630	1259	865	891	1756	377	4
4.	Kadalore	65	86	87	173	121	117	238	59	4

LIVELIHOOD SERVICES (FISHING)

In the coastal area, fishing is the main occupation. Devipattinam, Thirupalakudi, Kadalore, A.manakudi, vennathur were the coastal area villages where the fishing is the main occupation of the households. 5.2 % of the respondents use Catamarans,3.5 % of the use vallam, 3% FRP boat to the interior of the sea for the distance of 0- 3km (1.7 %) of the respondent of Vennathur, Devipattinam and Kadaloor have gone to the sea to the far distance more than 50 kms from the shore for their daily fish catch. They involve 1 to 10 fisherfolk with them when they go for fishing to the sea.

4.5 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.

Mitigation measures during construction

The primary recommendation that resource managers make to minimize potential adverse impacts from pile driving is a time of year restriction. Piling can be avoided during the spawning season so that there will be minimal impact on the overall fish population. Piling restriction can be reduced when necessary if certain measures are taken to limit the sound exposure level, duration of sound, exclude fish from the zone of influence, limit pile driving to lower tide stages when the work area is in the “dry”, or to limit pile driving to times of the day or tide states when species of concern could be expected to not be in the project area.

Means to reduce sound transmitted to surrounding water by pile driving include use of piles that vibrate less when struck such as timber vs. steel, smaller diameter piles, use of a cushion between the hammer and “stiffer” piles such as steel, use of a vibratory hammer rather than an impact hammer, or the use of a bubble curtain are inserted to create a buffer to prevent the spreading of noise vibration. Limitations on the number of pile driving hammers on a project site, the number of piles driven/day and the duration of pile driving/day can also be beneficial

Mitigation measures during operation

In the proposed project, the outfall temperature shall be increased only by 0.5 - 0.75°C from the ambient temperature, which is well below the standard prescribe by the statutory authority. Hence, no specific management measures are suggested. Salinity changes are expected to be within 38 ppt, hence impact of salinity and temperature on the marine biota is expected to be minimal.

However, it is recommended that TANGEDCO should implement all the good practices for intlet and outfall management for 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)

5.3 MANGROVE MONITORING PROGRAM

The Monitoring program for the management of potential impacts on mangrove vegetation will consist of:

- Mangrove mapping;
- Mangrove health surveys; and
- Monitoring of any sediment accumulation within mangrove vegetation associations; and
- Assessment of the potential for changes in soil salinity in the vicinity of the infrastructure corridor.

Mangrove Mapping

Aerial photography and field surveys will be used to map the distribution and coverage of mangrove vegetation associations situated near the project footprint. Aerial photography will be ortho-rectified to allow for determination of mangrove cover. Mangrove mapping will be undertaken:

- Prior to the commencement of the project to provide current information on mangrove distribution;
- At project milestones including the completion of clearing activities within the infrastructure corridor; and
- On completion of the project.

Mangrove distribution and cover will be compared to the baseline data to confirm that the area of direct disturbance of mangrove habitat does not exceed the approved limits.

Mangrove Health Surveys

Mangrove health surveys will be undertaken in an effort to ensure that any negative impacts are detected as soon as possible. Mangrove health monitoring will consist of:

- Regular visual assessments to determine mangrove condition; and
- Detailed mangrove health surveys prior to dredging, after six months (following commencement of construction) and on completion of the project.

Mangrove monitoring sites will be established prior to the commencement of construction activities. The number and location of these sites will be determined during a preliminary site investigation and via the interpretation of aerial photography. It is expected that three or four monitoring sites will be established, together with corresponding reference sites.

Some of the sites already established as reference sites for the Harriet Point mangrove monitoring program are likely to be suitable as they are located within areas that will have similar distribution, density and species composition and will be situated where they will not be impacted by the Outer Harbour Development. Within each site a 50 m permanent transect will be established.

Four randomly placed 4 m x 4 m (16 m^2) quadrats will be set up alongside each transect and the following parameters will be measured in each:

- The mangrove species present;
- The number of trees present;
- The number of dead limbs;
- The number of stems per tree;
- Stem diameters;
- Health status of trees;

- Height of trees; and
- Foliage density (using a densitometer).

Foliage density readings and mangrove species present will also be recorded every 2.5 m along each transect. Classification of the health status of mangrove trees will be based on the methods of Duke et al. (2005), using the three categories listed in Table 5.1.

Recent baseline mangrove health monitoring conducted as part of the Harriet Point mangrove monitoring program extended this classification by assigning a quantitative assessment to each health category (Table 5.1), based on data collected in February 2009 (SKM 2009e). The same methods will be applied to the Outer Harbour mangrove health monitoring program.

TABLE 5.1
Classification and characteristics of Mangrove tree condition

Classification (Duke et al. 2005)	Characteristics (Duke et al. 2005)	Quantitative (SKM 2009e)
Healthy	Leaves green, no visible signs of sickness	<10% dead, yellowing or wilting leaves
Sick	Yellow, wilting leaves Low foliage cover	10-50% dead, yellowing or wilting leaves
Dead	Plant dead	>50% dead/ yellow wilting leaves > 50% dead stems plant beyond recovery/almost dead

During the construction phase there shall be a disturbance for the mangroves in the vicinity of the project area. Hence it is recommended that TANGEDCO should implement the above said procedures to assess the health of the mangroves.

CHAPTER – 6

CONCLUSIONS

The Comprehensive Marine EIA Study was carried out to identify the impacts of outfall of the proposed Coal Based Thermal Power Project in Thiruvadanai Taluk, in Ramanathapuram Distt. on marine environment. The conclusions of the study are as follows:

- The currents in the study area are relatively weaker. During the spring period, the currents could range from 0.02-0.1m/s.
- Approximately 200 dilution takes place within a distance of 2.5km from the outfall location during flooding tide and ebbing tide.
- The spread of the plume is limited towards south to about 2km. Hence, it is concluded that a dilution of 200 is possible within a distance of about 2.5km from outfall.
- The temperatures in the sea will rise by only about 0.5-0.75°C within a radius of 2.5km. Beyond this, the plume will have ambient conditions.
- The rise in temerature is not likely to cause any alteration in the biotic community of the coastal waters of the project area.
- The pile supported jetty with offshore pump house is recommended since this will cause much lesser disturbance to prevailing marine and seabed environments.
- The control of biofouling is difficult in buried pipeline as this may clog and reduce the area of flow in the inlet system, hence it is recommneded for pipeline on the pile supported jetty.
- The marine water quality and ecology in and around the proposed outfall area is that of any normal coastal environment during the study period in all the seasons.

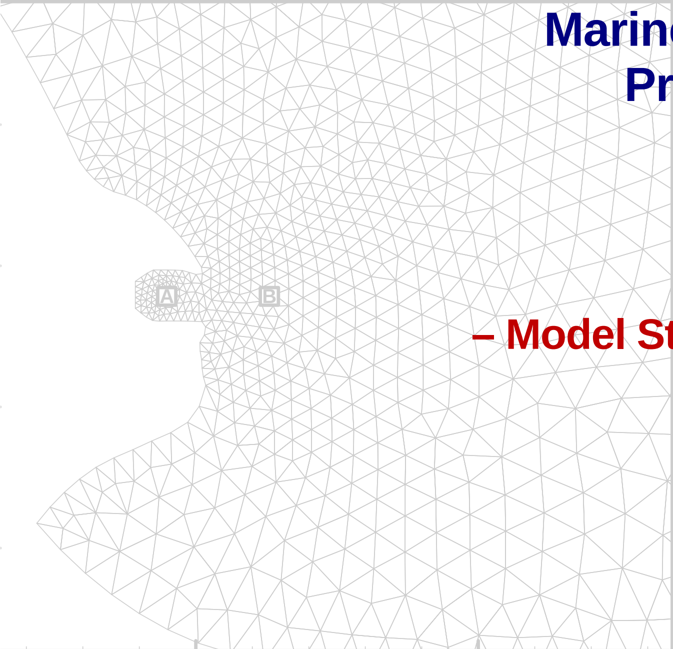
- The project area has biological features charecteristics of any coastal area in the occurence, abuandance and bio diversity of biological community of phytoplankton, zooplankton, benthos and fishes. No rare, endangered, threatend marine speices were recorded during marine survey.
- The survey made during periods of June 2013, September 2013 and January 2014 suggests that the physical, chemical and biological parameters exhibited only marginal variation which can be ascribed to seasonal changes. Various results on the chemical and biological parameters indicate that the water is well oxygenated and nutrients are adequate supporting fairly good plankton population, the base in the food chain. Similarly the levels heavy metals and petroleum hydrocarbon were found to be below permissible level.
- 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.
- Regular monitoring of the health of the mangroves in the vicinity of the project area is recommended.
- The outfall of the proposed Uppur Power Project would not change the quality of existing natural coastal environment.

Annexure-I

Maximum permissible level or condition of water pollutants discharged into the environment

No.	Water Pollutants Parameters or Substances	Level or Condition Inland Surface Water	Coastal Nearshore	Marine Offshore	Environmentally Sensitive Areas /Groundwater
1	Temperature	35	40	45	NIAA
2	Hydrogen ion (pH)	6-9	6-9	6-9	6-9
3	Five day Biological Oxygen Demand (BOD_5 at 20°C)	30	50	100	10
4	Chemical Oxygen Demand (COD)	250	250	250	60
5	Total Suspended Solids (TSS)	50	150	200	15
6	Total Oil and Grease (TO&G) or n-Hexane Extractable Material (HEM)	10	15	100	No discharge
7	Ammoniacal Nitrogen (as NH_3-N)	10	10	10	0.01
8	Total Phosphorus (as P)	5	5	5	0.1
9	Sulphide (as H_2S)	1	1	1	0.2
10	Chloride (as Cl^-)	250	NIAA	NIAA	NIAA
11	Total Residual Chlorine (as Cl_2)	1	1	2	0.2
12	Dissolved Hexavalent Chromium (Cr^{6-})	0.1	0.1	0.1	0.05
13	Total Chromium (Cr)	0.5	0.5	0.5	0.1
14	Dissolved Iron (Fe)	3.5	3.5	3.5	1.0
15	Total Petroleum Hydrocarbons (TPH)	25	40	80	No discharge
16	Total Nickel (Ni)	0.5	0.5	0.5	0.5
17	Total Copper (Cu)	0.5	0.5	0.5	0.01
18	Total Zinc (Zn)	2	2	2	0.1
19	Total Arsenic (As)	0.1	0.1	0.1	0.01
20	Total Cadmium (Cd)	0.1	0.1	0.1	0.01
21	Total Mercury (Hg)	0.01	0.01	0.01	0.005
22	Total Lead (Pb)	0.1	0.1	0.1	0.05
23	Total Cyanide (as CN^-)	0.1	0.1	0.1	0.01
24	Phenolic Compounds (as phenol)	0.5	0.5	0.5	0.1
25	Radioactivity	NIAA	NIAA	NIAA	NIAA
26	Toxicity	NATE	NATE	NATE	NATE
27	Faecal Coliforms	400	400	400	100
28	Solid Waste	NSD	NSD	NSD	NSD

[a] all units are in milligrams per litre (mg/L) except for temperature (°C), pH (pH units), faecal coliforms (counts per 100ml), radioactivity (Bq/L) and toxicity (toxic units).
NIAA – no increase above ambient
NATE – no acute toxic effects
NSD – no solid debris



Marine EIA/EMP studies for Outfall of Proposed 2 x 800 MW Coal based power plant at Uppur, Ramanathapuram District, TN.

– Model Studies for Tidal Hydrodynamics and Thermal & Salinity Dispersion

Client

TANGEDCO, Chennai

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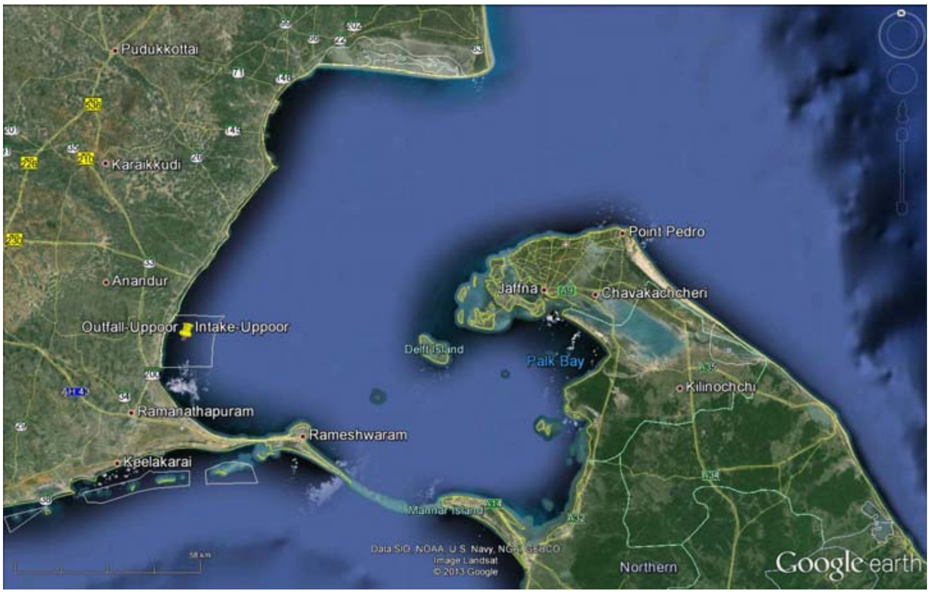

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Executive Summary

TANGEDCO (Tamil Nadu Generation and Distribution Corporation Limited) is setting up a thermal power project near Uppur in Ramanathapuram District. The plant will be designed for 2 x 800 MW as Coal based power plant. This report details the studies conducted by IIT Madras for evaluation tidal flow pattern and effluent dispersion at the site. The quantum of seawater required for the proposed power project is 15,400m^3/hr and about 10500 m^3/hr will be discharged into the sea. However, modelling has been carried out for 25,000 m^3/hr intake and about 16,650 m^3/hr outfall, in order to cater for any future expansion requirements. For modelling purposes, the temperature of effluent has been taken as 5 deg. C more than ambient condition for the purpose of evaluating worst case scenario (as the power plant is provided with cooling tower and hence 5 deg rise is actually not expected). The salinity of effluent is 16 ppt higher than ambient conditions. During the studies, the ambient temperature is taken to be corresponding to summer months as 31.5 deg. C (corresponding to highest summer temperature). The ambient water salinity is 33 ppt. The outfall is located at a water depth of 5.5m off the site near Uppur.

Intake and Outfall are proposed to be offshore and laid over pile supported jetties. A common jetty is provided for both intake and outfall until the intake point which is located at about 5 km from landfall point at a water depth of 4m. The outfall pipeline shall continue in the same alignment for another 2km to a water depth of 5.5m for final discharge through multiport diffusers.

Based on the studies,

(1) The currents in the study area are relatively weaker. During the spring period, the currents could range from 0.02-0.1m/s. The range of velocity at the intake / outfall location is about 0.02-0.085 m/s.

(2) The outfall for the refuse water shall be of multiport type with 48 ports of 250mm diameter. The pipeline shall be laid over a outfall jetty.

(3) 200 thermal dilution takes place (100 more than initial dilution) within a distance of 1.5km from the outfall location during flooding tide. Similar trend is observed during ebbing tide also.

(3) 200 salinity dilution takes place (100 more than initial dilution) within a distance of 1.2km from the outfall location during flooding tide. Similar trend is observed during ebbing tide also.

(4) However, spread of the thermal plume is limited towards south to about 1.2km. Hence, it is concluded that a total dilution of 200 is possible within a distance of about 1.5km from outfall.

(5) Intake shall be located beyond 1.5km away from outfall.

(6) The temperatures in the sea will rise by about 0.5-0.75deg. C within a radious of 1.5km. Salinity will rise by about 4 ppt within 1.2km distance from outfall. Beyond this, ambient conditions will be preserved. (5) Intake shall be located beyond 1.5km away from outfall.

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1. Introduction

TANGEDCO (Tamil Nadu Generation and Distribution Corporation Limited) is setting up a thermal power project near Uppur in Ramanathapuram District. The plant will be designed for 2 x 800 MW as Coal based power plant. **TANGEDCO** have approached IIT Madras for conducting mathematical model studies for tidal flow and thermal dispersion. TANGEDCO has entrusted IIT Madras with the task of studying the thermal dispersion characteristics of the outfall discharge for the purpose of assessing the Marine Environmental Impact due to the cooling water discharge 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. This report details the studies conducted by IIT Madras for evaluation tidal flow pattern at the site and thermal and salinity patterns of cooling water.

The proposed plant will be located at the vicinity of Uppur village in Ramanathapuram District. The quantum of seawater required for the proposed power project as originally envisaged by power plant planners is 25,000 m^3/hr and about 16,650 m^3/hr of this will be discharged into the sea. The outfall will be discharging at 5 deg. C and 16 ppt higher than ambient conditions. **However, the final (revised) intake quantity is 15400m^3/hr and outfall quantity is 10500m^3/hr.** Hence, model studies are originally done for the higher quantity. Based on this, an estimated impact for the reduced quantity is also provided.

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 plant into the sea. The scope of work is as follows.

1. Investigate the tide induced hydrodynamics in the marine spread. This will include the effect of outfall discharge into the sea.

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 31.5 deg. C.

4. Obtain the general salinity dispersion patterns over the subject area considering the following outfall water discharges and their operating salinity. The ambient water salinity is taken as 33 ppt.

2. Site location and Model domain

The site is located near Uppur, Valamavoor and Thiruppalaikudi villages of Thiruvandanai taluk, Ramanathapuram district in Tamil Nadu. The site is about 28 km north of Ramanathapuram Town. Fig.1 shows the location of Uppur Thermal Power Plant. Further, the bathymetry details of the study area is shown in Fig.2. The region if generally flat with the 5 m contour occurring at a distance of about 7km. The ovarall bay area shown in Fig.1 is considered for modelling tidal hydrodynamics and thermal dispersion. The latitude and longitude of the plant area is 1063228 N and 273859 E.

Table 1 gives the tidal levels at the site. The range of the tide is very moderate with the spring tidal range up to 0.7m and neap range about 0.2m. The MSL is +0.4m.

3. Tidal Hydrodynamics at Project Site

3.1 Modelling of Study Area

The solution domain for the present problem is the marine spread comprising of the sea spread up to 12m contour on the sea side and the lateral spread along and across the shore up to 120km. Since an unstructured approach is being used in the present model, no hybrid meshing scheme is needed for capturing small features in geometry and flow. 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.

Tidal hydrodynamics of the study area is controlled by oscillations from Bay of Bengal on the north and Gulf of Mannar on the south. Hence, the entire spread of 120 x 120km stretch is considered for modelling tidal hydraulics.

3.2 Methodology

The data for the entire area has been obtained from the hydrographic chart. After performing the mesh generation process for the study area as discussed earlier, the final mesh (Fig.3) has come out good and has sufficiently fine elements near the coastlines and shallower water depths. The average mesh size is found to be about 10-20m which is very fine for a simulation such as this. The mesh is coarser near the offshore boundaries where the water depths are greater.

3.3 Boundary Conditions

The present solver could work with tide elevation boundary conditions alone or velocity boundary conditions alone. Table.1 provides typical tidal levels at site. Free radiation of velocities along the open boundaries is enabled. Natural boundary conditions are imposed along the coastal boundaries. The tidal oscillations at site are primarily semi-diurnal with spring tidal range of about 0.7 m. The neap tidal range is about 0.2m. Figure 5 shows the typical tidal time history over 30 days spring-neap cycle in Palk Strait region.

3.4 Results and Discussion

Rigorous validation of the model Ocirc 1.0 has been performed in the past (Murali et al., 2002). Details of Ocirc 1.0 is provided in Annexure-A. Accurate simulation of the tidal hydrodynamics at Uppur site 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 typical computational mesh (Fig.3) depicts the ability of the meshing algorithm to exactly discretise the study area. Further, the mesh is able to resolve the bathymetrical details. It is seen that once again the bathymetry and mesh represent the project area very well with an average grid size of 10-20m.

3.4.1 Simulated Tidal Conditions for study area

The projected tidal hydrodynamic conditions at the site are mainly characterized by alternating northerly and southerly flow along the shoreline as the tide travels along the shoreline. As the tide rises in the Bay of Bengal, water flows along the shoreline, across the strait. For the purpose easy referencing of the hydrodynamics with the tide levels, the water level of the tide also is presented in the results as contour levels. The flow details are presented in details in Figs.6 to 15.

Flooding tide

The flow patterns during flooding of the study area are shown in Fig. 5 - 9 over the full model domain and exploded views. It should be noted that flow vectors are plotted at every 10 points only in the full model, for clarity of figures. The exploded views in above figures show velocity vectors and contours coloured with tide level. In order to understand the nature of velocity magnitudes, a reference vector with magnitude of 1m/s is shown in the figures. From this, the magnitudes of current at various locations of the project area can be deduced. There are fast moving tidal currents in the restricted area but not in the open areas as shown in figure 6. It is to be noted that during flooding tide, the tidal current direction is moving towards the shore. The range of velocities at the outfall point is about 0.02-0.08m/s.

Ebbing tide

During the ebbing phase of the tide, which is followed by the occurrence of high tide, the tide starts to recede from the harbour and reversal of flow starts to occur towards the sea with velocities up to 0.1m/s. It is to be noted that during ebbing tide, the tidal current direction is away from the shore. Figures 10-13 provides the details of flow characteristics during the ebbing phase of the tide. As the tide starts to recede, the currents in the strait reverse direction with magnitude of currents up to 0.1m/s. The tidal reversing current vectors on the tidal amplitude map of the outfall location are shown in figure 13. The range of velocity at the intake location is about 0.02-0.085 m/s.

The currents in the study area are generally less. This is brought out separately for outfall and intake locations in Fig.14 and Fig.15. The flow from Bay of Bengal is controlled and thus, the limited discharge causes less currents in the study area. The flat bathymetry with gently slopes also contribute to the lower levels of currents.

4. Modelling of effluent and thermal dispersion

4.1 Uppur intake & diffuser

The intake is designed to draw sea water at a rate of about 15,400 m^3/hr. The outfall will be discharging 10,500 m^3/hr at temperature 5° C higher and salinity 16 ppt higher than ambient conditions. The ambient temperature is taken to be corresponding to summer months as 31.5° C (corresponding to highest summer temperature). The ambient water salinity is 33 ppt. The outfall is located at a water depth of 5.0m off the site near Uppur. **Details of the intake and outfall design are provided in Annexure-B.**

In the outfall design, based on the Densimetric Froude Number and initial dilution calculations, 48 ports of 0.3 m diameter are provided. These ports are placed over a section of 208m located about 2.0km into the sea from the intake point. As the diffuser risers and ports are provided at 8 m interval, the total length of the diffuser is about 208m. The details of the diffuser configuration and geometry is given in Fig.16-18. The diffuser discharge is about 6.11 m^3/s at a maximum temperature of about (31.5+5)° C (5 degrees more than intake).

In order to assess the temperature and salinity dispersion in to the sea water, advection-dispersion studies are carried out. The estimated initial dilution for the respective discharges is taken to be 100, meaning that the temperature of the outfall is 34.0° C (31.5+2.5) and salinity is 41 ppt (33+8) for the purpose of advection dispersion modelling after the effects of initial dilution.

4.2 Advection - Dispersion of Effluent

4.2.1 Model approach

Advection - Dispersion studies are conducted using the modelling approach discussed in Annexure-C. As stated earlier, this is done for the higher discharges 25,000 m^3/hr for intake and about 16,650 m^3/hr for outfall. As the CFD model is more accurate and computes turbulence effects and thermal/ salinity mixing very well, the model is extended in the lateral direction to encompass the area of the Uppur project as projected in Figs.16-19. The figures indicate details of physical settings and domain considered for the advection-dispersion model with the mesh therein.

4.2.2 Model input

For the advection dispersion model, as suggested in the EIA report, the lean period is considered with a nominal current of 0.06-0.08 m/s. In other periods, the ocean is more turbulent and advection - dispersion takes place much faster. Hence, the scenario considered in the present studies may be said to be critical one for predicting highest concentrations of effluent in the vicinity of proposed Uppur outfall. The boundary conditions and model setup are discussed in the previous chapter. The grid used for the present study is an unstructured grid with grid size ranging from 40-60m. Since, mesh related errors could lead to bad solutions, quadrilateral grids are used all through. For modelling turbulence, the Spalart-Allmaras model is used as this is very well suited for coastal applications.

Based on the plume analysis, it is clear that more than 100% dilution will take place within 100m of diffuser. However, the conditions considered for simulations in the advection-dispersion model pertains to only 50% as this will give more conservative results leading to safe design and operation. The diffuser area is modelled with a block of 300 x 100 m having diluted effluents of100% dilution. Hence, the Outfall is set with a salinity of about 41ppt and temperature of 34.0 deg.

4.2.3 Results of Advection - Dispersion studies

The flow fields and features are simulated are as shown in Figs.20-24 for flood tidal condition (northerly current). The coastal currents flow almost parallel to the coastline with a small shoreward or offshore directionality due to the effects of wind.

Without considering effects of wind and waves.

The simulated thermal plumes are shown in Fig.20 during flooding and ebbing tide. For the Uppur outfall, the plume extends to a distance of about 2.0-2.5km alongshore direction and about 1.0km cross shore direction on east and western directions. Genrally, the plume dispersion appears to be weak due to the presence of lower current levels. As the winds and waves are very less, the ambient turbulence levels are very less. Hence, the plume spreads slowly and concentrated around the outfall area.

Considering the effects of wind.

The Uppur area receives wind of the average magnitude of about 37kmph (10.3 m/s). These winds are considered in the directions towards and away from shore for the purpose of studying effects of wind and waves on the thermal dispersion. The wave characteristics considered for the study is equivalent to H_s=0.5m.

Upon considering the wind and wave effects, the results of plume positions during flood and ebb are presented in Fig.21 and 22 respectively for offshore wind (towards shore) and onshore wind (away from shore). During the offshore wind, the plume extends towards the shore by about 0.5km additionally to no-wind condition. In the alongshore direction, the plume extends towards north by about 3km and by about 1km towards south. These properties show much better dispersion of the plume compared to that of no-wind condition. 200 dilution takes place (100 more than initial dilution) within a distance of 2.5km from the outfall location. Similar trend is observed during ebbing tide also. However, spread of the plume is limited towards south to about 2km. Hence, it is concluded that a dilution of 200 is possible within a distance of about 2.5km from outfall. Hence, the intake shall be located beyond 2.5km away from outfall.

Salinity dispersion in worst case condition.

In order to get the worst case salinity plume patterns, the salinity patterns at the time of flooding tide is given in Fig.23 and 24. The figures provide the salinity plumes for worst case conditions of onshore wind+wave and offshore wind conditions. The figures suggest 200 dilution at a distance of 1.5km. Beyond this distance the salinity will be within 4ppt from ambient conditions. As for as impact on shoreline is concerned, the plume will disperse more than 4 km away from shoreline and hence no impact will be felt on shoreline.

Thermal and Salinity dispersion with reduced intake and discharge quantities.

The final design and water balance details provided by TANGEDCO indicates an intake water requirement of 15400m^3/hr. Corresponding outfall water quantity will be 10500m^3/hr. The present model studies considered 60% higher quantities and corresponding thermal and salinity loads. Hence, the actual effects will be much less than indicated above, by about 30%. The design report provides for the above quantities accordingly.

5.0 CONCLUSIONS

Detailed numerical model studies have been carried out to investigate the hydrodynamics of the water spread off Uppur area where the intake and outfall for Uppur thermal power station is likely to be located. The following are observed for the scenario of 15,400 m^3/hr intake and about 10,500 m^3/hr outfall.

(1) The currents in the study area are relatively weaker. During the spring period, the currents could range from 0.02-0.1m/s. The range of velocity at the intake / outfall location is about 0.02-0.085 m/s.

(2) The outfall for the refuse water shall be of multiport type with 48 ports of 250mm diameter. The pipeline shall be laid over a outfall jetty.

(3) 200 thermal dilution takes place (100 more than initial dilution) within a distance of within 1.5km from the outfall location during flooding tide. Similar trend is observed during ebbing tide also.

(4) 200 salinity dilution takes place (100 more than initial dilution) within a distance of 1.2km from the outfall location during flooding tide. Similar trend is observed during ebbing tide also.

(5) However, spread of the plume is limited towards south to about 1.2km. There is a spread to a distance of about 0.3km towards north (total 1.5km). Hence, it is concluded that a total dilution of 200 is possible within a distance of about 1.5km from outfall.

(6) Intake shall be located beyond 1.5km away from outfall.

(7) The temperatures in the sea will rise by about 0.5-0.75deg. C within a radious of 1.5km. Salinity will rise by about 4 ppt within 1.2km distance from outfall. Beyond this, ambient conditions will be preserved.

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6.0 BIBLIOGRAPHY

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Annexure - A

A.0 TIDAL HYDRAULICS MODELING

The computational model used for simulation of tidal hydrodynamics in the present study is developed by Department of Ocean Engineering, IIT Madras. It is called as '*Ocirc 1.0*'. *Ocirc 1.0* has its own mesh generation software and produces output that is directly readable by Tecplot. Tecplot is post processing software. Various pre-processing tools available *in Ocirc 1.0* and the solver details are presented in this section. Details of numerical modelling of tidal flow in the proposed site are presented. Results are discussed for various scenarios as set out in objectives.

A.1 Mesh Generation

The complex tidal hydraulics study for the proposed area has to take care of irregular coast line and sea bed contours in that locality. The bathymetry has to be reproduced well. In order to achieve these objectives, an unstructured mesh generation technique has been adopted to produce high quality meshes suitable for shallow water equations. The mesh generation process begins with the construction of the boundary mesh. In this process, the domain boundaries are discretised considering a courant number criteria (C-criteria). The discretisation mainly aims at keeping the overall mesh courant number, required by the user, constant while it will also try to model the geometry as close as possible. The next step in the process is the construction of the background grid. The purpose of the background grid is to specify the local (isotropic) element size throughout the domain. The background grid is constructed by first performing a Delaunay triangulation of the surface nodes and then converting this to a (local) Min/Max triangulation by edge-swapping. The spacing value at each surface node is taken to be the average length of the incident boundary edges. Linear interpolation on the background grid then provides the spacing value throughout the domain. A procedure for introducing auxiliary points into the background grid is presented. This enables the user to prescribe the desired spacing at a given location. This can be useful when the triangulation calls for too fine (or coarse) a mesh in a given region. The domain mesh is then generated filling the domain with nearly equilateral triangles using a traditional face-based advancing front method. This is a method based largely on heuristics in which the mesh is generated one element at a time by propagating the boundary discretisation inwards. Two smoothing algorithms were used to smooth the mesh in overall sense.

A.2 User Input

Mesh generation for coastal modeling is generally time consuming. An attempt has been made here to minimize the amount of user input. The information needed from the user are summarized in this section. The solution domain is represented by a number of bodies representing exterior coastal lines and interior islands. Each body is composed of a series of non-intersecting curves that join at their endpoints. Each body must be closed, although a curve need not be. Each curve is given as a series of (x; y) coordinate pairs that form the knots of a parametric cubic spline. The splines are C2 (curvature) continuous in the interior and the degree of continuity (position, slope, or curvature) is specified at each endpoint. A set of optional user refinement parameters may also be supplied which serve to limit the maximum allowable spacing at a point on a curve. These consist of the curve number, the position (normalized arc-length), and the spacing value. Often, this can be useful for forcing additional refinement near a singular point in the geometry (e.g., a corner or a tiny island). Similarly, the spacing at a point in the interior of the domain can be controlled by specifying the position and local spacing value of an auxiliary point. These auxiliary points will then be inserted into the background grid that controls the spacing function of the grid.

A.3 Courant Number Criteria

The Courant number for shallow water flows can be defined as C = Udt/dx, where, C denotes the Courant number, U the phase velocity and dt and dx respectively the size of time step and size of mesh elements. For a given domain mesh, dt is dictated by the minimum dx/U ratio. As the phase velocity U depends on water depth, it is essential to vary the dx along the domain to obtain a mesh having a slim band of Courant numbers and choose an economical time step size, dt. Here, we have defined a spacing function for the domain by requiring a certain dt and C. Given, U□$(gd)^{1/2}$, where g is the acceleration due to gravity and d the water depth, the spacing function could be defined as $s(x,y)=(gd(x,y))^{1/2}$ □dt/C.

A.4 Advancing Front Method

Our desire is to generate an isotropic mesh composed of nearly equilateral elements over the entire 2D space. This is achieved here through use of an advancing front method. In this method, based largely on heuristics, the mesh is generated one element at a time by propagating the boundary discretisation inwards. In the process, the nodal positions and connectivities are constructed simultaneously.

The front is a dynamic collection of edges that is continually updated throughout the mesh generation process. Although the front can be composed of many disjoint pieces, each one must be a simple closed curve oriented such that the domain to be meshed lies to the left. The front is initialized to consist of the edges on the boundary of the domain to be triangulated. An edge on the front is selected to be the base of a new element which will generated. Based on the local spacing value obtained from the background grid, the location of an `ideal' point to be the third vertex of the new element is computed. Nearby nodes on the front are then found. A decision is made on whether to connect with one of these nodes or introduce the ideal point. The new element is then formed. The existing edges used in the formation of the new element are deleted from the front while the newly created edges are added to it. The process then repeats until there are no more edges on the front.

A.5 SWE Solver

The hydrodynamic equations governing the ocean flow field are the vertically integrated form of Shallow Water Equations (SWE). In the Cartesian co-ordinate frame fixed to the rotating earth, and after neglecting the internal stresses (Chitra et al., 1995), the SWE can be written as follows:

the continuity equation

$$q_{x,x} + q_{y,y} + \zeta_{,t} = 0, \tag{1}$$

and the momentum equations in x and y directions

$$q_{x,t} + \bar{u}\, q_{x,x} + \bar{v}\, q_{x,y} - f q_y = -\rho^{-1} H p_{a,x} - gH\zeta_{,x} + \rho^{-1}\left(\tau_{ax} - \tau_{bx}\right) \tag{2}$$

$$q_{y,t} + \bar{u}\, q_{y,x} + \bar{v}\, q_{y,y} + f q_x = -\rho^{-1} H p_{a,y} - gH\zeta_{,y} + \rho^{-1}\left(\tau_{ay} - \tau_{by}\right) \tag{3}$$

Here the origin of the co-ordinate system is chosen at the undisturbed sea surface, and the volume transport components are defined as $qx = \int u\,dz$ and $qy = \int v\,dz$, with the integration limits being taken from $-d$ to ζ, where (u, v) are the components of velocity in the directions of (x, y) respectively and t is the time. The suffixes preceded by ',' indicate partial derivatives. z is measured positive upwards. $H = d+\zeta$ is the total depth of water, d is the undisturbed depth of water and ζ is the sea surface elevation measured from the undisturbed sea surface. ρ is the density of water and g is the acceleration due to gravity.

The average velocities in (x,y) are defined as $\overline{u} = q_x / H$, $\overline{v} = q_y / H$. (τ_{ax} , τ_{ay}) and (τ_{bx}, τ_{by}) are the stresses at the air-sea interface and the bottom surface respectively. It is customary to express the mean tangential wind stress τ_a in the form (Ali, 1980),

$$\tau_a = \rho_a \, K_a \, W_z \, |W_z| \tag{4}$$

where K_a is a dimensionless constant, termed resistance coefficient or drag or friction coefficient and W_z is the wind velocity measured at a level z over the mean ocean surface. For this study, we have used $K_a = 1.8 \times 10^{-3}$.

For slow to moderate currents and also for very shallow waters, the bottom friction cannot be neglected and it is usually expressed as a quadratic function of average velocity of the ocean flow field (Chitra et al., 1995). In terms of volume transport,

$$\tau_{bx} = \rho K_b \, H^{-2} \, |q| \, q_x \tag{5a}$$

$$\tau_{by} = \rho K_b \, H^{-2} \, |q| \, q_y \tag{5b}$$

where, $q = (q_x , q_y)$ and K_b is the bottom friction coefficient, taken to be 2.0×10^{-3}.

Generally, in coastal hydrodynamic modelling, the initial conditions do not play any role. Hence the usual practice is to assume the ocean to be initially at rest, before the introduction of boundary conditions on lateral boundaries and on the sea surface, i.e η, qx, $qy = 0$; t=0.

The flow solver needs elevation and velocity boundary conditions to be specified along the open boundaries. It can also calculate boundary velocities from the solution domain based on a Sommerfeld radiation condition. For this, at least tide elevations along the open boundaries need to be provided in time. Natural boundary conditions are imposed along the coastal boundaries.

A.5.1 Numerical Solution

We have used a Finite Volume Method (FVM) to discretise the SWE. The FVM is chosen for the SWE as it will better conserve the mass and momentum in the truncated solution domain. To obtain a basic idea of the FVM, the reader is referred to Roache (1998). And for a detailed description of the method one should read Ashford (1996).

The FVM involves partitioning the domain into a set of non-overlapping control volumes. On each control volume, the integral form of the equations is required to hold. The solution unknowns are taken to be the cell-average quantities that interact through fluxes at the boundaries of the control volumes. Using the integral form of the equations guarantees that any discontinuities that arise in the solution will have the proper strengths (and speeds in an unsteady calculation). Several possible choices exist for the control volumes on an unstructured mesh. In this work, a cell-vertex method is used in which the unknowns are associated with the mesh vertices and the control volumes are taken to be the cells of the median dual mesh. The fluxes through the boundaries of the control volumes are computed using an upwind procedure based on Godunov's (Godonov, 1959) method. For this purpose, an explicit multistage scheme is chosen. With the spatial discretisation complete, the PDE reduce to a coupled system of ordinary differential equations that can be written as

$$\frac{dU}{dt} = R(U) \tag{6}$$

$$U(0) = U_0 \tag{7}$$

Where U is the global conserved state vector containing all the unknowns, R(U) is an operator representing the spatial discretisation and U_0 is the initial condition. A widely used explicit method for the above equations is the multistage scheme, where m is the stage, is

$$\begin{aligned} U^{(0)} &= U^n \\ U^{(k)} &= U^n + \alpha_k dt R(U^{(k-1)}), \quad k = 1,2,\ldots,m \\ U^{(n+1)} &= U^{(m)} \end{aligned} \qquad (8),$$

where (n) and (n+1) refer to recent and new time levels respectively, and α_k are the stage coefficients. We have implemented a 1 and a 2 stage scheme with α_0 = 1.0 for the 1 stage scheme and α_0=0.5 and α_1=1.0 for the 2 stage scheme.

Annexure - C

B.1 Computational Model for Advection-Dispersion studies

The computational model is based on a three-dimensional Navier-Stokes equation that solves the mass and momentum conservation of the fluid flow.

Mass conservation: $$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = S_m \tag{1}$$

where S_m = mass source term.

Momentum conservation: $$\frac{\partial}{\partial t}(\rho u_i) + \frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial P}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i + F_i \tag{2}$$

where, τ_{ij} = stress tensor = $[\mu(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i})] - \frac{2}{3}\mu \frac{\partial u_l}{\partial x_l}\delta_{ij}$, p = static pressure,

g_i = gravitational acceleration in the ith direction, and F_i = external body forces. Some of the important aspects of the model are described as follows.

B.2 Standard κ-ε Model

For the turbulent flow, additional conservation equations for κ (kinetic turbulence energy) and ε (turbulence energy dissipation) are solved. In the present project, a standard κ-ε model was adopted in the calculation. The standard κ-ε model is a semi-empirical model, which is valid for fully developed turbulent flows. It is derived from the Reynolds-Averaged Navier-Stokes equations based on the assumption that the flow is fully developed. The model has been found to work well for a wide range of wall-bounded and free shear flows. The equations of the standard κ-ε model are given below.

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho u_i k) = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right] + G_k + G_b - \rho\varepsilon \tag{3}$$

and

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho u_i \varepsilon) = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial \varepsilon}{\partial x_i}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}\{G_k + (1 - C_{3\varepsilon})G_b\} - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \tag{4}$$

where G_k is the generation of k due to the turbulent stress, and G_b is the generation of k due to buoyancy.

The model constants have the following default values:

$$C_{1\varepsilon} = 1.44, \quad C_{2\varepsilon} = 1.92, \quad C_{\mu} = 0.09, \quad \sigma_k = 1.0, \quad \sigma_{\varepsilon} = 1.3$$

These default values have been determined from experiments with air and water for fundamental turbulent shear flows. They have been found to work fairly well for a wide range of wall-bounded and free shear flows.

B.3 Boundary Conditions and Initial Condition

B.3.1 Wall boundary conditions - Shoreline

Non-slip boundary condition is used at walls. The modified law-of-the-wall was evaluated using the applied roughness height to calculate the shear stresses at walls. A roughness constant of 0.5 as the default value was used for the simulation.

B.3.2 Velocity boundary conditions - for tidal flow inlet

The intake and diffuser ports are assigned with known discharges. The velocity inlet boundary condition was applied. The inflow is assumed to be fully open to allow the flow ramp up to the maximum flow rate from start of simulations with the specified pressure head corresponding to the water depth. Velocities obtained in the tidal hydrodynamics study is used for this purpose.

B.3.3 Pressure boundary condition - outlet

Atmosphere pressure was applied at the free surface boundary. Slip condition has been used for velocities tangential to the boundary.

B.3.4 Initial condition

The model simulation starts from rest. This is a suitable condition as the dispersion process is governed predominantly by advection and diffusion.

Table.1. Tide levels at the Uppur site

(As per NHC 317).

S.L	Description	Level w.r.t. Chart Datum
1	**Mean High water Spring (MHWS)**	**(+)0.7m**
2	**Mean Low water Spring (MLWS)**	**(+)0.1m**
3	**Mean High water Neap (MHWN)**	**(+)0.5m**
4	**Mean Low water Neap (MLWN)**	**(+)0.3m**
5	**Mean Sea Level**	**(+)0.4m**

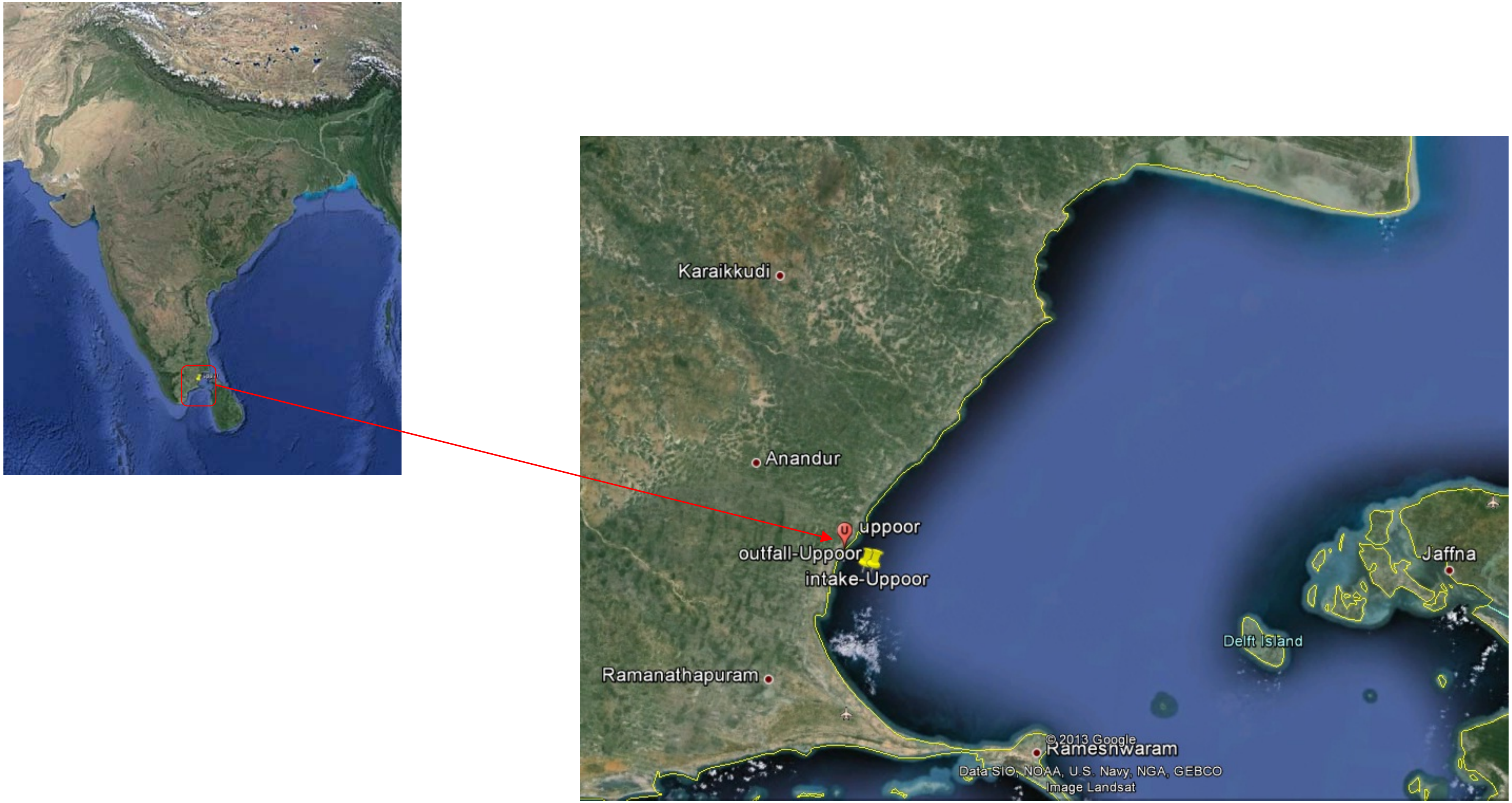


Fig.1. Location of Study Area .

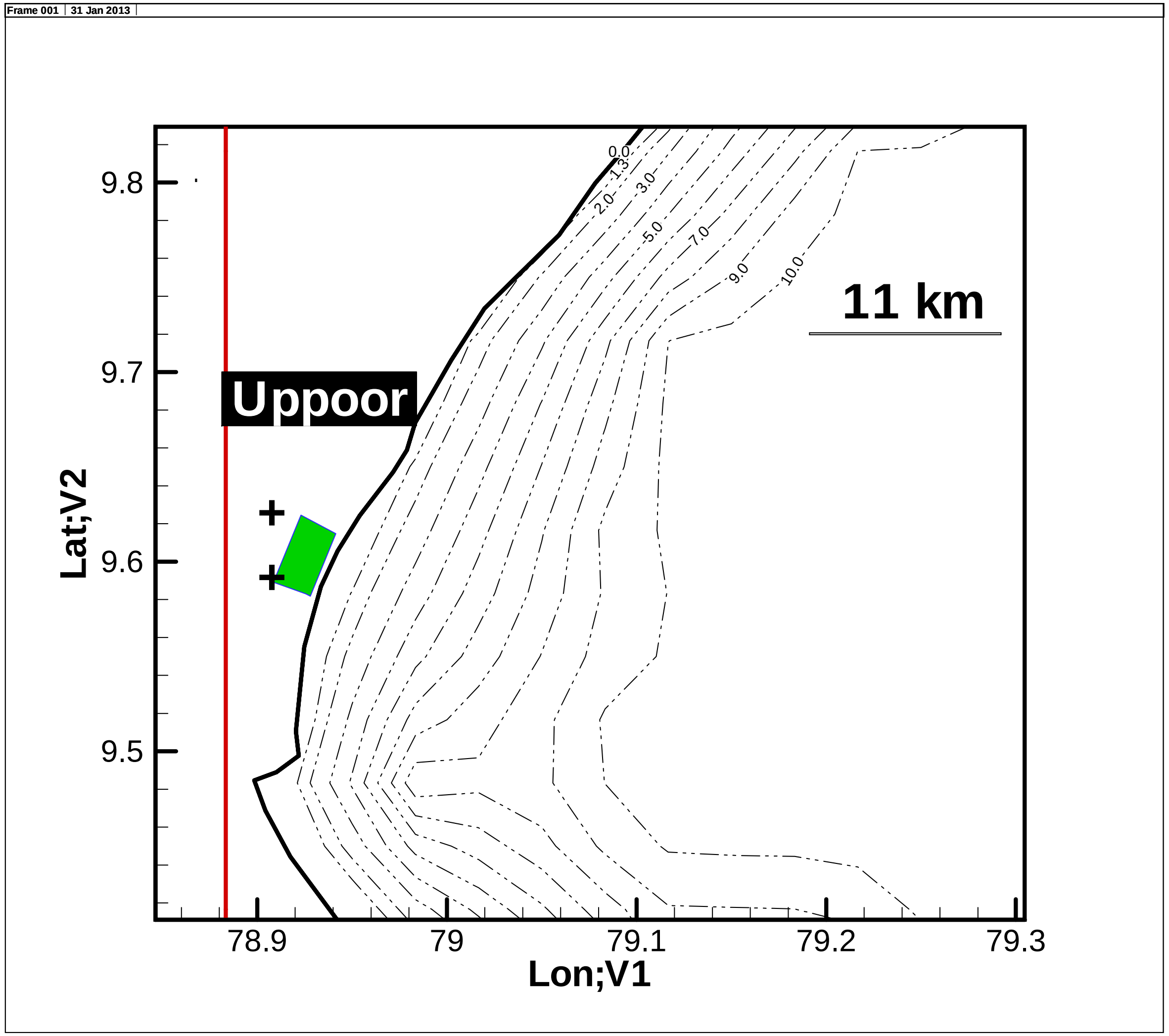


Fig.2. Bathymetry details of the study area near Uppur.

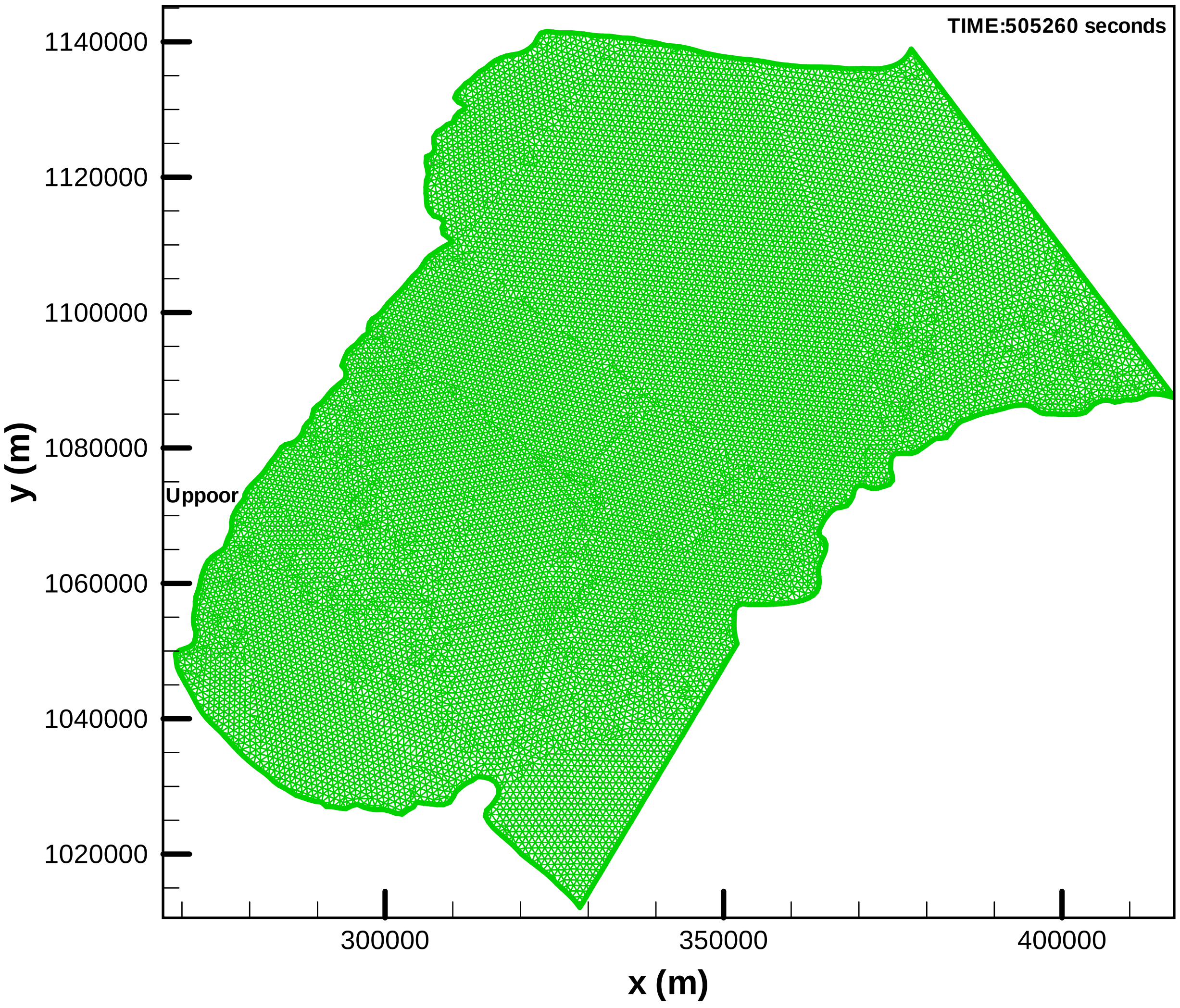


Fig.3. Computational mesh for study area

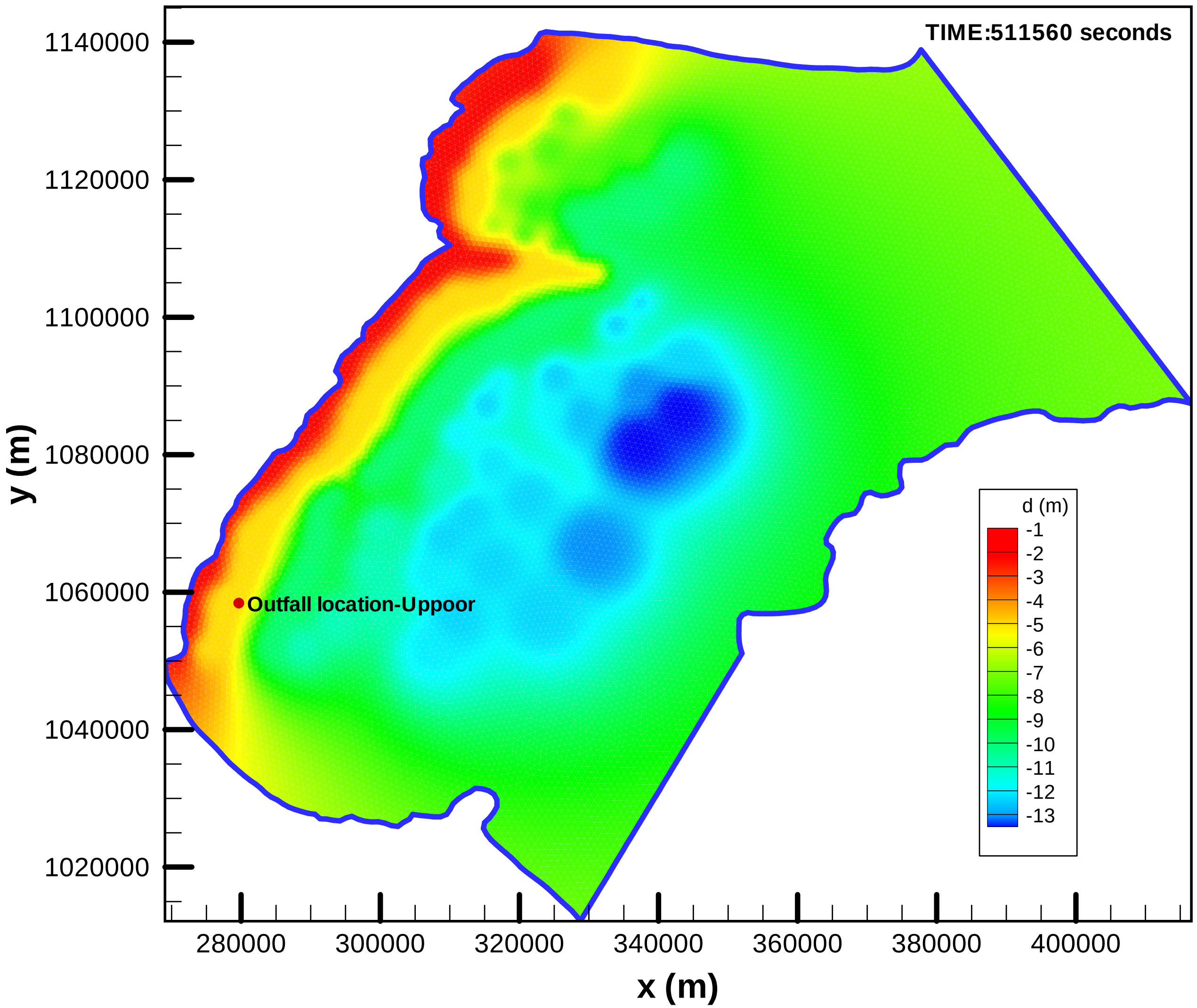


Fig.4. Simulated bathymetry for study area

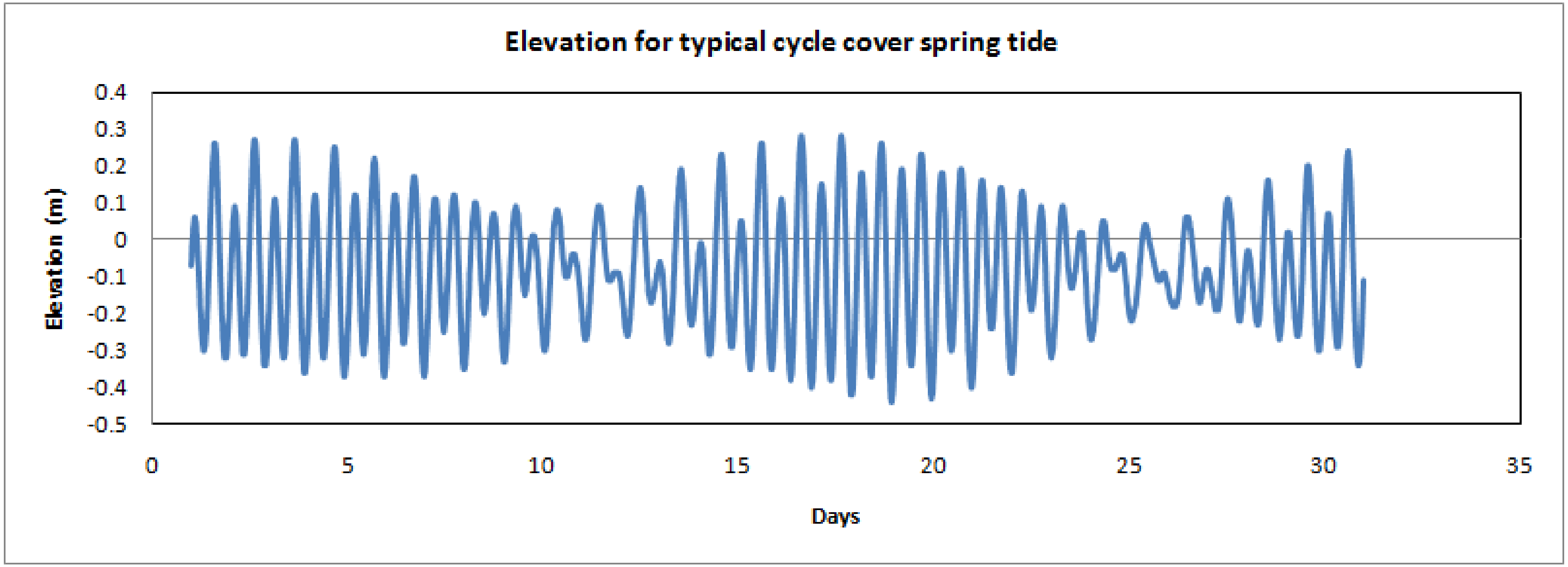


Fig.5. Typical tide profile covering spring-neap cycle in Palk Strait.

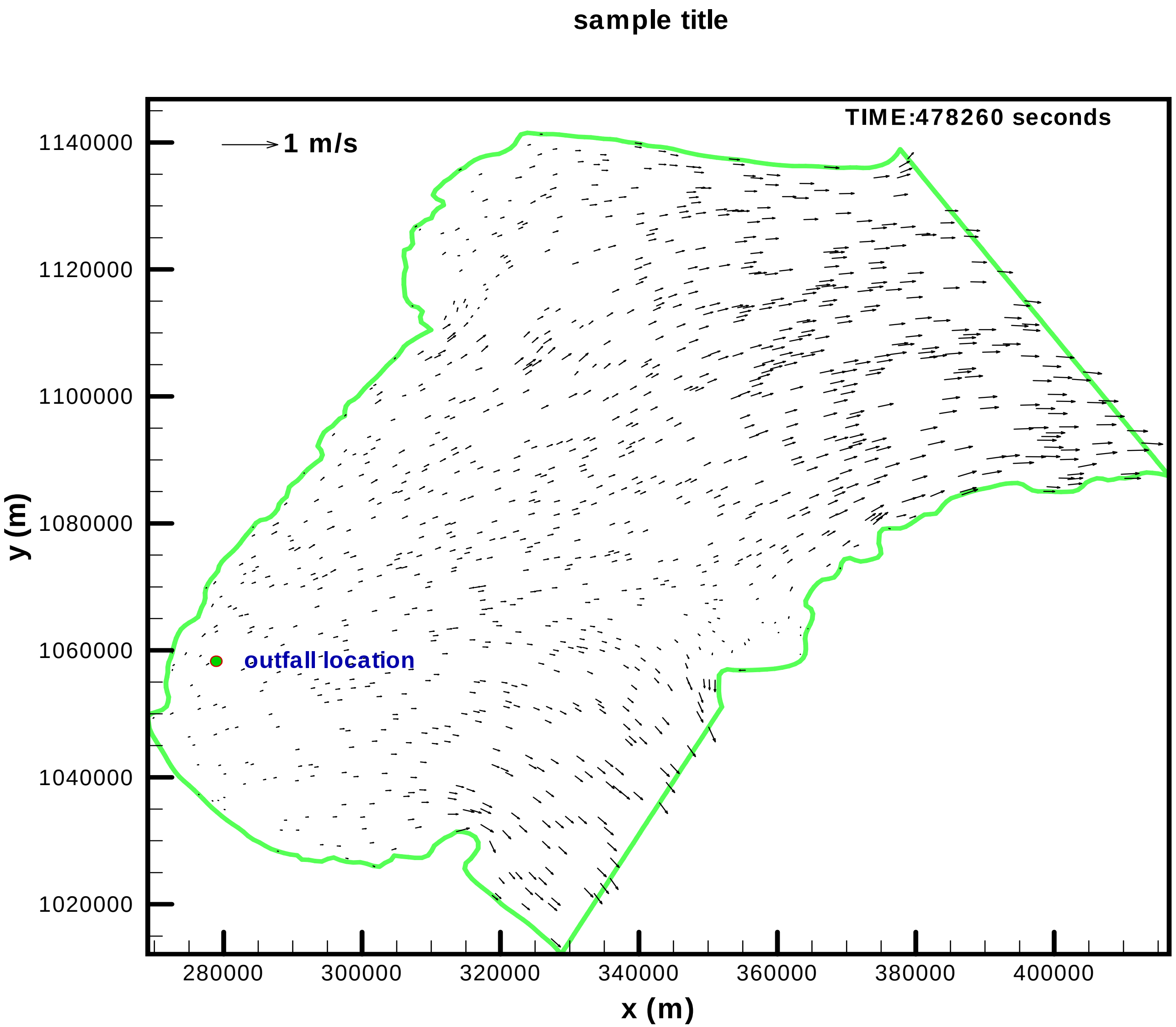


Fig.6. Spring tide - velocities at low tide - Full model.

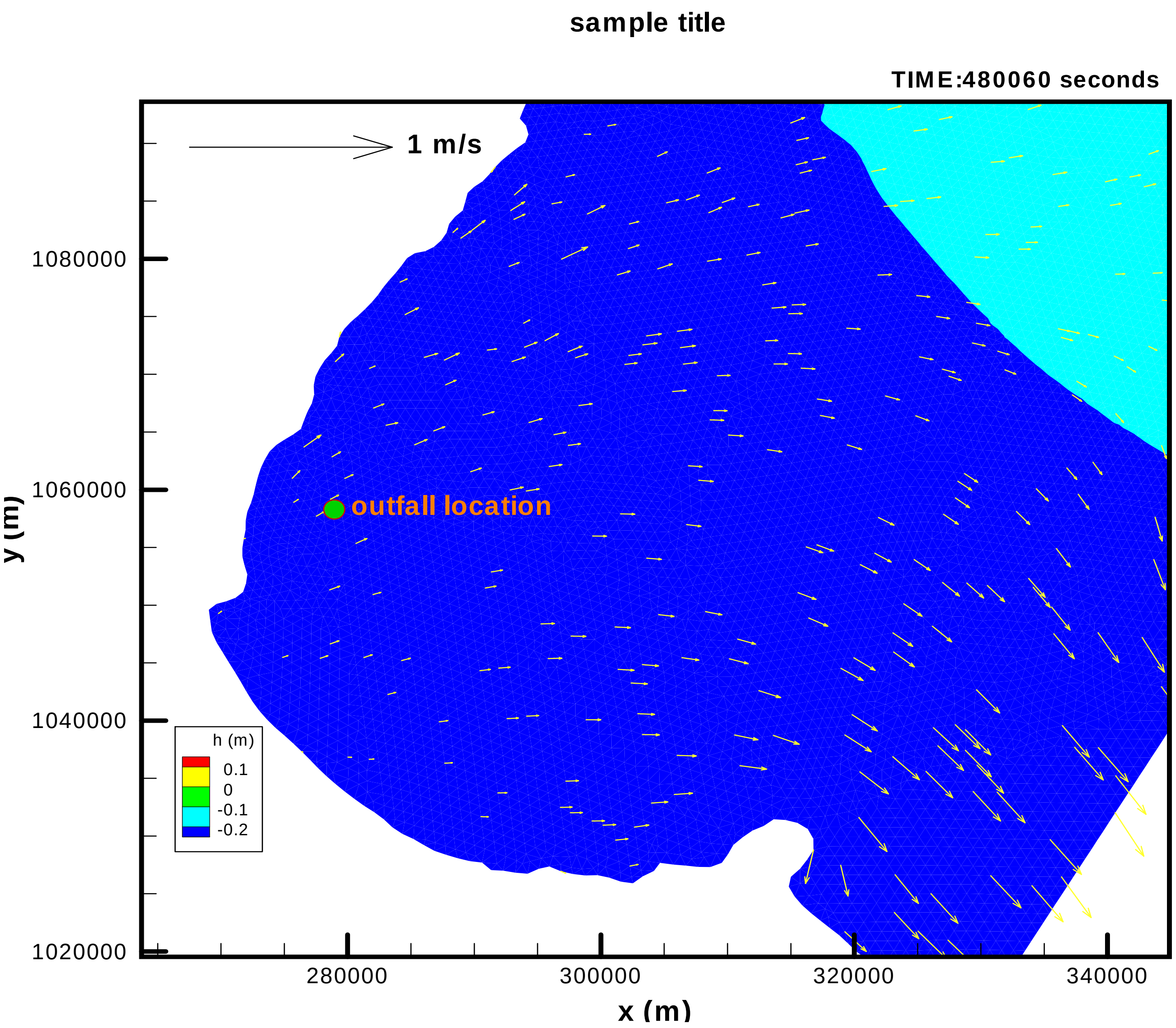


Fig.7. Spring tide - velocities at low tide - in Outfall point.

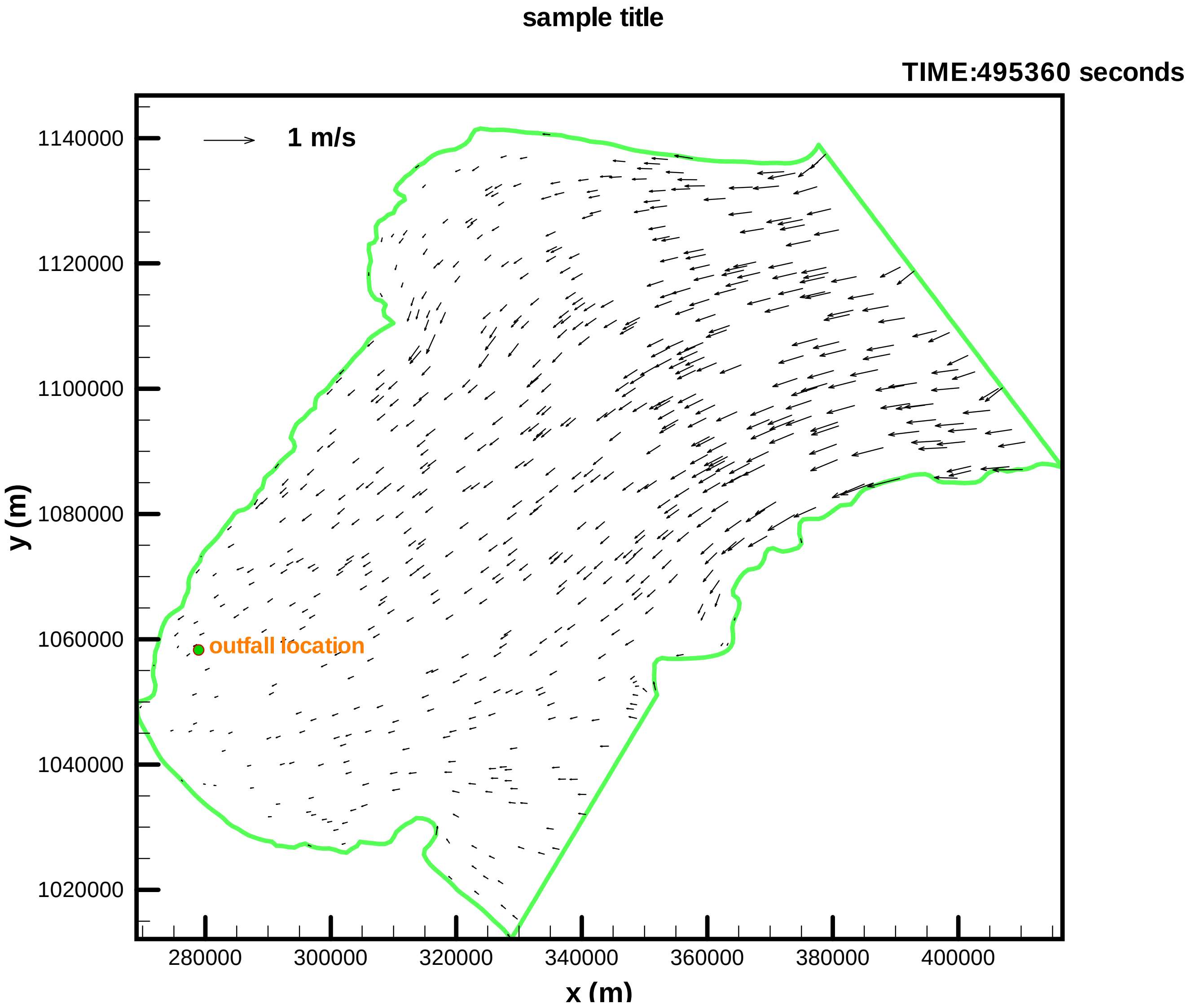


Fig.8. Spring tide- velocities during flooding tide - Full model.

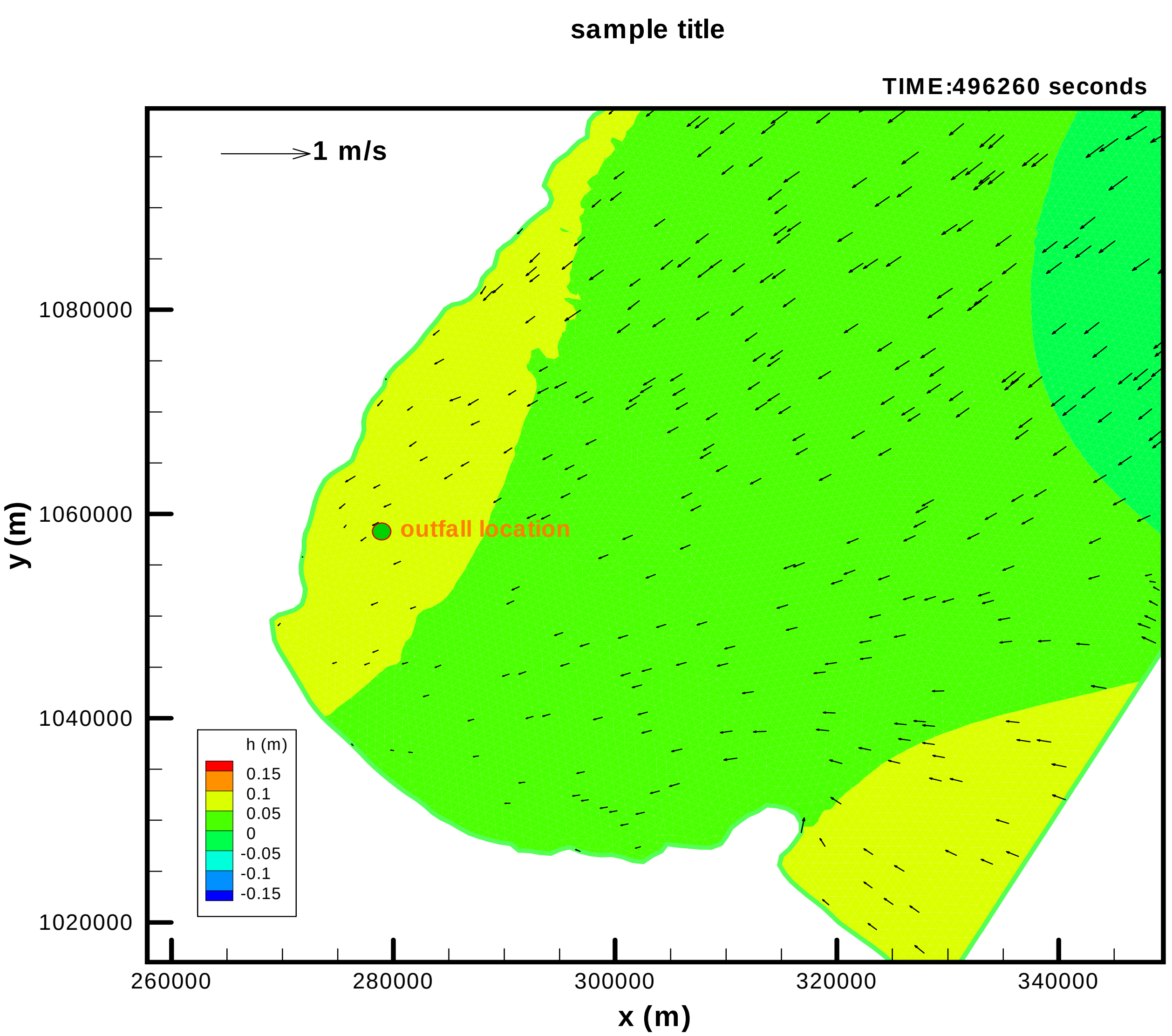


Fig.9. Spring tide - velocities during flooding tide – in Outfall Point.

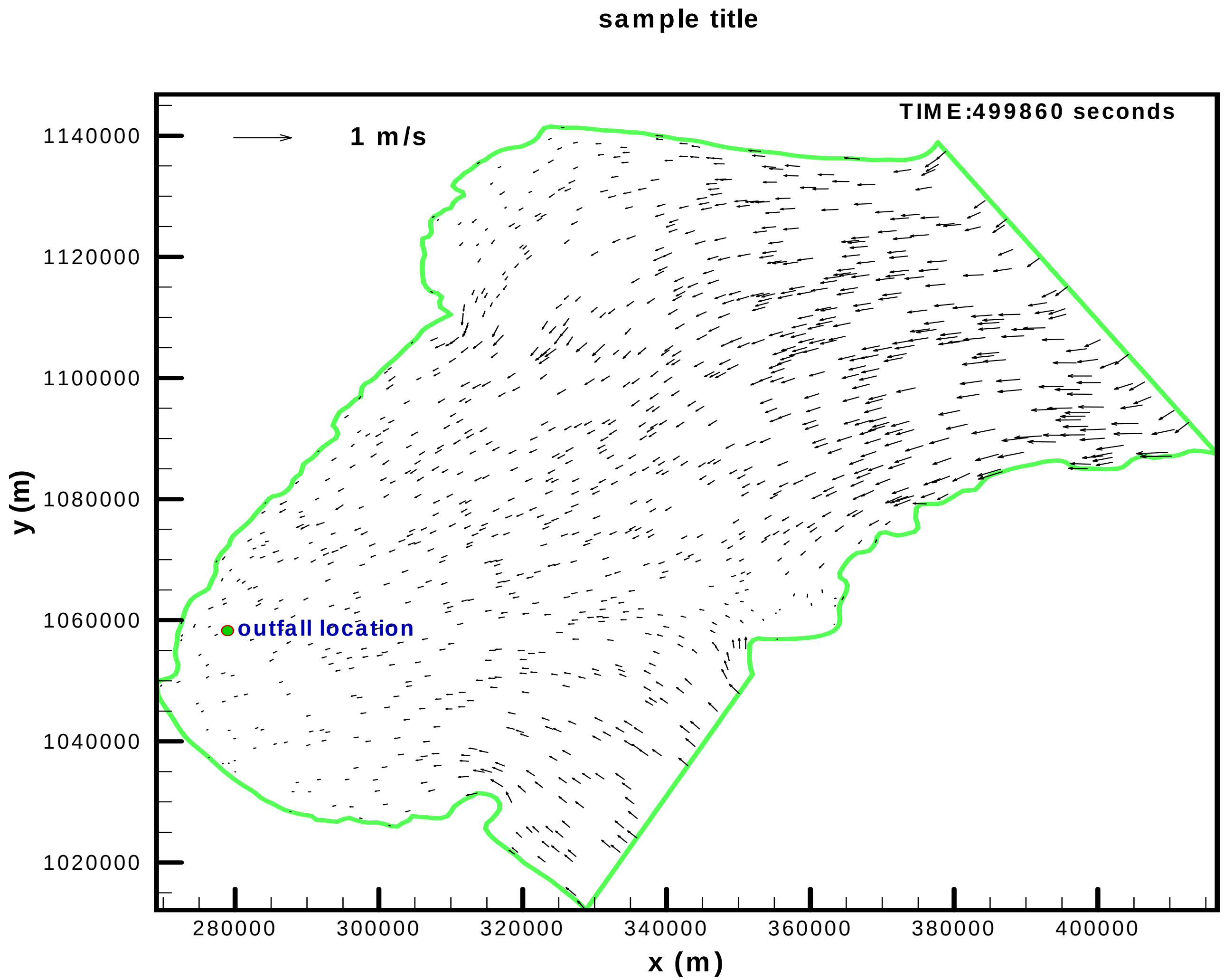


Fig.10. Spring tide - velocities at high tide - Full model.

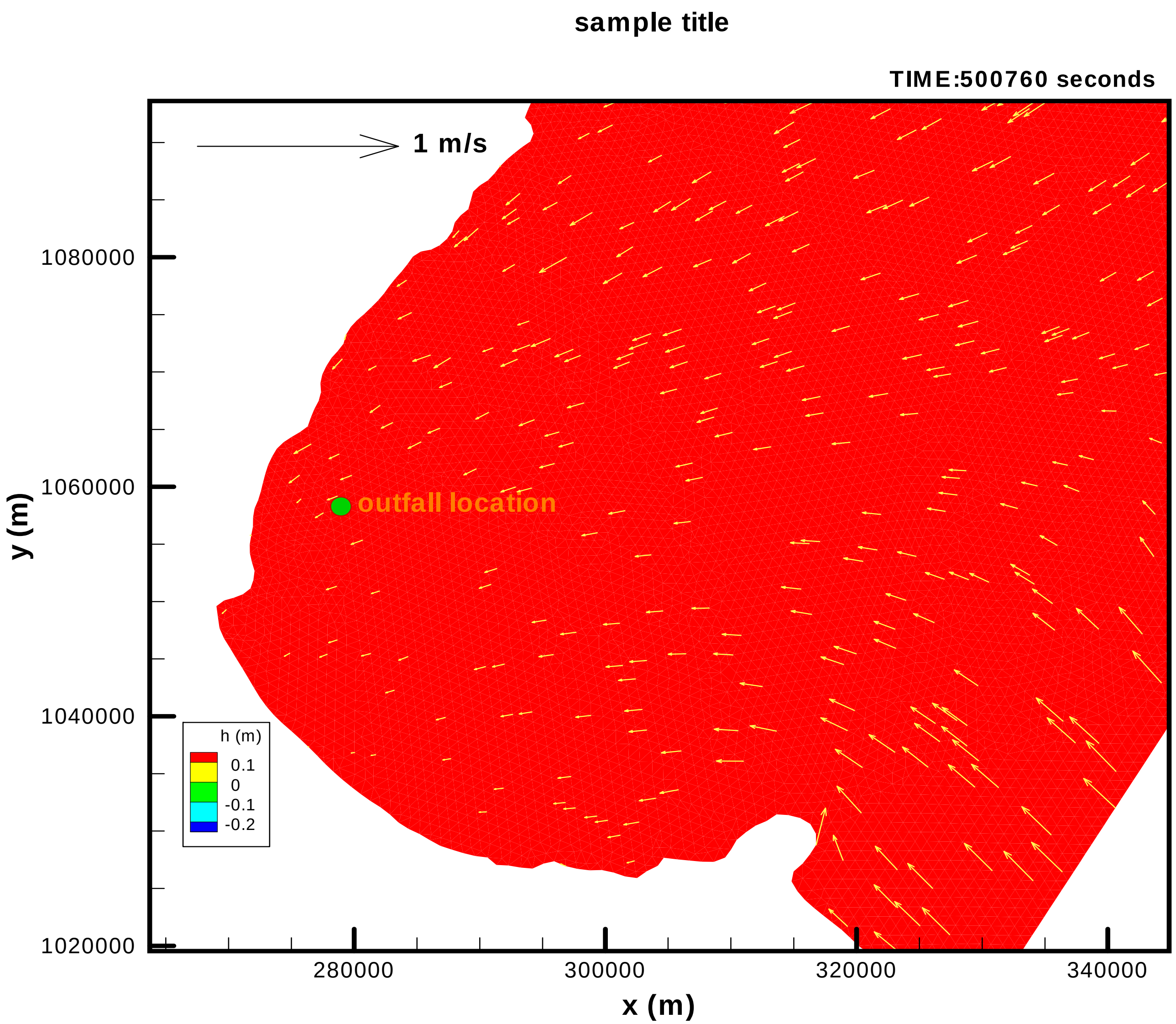


Fig.11. Spring tide - velocities at high tide - in Outfall point.

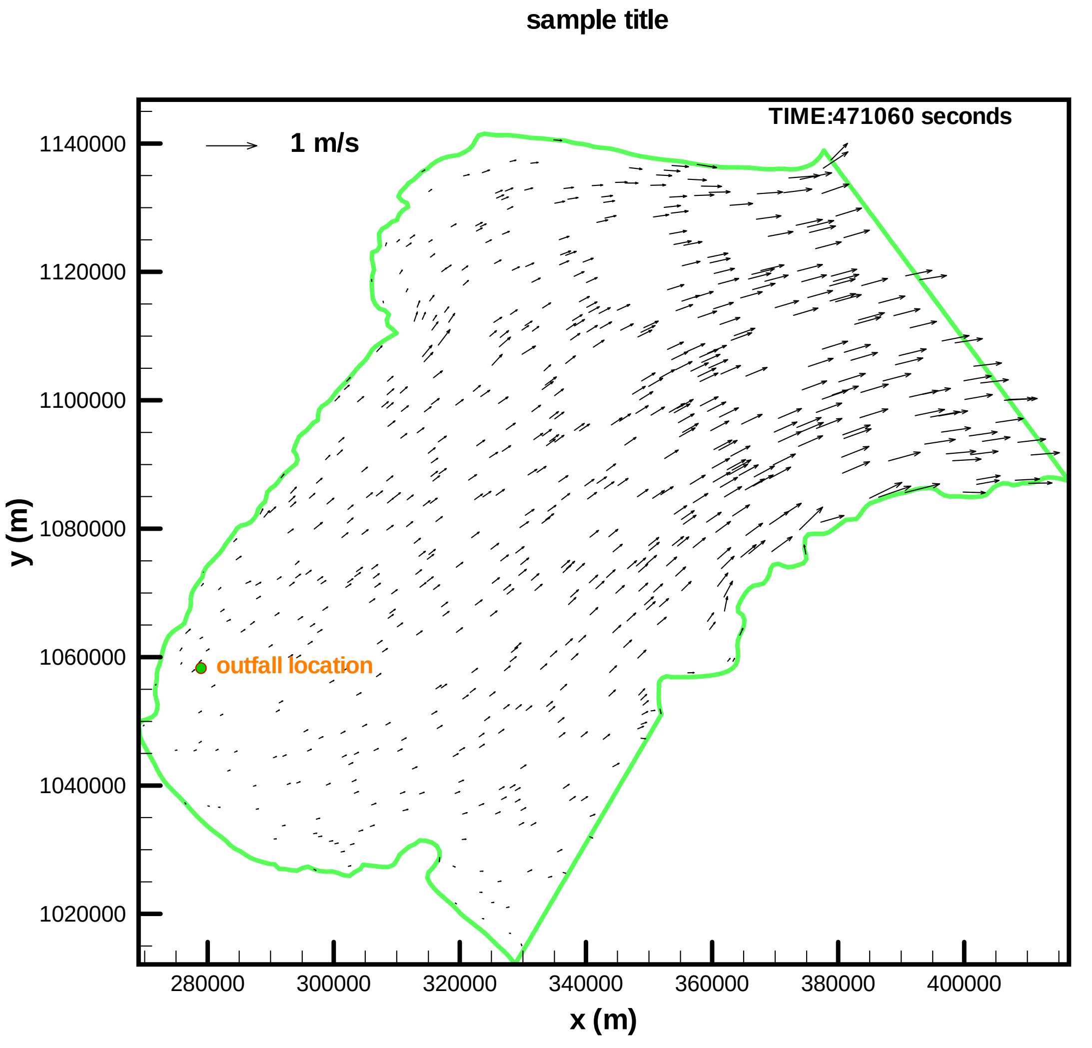


Fig.12. Spring tide- velocities during ebbing tide - Full model.

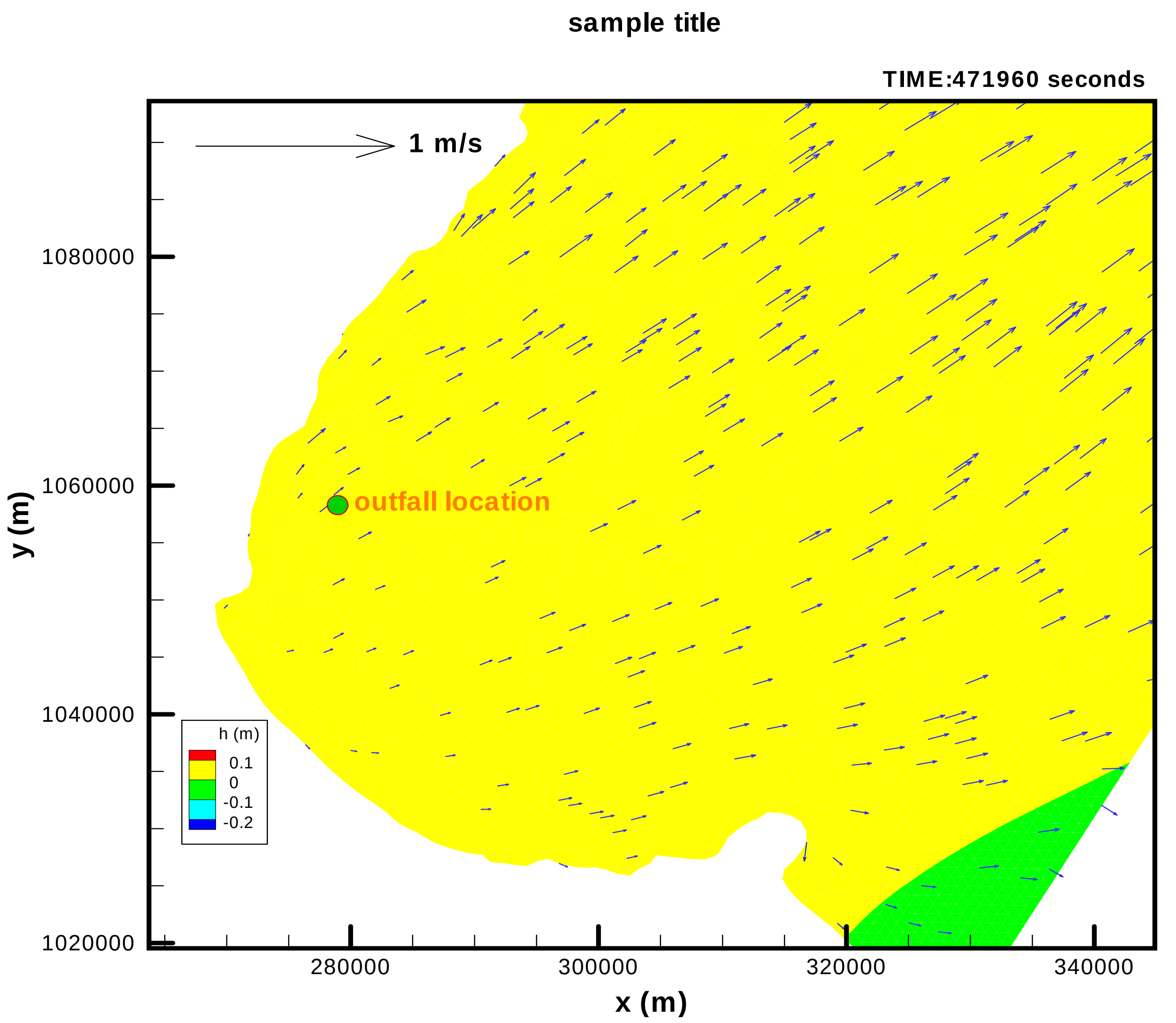


Fig.13. Spring tide - velocities during ebbing tide – in Outfall Point.

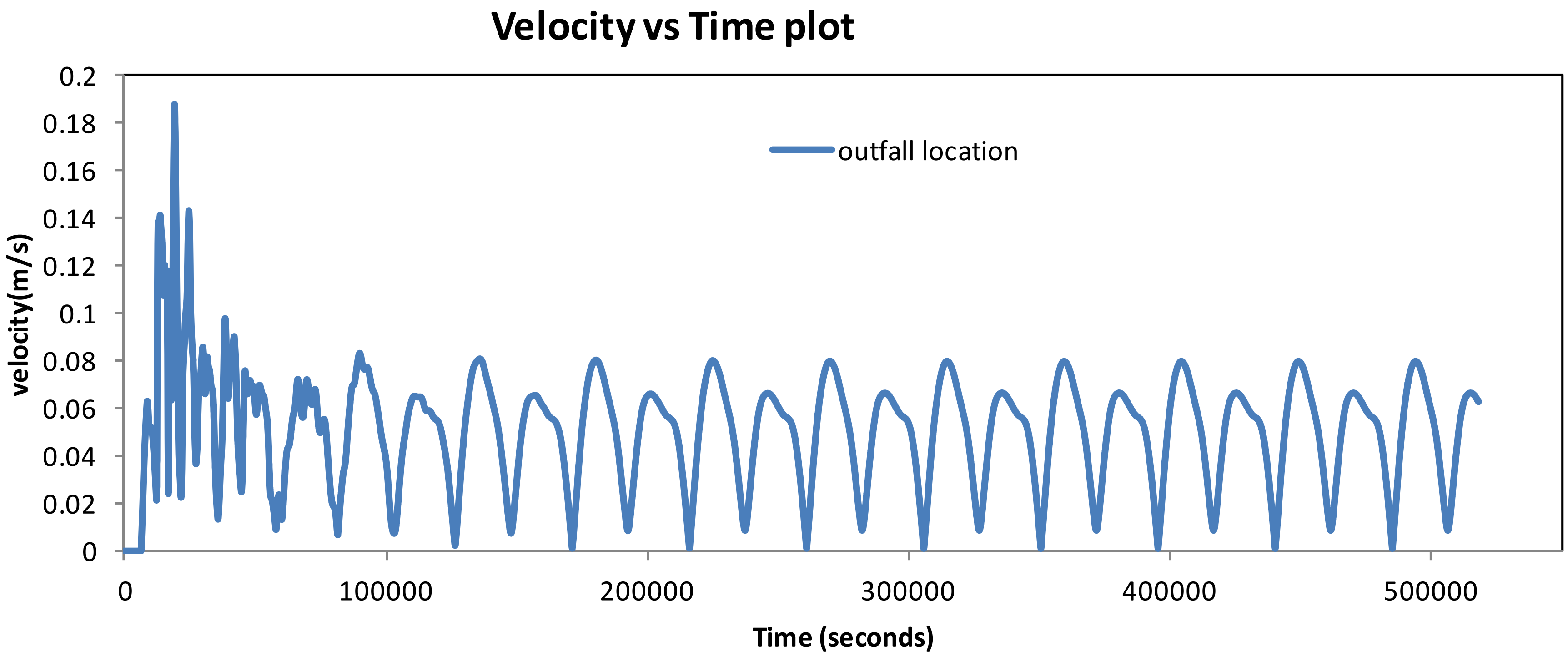


Fig.14. Velocity Vs Time Plot at Outfall location.

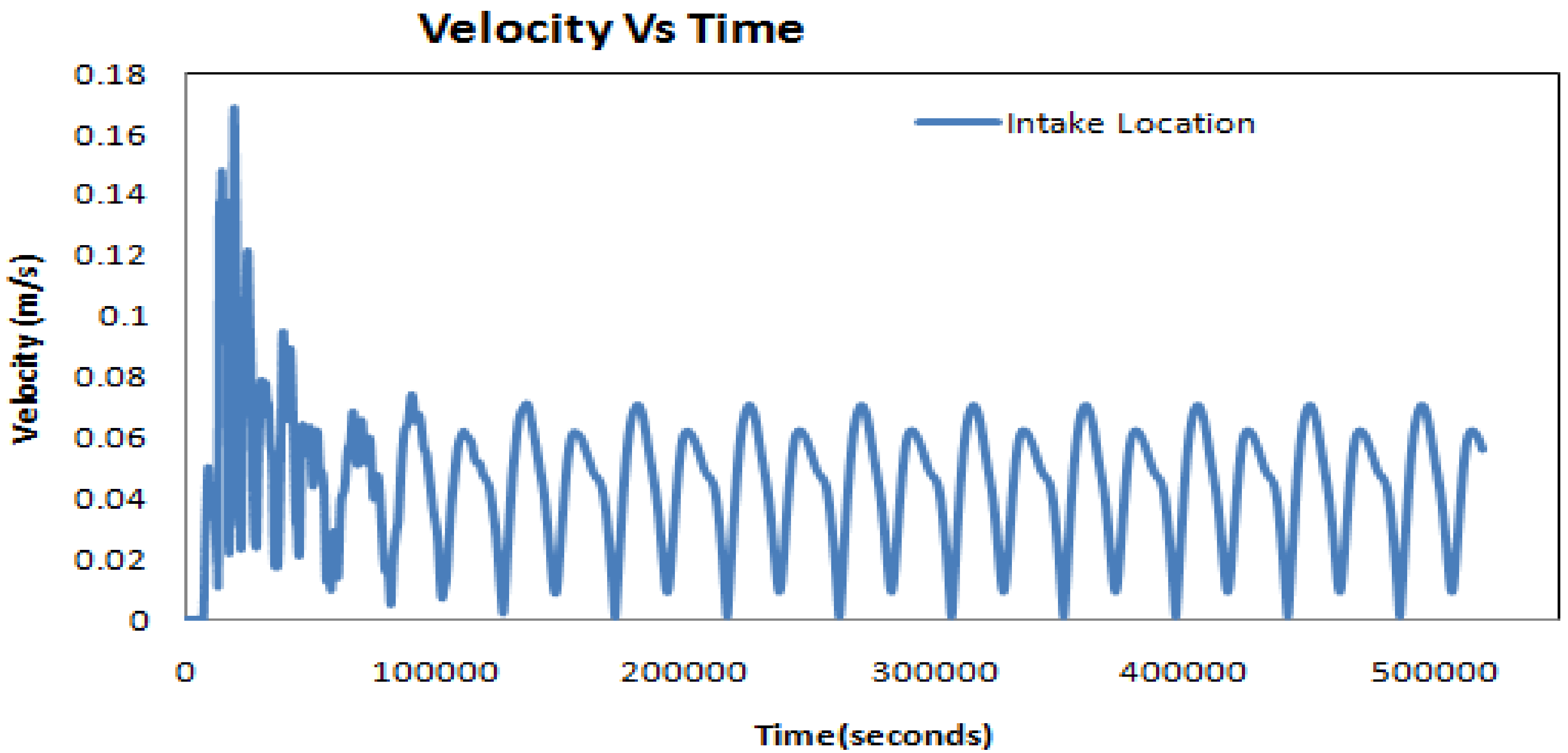


Fig.15. Velocity Vs Time Plot at Intake location.

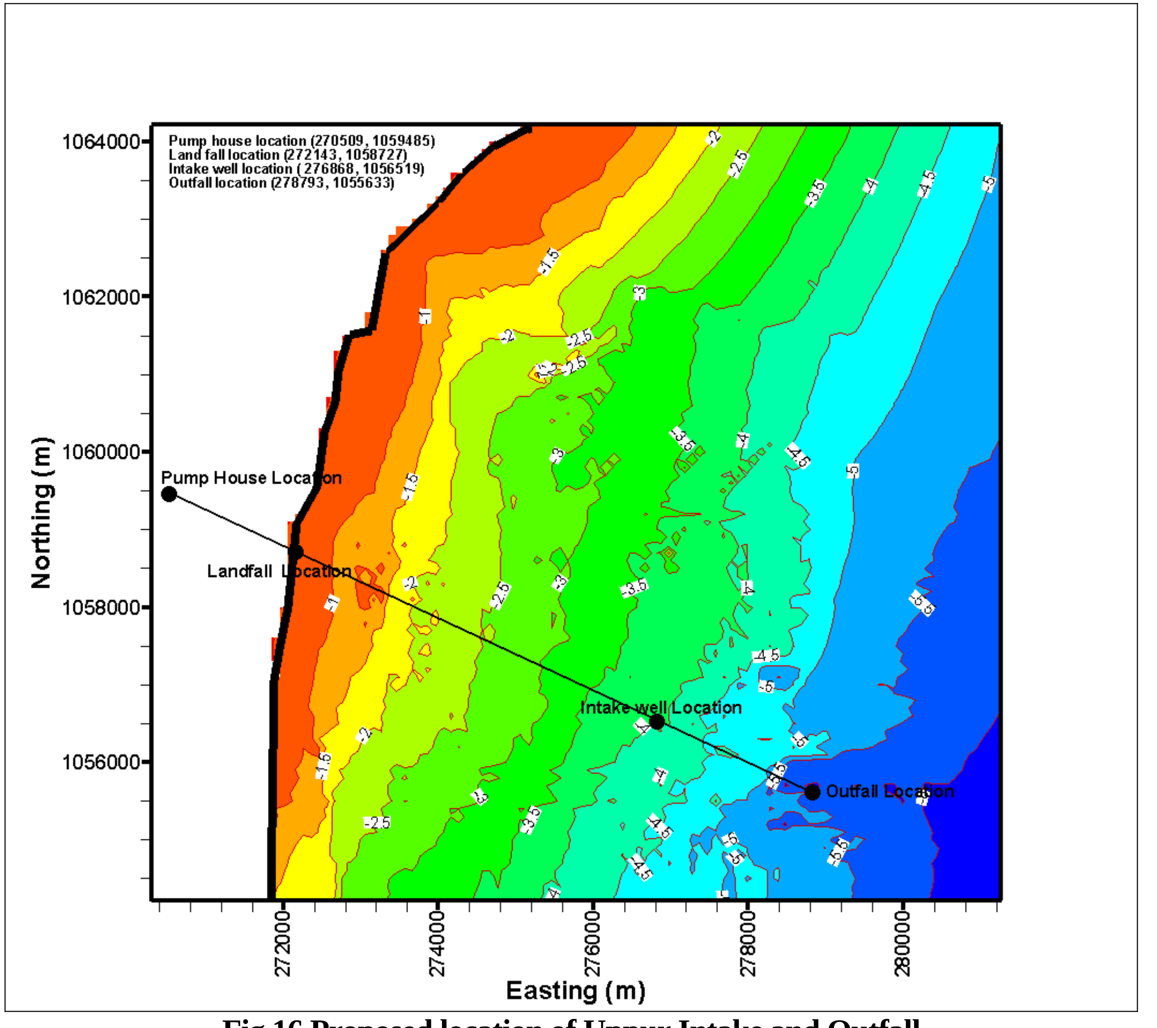


Fig.16 Proposed location of Uppur Intake and Outfall

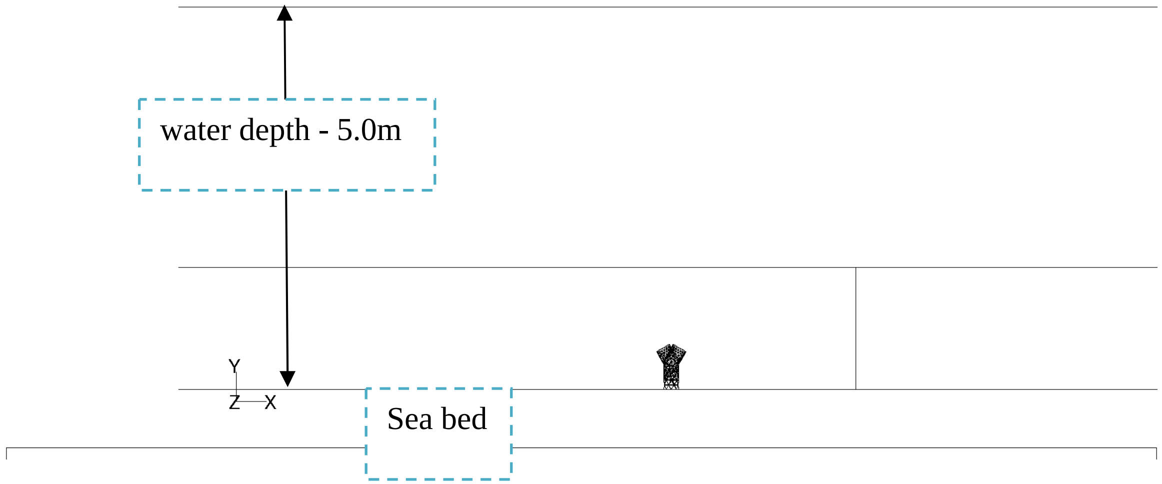


Fig.17. Overall view of Outfall pipe and 8 diffusers within domain.

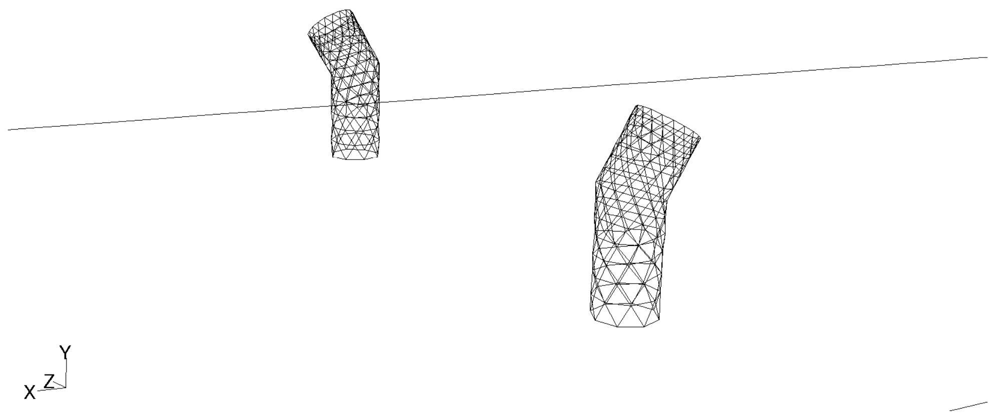


Fig.18. Closer view of Outfall flow pipe and diffusers within flow domain – details of geometry of 2 diffusers.

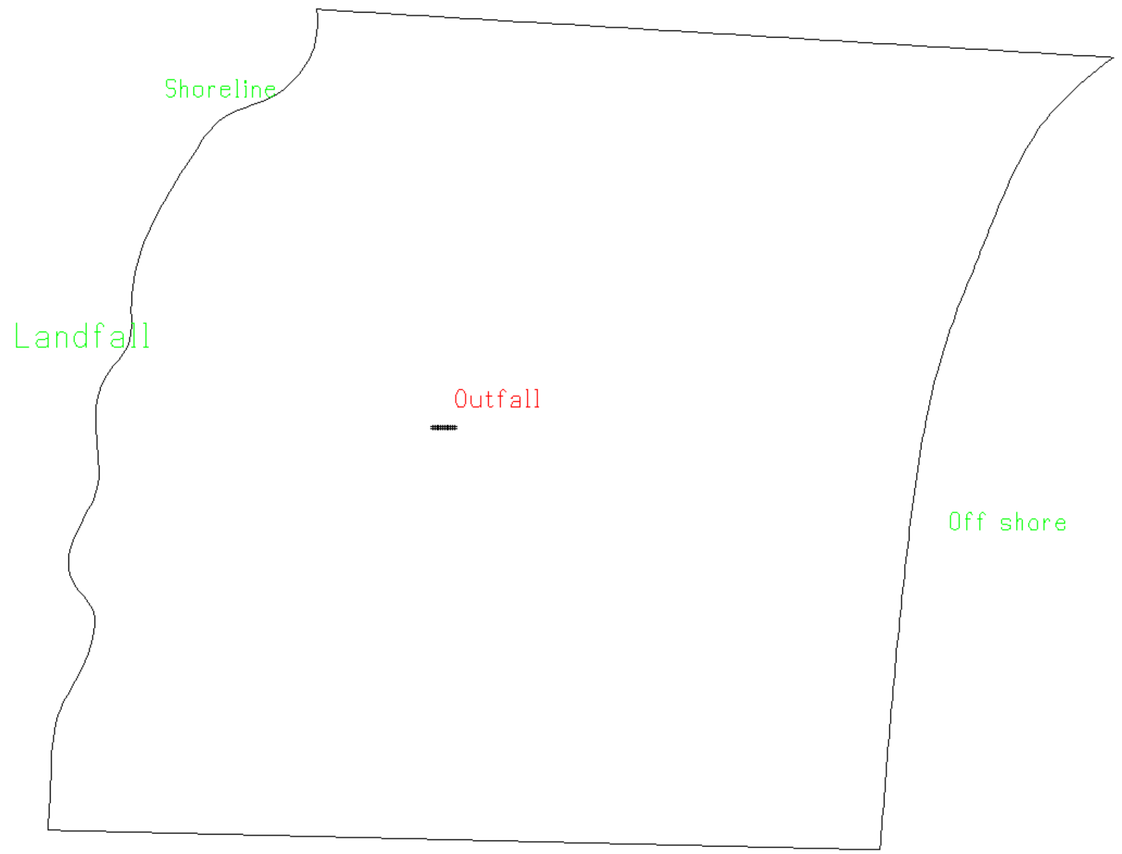


Fig.19a. View of study area with location of outfall shown.

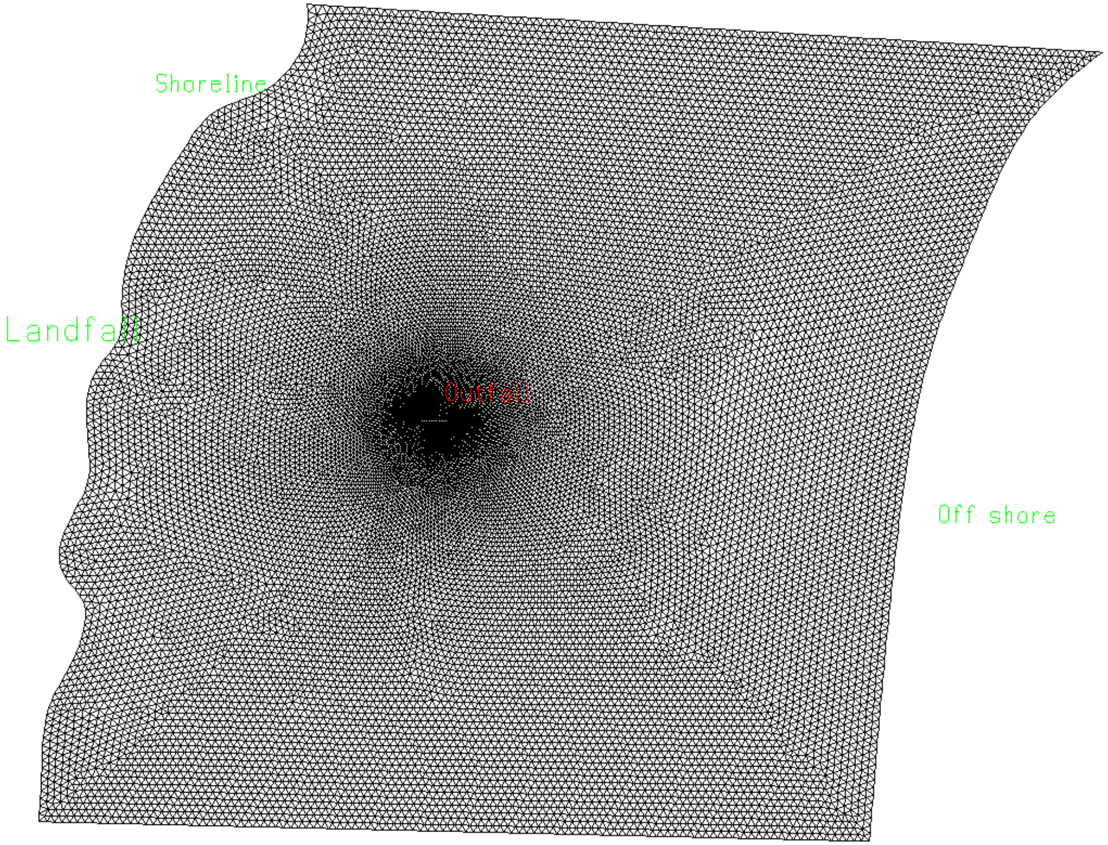


Fig.19b. Computational mesh with location of outfall shown.

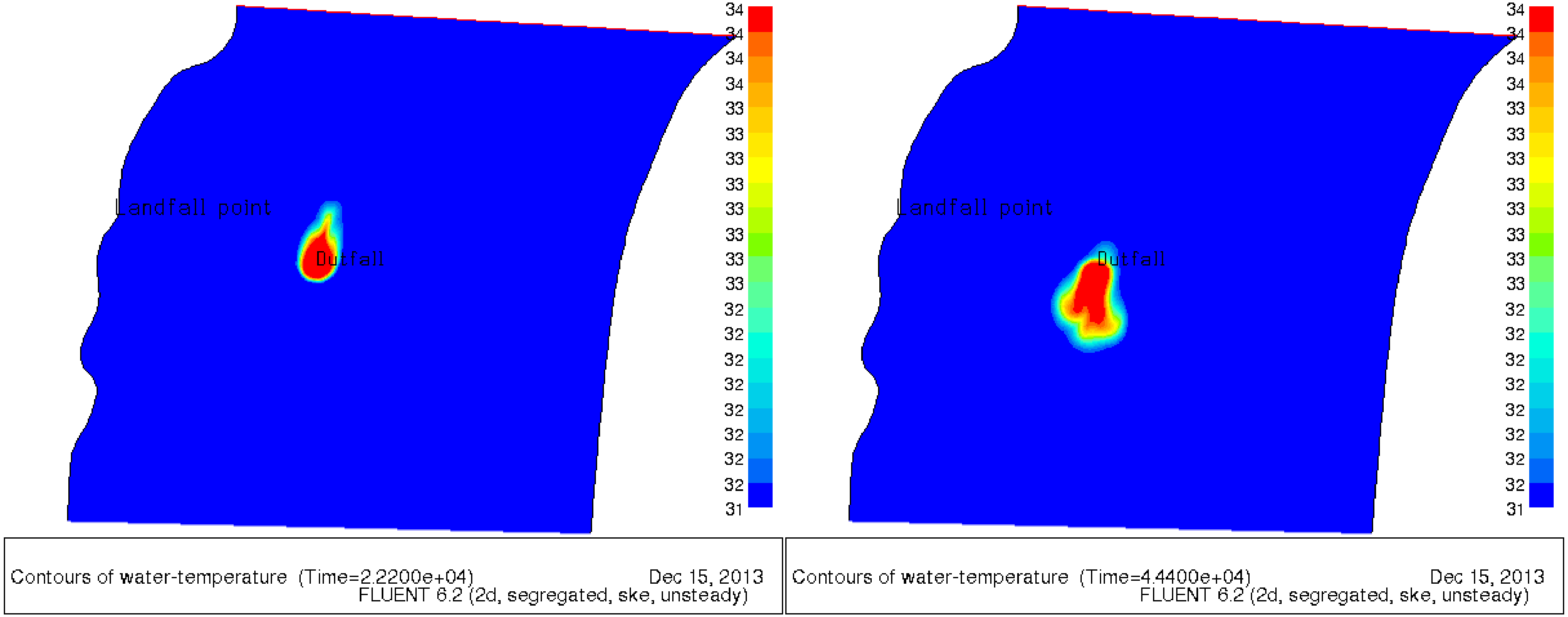


Fig.20. Thermal dispersion patterns during flooding and ebbing - no Wind and waves.

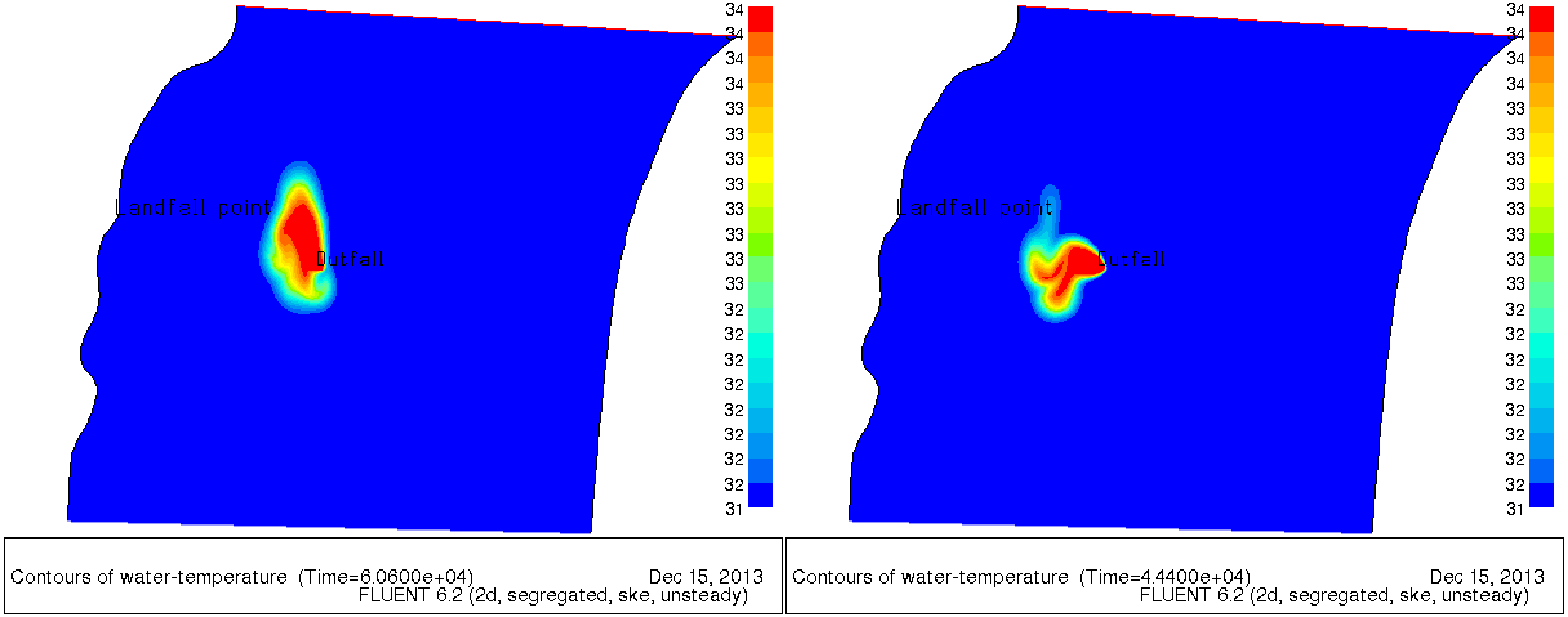


Fig.21. Thermal dispersion patterns during flooding and ebbing - Wind and waves towards shore.

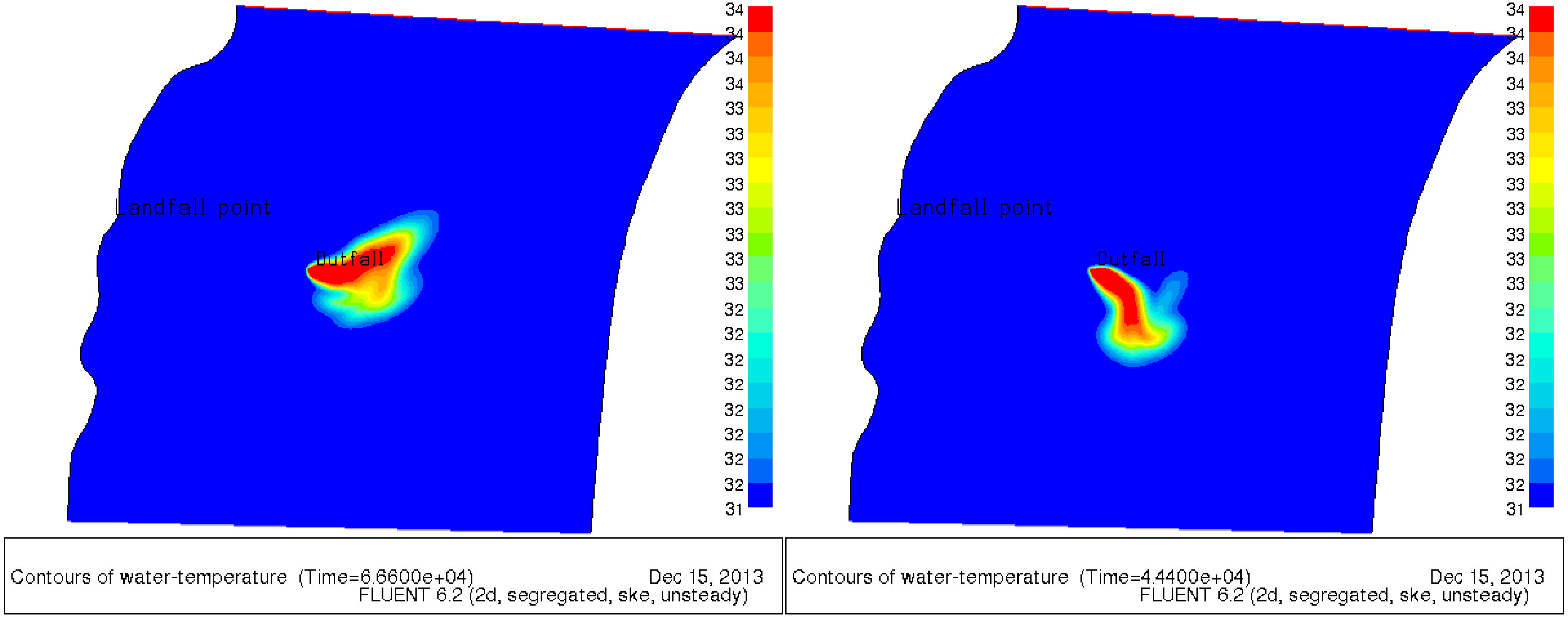


Fig.22. Thermal dispersion patterns during flooding and ebbing - Wind and away from shore.

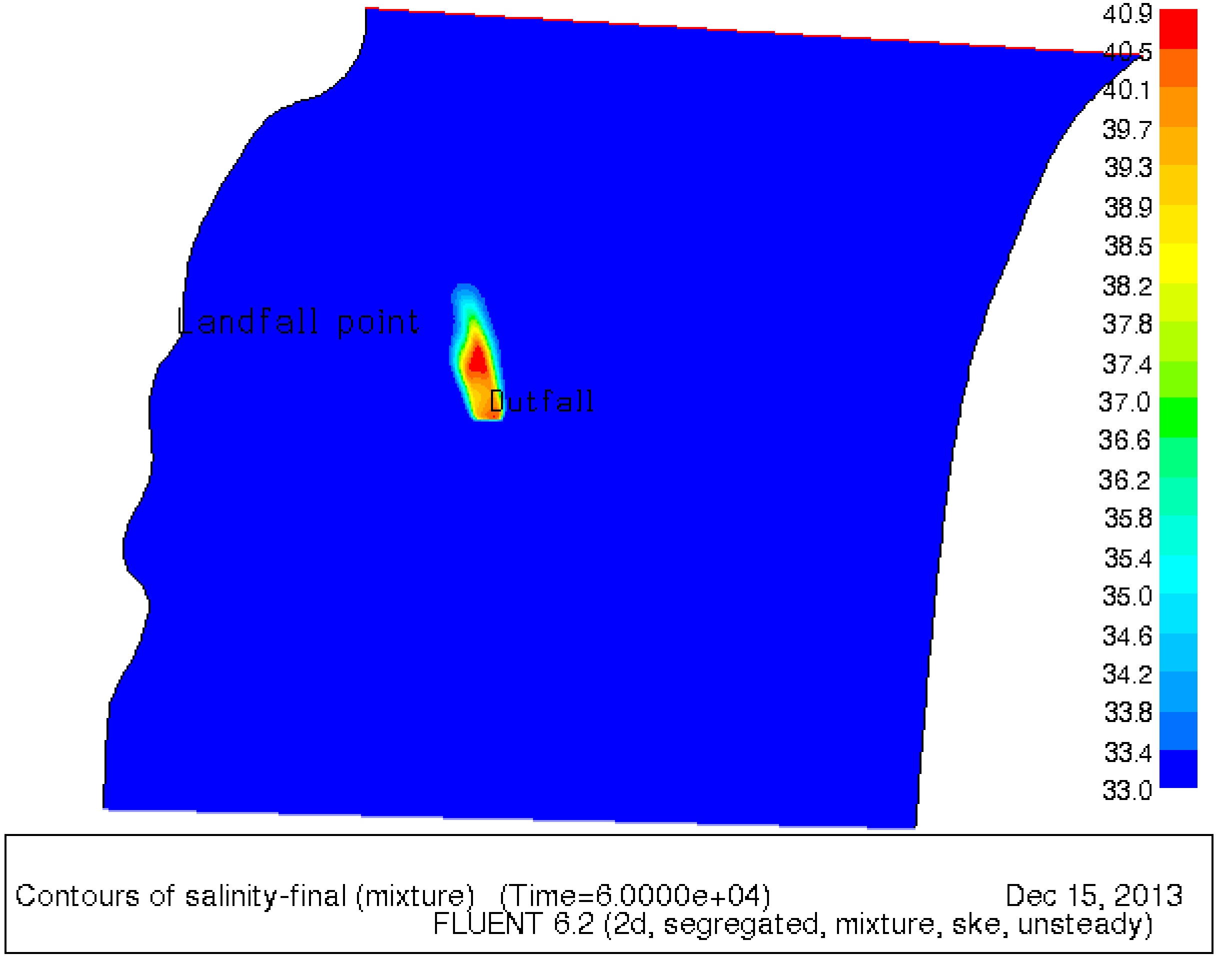


Fig.23. Salinity plume patterns during flooding - Wind and wave towards shore.

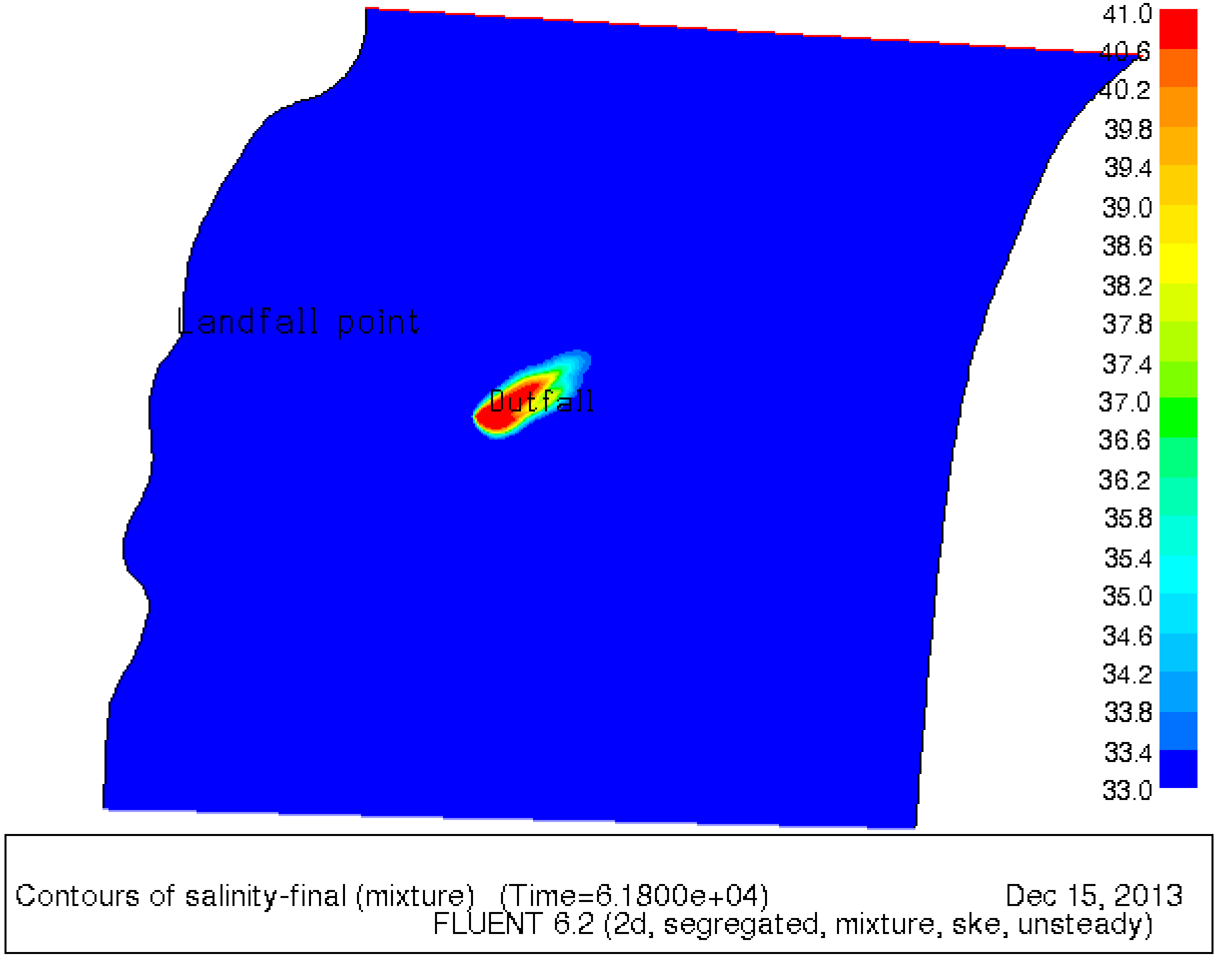
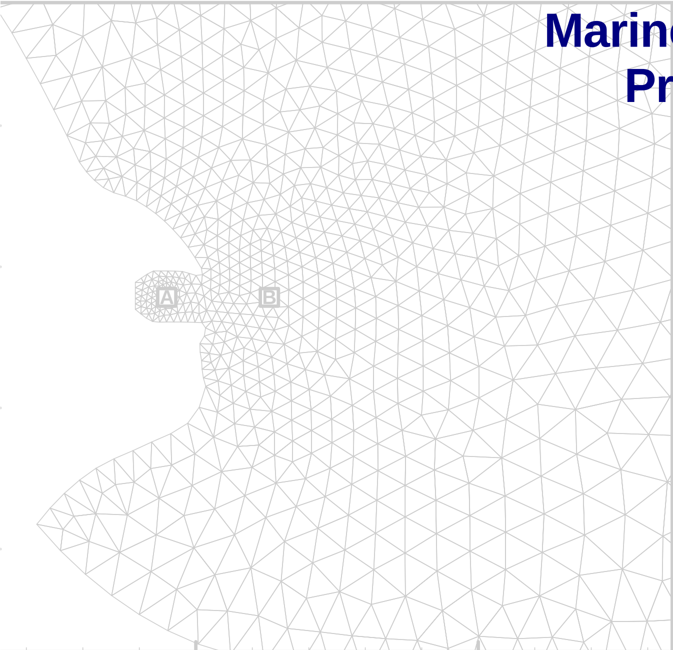


Fig.24. Salinity plume patterns during flooding - wind away from shore.



Marine EIA/EMP studies for Outfall of Proposed 2 x 800 MW Coal based power plant at Uppur, Ramanathapuram District, TN.

Annexure-B

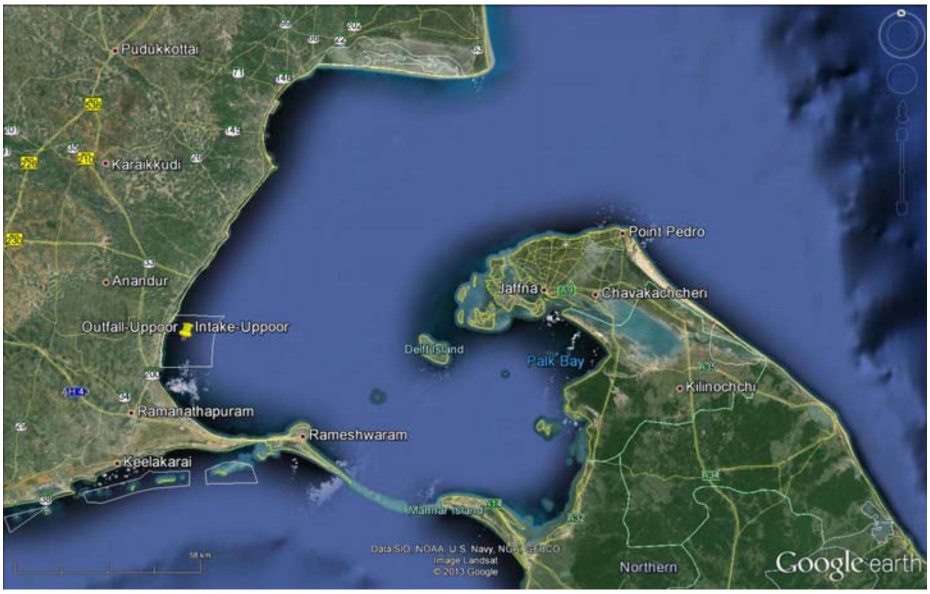
– Design of Intake and Outfall

Client

TANGEDCO, Chennai

Consultants

Prof. K. MURALI
Prof. S. A. SANNASIRAJ
Prof.R.SUNDARAVADIVELU



DEPARTMENT OF OCEAN ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY MADRAS
CHENNAI, INDIA - 600 036

Nov. 2014

HYDRAULIC CALCULATIONS

1. INTAKE STRUCTURE

1.1 Design calculations

Total sea water required for the total units (15,400m^3/hr)	=	4.28 cumecs
No of pipes of 1.4m diameter connected in parallel	=	2
Discharge in a single pipe	=	2.14 cumecs
Velocity of water flow in the pipe	=	1.39 m/s

The total length of each pipeline is 5.3km in sea and 1.8 km in land = 7.1 km

Well design:

Fish escape velocity	=	0.15m/s
Opening area to be provided	=	4.28 / 0.15 m^2
Size of Circular openings	=	2.1 m dia.
No. of openings	=	8
Diameter of well	=	14m dia single well
No of pumps	=	4 no. x 5000 m^3/hr
Stand-by pump	=	1 pump (3 pumps operating at any time)

1.2 Head loss calculation

<u>Major loss</u>

The Darcy – Weisbach friction formula is used to establish the head loss due to pipe friction.

$$h_f = \left[\frac{flv^2}{2gD}\right]$$

where,

h_f – Head loss in m.

f – Moody's Friction Factor

v – Velocity of the influent water in the pipe in m/s.

h_f **= 5.7m for 7000m length of pipeline.**

The major head loss shall be considered for fixing pumping heads.

2. HYDRAULIC PERFORMANCE OF INTAKE WELL

The intake well has a total outer diameter of 14m . The maximum current speed at site has been observed to be 0.1m/s. Correspondingly, the Reynolds number (*Re*) will be 1.4×10^6 and Froude number (*Fr*) will be 0.077. Hence, the flow around the well will be fully turbulent. Hence, the buondary layer will be broken down around the cylinder with no strong velocity gradients and pressure gradients around it. Because the *Fr* is very low, there will not be significant variations in the water level as the current passes the well.

In terms of waves, we shall look at the KC (Keulegan Carpenter) number. The KC number will be about 1.0. Hence, no flow separation is expected and almost smooth flow is expected around the cylinder due to waves and as diffraction parameter will be less than 0.2 for most waves, there will not be significant diffraction taking place. The above observations means that no abrupt change is pressure and velocities is expected around the intake well and hence the currents and waves will smoothly flow around the well.

The intake velocity is restricted to about 0.15m/s. There are 8 openings of 2.1m diameter in the well with total area of 28.5 m^2. The holes are placed in a regular manner so that the inflow will not be able to develop any continuous gradients in the vertical and horizontal direction. Hence, there will not be a chance of forced vortex formation around the well.

Moreover, the velocity of 0.15m/s will allow most fish species to escape without getting caught in the inflow. Furthermore, bar screens with 150-200mm openings shall be provided to prevent large fish from entering the well and small fish to escape.

Conclusion: Hence, the present design of Intake well satisfies all marine requirements.

3. OUTFALL STRUCTURE

3.1 Design calculations

The port design is governed by Densimetric Froude Number,

$$F_o = \frac{u}{\sqrt{g_o' d_o}}$$

Where,

u = velocity through the port in m/s

g_o' = buoyant acceleration in m^2/s

d_o = diameter of port in m

Flow condition:

The densimetric Froude Number, F_o should be more than 15

Discharge through each port of 250mm,

$$Q_d = Q/48$$

$$= 0.06 \text{cumecs.}$$

Velocity through each port,

$$u = Q_d / \pi d_o^2 / 4$$

$$= 1.24\, m/s$$

$$g_o' = g(\rho_d \sim \rho_a)/\rho_a = 0.019\, m^2/s$$

$$F_o = \frac{2.6}{\sqrt{0.015 \times 0.25}}$$

$$F_o = 17.9$$

F_o lies more than 15. Hence the diameter of 250mm is acceptable with 48 ports.

4. LAYOUT AND GENERAL ARRANGEMENTS

The layout of the intake and outfall systems is given in **Fig.B1.** The intake/outfall pipelines will follow a common corridor from landfall point at shoreline to offshore location at 4m contour which is at a distance of approximately 5.0 km. From this point the outfall will continue in the same alignment upto 5.5m contour for an additional length of 2.0km. Locating the outfall at deeper water will enable better dilution of effluent, while the intake is provided at a location away from outfall and where circulation of water will be better due to higher currents in lower water depth. The total length of intake line will be about 5.0 km and outfall line will be a further 2.0km.The schematic drawing is shown in **Fig.B2.**

4.1. Deck level / bottom clearance of structures

The elevation of structures shall be decided as per expected water levels at site. A combination of Storm surge, wave, and tide shall be considered for fixing the elevation of the structures. Apart from this the height of vessels plying in the area, especially fisherman vessels and coast guard vessels, shall also be taken into account for this purpose of providing sufficient clearance.

Tides

As per Naval Hydrographic Office (Chart No.317), the maximum Tide range is 0.6m, with the MHWS as 0.7m.

Waves

Available data and wave hindcasting suggests maximum annual significant wave height of 1.78m. This shall be considered for fixing the deck level.

Storm Surge

It is unusual for cyclonic storms to cross in the Palk bay. However, there was one severe cyclonic storm in the last 100 years which produced about 6m surge in the north of Palk Bay. For this area of Uppur, it is assumed that maximum surge will be little less, of the order of 5m. The nominal surge for east coast is 3m and the same is taken for fixing deck level.

Nearshore vessels' clearance

As per the data available, the maximum fishing vessels that could be operating in the area will have less than 6m mast height. Hence, 6m clearance under the beam will enable free passage of such vessels. Coastal patrol boats are of high speed and hence will have much lesser mast height.

Deck level

As per "Petroleum and natural gas industries – Fixed steel offshore structures ISO 19902:2007", the deck level shall be fixed as 7.5m, with an airgap of 1.5m. Considering the long intake-outfall jetty, it is recommended to provide bottom of beam at +6.0m for the Intake Jetty and deck level +7.0-7.5m. The deck level shall be suitably designed. However, during design the entire deck structure shall be considered submerged. However, the deck level of Intake well / pump house is provided at +8.0m.

4.2. Intake System

The scheme proposed for the intake system is as follows :

Pipe over jetty with offshore pump house is proposed. Two pipelines 1.4m diameter GRP pipe supported on RCC bored cast in situ piles with a roadway, connected to the offshore caisson well housing the pump house (**Fig.B3**).

4.2.1 Pipe over jetty with offshore pump house.

The intake consists of a caisson of diameter 14m housing 4 pumps of about 5000 m^3/hr (with 3 active pumps at any time). Two lines of each 7710 m^3/hr capacity from the pump house are connected to the pumps leading to the plant. The diameter of the line is 1.4m and the material will be in GRP for lesser flow resistance and lesser fouling. The piles supporting the jetty and pipeline will be 1100mm diameter placed at 20m centre to centre along the jetty. There will be two piles across a cross section. Details of this arrangement is shown in Fig.B3 as discussed earlier (with 25 m c/c of piles). The distance between piles could be fixed between 20-25m depending on design limitations when considering extreme loads.

4.3. Outfall System

The outfall scheme consists of a pipe with 1.6m diameter steel supported on RCC bored cast insitu piles with a reservoir.

4.3.1 Pipe over jetty with Outfall reservoir.

The outfall is in line with the intake. It consists of the outfall line running along with the intake line extending till the contour of 5.5m. The single line will carry about 10500 m^3/hr reject water from a seal pit located onshore. The seal pit shall be designed in such a way that the difference in head between seal pit and outfall reservoir shall be sufficient enough to drive the flow upto outfall reservoir. The head loss expected in this pipeline will be about 7-9m. From the outfall reservoir, effluent will discharge into the ocean by means of vertical pipelines with side looking diffuser ports of diameter 250mm with 48 in numbers. Details of this arrangement is shown in **Fig.B4** as discussed earlier.

5. DESIGN CONDITIONS FOR JETTY STRUCTURE

The jetty shall be designed with loading as per standard procedure following loadings due to waves (IS4562) and winds (IS875). However, considering recent extreme cyclonic events, we recommend 25% higher loads shall be considered for design wind and wave pressures. All other relevant loading conditions shall be in line with this. The run-up on caisson shall be given due consideration for fixing deck levels. Wave heights shall be carefully assessed considering 1 in 100 yr occurrence probability. All slabs and beams shall be considered submerged to assess extreme upward loads.

6. CHLORINATION OF SEA WATER INTAKE SYSTEM

Power plants located near marine or estuarine waters encounter bio fouling. Chlorination is practiced at power plants to control the development of bio fouling. The frequency, duration, and quantity of chlorine applications are dependent upon the composition of the fouling organisms, the severity of fouling of the cooling system, and the inorganic and organic content of the water.

The effectiveness of chlorination is controlled by two important factors

- The concentration of chlorine used
- The period of application.

In an open, once-through system, the chlorine injected into the condenser inlet will be discharged directly with the heated effluents. Because of the toxic nature of reactive chlorine, it is generally recognized that discharges should be regulated to be adequately protective of aquatic life. The current Environmental Protection Agency **(EPA)** effluent limitation guideline is 0.5 mg/L maximum, and 0.1 mg/L average free available chlorine, with a limit of two hours per day for any unit. Generally a maximum limit of 0.5 ppm TRC in the outfall for a normal 30 min chlorination dosage will not cause any toxic effects.

2. Continuous chlorination at the offshore caisson with pump house

Continuous chlorine dosing is done near to the pump house ahead of trash racks and travelling water screen. 1-2 ppm is recommended so that the complete trash racks and travelling water screen can be kept clean and free from any bio fouling. This will also ensure the pump sump and pump suction side free from any slime growth.

At sea water intake head of inlet pipe, continuous dosing of approx. 1 - 2 ppm will be effective in control of Mollusks, algae, slime and weed. They constrict the flow of Sea water in the intake pipe. It also prevents sea shell deposition in the pipeline which is a most trouble-some to remove.

3. Shock dosing chlorination for condenser

Shock dosing of chlorination is done effectively at 1 - 5 ppm depending upon the quality of sea water. The recommended dosing time is one cycle time for every 8 hours shift which would be sufficient to keep the condenser cooling surface free from bio fouling and maintain the efficiency of the condenser and power generation.

7.0 RECOMMENDATION

- The pile supported jetty with offshore pump house with the common corridor is recommended since this will cause much lesser disturbance to prevailing marine and seabed environments. Hence the intake and outfall pipeline supported on jetty with the common corridor is recommended with offshore pump house and outfall reservoir respectively. Piles shall be placed at 20-25m c/c along the jetty for minimizing environmental impacts.

- However, considering recent extreme cyclonic events, we recommend 25% higher loads shall be considered for design wind and wave pressures. All other relevant loading conditions shall be in line with this. The run-up on caisson shall be given due consideration for fixing deck levels. Wave heights shall be carefully assessed considering 1 in 100 yr occurrence probability. All slabs and beams shall be considered submerged to assess extreme upward loads.

Department of Ocean Engineering
IIT Madras, Chennai.

FIGURES / DRAWINGS

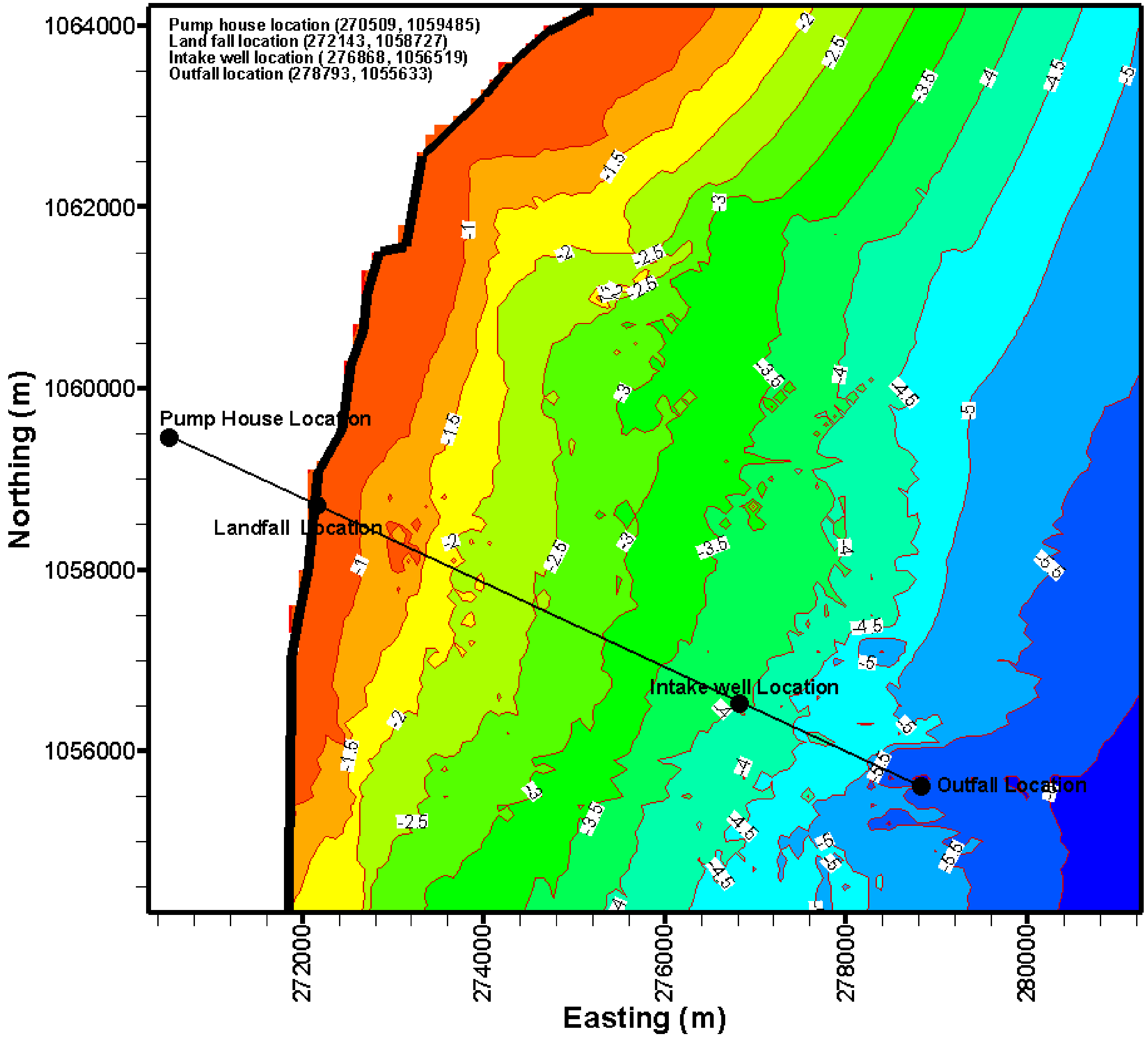


Fig:B1 Local bathymetry at uppur and layout of Intake and Outfall

FIGURE IN SEPARATE SHEET

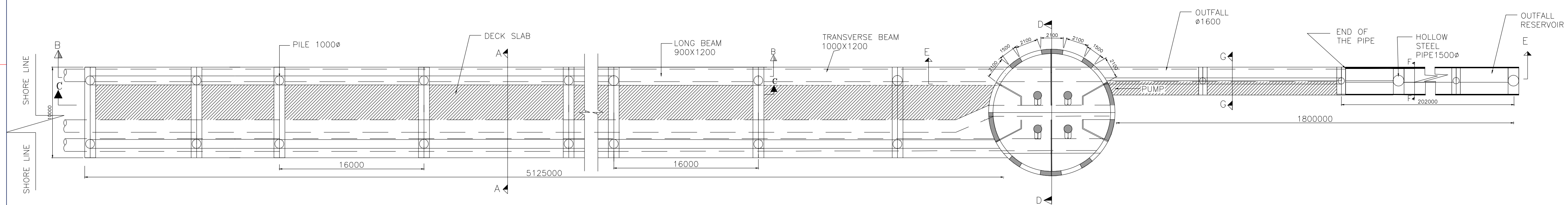
Fig.B2. General Arrangement of Intake and Outfall

FIGURE IN SEPARATE SHEET

Fig.B3. Details of Intake structure and Jetty supporting intake pipeline.

FIGURE IN SEPARATE SHEET

Fig.B4. Détails of Outfall structure and Jetty supporting Outfall pipeline.



PLAN

NOTES :
ALL DIMENSIONS ARE IN 'mm'
ALL LEVELS ARE IN 'm'

CONSULTANT:

DEPARTMENT OF OCEAN ENGINEERING
IIT MADRAS, CHENNAI - 36

CLINET:

TANGEDCO

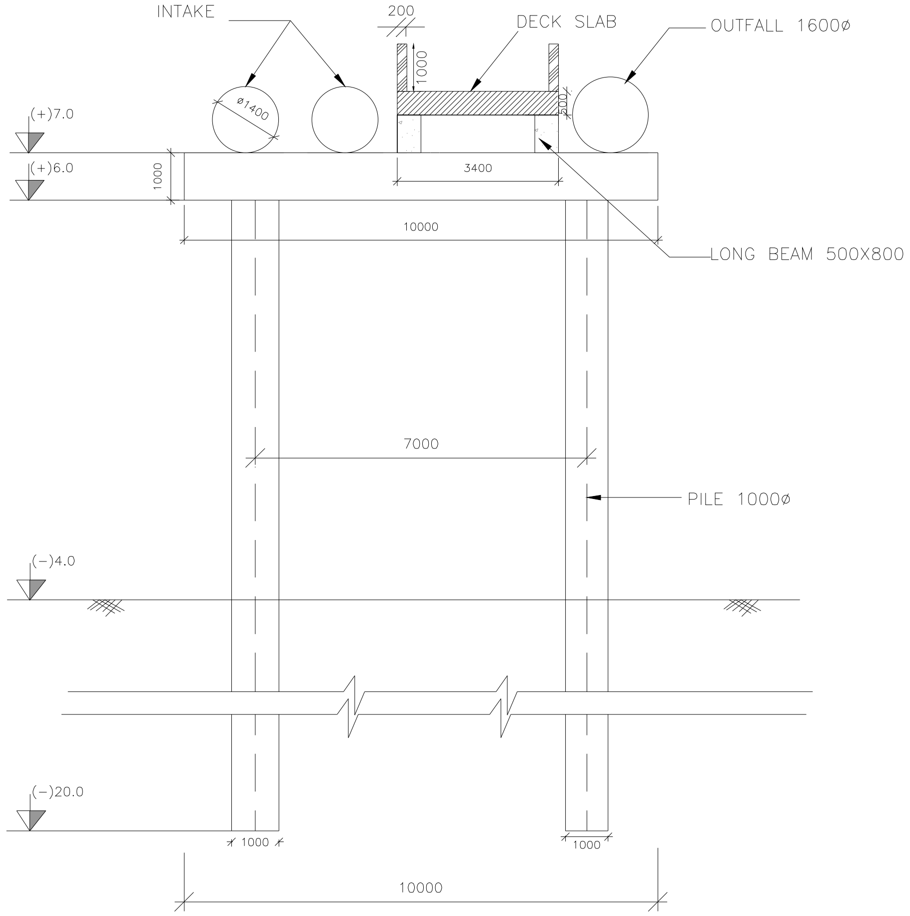
PROJECT: DESIGN OF SEA WATER INTAKE AND OUTFALL SYSTEMS FOR 2X660MW THOOTHIKUDI THERMAL POWER PROJECT IN TAMILNADU

TITLE:

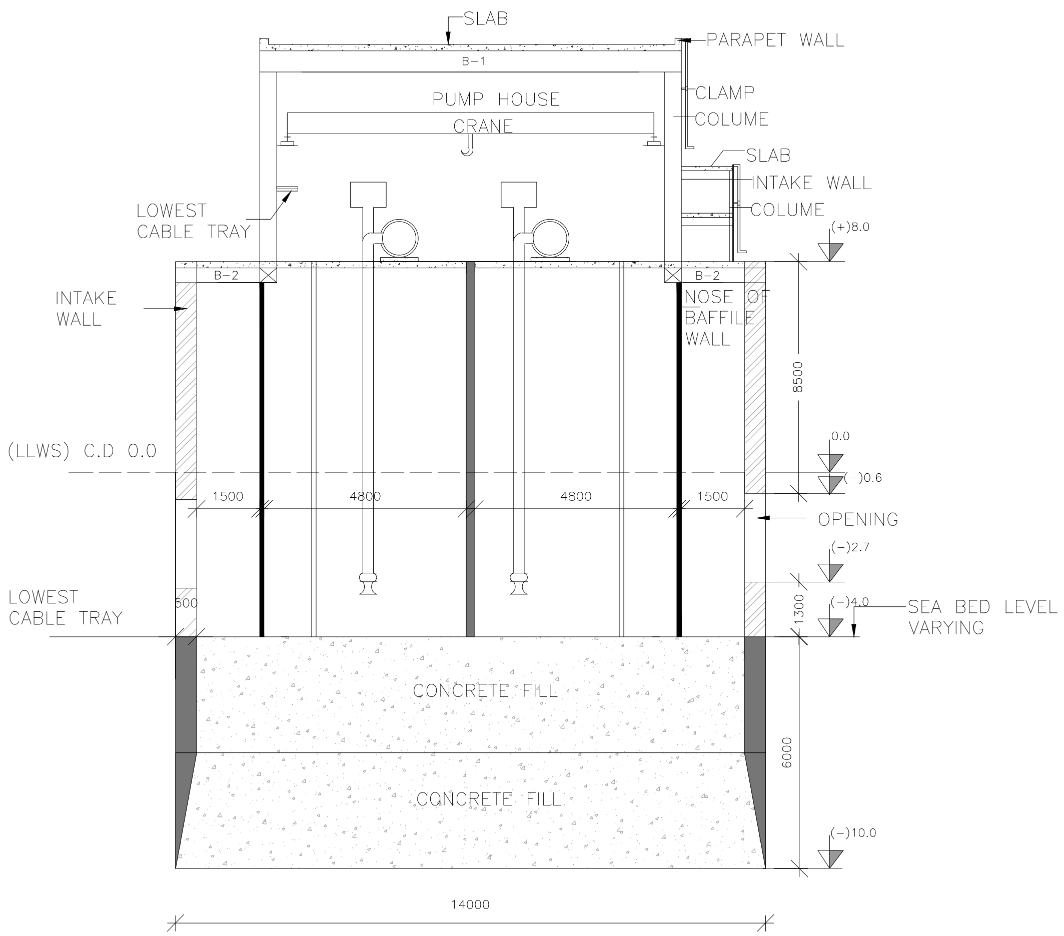
DETAIL OF SEA WATER INTAKE SYSTEM WITH PUMPHOUSE–B2

(Prof. K. MURALI)
DEPARTMENT OF OCEAN ENGINEERING

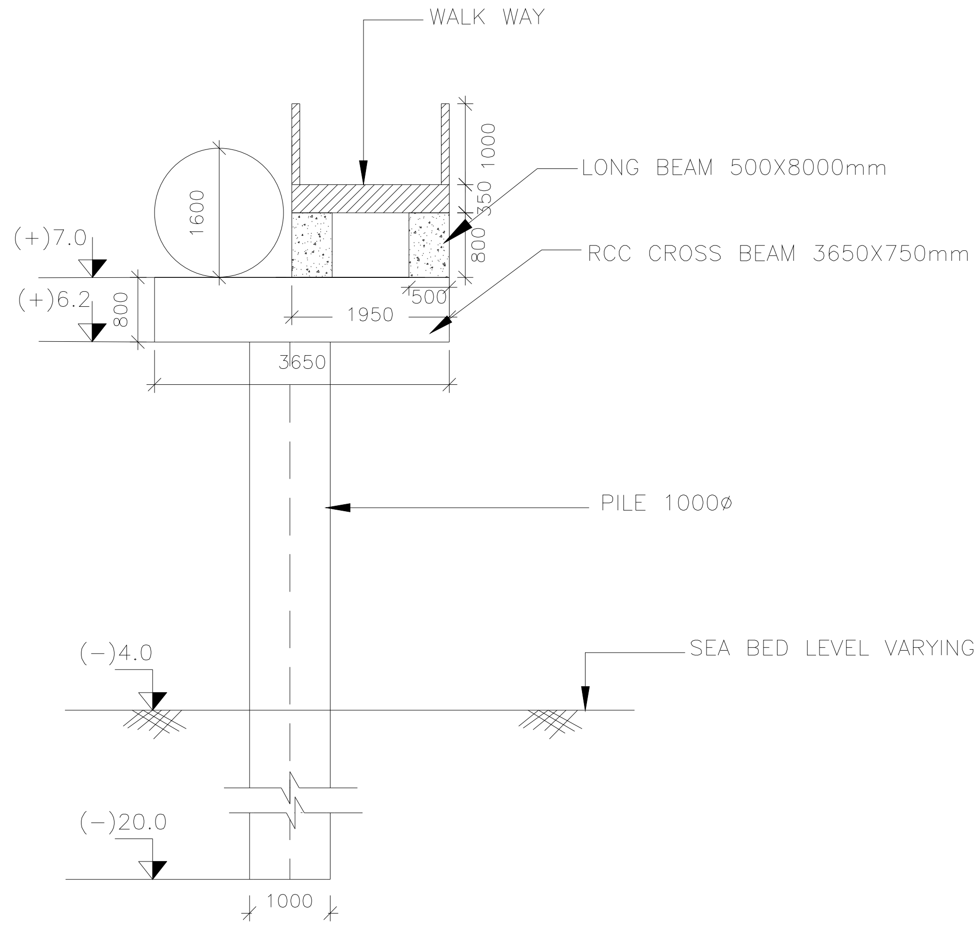
DRAWING NO: IITM/TANGEDCO	DATE:07.08.2014	REV: 00



SECTION A–A



SECTION D–D



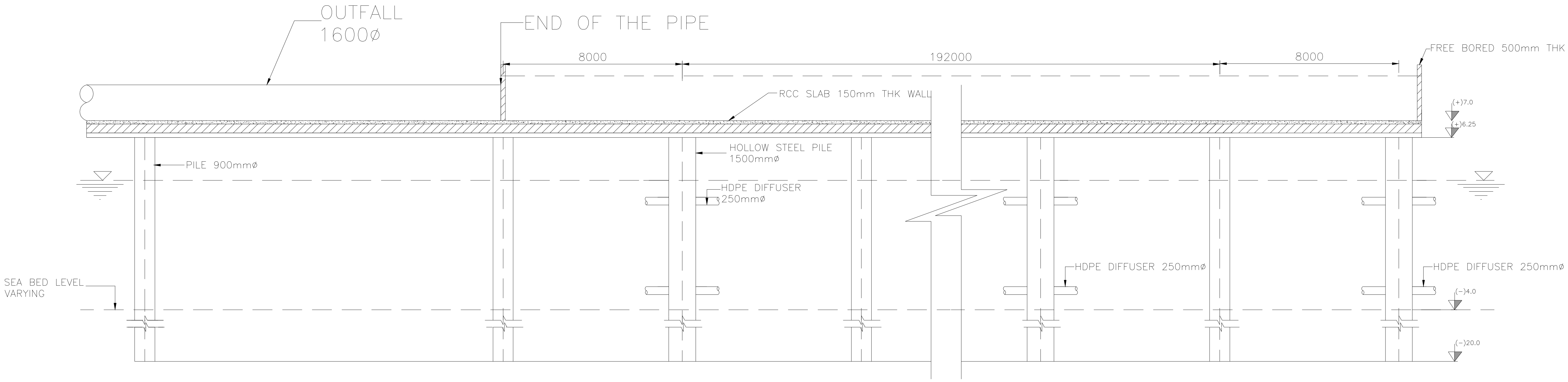
SECTION G–G

NOTES :
ALL DIMENSIONS ARE IN 'mm'
ALL LEVELS ARE IN 'm'

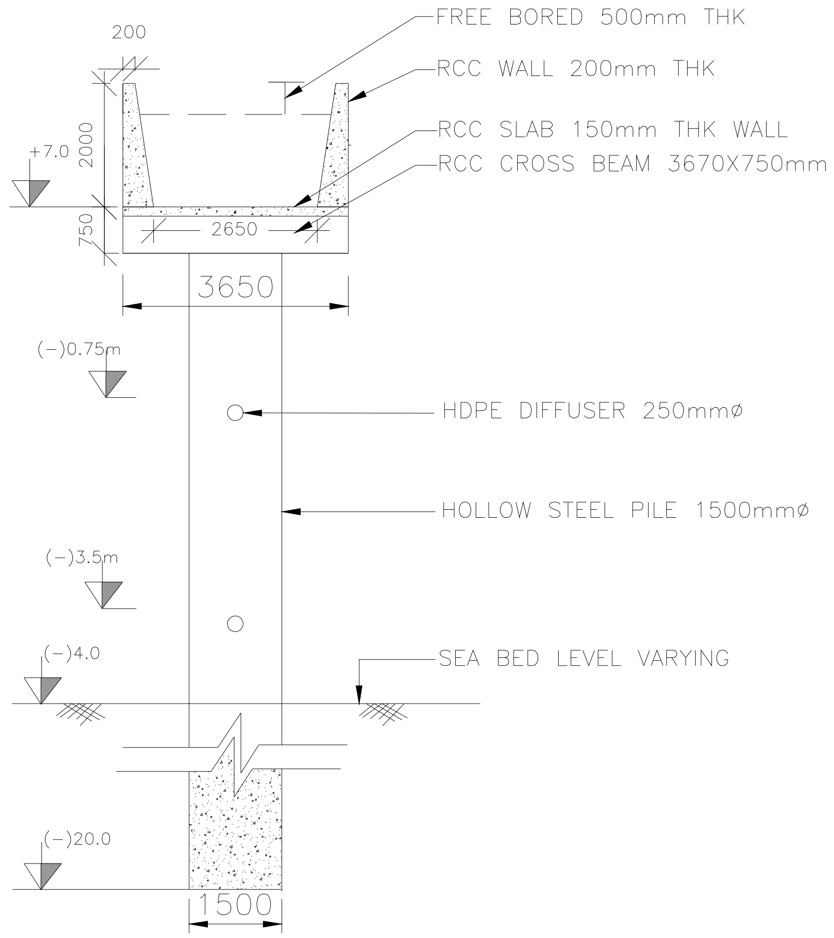
CONSULTANT:	DEPARTMENT OF OCEAN ENGINEERING IIT MADRAS, CHENNAI - 36
CLINET:	TANGEDCO
PROJECT:	DESIGN OF SEA WATER INTAKE AND OUTFALL SYSTEMS FOR 2X660MW THOOTHIKUDI THERMAL POWER PROJECT IN TAMILNADU
TITLE:	DETAIL OF SEA WATER INTAKE SYSTEM WITH PUMPHOUSE–B3

(Prof. K. MURALI)
DEPARTMENT OF OCEAN ENGINEERING

DRAWING NO: IITM/TANGEDCO	DATE:07.08.2014	REV: 00



SECTION E–E



SECTION F–F

NOTES :
ALL DIMENSIONS ARE IN 'mm'
ALL LEVELS ARE IN 'm'

CONSULTANT:
DEPARTMENT OF OCEAN ENGINEERING
IIT MADRAS, CHENNAI - 36

CLINET:
TANGEDCO

PROJECT: DESIGN OF SEA WATER INTAKE AND OUTFALL SYSTEMS FOR 2X660MW THOOTHIKUDI THERMAL POWER PROJECT IN TAMILNADU

TITLE:
DETAIL OF SEA WATER INTAKE SYSTEM WITH PUMPHOUSE–B4

(Prof. K. MURALI)
DEPARTMENT OF OCEAN ENGINEERING

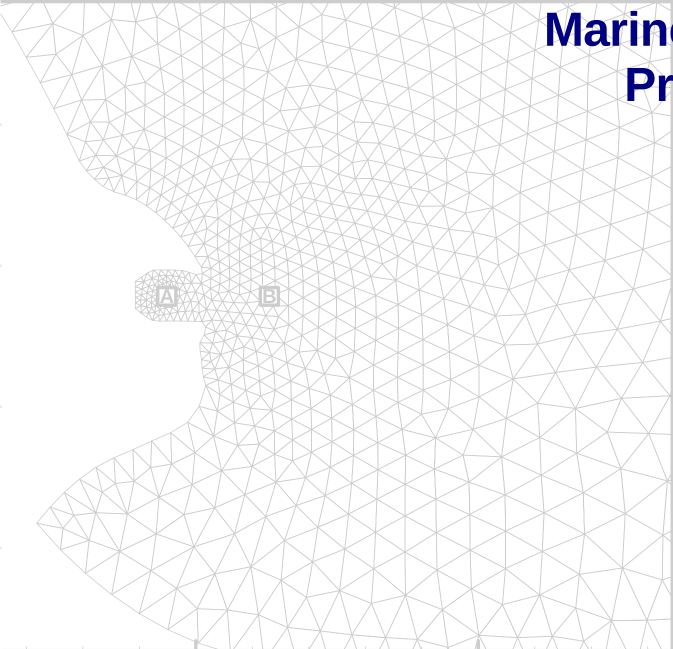
DRAWING NO: IITM/TANGEDCO | DATE:07.08.2014 | REV: 00

BILL OF QUANTITY FOR SEAWATER INTAKE AND OUTFALL FOR TANGEDCO AT UPPUR							
DETAILED ESTIMATION FOR INTAKE & OUTFALL SYSTEM							
SI.NO	**DESCRIPTION OF WORK**	**NOS**	**LENGTH**	**BREADTH**	**DEPTH**	**QTY**	**UNITS**
1	Positioning and setting upon and/or shifting and setting up piling equipments required for piling work at each piling locations for 1000mm dia as for approach jetty as directed including all labour, material, fuel, tools equipment etc., complete						L.S
2	Positioning and setting upon and/or shifting and setting up piling equipments required for piling work at each piling locations for 1000mm dia for out fall jetty as directed including all labour, material, fuel, tools equipment etc., complete						LS
3	Providing and placing in situ concrete of grade M35for piles						
a)	*Main jetty*	410	27	0.94985		10,515	m^3
b)	*Outfall jetty*	84	27	0.94985		2,154	m^3
	Total					**12,669**	m^3
4	Providing and placing in-situ concrete of grade M30 for Beams/slabs For approach jetty						
a)	*Cross Beam*	205	10	1	1	2,050	m^3
b)	*Longitudinal Beam*	410	25	0.5	1.3	6,663	m^3
c)	*Slab*	332	25	3.4	0.5	14,110	m^3
	For Outfall jetty						
a)	*Cross Beam*	84	3.65	0.75	0.8	183.96	m^3
b)	*Longitudinal Beam*	166	25	0.5	1.3	2703.74	m^3
c)	*Slab*	84	25	1.95	0.35	1433.25	m^3
	Total					**27,143**	m^3
5	Providing and placing in-situ concrete of grade M35 for Intake well						
a)	*Intake Well Bottom Foundation*	1	6	153.86		923.16	m^3

b)	*Intake Well Top Level With Deduction of inlet*	1	9.7	21.2		205.64	m^3
	Total					**1128.8**	m^3
6	Providing, Placing, positioning and setting of 2No.s intake pipes of 1400mm dia & 1.No. outfall 1600mm dia						
a)	*Main Jetty*	3	5215			18000	m
b)	*Outfall Jetty(continuation after intake well)*	1	1725			1725	m
	TOTAL					**19725**	**m**
7	Boring for the Piles to required depth						
a)	*Main Jetty*	641	16			10250	m
b)	*Outfall Jetty*	131	16			2100	m
	TOTAL		**32**	**m**		**12350**	
8	Supplying fabrication and placing of TMT, Fe 415 grade for piles						
a)	*Main Jetty & outfall jetty*		12,669	200	kg/m3	2,534	T
9	Supplying fabrication and placing of TMT, Fe 415 grade for beams & slabs						
a)	*Main Jetty & outfall Jetty*		27,143	200		5,429	T
10	Supplying fabrication and placing of TMT, Fe 415 grade for beams & slabs M35 for Intake well						
a)	*Intake well- Foundation*		461.58	180		83	T
b)	*Intake well wall*		205.64	250		51	T
						134	
11	Supplying, fabricating and providing steel cylindrical liners of 6mm thick M.S plate to the required depth including providing additional stiffener plates 12mm thick, 1000mm high						
a)	*Main Jetty*	410			27	1,638	T
b)	*Outfall Jetty*	168			27	671	T
	TOTAL					**2,309**	**T**
12	Providing, Installing, Positioning, Transporting and Setting of Three(4) numbers of Vertical Turbine (VT) type sea water intake Pumps	4	-	-	-	4	

		ESTIMATION			
SI.NO	QTY	DESCRIPTION OF WORK	UNITS	RATES(Rs)/unit	TOTAL RATE FOR ITEM(Lakhs)
1	LS	Positioning and setting upon and/or shifting and setting up piling equipments required for piling work at each piling locations for 1000mm dia as for approach jetty as directed including all labour, material, fuel, tools equipment etc., complete			200
2	LS	Positioning and setting upon and/or shifting and setting up piling equipments required for piling work at each piling locations for 1000mm dia as for outfall jetty as directed including all labour, material, fuel, tools equipment etc., complete			200
3	12,669	Providing and placing in-situ concrete of grade M35 for piles using tremmie method up to cut off level.using bentonite slurry including all sampling testing and records and all labour, materials, tools, equipment, fuel, etc., complete.,)	m^3	7,500	950
4	27,143	Providing and placing cast in situ concrete of grade M30 for beams & slabs including all sampling, necessary formwork, mixing, transporting, placing, vibrating, curing of concrete, testing and maintaining records including all labour, materials, tools, equipments ,fuel etc., complete.	m^3	4,500	1,221
5	1128.8	Providing and placing in-situ concrete of grade M35 for piles using tremmie method for intake structure .using bentonite slurry including all sampling testing and records and all labour, materials, tools, equipment, fuel, etc., complete.,)	m	7,500	85
6	19725	Providing, Placing, positioning and setting of Pipes of 1600mm dia..complete.	m	25,000	4,931

7	12350	Boring for the piles to the required depth through all types of soil strata including cemented sand, boulder layers and hard rock if any up to the founding level and stacking the bored soil at convenient place and transported to the low lying area any where inside the harbour area within a lead of 4 Km as directed by the Engineer's representative and pile shaft cleaning and keeping of all records etc., including bentonite.. solution, labour, tools, equipment, fuel etc., all as per drawing, specification etc., complete	m	7,000	865
8	2,534	Supplying, fabricating and placing of TMT, Fe 415 grade steel for pile reinforcement cage in piles including welding, binding, with binding wire all as per drawing, technical specifications and including all labour, materials, tools transport, cage lowering, equipments, fuel etc., complete	T	60,000	1,520
9	5,429	Supplying, fabricating and placing of TMT, Fe415 grade steel bars for precast/ in situ components of beams, slabs, etc., including lifting hooks for precast units and cutting, bending, welding, binding wire all as per technical specification, drawing, including all labour, materials tools, equipment, fuel and all sampling, testing and records etc., complete	T	60,000	3,257
10	134	Supplying fabrication and placing of TMT, Fe 415 grade for beams & slabs M35 for Intake well	T	60,000	81
11	2,309	Supplying, fabricating and providing steel cylindrical liners of 6mm thick M.S plate to the required depth including providing additional stiffener plates 12mm thick, 1000mm high	T	50,000	1,154
12	4	Providing, Installing, Positioning, Transporting and Setting of Three(4) numbers of Vertical Turbine (VT) type sea water intake Pumps		50,00,000	200
		TOTAL			14,665



Marine EIA/EMP studies for Outfall of Proposed 2 x 800 MW Coal based power plant at Uppur, Ramanathapuram District, TN.

Annexure-B

– Design of Intake and Outfall Addendum-I

Client

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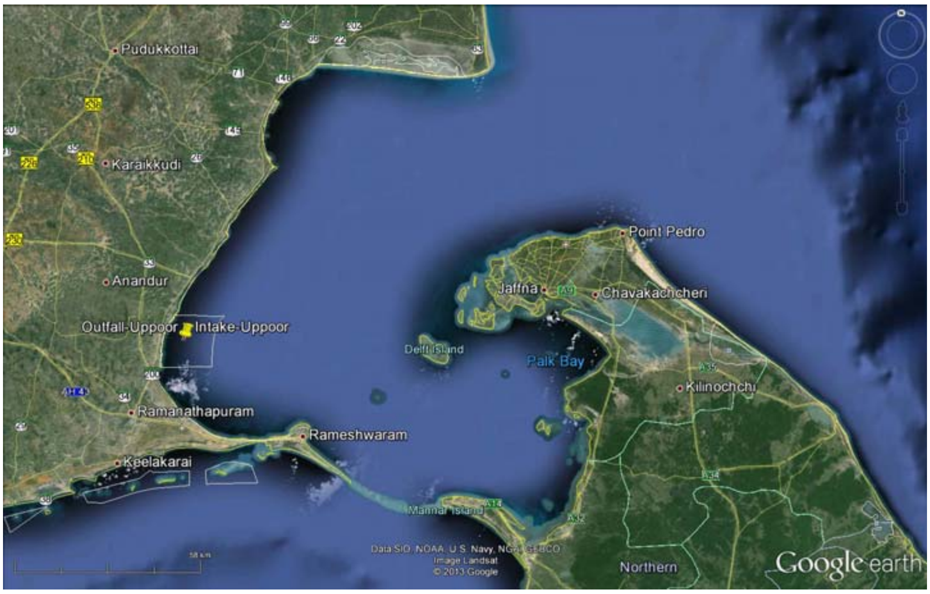

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SHORELINE CHANGE AND TURBIDITY EFFECTS

1. SHORELINE CHANGES

1.1 Permanent effects.

The jetty is (Fig.B2) supported by piles at a distance of 20m c/c. The diameter of piles is 1.1m. So, the blockage caused by the piles is of the order of 3 %. Also, the piles have diameters of 1.1m. Compared to the waves, this is a very small diameter and hence no significant change is wave angle and wave height is expected due to the presence of jetty structure. Hence, There will be only negligible effects on the wave characteristics and hence change in the shoreline caused be the jetty structure.

1.2 Shoreline change due to construction activities

During construction activities, the shoreline may be fully blocked. Hence, this scenario is considered for estimation of worst effects on shoreline. The results of the same are brought out below. The wave data (wave height, wave period and wave direction) is adopted from the wave atlas published by National Institute of Oceanography (NIO), Goa. Based on the wave data, sediment transport is calculated and presented month-wise in Fig.B1.2.

The results obtained by various three methods have yielded similar results. The net drift is towards north to an extent of about 0.25 lakh m^3/year. However, since there can be considerable variations in the sediment quantity estimates, the range of net drift could be taken to be 2.3 – 4.6 lakh m^3/year. The corresponding shoreline change patterns are given in Fig.B.1.3. In it expected that shoreline may be changing upto a few meters in the first year. In the long term, up to 8m accretion and upto 3 erosion may be expected.

2. TURBIDITY OF WATER

2.1 During construction phase

The jetty is (Fig.B2) supported by piles at a distance of 20m c/c. While installation, they boring activity will produce some turbidity. Based on a study conducted in the U.S, the turbidity could increase by a magnitude of about 13 ppm. However, we have considered upto 20ppm change for prediction of impacts. The extent of additional turbidity is shown in Fig.B.1.4. The worst effect will be in shallow water where upto 20m, the increase in turbidity will be significant. Beyond this point, the turbidity will increase by about 8 ppm within radious of about 50m.

3. TURBULENCE AT INTAKE & OUTFALL

3.1 At Intake openings

The intake velocity is about 0.15m/s. This is fixed as very low due to sensitivity of the region and requirement of small juvenile fishes to escape intake suction. This velocity is very close to the ambient velocity of tide, which is about 0.1-0.12m/s. Hence the turbulence generated will be insignificant at the intake.

3.2 At outfall discharge.

Figures B.1.4 shows the typical turbulence levels in the outfall discharge as water comes out of the port. The outfall is provided in such a way to direct the flow into water column. Hence, the sea bed around the diffuser will have minimum impact due to the discharge. In this case, the results suggest that the levels of turbulence becomes less than 10% within few meters from diffuser. Less than 5% levels are reached with in 5-7m. The ambient turbulence of seawater will be of the order of 10%. Hence, turbulence will not have any significant impact on the environment. The turbulence near sea bed is less the 3%. This will not cause any sediment movement.

4. CONCLUSIONS

- Shoreline investigations show no change in shoreline due to construction of the jetty. However, during construction phase there could be a few meteres of shoreline that could be disturbed.
- The turbidity patters show up to 8 ppm increase to extent of about 50m in radious.
- The diffuser induced turbulence is less than 10% within 5-7m. Hence, the diffuser induced turbulence will not have any impact on the existing environment. There is not turbulence effect at the intake.

Prof.K.Sannasiraj **Prof.K.Murali**

FIGURES / DRAWINGS

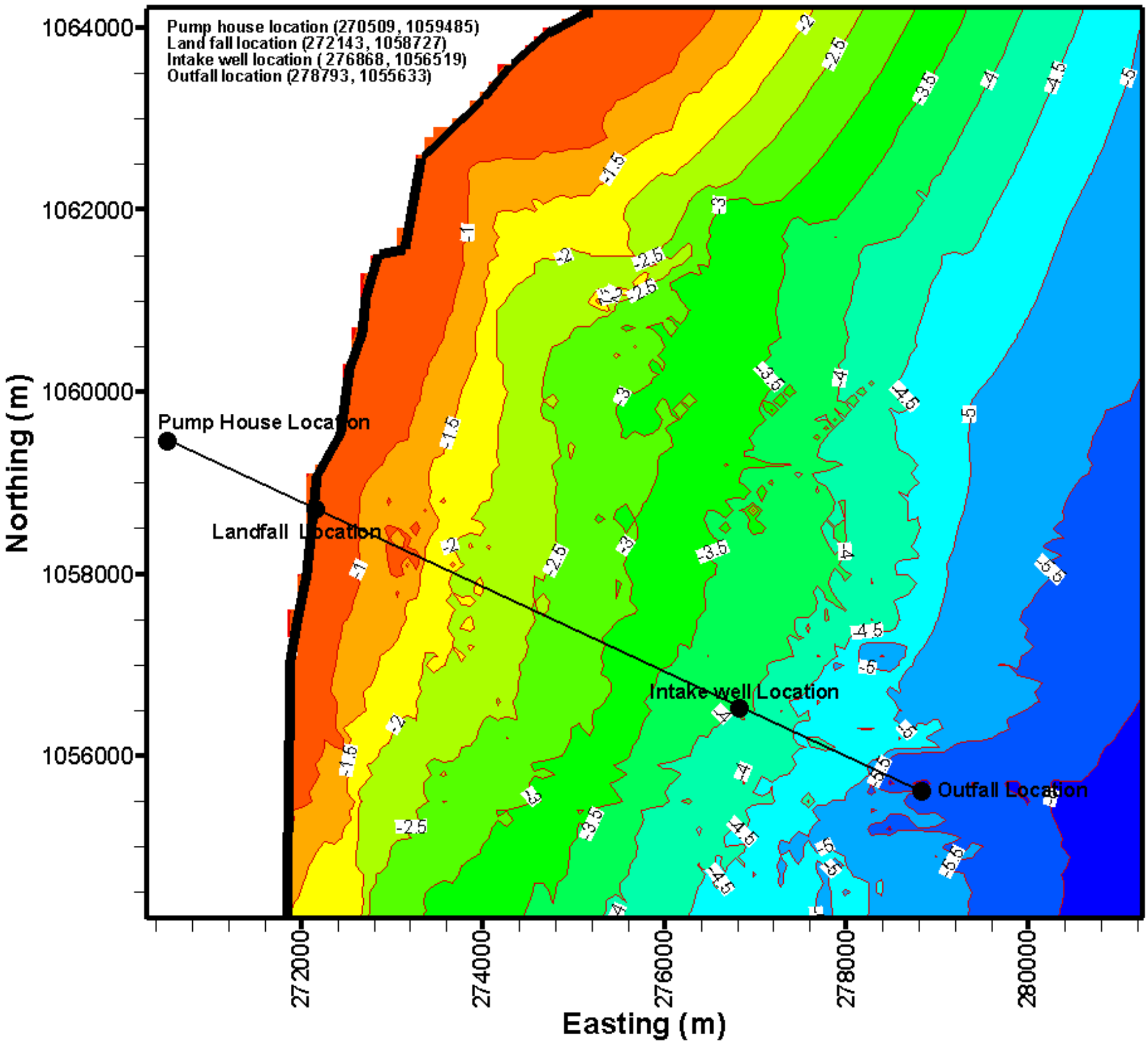
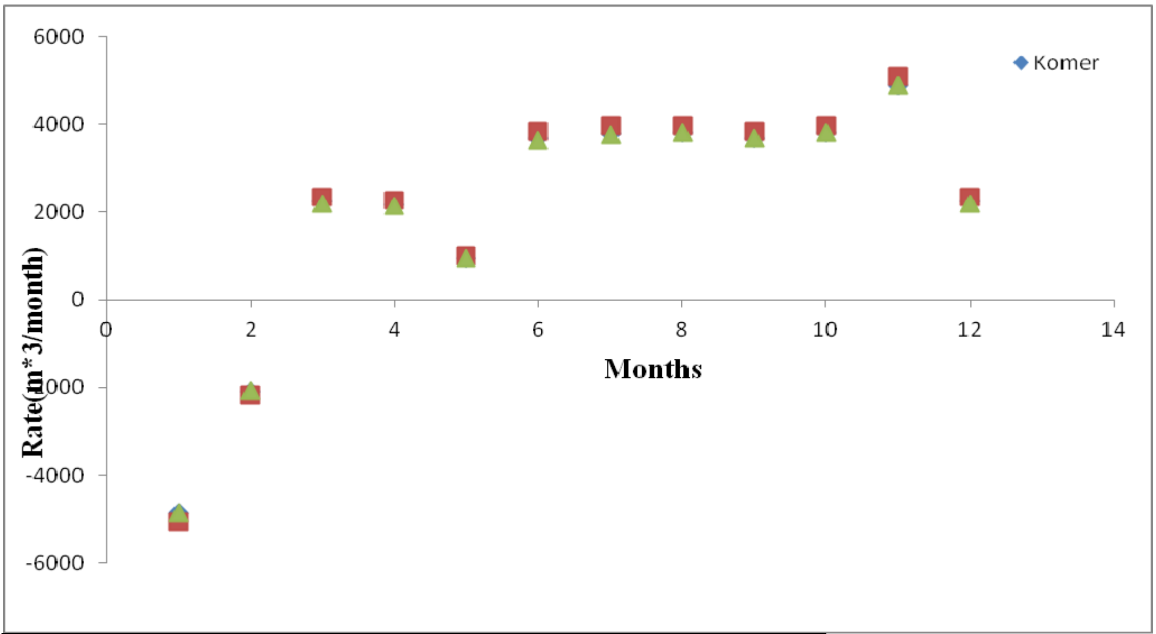


Fig:B.1.1 Local bathymetry at uppur and layout of Intake and Outfall



The annual sediment transport in cubic meter volume for the given site Uppur, Ramanathapuram district Tamil Nadu is estimated using the following methods
a) Komar (b) CERC (c) Distribution

The net annual sediment transport derived using the above methods was found to be 24230m³, 25240m³ and 24100m³ respectively.

Fig:B.1.2 LIttoral transport rates for Uppur.

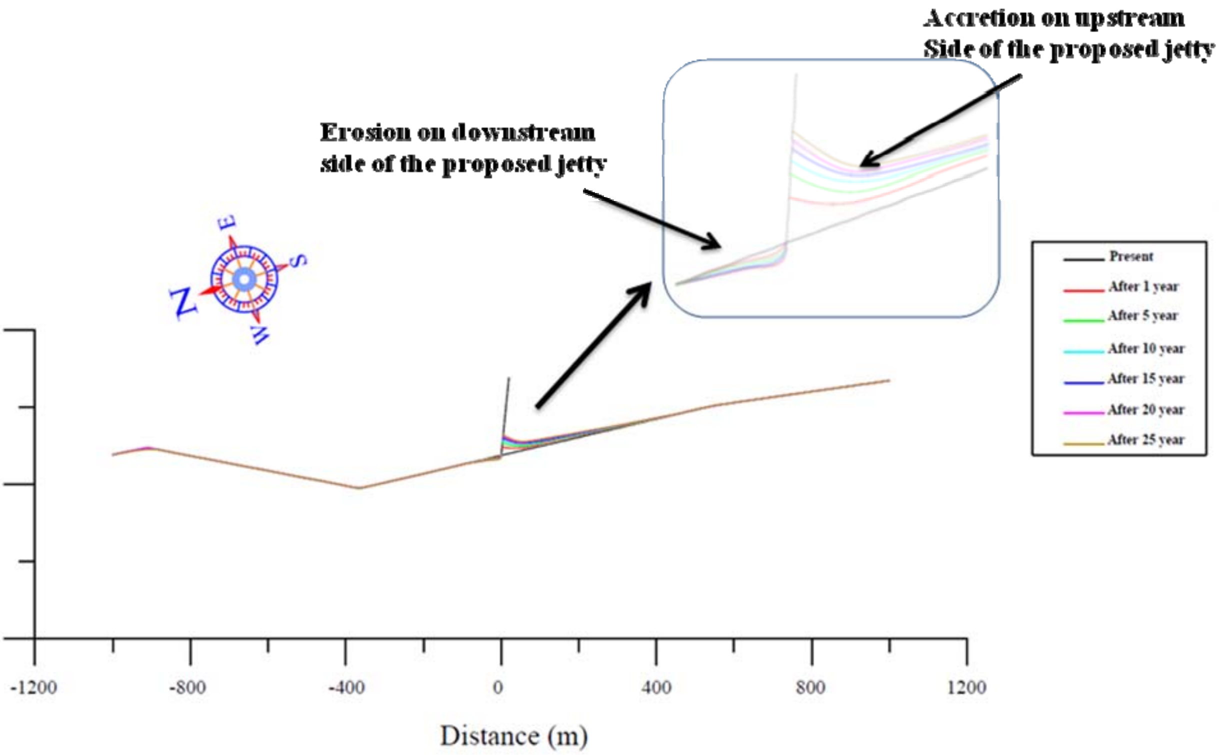


Fig:B.1.3 Estimated shoreline oscillation for Uppur.

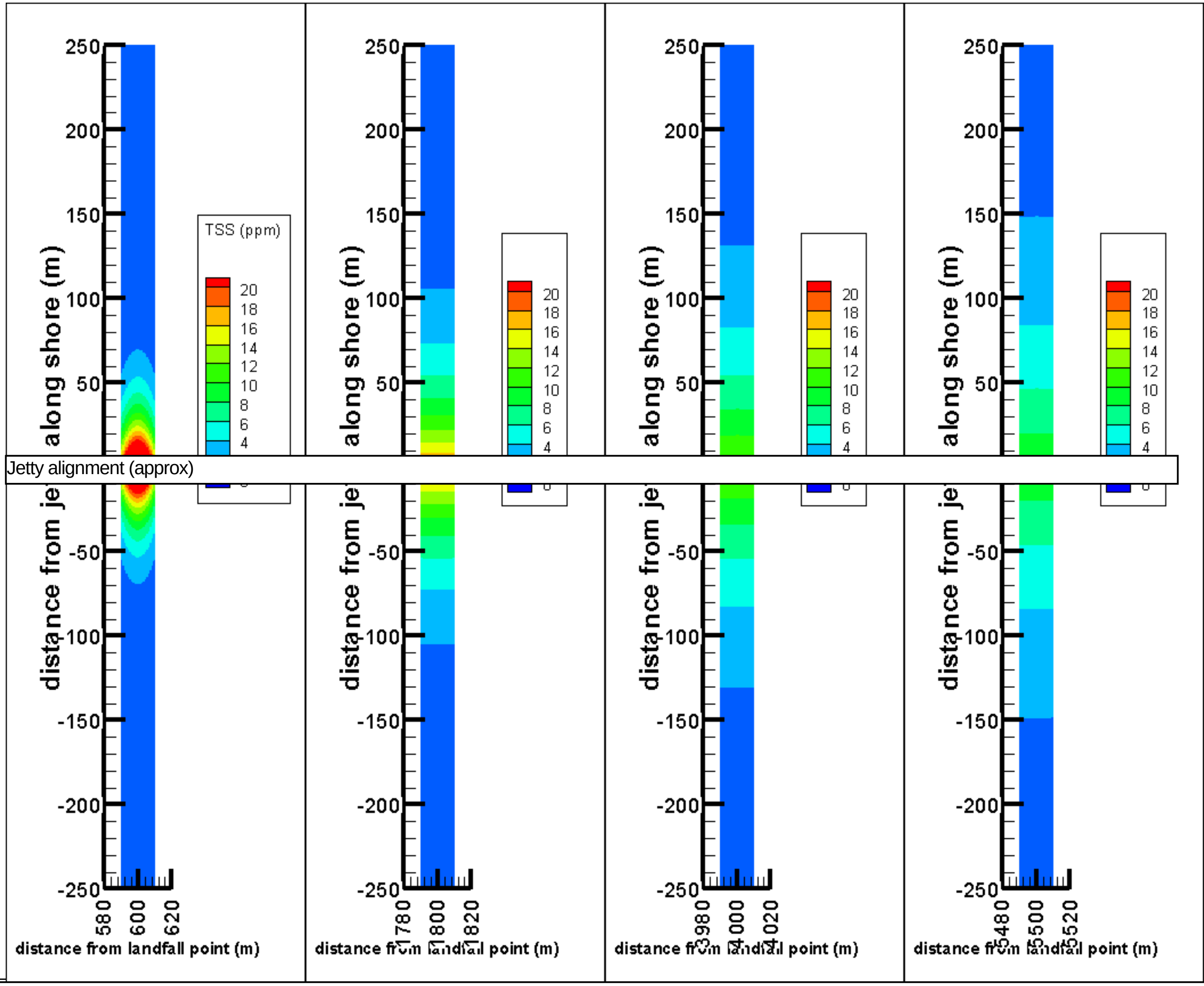
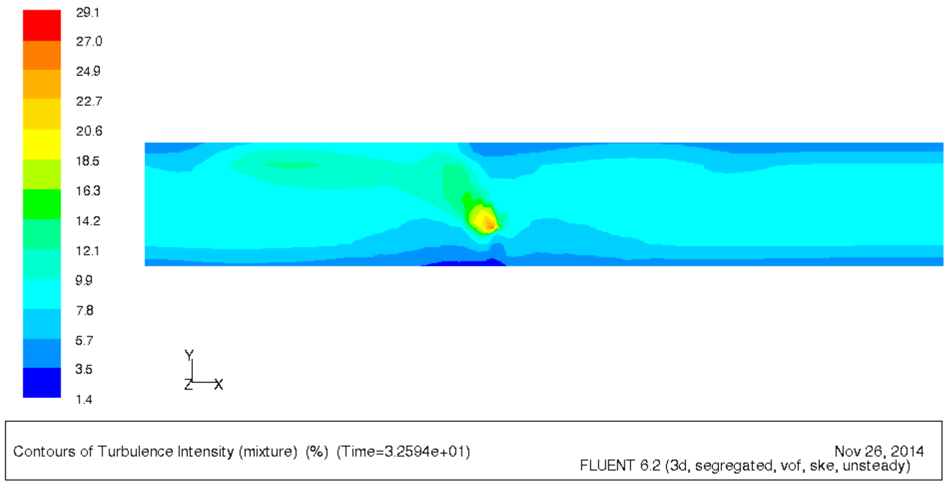


Fig:B.1.4 Estimated turbidity patterns during construction for Uppur for 1m to 4m water depth.



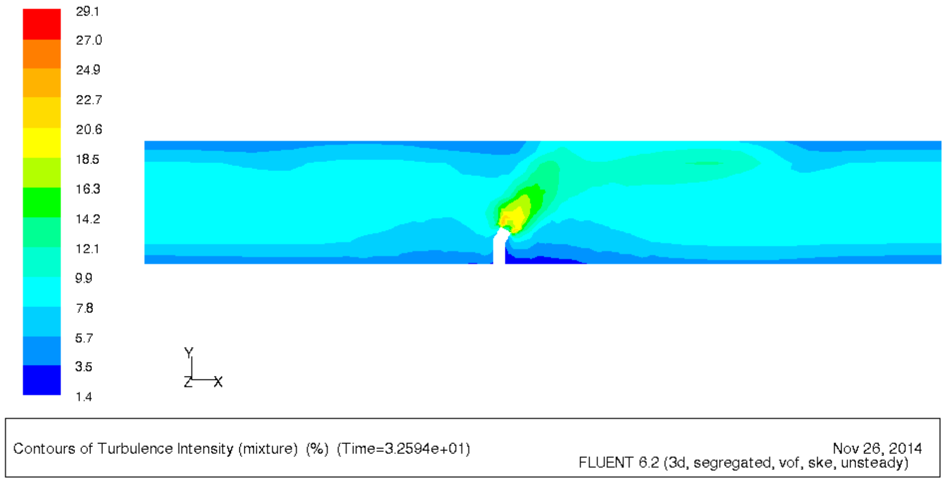


Fig.B.1.5. Typical turbulence levels due to outfall discharge (water depth 4-6m).