

**BEFORE THE NATIONAL GREEN TRIBUNAL  
SOUTHERN ZONE, CHENNAI  
OA No. 180 of 2023 (SZ)**

**IN THE MATTER OF :**

**Tribunal on its own motion SUO MOTU**

**... Applicant**

**Vs**

**The District Collector,  
and Ors.**

**... Respondents**


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Dated at Chennai on this the 21<sup>st</sup> March, 2025

  
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भूयांत्रिकीय प्रयोगशाला  
एसपीई आईआईटी मद्रास चैप्टर के लिए संकाय प्रायोजक  
महासागर इंजीनियरिंग विभाग, आईआईटी मद्रास

**1**

**Department of Ocean Engineering, Indian Institute of Technology Madras  
Chennai - 600036**

**Annexure - R1**

To  
Mr. K. Rajasekaran  
GM (HSE)  
Chennai Petroleum Corporation Limited (CPCL)  
Chennai 600018

**Subject: Submission of Final Report on "Study of Oil Spills in the Ennore Region"**

We are pleased to submit the final report titled "**Study of Oil Spills in the Ennore Region**," prepared as part of our research collaboration with Chennai Petroleum Corporation Limited (CPCL). This report presents a comprehensive comparative analysis of the oil spill incidents that occurred in the Ennore region in 2017 and 2023, with a specific focus on the volume, extent, and environmental impact of each event.

Furthermore, the study includes an assessment of tank integrity at CPCL using Ground Penetrating Radar (GPR) technology. This analysis provides insights into potential vulnerabilities and helps in enhancing preventive measures for future incidents.

We appreciate the opportunity to contribute to CPCL's efforts in environmental protection and operational safety. We hope that the findings and recommendations in this report will be valuable for future preparedness and mitigation strategies.

Please find enclosed the final report for your perusal. Should you require any further clarifications or discussions on the study, please feel free to contact us.

We look forward to your feedback and continued collaboration.

Sincerely,

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GREEN HYDROGEN  
& HYDROCARBONS  
TECH CONSORTIUM  
IIT MADRAS

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Chennai - 600036

Final Report

on

# Study of Oil Spills in Ennore Region

Date: 19.03.2025

Submitted By,

**Prof. Rajesh R Nair**

Principal investigator of the project

Petroleum Engineering Team

IIT Madras

Submitted To,

Chennai Petroleum  
Corporation Limited

Chennai-600018



## Executive Summary

Cyclone Michaung caused continuous rainfall during the night of December 3, 2023, which persisted for approximately 36 hours in Chennai, affected areas such as the Manali Industrial Area (MIA) and Ennore. Due to the heavy downpour, water was discharged from the Poondi and Puzhal reservoirs near Chennai on December 4, 2023. This aggravated the waterlogging and flooding conditions in MIA and resulted in oil spill in the Ennore Creek region.

CPCL shared the reports of a IIT Madras, National Centre for Coastal Research (NCCR), National Institute of Oceanography (NIO), The Energy and Resources Institute (TERI) and Tamil Nadu Pollution Control Board – report filed in NGT to study and requested comments on the report. The above reports are enclosed as Annexure to this report.

- IITM CE report - Submitted in NGT in Sep-24 by TNPCB – Annexure-1
- National Centre for Coastal Research (NCCR) – Submitted to TNPCB & CPCL – Annexure-2
- National Institute of Oceanography (NIO) – Submitted to NGT in Sep-24 by TNPCB– Annexure-3
- The Energy and Resources Institute (TERI) - Submitted to NGT in Sep-24 by CPCL– Annexure-4
- Tamil Nadu Pollution Control Board – report filed in NGT in Feb-24– Annexure-5

CPCL also intended to carry out an assessment of oil quantity occurred during Dec’ 23 Michaung cyclone through a scientific way and also a comparison study on the Oil spill incident occurred during the ship Collision incident in Jan 2017 with the Dec 2023 incident and approached IIT, Madras. In addition to the above, CPCL requested to carry out the integrity study of petroleum storage tanks.

This report encapsulates the findings from the study of two significant oil spills in the Ennore region, occurred in 2017 and 2023. This investigation is focused on estimating the spatial extent and volume of contamination, performing a comparative analysis of the incidents.

The analysis leveraged Sentinel-1 SAR and Cosmo-SkyMed imagery, processed through the Sentinel Application Platform (SNAP), employing techniques like radiometric calibration, texture analysis, and change detection to map spill extents and estimate volumes using reflectivity-based models correlating SAR backscatter values to oil film thickness.

Evaluating the structural integrity of storage tanks through Ground Penetrating Radar (GPR) was carried out. GPR is a non-destructive testing (NDT) method that can help detect subsurface anomalies, such as corrosion, voids, and structural weaknesses, in storage tank floors and foundations.

A handwritten signature in blue ink, appearing to read "Rajinder", with a horizontal line underneath it.

## 1 Observations & Findings

### A. Based on the review of the IITM Civil Engineering report, National Centre for Coastal Research (NCCR), National Institute of Oceanography (NIO), The Energy and Resources Institute (TERI) and Tamil Nadu Pollution Control Board reports observations and comments by IITM Petroleum Engineering team are given below:

1. Total Petroleum Hydrocarbon (TPH) content in water is very high in IIT Madras CE report (280 – 7210 mg/lit) compared to TNPCB, NCCR, NIO & TERI reports (0.0277 – 3.9 mg/lit). This may be due to random sampling. (Pl refer page No.: 17 of this report)
2. Total Petroleum Hydrocarbon (TPH) content in sediments is very high in IITM-CE report (13,600 – 46,550 mg/Kg) compared to NCCR, NIO and TERI reports (5.84 – 1830 mg/Kg). Oil estimation by IITM-CE using such higher TPH values in sediments resulted in huge quantity of oil. This is due to extrapolation of TPH content, taking sample at few concentrated locations and applying the same for the entire area. Refer assumption 1 in page no. 29 of this report (Pl refer page No.: 17 & 18 of this report)
3. Oil being a lighter component /low density, tends to float over the surface of water. Settling & percolation of oil in the sediment requires longer duration. TPH value of IITM CE report in the range of 13,600 – 46,550 mg/Kg is unrealistic. (Pl refer page No.: 17 & 18 of this report)
4. The effects due to preexisting TPH values due to urban runoff, domestic discharge and also through other anthropogenic activities have not been considered in the IITM-CE report
5. Estimation of oil quantity using TPH values of NIO, NCCR & TERI is around 0.34 to 12.9 Tons of oil (Pl refer page No.: 18 & 19 of this report) and the values of these reports are consistent with the present oil estimation through satellite image study viz. 14.48 MT. (pl refer page No 35 of this report). However, wide variance is observed in estimation of oil quantity by IITM – CE report (517 MT).

517 MT of oil in sediments is a case of over-estimation, arrived due to higher TPH value reported in the IITM CE report. TPH value has been taken at certain concentrated locations and extrapolated for the entire area. Oil quantity estimated on this basis is not an appropriate method.

On the other hand, Satellite image captures oil quantity (14.48 MT) based on the thicknesses spread across the area. Oil estimation based on the Spatial Distribution will be more accurate

6. IITM-CE report has identified 30 Nos of open reservoirs as the main source of oil spill. Based on the field visit to CPCL and google map coordinate study it is confirmed that 13 open reservoirs are not inside CPCL and belong to other companies. (Pl refer page No.: 20 - 21 of this report)
7. Out of 30 open reservoirs, IITM-CE pointed out 12 reservoirs as the main source of oil spill. However, it may be noted that:
  - 2 of these reservoirs are outside CPCL and belong to other companies.
  - 8 reservoirs are used as raw water reservoirs, storm ponds, Guard Pond, Fire water ponds for storing oil free water only
  - 2 reservoirs are above ground and are used for storing sediments.
8. Apart from the above, IITM-CE report has considered numerous assumptions, as listed below and are not based on true measurements, as detailed in this report.
  - **Assumption 1:** TPH content estimated in discrete points was considered as average TPH and used to calculate oil quantity for the entire area (IITM CE report page No: 26, Annexure-1).
  - **Assumption 2:** Uniform thickness (0.1 mm) was assumed for entire residential and industrial area without any basis. (IITM CE report page No: 30, Annexure-1).
  - **Assumption 3:** Depth of oil estimation in pool was assumed as 1 mm without any measurement and applied uniformly to all the area. (IITM CE report page No: 28, Annexure-1)
  - **Assumption 4:** 10,000 sq.m of oil pool was arbitrarily considered in mangrove area and another 10,000 sq.m of oil pool near pipelines.
  - **Assumption 5:** Area calculated based on the oil marking height & length of the mangrove tree area, is unscientific as the mangroves will have branches & space between trees etc. The report considered the whole area like a wall and arrived at the area. (IITM - CE report page No: 32, Annexure-1)
  - **Assumption 6:** The report has erroneously assumed 0.01 mm oil thickness over the mangrove trees. (IITM - CE report page No: 32, Annexure-1)

- **Assumption 7:** Assumption of oil layer of 10 mm without any basis in open reservoir tanks. (IITM - CE report page No: 36, Annexure-1).

Oil estimation based on such assumptions would always leads to erroneous value.

**B. Observation and findings of estimation of oil quantity & comparison of 2017 ship collision incident through satellite images are furnished below.**

1. Based on the satellite image of 29<sup>th</sup> Jan 2017, it is confirmed that the 2017 oil spill, caused by a collision near the Ennore port, resulted in a dense oil slick extending over 197 KM<sup>2</sup> and impacting more than 60 KM of coastline with a volume of approximately 223.5 cubic meter (178.8 MT)

This is consistent with the established reports of 194 MT from published articles and confirms that Satellite based estimation methodology, as a suitable and reliable tool.

2. On similar lines, Satellite image estimation was carried out for 2023 oil spill. Based on the satellite image of 6<sup>th</sup> Dec 2023, oil spill triggered by cyclone Michaung affected 1.81 KM<sup>2</sup> in the stretch from Manali Industrial Area to Ennore Creek area. The quantum of oil assessed through the satellite image in the Buckingham canal, Kosasthalaiyar river and nearby area shows spillage of 18.1 cubic meters (14.48 metric Tons).
3. Extent of spillage & quantity assessed through satellite image above clearly indicates that the quantum of oil spill in ship collision incident occurred in Jan 2017 is much higher than Dec'23 incident.

**C. Observation and findings of GPR study on tank integrity.**

1. IITM-CE Department have indicated that breach of oil from storage tanks could be one of the source of oil spill. (page No.: 36 of IITM-CE Report- Annexure-1).

In order to ascertain the Integrity of the Tanks, Five critical Tanks were chosen on random basis for the GPR study. Based on tank integrity study using GPR (in Tanks 106, 119, 121, 801 & 802) carried out by IIT – PE, the structural integrity remains sound, with no signs of material degradation.

2. Physical verification of the tanks and scrutiny of Maintenance & Inspection (M&I) records of storage tanks maintained by CPCL revealed that all the tanks are in good condition.

In conclusion, the following inference are drawn:

- A. TPH values of IITM CE report are abnormally high and resulted in higher estimation of oil quantity. Further source validation was not also reflecting real scenario
- B. Based on the analysis of satellite images in 2017 & 2023 & the field survey carried out, it is concluded that the quantum of oil spill is estimated to be 18.1 cubic meters (14.48 metric tonnes).
- C. CPCL tanks are intact and there are no oil leaks observed from the tanks.

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## 1 Introduction

This report encompasses the review of following reports and details furnished by CPCL regarding the Oil spill incident:

- IITM CE report - Submitted in NGT in Sep-24 by TNPCB
- National Centre for Coastal Research (NCCR) – Submitted to TNPCB & CPCL
- National Institute of Oceanography (NIO) – Submitted to NGT in Sep-24 by TNPCB
- The Energy and Resources Institute (TERI) - Submitted to NGT in Sep-24 by CPCL
- Tamil Nadu Pollution Control Board – report filed in NGT on 27.02.24

Our team has reviewed the above referred reports and also conducted field visit to CPCL. During field visit the open reservoir were inspected and utilisation of reservoirs were physically verified. Using the coordinates of the open reservoir given IITM CE report, the location all reservoirs were reverified.

Further, this report details the investigation of two major oil spills associated with Ennore region, occurred in 2017 and 2023. The primary objectives of the study include estimating the spatial extent of oil spill, determining the volume of oil released, and conducting a comparative analysis of the two oil spill events. The investigation also involves assessing tank integrity using Ground Penetrating Radar (GPR) to identify any structural weaknesses that may have contributed to leakage. Existing reports, field data, and analytical results have been synthesized to provide a comprehensive overview of the current status of the study.

The 2017 Ennore oil spill occurred outside the Kamarajar Port in Ennore near Chennai. The spill occurred on 28 January 2017 when an outbound empty tanker BW Maple collided with an inbound loaded oil tanker Dawn Kanchipuram at 04:00 local time.

Cyclone Michaung brought persistent rainfall to Chennai during the night of December 3, 2023, lasting for around 36 hours and impacting regions including the Manali Industrial Area (MIA). Subsequently, water was released from the Poondi and Puzhal reservoirs on December 4, 2023. This measure exacerbated the existing waterlogging and flooding issues in MIA, leading to an oil spill in the Ennore Creek area.

To assess the extent of the spill, Sentinel-1 SAR (Synthetic Aperture Radar) imagery acquired on January 29, 2017, was analysed to quantify the volume of spilled oil of 2017 incident. Additionally, Sentinel-1 SAR imagery of January 17, 2017, prior to the incident, was acquired and analysed to establish a baseline. The Ennore region was selected as the focal area due to the severity of the spills. Sentinel-1 SAR and Cosmo-SkyMed satellite imagery were utilized to delineate the spills spatial extent and assess their temporal evolution.

Both historical data and industry standards to design an appropriate methodological framework were considered while checking the integrity of tanks. Key aspects include the use of remote sensing and GIS techniques for mapping the spill areas, the analysis of tank records to estimate released volumes, and a set of GPR surveys to evaluate the condition of storage tanks at the facility. A particular emphasis has been placed on the GPR method due to its non-destructive nature and its ability to produce high-resolution images of the subsurface. GPR operates by transmitting high-frequency electromagnetic waves into the ground, which are then reflected back to the receiver upon encountering materials with different dielectric properties. By interpreting the time delay and strength of the reflected signals, it is possible to detect buried features or anomalies that may indicate corrosion, cracks, or structural voids. List of tanks shared by CPCL is attached as Annexure- 6 In the context of this study, GPR was employed specifically to examine steel storage tanks—namely Tank No. 106, Tank No. 119, Tank No.120, Tank No. 802, and Tank No. 801—to verify whether they had suffered corrosion, cracking, or other forms of degradation that could have contributed to the oil spills. These tanks are chosen randomly among the tank list provided.

The sections that follow detail of the study overall methodology, summarize findings to date, and present conclusions regarding the spills impact and the condition of the storage tanks. The findings of this report build on established methodologies and leverage advanced tools to provide actionable insights.

## 2 Methodology

### 2.1 Methodology of reviewing of IITM-CE report & others reports

CPCL has furnished the following Ennore Oil Spill reports to review the same and provide comments:

- IITM CE report – Assessment of Ennore Oil Spill during Michuang Cyclone - Submitted in NGT in Sep-24 by TNPCCB

- NCCR – Report on Impact of Oil Spill in Ennore Creek post cyclone Michuang - Submitted to TNPCB & CPCL
- NIO – Pilot Studies for assessing Environmental Benefits for cleaning / bio remediation of oil spillage - Submitted to NGT in Sep-24 by TNPCB
- TERI - Assessment of environmental quality of oil spill due to cyclone Michuang - Submitted to NGT in Sep-24 by CPCL
- TNPCB – report filed in NGT, Southern Zone on 27.02.24

IIT – Madras Petroleum Engineering team has reviewed the above reports and compared the TPH values of all reports. The team has carried out both field survey & desk study.

## 2.2 Spatial Extent and Volume Estimation

Remote sensing offers several methods for oil spill detection, including optical imaging, thermal infrared sensing, and Synthetic Aperture Radar (SAR). Among these, SAR-based detection is considered more precise and effective due to its all-weather, day-and-night capabilities, allowing it to penetrate clouds and fog. SAR-based oil spill estimation methodology employed in this analysis is widely accepted and utilized in numerous publications globally, demonstrating its robust and established nature. Optical imaging is limited by cloud cover and daylight availability, while thermal infrared sensing is highly influenced by atmospheric conditions and often struggles to differentiate between oil and other temperature anomalies on the water's surface.

Satellite imagery from Sentinel-1 SAR and Cosmo-SkyMed was processed using the Sentinel Application Platform (SNAP). This software enabled radiometric calibration, speckle filtering, and oil spill detection through texture analysis and image differencing techniques. SAR data from January 17<sup>th</sup> and 29<sup>th</sup> January, 2017, captured the 2017 spill, while satellite data on November 20<sup>th</sup> and December 6<sup>th</sup>, 2023, documented the 2023 spill.

To enhance data accuracy, radiometric corrections and geometric terrain corrections were applied. Texture analysis using Gray Level Co-occurrence Matrix (GLCM) differentiated oil slicks from other low-reflectance features, such as calm water or ship wakes. Spill volumes were estimated by correlating SAR backscatter values with empirical oil thickness models.

## 2.3 Dataset and Tool

**Sentinel 1** is a constellation of two radar-equipped satellites, Sentinel-1A and Sentinel-1B, launched by the European Space Agency (ESA) as part of the Copernicus program. They orbit Earth at an altitude of around 693 km, capturing data continuously day and night, regardless of weather conditions.

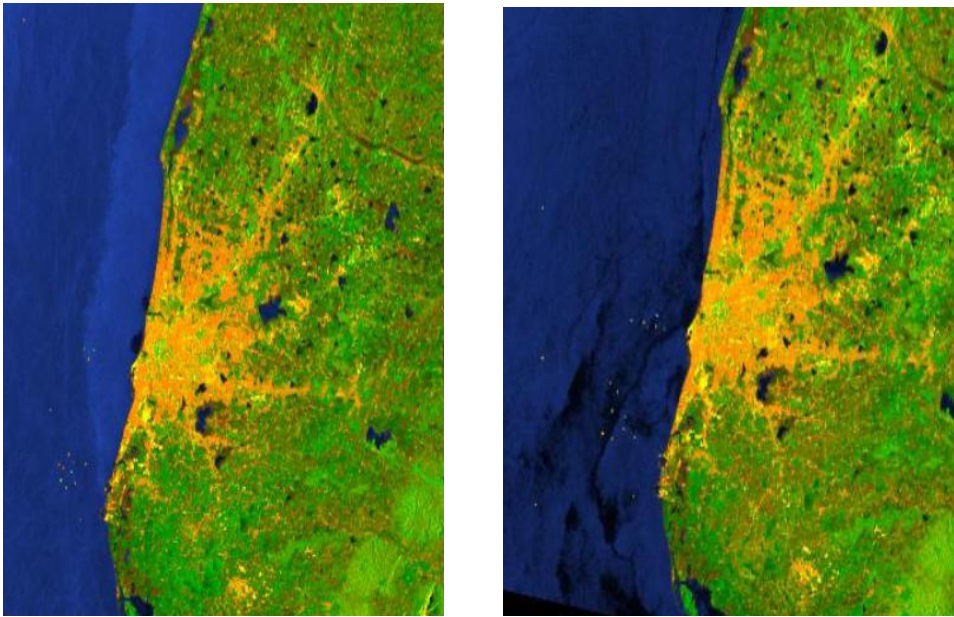
**Cosmo-SkyMed**, Italy's constellation of four radar-equipped satellites, offers a high-resolution, versatile window into Earth's hidden details. Unlike its cousin Sentinel-1, COSMO-SkyMed boasts multiple imaging modes and advanced features, making it a premier choice for scientific research, environmental monitoring, and even defence. applications.

### **Sentinel Application Platform (SNAP)**

The Sentinel Application Platform (SNAP) is a powerful software for processing and analysing Synthetic Aperture Radar (SAR) data from satellites like Sentinel-1, COSMO-SkyMed, and ALOS-2, offering advanced tools for detecting and estimating oil spills in ocean and land environments. By leveraging SAR's sensitivity to surface roughness, SNAP highlights oil slicks through enhanced visualization features, including brightness, contrast, and colour adjustments, which make dark areas on water surfaces—the primary indicator of oil spills—more discernible. Its texture analysis tools, such as the Gray Level Co-occurrence Matrix (GLCM), enable differentiation of oil slicks from other dark features like wakes or land shadows by assessing their unique smoothness and homogeneity. These capabilities, combined with time-series analysis to track spill evolution, make SNAP an indispensable tool for environmental monitoring and effective oil spill management.

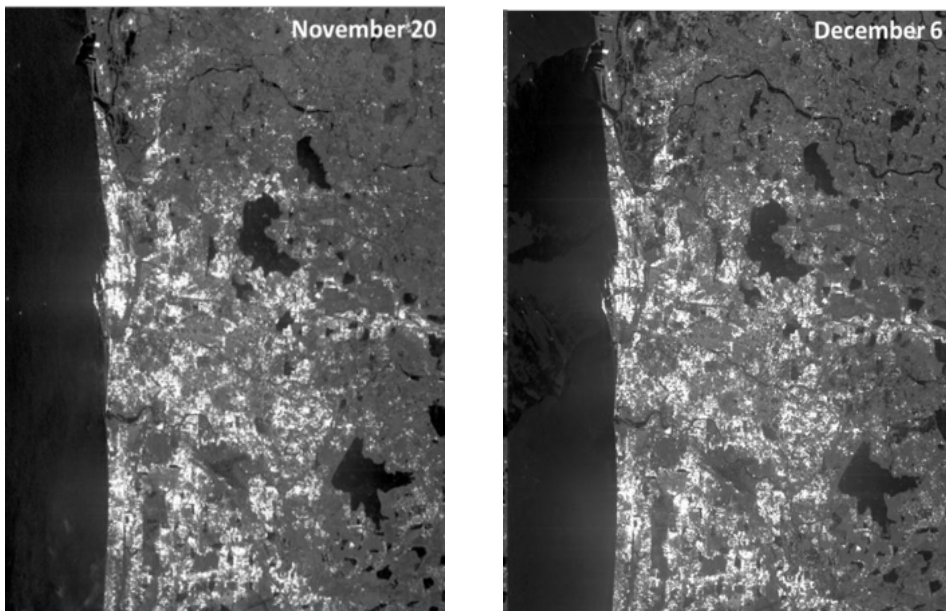
### **Dataset Description**

For the analysis of the 2017 ship collision, SAR data from Sentinel-1 was used. Specifically, Sentinel-1 data acquired on January 17<sup>th</sup> and January 29<sup>th</sup> covering the Ennore region was procured.



*Figure 1: January 17<sup>th</sup> (Left) and January 29<sup>th</sup> (Right) ,2017 Sentinel-1 SAR Data showing pre and post incident*

For the analysis of the oil spills that occurred during the Michaung Cyclone, we leveraged a combination of SAR datasets. This includes Cosmo-SkyMed data acquired on November 20th and December 6th, 2023. The integration of these datasets will provide a comprehensive understanding of the spatial and temporal dynamics of oil spills associated with the cyclone



*Figure 2: November 20<sup>th</sup> (Left) and December 6<sup>th</sup> (Right), 2023, Cosmo-SkyMed Raw SAR Data Pre and Post Cyclone*

## **Data Acquisition and Loading**

The analysis begins with acquiring SAR imagery from satellites like Sentinel-1, which is known for its high-resolution data and consistent monitoring capabilities. The imagery for the 2017 and 2023 archives is loaded into SNAP for further preprocessing. This dataset serves as the foundation for identifying and analysing the spatial extent of the oil spill.

## **Subsetting**

To streamline the analysis, the region of interest (ROI) around the Ennore port and the affected coastline is extracted using SNAP's Subsetting Tool. By isolating the spill area, this step reduces processing time and ensures the focus remains on the most relevant portions of the dataset.

## **Radiometric Calibration**

Radiometric calibration is a critical preprocessing step that converts raw SAR intensity values into calibrated backscatter coefficients, such as sigma naught. This step ensures the data is consistent and reliable for quantitative analysis, making it suitable for comparing reflective properties and identifying anomalies caused by oil slicks.

## **Speckle Filtering**

SAR imagery often contains speckle noise, which can obscure key details. To enhance image quality, speckle filtering is applied using algorithms such as the Lee or Gamma Map filter. These filters reduce noise while preserving edges and critical features, ensuring clearer visualization of the oil spill.

## **Oil Spill Detection**

The 2017 oil spill detection process utilizes SNAP's Oil Spill Detection Toolbox. This tool identifies dark areas on the water's surface, caused by the dampening effect of oil on surface capillary waves. Thresholding

techniques are applied to separate oil slicks from other low-reflectance features, such as calm water or shadows, ensuring accurate detection of the spill's extent.

In 2023, oil spill detection was conducted using Cosmo-SkyMed data. The methodology focused on identifying changes in the reflective properties of the surface between a pre-spill image (November 20th) and a post-spill image (December 6th). Oil spills significantly alter the surface's reflectivity due to the presence of hydrocarbons. This change in reflectivity was detected by employing change detection algorithms within the SNAP environment. Techniques like image differencing, and Band maths, Reflectivity were utilized to quantify the magnitude and spatial extent of these reflectivity changes. By analysing these differences, potential oil spill areas were identified and further investigated

## **Texture Analysis**

To further refine the analysis, texture analysis is performed using tools like the Gray Level Co-occurrence Matrix (GLCM). These tools calculate metrics such as homogeneity, contrast, and entropy, which help distinguish oil slicks from other dark features, such as ship wakes or land shadows, based on their smoothness and uniformity.

## **Terrain and Ellipsoid Correction**

Geometric distortions caused by the satellite's orbit and terrain variations are corrected using Terrain and Ellipsoid Correction. By referencing a Digital Elevation Model (DEM) such as SRTM, this step ensures the SAR data is georeferenced accurately, aligning it with real-world coordinates for precise spatial analysis.

## **Exporting Results**

Once the oil spill area is identified and analysed, the results are exported in GeoTIFF format. This format facilitates integration with GIS platforms for further mapping, overlaying additional datasets, and generating visual representations of the spill.

## **Volume Estimation**

The volume of the spill is estimated using the reflective properties of the oil-affected areas in the SAR data. By correlating backscatter values with empirical models that determine oil thickness, the total volume of the spill is calculated. This provides a quantitative measure of the spill's impact and helps in assessing the severity of the incident.

## 2.4 Tank Integrity Assessment Using GPR

The GPR analysis employed a 2000 MHz antenna for its balance between penetration depth and resolution. Pre-scanning site inspections identified obstructions, such as pipe connections, which were accounted for during data collection. The GPR antenna was systematically moved across the tank surfaces, focusing on weld joints and areas prone to wear or corrosion.

Data collected during GPR scans were analysed for subsurface anomalies, including cracks, voids, or material degradation. Visual representations of the scans, supplemented with annotations, highlighted critical findings. Recommendations for further inspection or maintenance were developed based on these results.

Out of the around 188 Crude and other petroleum products storage tanks, 5 tanks were selected on a random basis to carry out Tank integrity inspection job using GPR. List of tanks shared by CPCL is attached as Annexure- 6

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## 3 Findings

### 3.1 Observation of IITM-CE report & others reports

IIT – Madras Petroleum Engineering team has reviewed the above reports and the salient observations are given below:

#### 1. TPH values

Based on the comparison of all the above reports, TPH content in water & sediments is observed to be much higher in the IITM CE report.

**a. Comparison of TPH value in water**

In the water, the TPH content as per IIT-Madras report was in the range of 280 – 7210 mg/lit whereas in TNPCB, NCCR, NIO and TERI reports were in the range of 0.0277 – 3.9 mg/lit only.

- TNPCB TPH values in water is in the range from 0.217 – 2.458 mg/lit (Refer page No 42 – 43 of TNPCB filing, Annexure-5)
- NIO TPH values in water is in the range from 0.025 – 2.11 mg/lit (Refer page No 80 of NIO report, Annexure-3)
- NCCR TPH values in water is in the range from 0.0277 – 1.008 mg/lit (Refer page No 15 of NCCR report, Annexure-2)
- M/s TERI TPH values in water is in the range from 0.2 – 3.9 mg/lit (Refer page No 9 of M/s TERI report, Annexure-4)
- IITM-CE TPH values in water is in the range from 280 - 7210 mg/lit (Refer page No 24 of IITM-CE report, Annexure-1)

Name of the Agency	TPH values, mg/lit
TNPCB	0.217 – 2.458
NIO	0.025 – 2.11
NCCR	0.0277 – 1.008
TERI	0.2 – 3.9
IITM-CE	280 - 7210

*The above indicates that IITM CE report results are not in tandem with other reports and are abnormally high. This may be due to improper sampling.*

**b. Comparison of TPH value in sediments:**

In the sediment, the TPH content as per IITM CE report was in the range of 13,600 – 46,550 mg/Kg whereas NCCR, NIO and TERI reports were in the range of 5.84 – 1830 mg/Kg only.

- NIO TPH values in sediments is in the range from 630 – 1830 mg/kg (Refer page No 29 of NIO report, Annexure-3)
- NCCR TPH values in sediments is in the range from 100 – 1000 mg/kg (Refer page No 16 of NCCR report, Annexure-2)
- M/s TERI TPH values in sediments is in the range from 5.84 – 47.34 mg/kg (Refer

page No 35 of M/s TERI report, Annexure-4)

- IITM-CE TPH values in sediments is in the range from 13,600 – 46,550 mg/kg  
(Refer page No 24 of IITM-CE report, Annexure-1)

Name of the Agency	TPH values, mg/kg
NIO	630 – 1830
NCCR	100 – 1000
TERI	5.84 – 47.34
<b>IITM-CE</b>	<b>13,600 – 46,550</b>

Based on the comparison of all the above reports, TPH content in sediments is observed to be much higher in the IITM CE report.

Due to low density, oil tends to float over the surface of water, and it requires a medium such as particulate matter, solid particle etc to reach the channel bed and during continuous motion it requires very longer period to settle. Also, percolation of oily matter further into the sediments would take much more period.

***Hence, TPH content analysed by NCCR, NIO and TERI would be correct results. TPH value of IITM CE report in the range of 13,600 – 46,550 mg/Kg is unrealistic.***

***It is to be noted that TPH is the one of the components from urban runoff, domestic discharge and also through other anthropogenic activities. The preexisting TPH content was not factored by the IITM CE report.***

## **2. Quantification of oil using high TPH values:**

On scrutinizing IITM CE report, it is observed that the entire study region was divided into zones and average of concentrated TPH content observed in discrete points has been utilized to calculate the oil quantity for the entire area.

Based on the sediment TPH values of all agencies, estimation of oil quantity was carried out and the results are tabulated below.

Name of the agency	Average TPH content, g/Kg	Oil quantity based on TPH Value	
		KL	MT
NIO *	1.23	16.24	12.99
NCCR *	0.55	8.93	7.14
TERI *	0.026	0.42	0.34
<b>IIT – M CE report</b>	<b>30</b>	<b>487.12</b>	<b>389.7</b>
Present study	Based on Satellite image	18.1	14.48

\* Oil quantity estimated based on TPH value

Since the satellite image was taken on 6<sup>th</sup> Dec'23, oil estimates cover total oil spill.

The above table clearly depicts that 487.12 KL of oil in sediments (IITM CE report page no 26 & 33) is a case of over-estimation. This is due to higher TPH value reported in the IITM CE report.

Further, TPH value was taken at certain concentrated locations and extrapolated for the entire area. Oil quantity estimated on this basis is not an appropriate method.

On the other hand, Satellite image captures oil quantity based on the thicknesses spread across the area. Hence, Oil estimation based on the Spatial Distribution will be more accurate

### 3. Incorrect source matching:

IITM CE report has assessed the oil spill quantity as 517 MT (647 KL) and has identified the following as the source of oil spill:

- ❖ 30 open reservoirs in CPCL (coordinates given in IITM CE report)
- ❖ Oily sludge collected from Ennore area (395 MT)
- ❖ Breach of oil from storage tanks of CPCL

Our team visited CPCL on 13<sup>th</sup> Jan and 14<sup>th</sup> Jan 2025 and inspected 30 open reservoirs. It was observed that out of 30 open reservoirs mentioned in IITM CE report, 13 tanks are not present inside CPCL and are available in the nearby industries. Pursuant to physical verification, in order to check the location of the tanks google map was used.

Tank ID As referred by IITM CE report	Location of the tank	CPCL's tank usage
0	CPCL	ETP I surge pond (Not in use now)
1	TPL (Tamil Nadu Petrochemicals Limited)	Not in CPCL
2	CPCL	ETP-4 API oil separator Above ground
3	CPCL	ETP-1 – Pit (Not in use) Above ground
4	CPCL	ETP I POND A (Storm Pond)
5	CPCL	Raw water reservoir (East of DCU)
6	CPCL	Refinery III Fire water pond (West)
7	CPCL	Refinery III Fire water pond (East)
8	CPCL	DM Plant regeneration water storage
9	CPCL	REF III POND D (Storm Pond)
10	TPL	Not in CPCL
11	TPL	
12	TPL	
13	TPL	
14	MPL-I(Manali Petrochemicals Limited-I)	
15	IAL(Indian Additives Limited)	
16	IAL	
17	IAL	
18	IAL	
19	TPL	
20	IAL	
21	IAL	
22	CPCL	Coke Pit above ground
23	CPCL	ETP-III Treated water pond above ground
24	CPCL	Pond E (Storm Pond)

25	CPCL	ETP II Treated water pond (Above ground)
26	CPCL	Pit for storing sediment east (2.5 m above ground)
27	CPCL	ETP I aerator (Not in use)
28	CPCL	Pit for storing sediment North (2.5 m above ground)
29	CPCL	Pond C (Storm pond )

Out of 30 open reservoirs, IITM-CE pointed out 12 reservoirs as the main source of oil spill.

However, it may be noted that :

- 2 of these reservoirs are outside CPCL and belong to other companies.
- 8 reservoirs are used as raw water reservoirs, storm ponds, Guard Pond, Fire water ponds for storing oil free water only
- 2 reservoirs are above ground and are used for storing sediments.

<b>Tank ID As referred by IITM CE report</b>	<b>Location of the tank</b>	<b>CPCL's tank usage</b>
6	CPCL	Refinery III Fire water pond (West)
7	CPCL	Refinery III Fire water pond (East)
8	CPCL	DM Plant regeneration water storage
9	CPCL	REF III POND D (Storm Pond)
10	TPL	Not in CPCL
21	IAL	Not in CPCL
23	CPCL	ETP-III Treated water pond above ground
24	CPCL	Pond E (Storm pond )
25	CPCL	ETP II Treated water pond (Above ground)
26	CPCL	Pit for storing sediments (above ground at a height of 2 meter) East
28	CPCL	Pit for storing sediments (above ground at a height of 2 meter) West
29	CPCL	Pond C (Storm Pond)

IMAGES OF 10 OPEN RESERVOIRS IN CPCL

Tank ID (IIT report page No: 35)	<b>Refinery III Fire water pond (West &amp; East)</b>
Tank ID 6 & 7	
View of Refinery Fire water ponds	
	

Tank ID (IIT report page No: 35)

Tank ID 8

## DM Plant effluent water storage

View of DM effluent water storage



Tank ID (IIT report page No: 35)	<b>REF III STORM POND - D</b>
Tank ID 9	

View of Refinery III Storm Pond - D



Tank ID (IIT report page No: 35)	<b>ETP-III Guard Pond</b>
Tank ID 23	
View of ETP III Treated Water Pond	
	

Tank ID (IIT report page No: 35)	<b>Pond E (Storm Pond storing water without any oil)</b>
Tank ID 24	
View of Pond E	
	

Tank ID (IIT report page No: 35)	<b>ETP II Guard Pond (Treated water storage and not oil)</b>
Tank ID 25	

View of ETP II Treated Water Pond



Tank ID (IIT report page No: 35)	<b>Pit for storing sediments</b>
Tank ID 26 & 28	

View of pits for storing sediments



Tank ID (IIT report page No: 35)	<b>Pond C (Storm water pond for water)</b>
Tank ID 29	

View of Pond C



- Tank integrity study using Ground Penetrating Radar revealed that the tank integrity in CPCL is good. Among the list of tanks furnished by CPCL, Tanks were chosen on random basis for the GPR study. GPR scans of Tanks 106, 119, 121, 801, and 802 revealed no structural defects such as cracks or significant corrosion. The tanks are fit for continued service.
- The GPR study on CPCL tanks did not reveal any integrity issues. The findings suggest that these tanks are fit for continued service.
- Detailed report of tank integrity is furnished as Annexure-1

### 1. Numerous Assumptions:

In IITM CE report has indicated the following assumptions and are not based on true measurements.

- **Assumption 1:** TPH content estimated in discrete points was considered as average TPH and used to calculate oil quantity for the entire area (IITM CE report page No: 26, Annexure-1).
- **Assumption 2:** Uniform thickness (0.1 mm) was assumed for entire residential and industrial area without any basis. (IITM CE report page No: 30, Annexure-1).
- **Assumption 3:** Depth of oil estimation in pool was assumed as 1 mm without any measurement and applied uniformly to all the area. (IITM CE report page No: 28, Annexure-1)
- **Assumption 4:** 10,000 sq.m of oil pool was arbitrarily considered in mangrove area and another 10,000 sq.m of oil pool near pipelines.
- **Assumption 5:** Area calculated based on the oil marking height & length of the mangrove tree area, is unscientific as the mangroves will have branches & space between trees etc. The report considered the whole area like a wall and arrived at the area. (IITM - CE report page No: 32, Annexure-1)
- **Assumption 6:** The report has erroneously assumed 0.01 mm oil thickness over the mangrove trees. (IITM - CE report page No: 32, Annexure-1)
- **Assumption 7:** Assumption of oil layer of 10 mm without any basis in open reservoir tanks. (IITM - CE report page No: 36, Annexure-1).

Oil estimation of oil quantity based on such assumptions would always leads to erroneous value.

### 3.2 2017 Oil Spill

The 2017 spill, caused by a collision between MT BW Maple and MT Dawn Kanchipuram, resulted in extensive environmental damage more than 60 KM of coast line. Sentinel-1 SAR imagery from January 29, 2017, revealed a spread of dense, viscous furnace oil.

The analysis conducted using the Sentinel Application Platform (SNAP) revealed the significant spatial extent of the oil slick. The detected oil slick covered an area of 197.4 KM<sup>2</sup> extending approximately 60 kilometres along the coastline from Pulicat towards Panaiyur beach. The analysis involved rigorous image preprocessing to correct for geometric distortions and atmospheric effects, ensuring the accuracy of subsequent analyses. The detected oil slick areas were then meticulously mapped and visualized in figure 3.

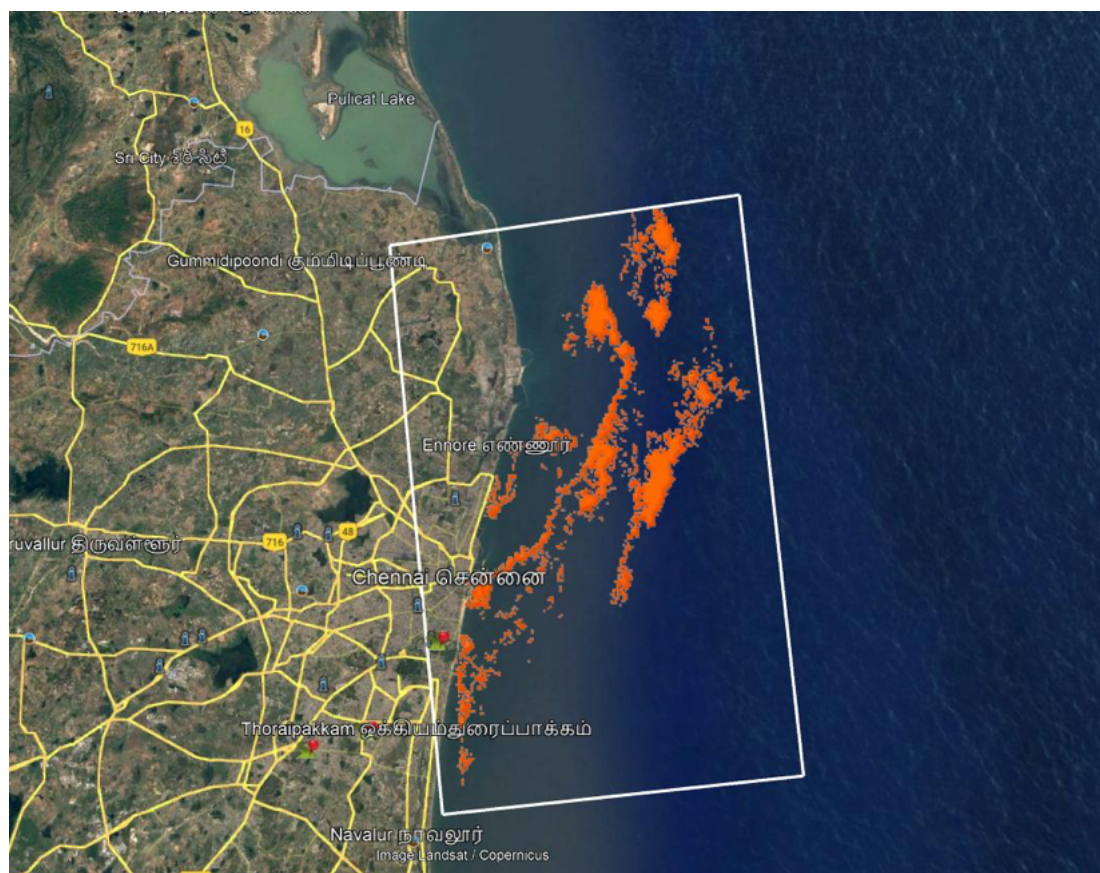
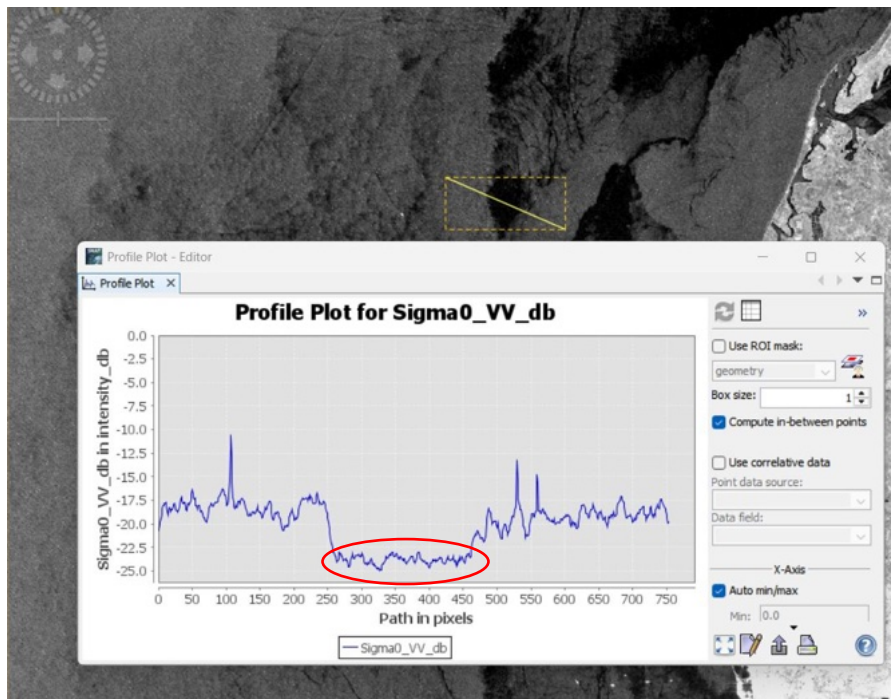


Figure 3: Oil Spill detected on January 29<sup>th</sup>, 2017

Synthetic Aperture Radar (SAR) sensors detect oil spills by measuring changes in radar backscatter caused by the presence of oil on the water surface. Oil slicks smooth out the water surface, reducing roughness and decreasing the amount of radar energy scattered back to the sensor. This results in lower backscatter values, typically ranging between -20 dB and -22.5 dB for thin oil films (1-20 micrometres). As shown in Figure 4, the observed backscatter values within the detected oil slick area fall within this range, suggesting the presence of oil films with an estimated thickness of approximately 10 micrometres.



*Figure 4: Backscatter Profile plot of Oil Slick (2017)*

### Volume Estimation

Spatial distribution analysis of impacted area of 197.4 KM<sup>2</sup> through the ArcGIS shows that 22.35 KM<sup>2</sup> area is observed with dense oil slick.

The combination of oil volume and thickness offered a comprehensive spatial depiction of the contamination. Satellite observations indicated that the oil spill, which extends from the Manali industrial area to Ennore Creek and affects nearby residential and adjacent areas, amounts to 223.5 cubic meters (178.8 tons) in 2017 oil spill.

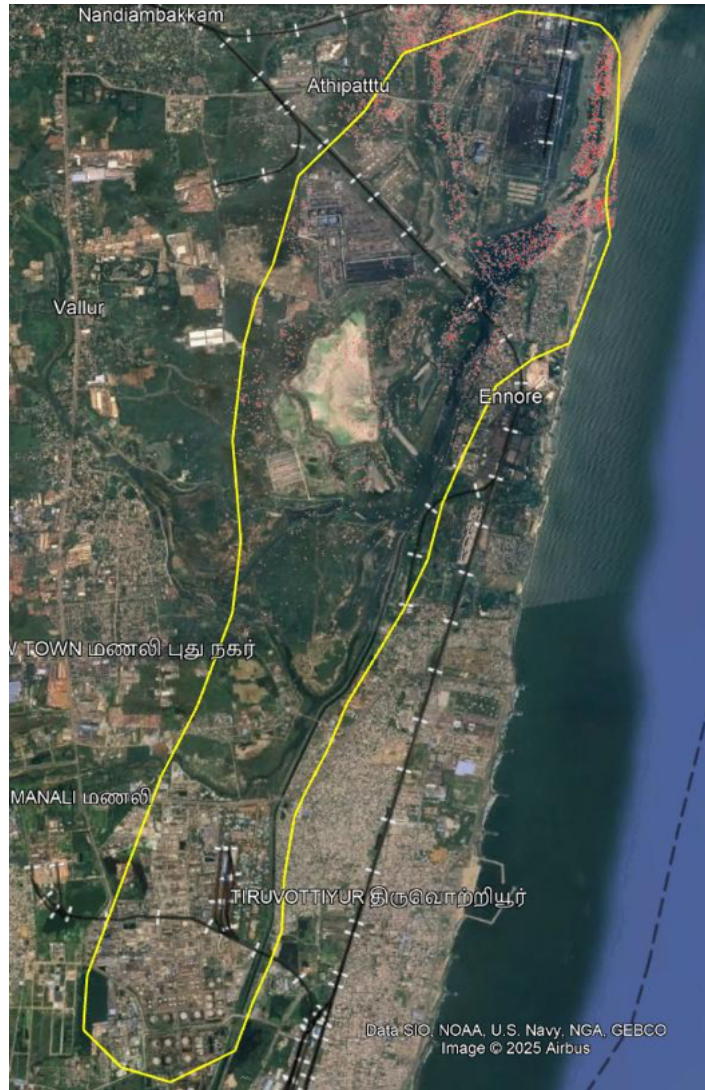
Source	Reported Oil Spill Volume (Metric Tonnes)	DOI (Digital Object Identifier)
An assessment on oil spill trajectory prediction: Case study on oil spill off Ennore Port	196.4	<a href="https://rdcu.be/edQKC">https://rdcu.be/edQKC</a>
Report No.29, 2017: Oil Spill along Chennai Coast by NCSCM	194	<a href="https://ncscm.res.in/technical-reports/#2017">https://ncscm.res.in/technical-reports/#2017</a>

The oil spill volumes presented in the table represent reported values from published articles. Our SAR-based estimation of 178.8 metric tonnes falls within the range established by these independent sources. This close alignment suggests that our estimation methodology, utilizing SAR data, provides a suitable and reliable approach for determining oil spill volume of 2023.

### 3.3 2023 Oil Spill

The 2023 spill, associated with the Michaung cyclone, was documented using Cosmo-SkyMed data. Advanced image differencing techniques identified changes in reflectivity between pre- and post-spill conditions.

This analysis utilized the Sentinel Application Platform (SNAP) to investigate an oil spill event suspected to be associated with Cyclone Michaung. a Cosmo-SkyMed image acquired on December 6<sup>th</sup> and December 14 was analysed.



*Figure 5: Oil Spill Detected on December 6<sup>th</sup>, 2023*

*Oil slick patches shown in red spots yellow line indicates the ROI (Region of Interest)*

**This analysis method relied on the distinct backscatter properties of oil on radar imagery.** Oil slicks exhibit unique radar backscatter signatures compared to surrounding water and land surfaces. By analysing variations in backscatter intensity within the imagery, areas indicative of oil slicks were identified and delineated.

The total area of the detected oil slick was determined to be 1.81 square kilometres. Oil slick patches were observed within the Buckingham Canal and the Kosasthalaiyar River, located south and north of Ennore Creek, respectively and adjacent area where water stagnation was observed. Oil slick concentrations were observed and marked within the map in the region between Ernavur and Kattuppalli.



*Figure 6: Backscatter profile plot on oil slick (2023)*

The analysis utilized Cosmo-SkyMed imagery with HH polarization, revealing backscatter values within the range of -18 dB to -22.5 dB within the detected oil slick areas. This range of backscatter values, characteristic of thin oil films shown in figure, suggests an oil film thickness between 1 micrometre and 20 micrometres. For this analysis, an average oil film thickness of 10 micrometres is considered.

The combination of oil volume and thickness offered a comprehensive spatial depiction of the contamination. Satellite observations indicated that the oil spill, which extends from the Manali industrial area to Ennore Creek and affects nearby residential and adjacent areas, amounts to 18.1 cubic meters (14.48 tons).

### **Comparison of 2017 and 2023 Oil Spills**

Analysis of the 2017 and 2023 oil spills in the Ennore region reveals a significant disparity in both volume and extent. The 2017 spill, estimated at 178.8 metric tonnes, affected an area of

22.35 sqkm, stretching from Pulicat to Panaiyur. In contrast, the 2023 spill involved a much smaller volume of 14.48 metric tonnes and impacted a significantly reduced area of 1.81 sqkm within the same region.

This stark difference is visually apparent in the accompanying figures, where the 2023 spill appears considerably smaller. The limited extent of the 2023 spill is such that it is barely discernible in the images, even after magnifying the area in 2023 oil spill incident (Fig 7c).

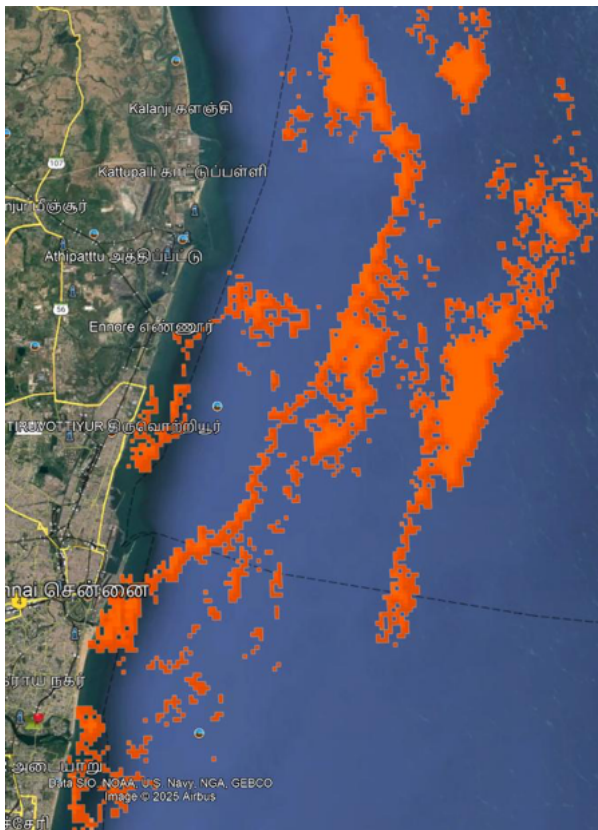


Figure 7 (a) 2017 Spill (2000 sqkm view)

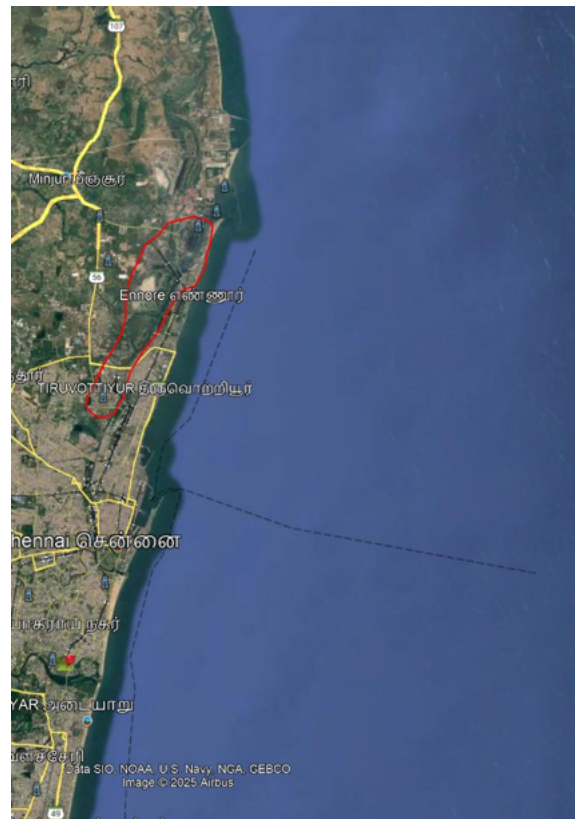
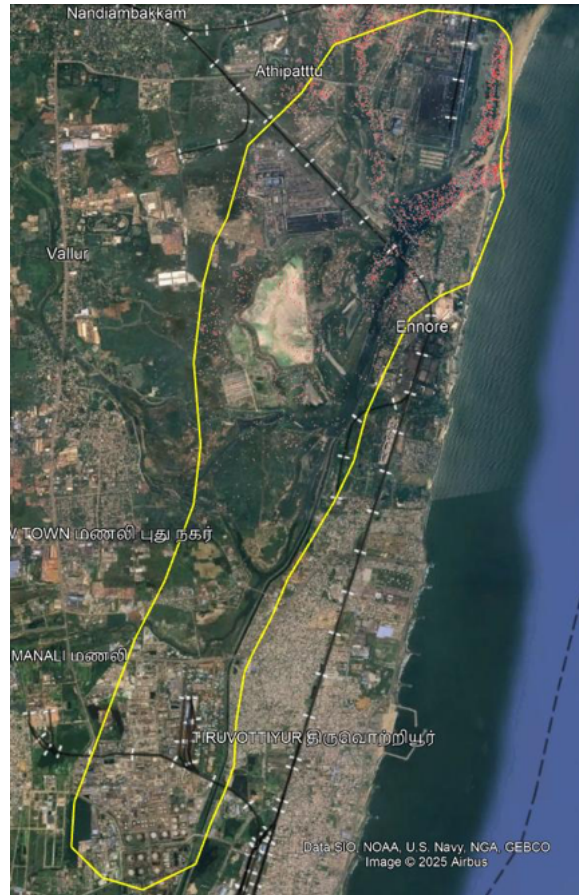


Figure 7(b) 2023 Spill (2000 sqkm view)



*Figure 7(c) 2023 Spill (100 sqkm view)*

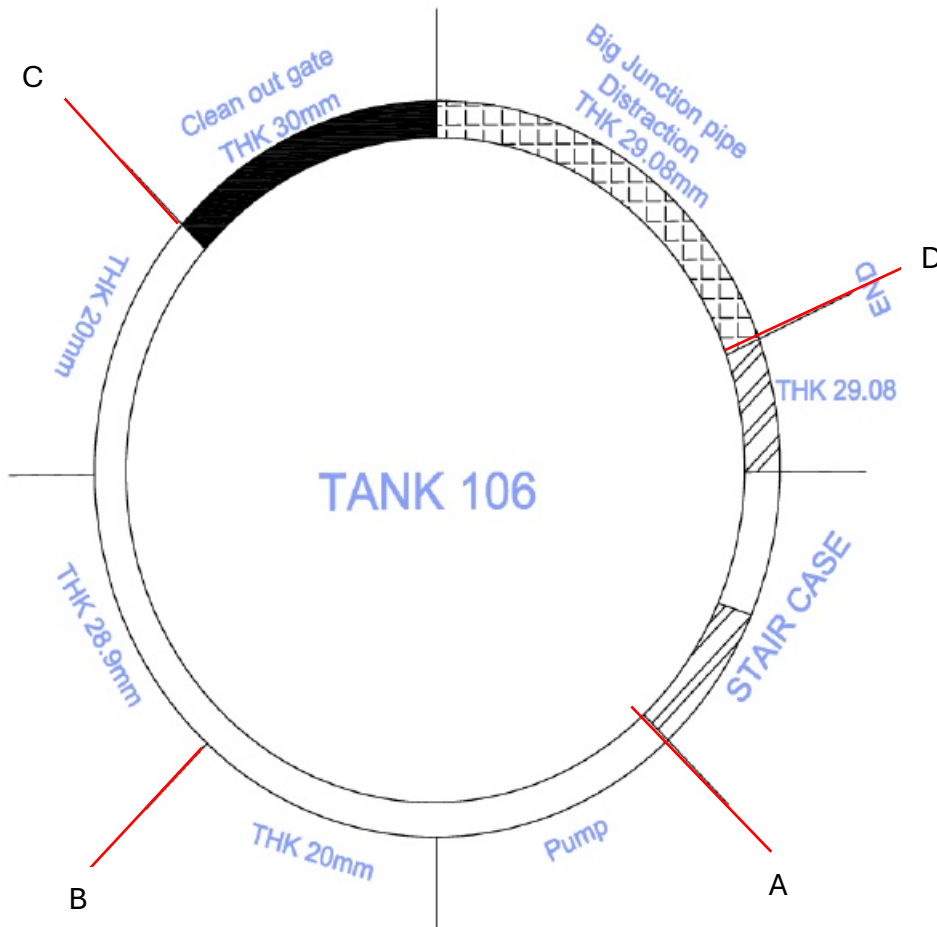
### 3.4 GPR Findings on Tank Integrity

#### **Tank No. 106:**

Tank 106, is a large steel storage tank for storing Crude oil with a diameter of 79 meters and a height of 14.4 meters. The tank's thickness varies from 12mm to 30mm, depending on the elevation, and it consists of 8 shell courses. During the GPR scanning process, some areas along the tank's circumference had obstructions, such as pipe connections and other structural elements, which limited the ability to obtain clear readings in those regions. However, in the accessible areas, the GPR scan revealed a parabola-shaped reflection in the main welding areas, indicating that the welds were intact. The scan showed no signs of significant damage, such as corrosion, cracking, or leakage. The tank was found to be in good condition overall, with no cracks or leakage detected as per the GPR scanning. Structural integrity remains sound, with no signs of severe material degradation or voids. In Figure-8-10, the round mark indicates the location of the massive welding.

Records of previous Maintenance and Inspections (M&I) activities were checked by IIT – PE and the details are given below:

Tank No	Tank Dia, m	Tank ht, m	Thickness, mm	Nos. of shell courses	Previous Internal inspection	JOB DONE
106	79	14.4	30.0/24.0/22.0/18.0/14.0/12.0/12.0/12.0	8	Sep-23	M&I Completed in Sep-2023 Bottom, Annular & Roof top plate (Partial) Replacement was done. Tank Internal painting also done.



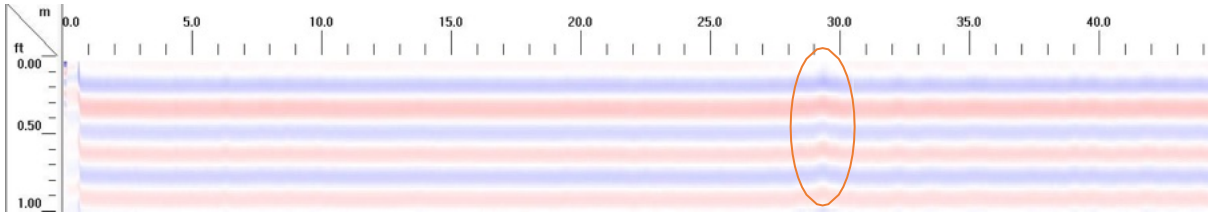


Figure 8, shows the GPR reading between points A-B, and red circle indicates joint welding which is intact.

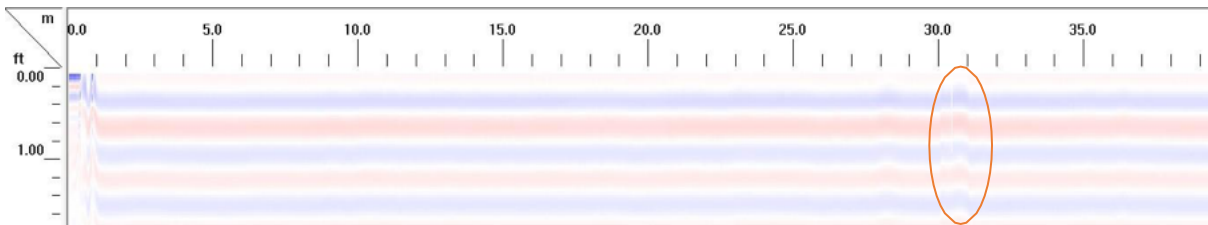


Figure 9, shows the GPR reading between points B-C, and red circle indicates joint welding which is intact.

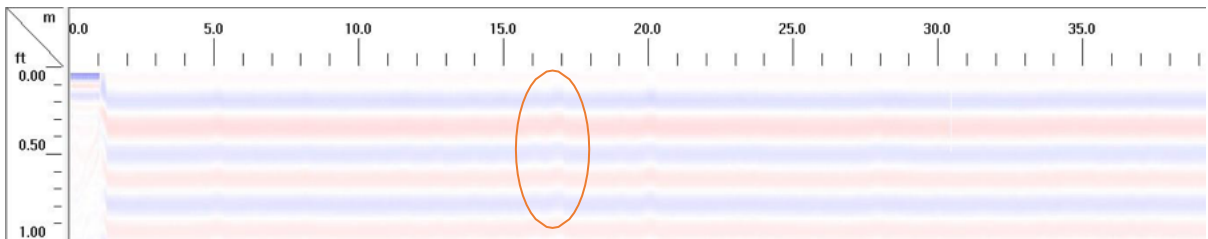


Figure 10, shows the GPR reading between points C-D, and red circle indicates joint welding which is intact.

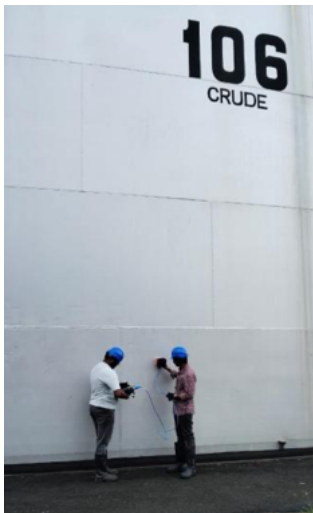


Figure 11(a) and 11(b) show site photographs taken during the GPR scanning process, illustrating the readings being captured

**Tank No.119:**

The tank 119 is a large steel storage tank with a diameter of 79 meters and a height of 13.5 meters. The tank's thickness varies from 12mm to 30mm, depending on the location, and it consists of 8 shell courses. During the GPR scanning process, it was observed that in certain areas along the circumference, clear readings could not be obtained due to pipe connections and other structural distractions. These obstructions interfered with the ability to capture data in those specific regions.

However, in the accessible areas, the GPR scan revealed a parabola-shaped reflection in the main welding areas, indicating that the welds were intact. The scan showed no signs of significant damage, such as corrosion, cracking, or leakage. The tank was found to be in good condition overall, with no cracks or leakage detected as per the GPR scanning.

Structural integrity remains sound, with no signs of severe material degradation or voids. In Figure-12 the round mark indicates the location of the massive welding. In Figure13- GPR technology during the inspection of Tank 119

Records of previous M&I activities were checked by IIT – PE and the details area given below:

<b>Tank No</b>	<b>Tank Dia, m</b>	<b>Tank ht, m</b>	<b>Thickness, mm</b>	<b>Nos. of shell courses</b>	<b>Previous Internal inspection</b>	<b>JOB DONE</b>
119	79	13.5	30.0/24.0/22.0/18.0/14.0/12.0/12.0/12.0	8	Aug-23	Roof conversion into double deck and Bottom / Annular plate replaced with product side phenolic epoxy coating in the M&I last outage.

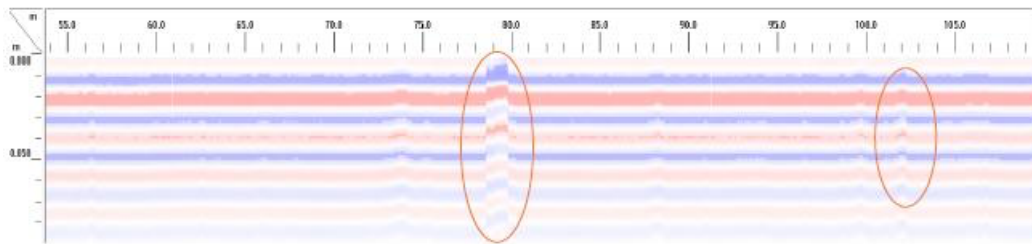
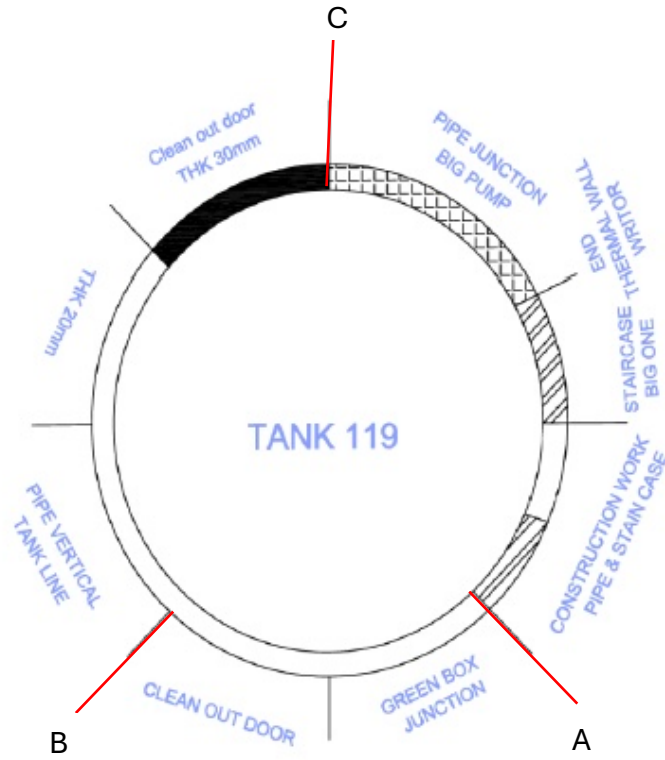


Figure 12(a), shows the GPR reading between points A-B, and red circles indicates joint welding which is intact.

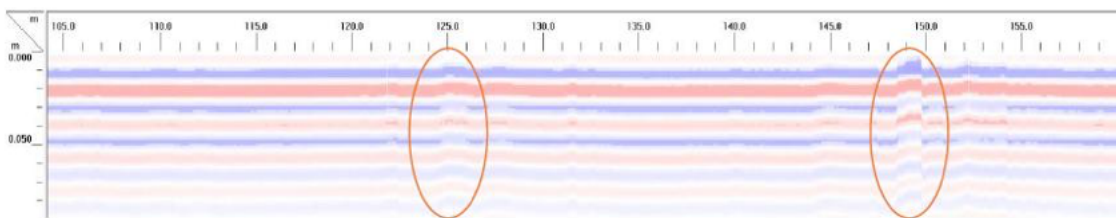
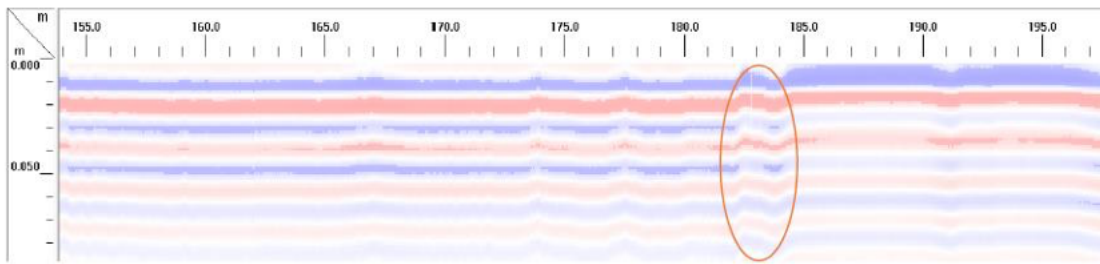


Figure 12 (b), shows the GPR reading between points B-C, and red circles indicates joint welding which is intact.



*Figure 12 (c), shows the GPR reading between points C-A, and red circles indicates joint welding which is intact.*



*Figure 13 shows site photograph taken during the GPR scanning process for tank 119.*

### **Tank No.121:**

Tank 121 is a large steel storage tank with a diameter of 64 meters, a height of 17.5 meters, and wall thickness varying between 12mm and 30mm across its 8 shell courses. The tank was constructed to meet industry standards for durability and reliability in large-scale storage applications. Ground Penetrating Radar (GPR) scan was conducted to assess its structural condition and ensure continued safety and performance.

During the GPR scanning process, it was observed that certain areas along the tank's circumference could not be inspected due to obstructions caused by pipe connections, nozzles, and other structural features. These obstructions interfered with the radar signals, making it challenging to collect data in those specific regions. Despite this, the majority of the tank's accessible areas were successfully scanned, allowing for a detailed evaluation of its structural integrity and condition.

The GPR scan revealed distinct parabola-shaped reflections in the primary welding zones, a strong indication that the welds are intact and structurally sound. No anomalies such as gaps, cracks, or separations were detected in the welds, which are critical for the tank's structural stability. Furthermore, the scan showed no significant signs of corrosion, thinning, or material degradation in the steel, demonstrating that the tank's construction materials have remained durable and resilient over time.

In addition to confirming the integrity of the welds and the absence of corrosion, the scan found no evidence of cracks, voids, or leakage. The tank's structural integrity remains uncompromised, with all critical components performing as expected. These findings suggest that Tank 121 is in good operational condition and is capable of safely continuing its storage function without immediate concerns. To ensure long-term performance and reliability, periodic inspections and maintenance are recommended. Particular attention should be given to the obstructed areas during future assessments, using alternative methods to improve access. Routine maintenance of pipe connections and nozzles will also help prevent potential issues and prolong the tank's lifespan. With proper upkeep and continued monitoring, Tank 121 is expected to remain a reliable and safe storage asset for years to come.

Records of previous M&I activities were checked by IIT – PE and the details are given below:

<b>Tank No</b>	<b>Tank Dia, m</b>	<b>Tank ht, m</b>	<b>Thickness, mm</b>	<b>Nos.of shell courses</b>	<b>Pervious Internal inspection</b>	<b>JOB DONE</b>
121	64	17.5	30.0/30.0/24.0/22.0 /18.0/16.0/14.0/12.0	8	Nov-19	Bottom Plate painting was found good and touch work was done at steam coil support bottom.

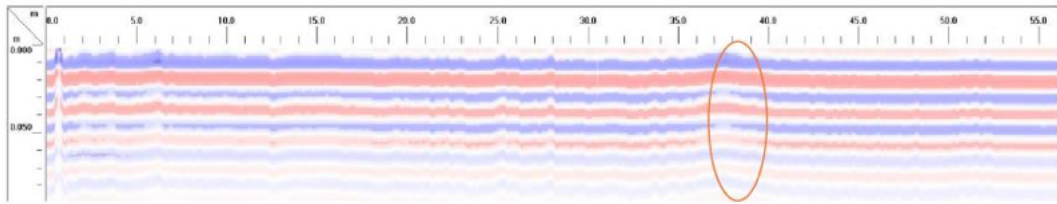
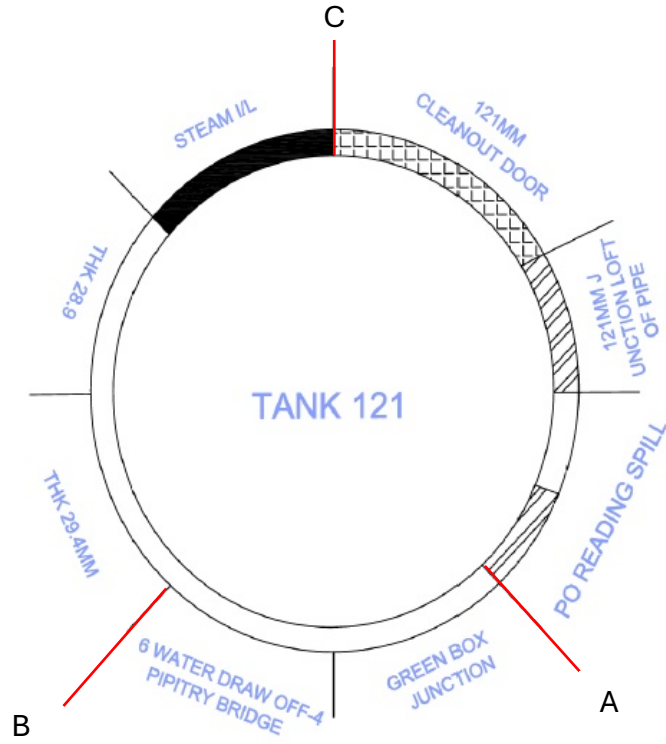


Figure 14(a), shows the GPR reading between points A-B, and red circle indicates joint welding which is intact.

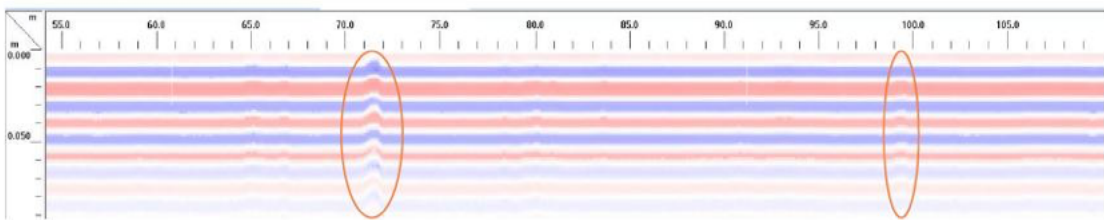


Figure 14 (b), shows the GPR reading between points B-C, and red circle indicates joint welding which is intact.

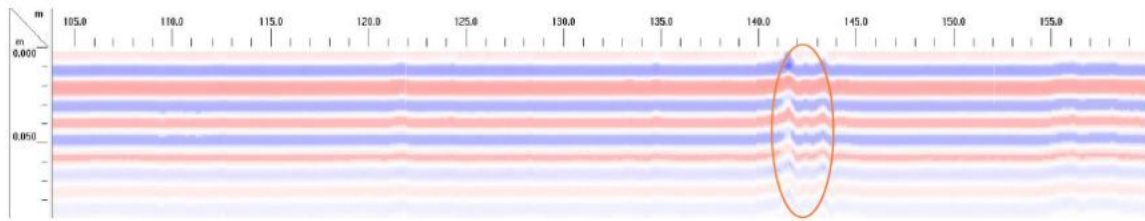


Figure 14 (c) shows the GPR reading between points C-A, and red circle indicates joint welding which is intact.

**Tank No. 802:**

The Tank 802, is a slab-type steel storage tank with a diameter of 16.8 meters and a height of 7.2 meters. This tank is specifically designed to collect various kinds of oil (slop oil), making it a critical component in the storage system. The tank has a thickness of 8mm and is composed of 4 shell courses. During the GPR scanning process, some areas along the tank’s circumference had obstructions, such as pipe connections and other structural elements, which limited the ability to obtain clear readings in those regions. Its dry slab in the context of storage tanks ensures that the tank has a stable and moisture-free foundation, reducing the risk of corrosion and ensuring the long-term integrity of both the tank and the substances being stored within it.

Nevertheless, the accessible areas of Tank 802 revealed a deep small parabola-shaped reflection in the welding areas, indicating that the welds are intact with no visible damage such as cracking. The GPR scan did not detect any cracks, leaks, or significant degradation in the tank’s structure. The overall condition of the tank was assessed to be good, with no signs of severe material degradation or structural weaknesses. Figure 15 shows GPR scan images, demonstrating the good integrity of the tank. Figure 16 shows site photographs taken during the GPR scanning of the tank.

Records of previous M&I activities were checked by IIT – PE and the details area given below:

Tank No	Tank Dia, m	Tank ht, m	Thickness, mm	Nos.of shell courses	Previous Internal inspection	JOB DONE
802	16.8	9	8.0 / 8.0 / 8.0 / 8.0	4	Sep-17	Top shell course replaced with 8mm plates. Entire roof plate replaced and roof slope increased to 1:6. Sprinkler provided.

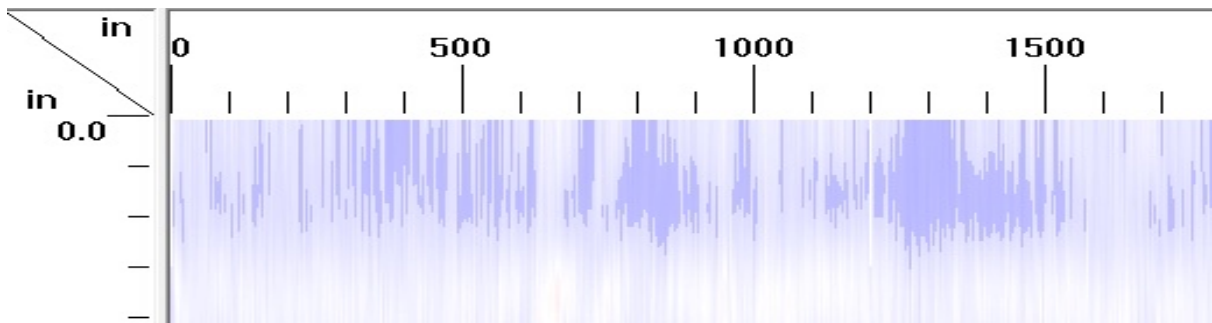
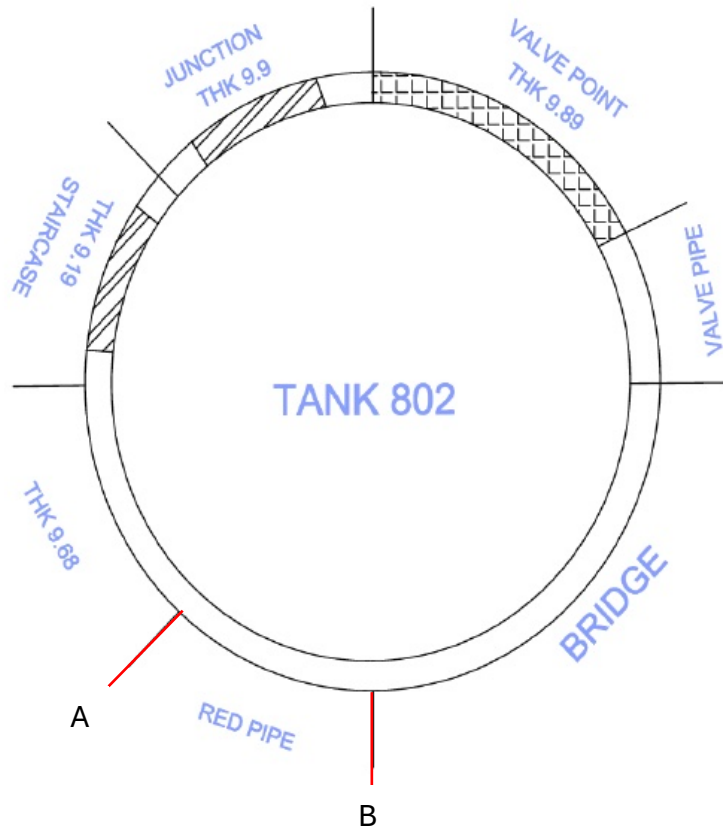


Figure 15 shows the GPR reading between points A-B



*Figure 16 shows site photograph taken during the GPR scanning process for tank 802.*

### **Tank No. 801:**

The Tank 801, is a slab-type steel storage tank with a diameter of 16.8 meters and a height of 9 meters. This tank is specifically designed to collect various kinds of oil (slop oil), making it a critical component in the storage system. The tank has a thickness of 8mm and is composed of 4 shell courses. During the GPR scanning process, some areas along the tank's circumference had obstructions, such as pipe connections and other structural elements, which limited the ability to obtain clear readings in those regions. Its dry slab in the context of storage tanks ensures that the tank has a stable and moisture-free foundation, reducing the risk of corrosion and ensuring the long-term integrity of both the tank and the substances being stored within it.

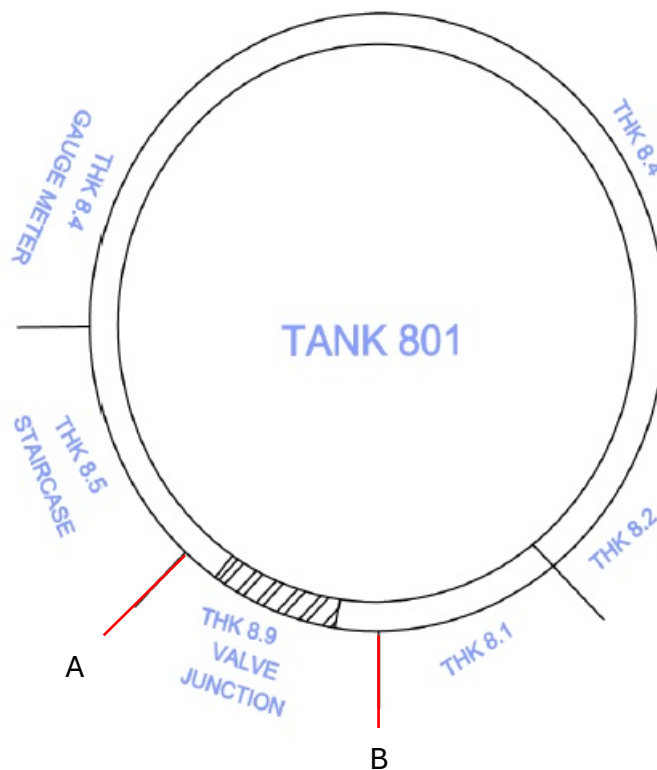
Nevertheless, the accessible areas of Tank 801 revealed a deep small parabola-shaped reflection in the welding areas, indicating that the welds are intact with no visible damage such as or cracking. The GPR scan did not detect any cracks, leaks, or significant degradation in the

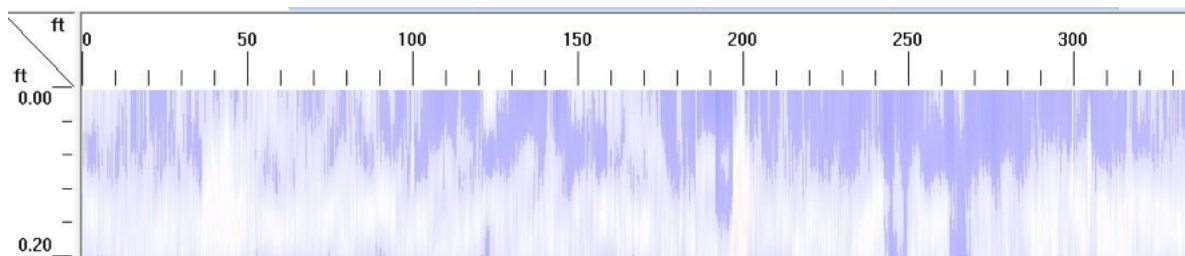
tank’s structure. The overall condition of the tank was assessed to be good, with no signs of severe material degradation or structural weaknesses.

Figure 17 shows GPR scan images, demonstrating the good integrity of the tank. Figure 18 shows site photographs taken during the GPR scanning of the tank.

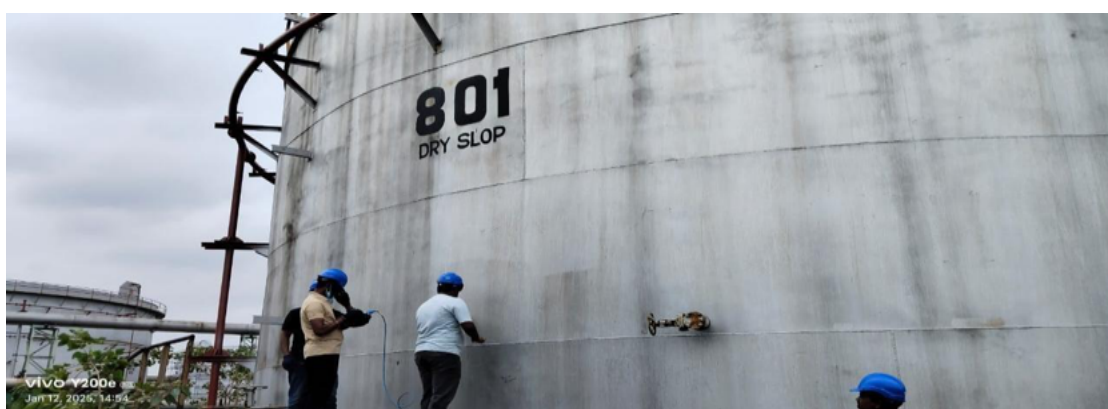
Records of previous M&I activities were checked by IIT – PE and the details area given below:

Tank No	Tank Dia, m	Tank ht, m	Thickness, mm	Nos.of shell courses	Previous Internal inspection	JOB DONE
801	16.8	7.2	8.0 / 8.0 / 8.0 / 8.0	4	Sep-22	M&I completed on Sep-2022. Roof complete replacement. Shel external patch repair & internal painting completed.





*Figure 17 shows the GPR reading between points A-B*



*Figure 18 shows site photograph taken during the GPR scanning process for tank 801.*

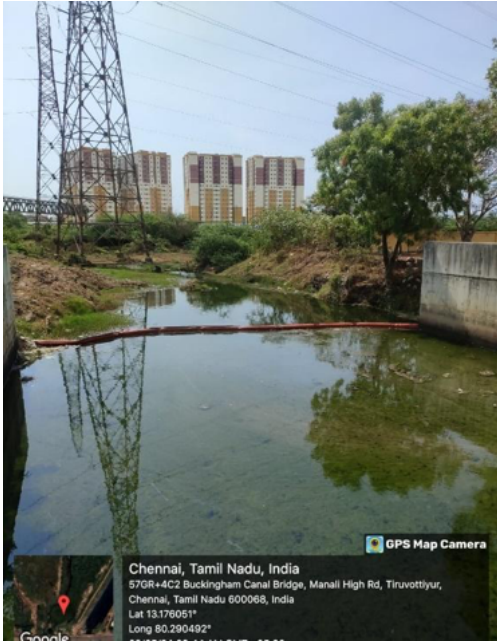
### 3.5 WAPCOS study:

To further strengthen the system, CPCL entrusted Water And Power Consultancy Services (WAPCOS), a leading PSU and they have carried out study on flood management and shared the salient findings (Annexure-7). On physical verification the following recommendations were implemented by CPCL:

- ❖ Rain water collection capacity has been increased from 58000 M3 to 79000 M3
- ❖ Height of the ponds handling rain water collection increased by 2 to 3 feet
- ❖ Construction of ramps at the entry points
- ❖ Desilting of storm ponds
- ❖ Six more Oil catchers have been installed.

Apart from the above, as precautionary measure, CPCL has installed permanent booms at 8 locations outside CPCL and images of few is below:





## 4 Conclusion

**A. Based on the review of the IITM Civil Engineering report, National Centre for Coastal Research (NCCR), National Institute of Oceanography (NIO), The Energy and Resources Institute (TERI) and Tamil Nadu Pollution Control Board reports observations and comments by IITM Petroleum Engineering team are given below:**

1. Total Petroleum Hydrocarbon (TPH) content in water is very high in IIT Madras CE report (280 – 7210 mg/lit) compared to TNPCB, NCCR, NIO & TERI reports (0.0277 – 3.9 mg/lit). This may be due to random sampling. (Pl refer page No.: 17 of this report)
2. Total Petroleum Hydrocarbon (TPH) content in sediments is very high in IITM-CE report (13,600 – 46,550 mg/Kg) compared to NCCR, NIO and TERI reports (5.84 – 1830 mg/Kg). Oil estimation by IITM-CE using such higher TPH values in sediments resulted in huge quantity of oil. This is due to extrapolation of TPH content, taking sample at few concentrated locations and applying the same for the entire area. Refer assumption 1 in page no. 29 of this report (Pl refer page No.: 17 & 18 of this report)
3. Oil being a lighter component /low density, tends to float over the surface of water. Settling & percolation of oil in the sediment requires longer duration. TPH value of IITM CE report in the range of 13,600 – 46,550 mg/Kg is unrealistic. (Pl refer page No.: 17 & 18 of this report)
4. The effects due to preexisting TPH values due to urban runoff, domestic discharge and also through other anthropogenic activities have not been considered in the IITM-CE report
5. Estimation of oil quantity using TPH values of NIO, NCCR & TERI is around 0.34 to 12.9 Tons of oil (Pl refer page No.: 18 & 19 of this report) and the values of these reports are consistent with the present oil estimation through satellite image study viz. 14.48 MT. (pl refer page No 36 of this report). However, wide variance is observed in estimation of oil quantity by IITM – CE report (517 MT).

517 MT of oil in sediments is a case of over-estimation, arrived due to higher TPH value reported in the IITM CE report. TPH value has been taken at certain concentrated locations and extrapolated for the entire area. Oil quantity estimated on this basis is not an appropriate method.

On the other hand, Satellite image captures oil quantity (14.48 MT) based on the thicknesses spread across the area. Oil estimation based on the Spatial Distribution will be more accurate

6. IITM-CE report has identified 30 Nos of open reservoirs as the main source of oil spill. Based on the field visit to CPCL and google map coordinate study it is confirmed that 13 open reservoirs are not inside CPCL and belong to other companies. (Pl refer page No.: 20 - 21 of this report)
7. Out of 30 open reservoirs, IITM-CE pointed out 12 reservoirs as the main source of oil spill. However, it may be noted that:
  - 2 of these reservoirs are outside CPCL and belong to other companies.
  - 8 reservoirs are used as raw water reservoirs, storm ponds, Guard Pond, Fire water ponds for storing oil free water only
  - 2 reservoirs are above ground and are used for storing sediments.
8. Apart from the above, IITM-CE report has considered numerous assumptions, as listed below and are not based on true measurements, as detailed in this report.
  - **Assumption 1:** TPH content estimated in discrete points was considered as average TPH and used to calculate oil quantity for the entire area (IITM CE report page No: 26, Annexure-1).
  - **Assumption 2:** Uniform thickness (0.1 mm) was assumed for entire residential and industrial area without any basis. (IITM CE report page No: 30, Annexure-1).
  - **Assumption 3:** Depth of oil estimation in pool was assumed as 1 mm without any measurement and applied uniformly to all the area. (IITM CE report page No: 28, Annexure-1)
  - **Assumption 4:** 10,000 sq.m of oil pool was arbitrarily considered in mangrove area and another 10,000 sq.m of oil pool near pipelines.
  - **Assumption 5:** Area calculated based on the oil marking height & length of the mangrove tree area, is unscientific as the mangroves will have branches & space between trees etc. The report considered the whole area like a wall and arrived at the area. (IITM - CE report page No: 32, Annexure-1)

- **Assumption 6:** The report has erroneously assumed 0.01 mm oil thickness over the mangrove trees. (IITM - CE report page No: 32, Annexure-1)
- **Assumption 7:** Assumption of oil layer of 10 mm without any basis in open reservoir tanks. (IITM - CE report page No: 36, Annexure-1).

Oil estimation based on such assumptions would always leads to erroneous value.

**B. Observation and findings of estimation of oil quantity & comparison of 2017 ship collision incident through satellite images are furnished below.**

1. Based on the satellite image of 29<sup>th</sup> Jan 2017, it is confirmed that the 2017 oil spill, caused by a collision near the Ennore port, resulted in a dense oil slick extending over 197 KM<sup>2</sup> and impacting more than 60 KM of coastline with a volume of approximately 223.5 cubic meter (178.8 MT)

This is consistent with the established reports of 194 MT from published articles and confirms that Satellite based estimation methodology, as a suitable and reliable tool.

2. On similar lines, Satellite image estimation was carried out for 2023 oil spill. Based on the satellite image of 6<sup>th</sup> Dec 2023, oil spill triggered by cyclone Michaung affected 1.81 KM<sup>2</sup> in the stretch from Manali Industrial Area to Ennore Creek area. The quantum of oil assessed through the satellite image in the Buckingham canal, Kosasthalaiyar river and nearby area shows spillage of 18.1 cubic meters (14.48 metric Tons).
3. Extent of spillage & quantity assessed through satellite image above clearly indicates that the quantum of oil spill in ship collision incident occurred in Jan 2017 is much higher than Dec'23 incident.

**C. Observation and findings of GPR study on tank integrity.**

1. IITM-CE Department have indicated that breach of oil from storage tanks could be one of the source of oil spill. (page No.: 36 of IITM-CE Report- Annexure-1).

In order to ascertain the Integrity of the Tanks, Five critical Tanks were chosen on random basis for the GPR study. Based on tank integrity study using GPR (in

Tanks 106, 119, 121, 801 & 802) carried out by IIT – PE, the structural integrity remains sound, with no signs of material degradation.

2. Physical verification of the tanks and scrutiny of Maintenance & Inspection (M&I) records of storage tanks maintained by CPCL revealed that all the tanks are in good condition.

In conclusion, the following inference are drawn:

- A. TPH values of IITM CE report are abnormally high and resulted in higher estimation of oil quantity. Further source validation was not also reflecting real scenario
- B. Based on the analysis of satellite images in 2017 & 2023 & the field survey carried out, it is concluded that the quantum of oil spill is estimated to be 18.1 cubic meters (14.48 metric tonnes).
- C. CPCL tanks are intact and there are no oil leaks observed from the tanks.



**ASSESSMENT OF ENNORE OIL SPILL DURING  
MICHAUNG CYLCONE**



**March 2024**



**Environment Engineering Division  
Department of Civil Engineering  
Indian Institute of Technology Madras, Chennai – 600036**

## Executive Summary

The "MICHAUNG" cyclonic storm caused extensive oil spillage from Chennai Petroleum Corporation Limited (M/s CPCL). The resulting contamination adversely affected biodiversity, daily life, and livelihoods in the impacted regions. IIT Madras research team conducted a comprehensive field assessment, mapping oil contamination across 20 zones. Notable hotspots included stormwater outlets of M/s CPCL, residential areas and industrial areas in Ennore. Field surveys, mapping efforts using drones, questionnaire surveys provided deep insights into the extent of oil contamination. Oil pools, sheens, and stains were observed in residential, industrial, and natural areas, threatening biodiversity, and public health.

Two sources of the oil spill into the environment were identified. One being the storm water discharge outlet at the south-eastern wall of CPCL into the Buckingham Canal and the other being the storm water canal discharging into surplus canal of Kosasthalaiyar River. The flood levels of the Kosasthalaiyar River rose to 5 to 6 ft above the Buckingham Canal bund level causing the entry of oil and water into the adjoining residential areas of Ernavoor and Sathyamoorthy Nagar. The mangroves along the banks and the islands in Kosasthalaiyar River were impacted up to a height of 10 ft near the surplus canal and 3 ft in other areas with complete loss of mangrove saplings. The team observed several dead fish and crabs and oil coated birds.

Laboratory analysis of water, soil and sediment samples revealed Total Petroleum Hydrocarbon (TPH) concentrations ranging from 0.28 to 7.21 g/L in water and 13.6 to 46.55 g/kg in sediments. The estimated volume of oil contamination in the environment ranged from 517 tonnes to 2097 tonnes without including oily sludge collected by CPCL and oil in inaccessible islands and sediments of Kosasthalaiyar River. The oil estimates from our assessment (517 tonnes) and the oily sludge removed by CPCL (395 tonnes) together sums up to 912 tonnes without including the inaccessible areas and bottom sediments of B Canal and K river. Fingerprinting analysis using GC-MS suggests that it could be slop oil or furnace oil or mix of both.

The Tamil Nadu Pollution Control Board's survey of M/s CPCL premises has suspected breaches in stormwater drainage systems and potential risks associated with oil storage and handling practices. An assessment of the open tanks in M/s CPCL premises indicated that 417 tonnes of oil could have been stored before flooding which is much less than 912 tonnes of oil estimated. This mismatch suggests that the flood induced release from the open tanks

may not have been the sole reason of the oil spill. Other possibilities could be breach of oil from enclosed storage tanks of CPCL premises. Urgent remedial actions are imperative to mitigate the environmental and socio-economic consequences of this oil spillage. Efforts should focus on environmental restoration, alongside regulatory measures to enhance industrial safety.

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## 1. Introduction

A severe cyclonic storm named "MICHAUNG" which formed over the Bay of Bengal, resulted in exceptionally heavy rainfall in the coastal districts of North Tamil Nadu and South Andhra Pradesh states (IMD, 2023). Chennai city experienced significant rainfall, with the Nungambakkam Meteorological Station recording a maximum of 530 mm between December 2 and 4, 2023. This extreme weather event had detrimental effects on the daily lives, livelihoods, and biodiversity of the affected regions.

Chennai Petroleum Corporation Limited, also known as CPCL, which stands as one of the foremost public sector refining companies in India, found itself at the centre of another crisis. Cyclone Michaung led to the leakage of oil deposits from M/s CPCL's guard ponds and stormwater drain ponds. These deposits were released on the flood plains of Kosasthalaiyar River and into the Buckingham Canal. The oil was carried along with the flood water through these waterways ultimately reaching the Ennore Creek and contaminating the Bay of Bengal.

The IIT Madras research team started their field campaign to assess the oil spill contaminations in water and sediments for a 12 km stretch in Buckingham Canal. The field campaign encompassed various activities, including flow measurements in Buckingham Canal, the collection of water and sediment samples, and mapping the spread of oil contamination in the affected area. This preliminary assessment report provides in-depth findings from both field investigations and laboratory analysis, offering insights into the severity of the oil spill contamination. Additionally, it provides a summary of the coast guard's estimation of the oil spill, along with insights gathered from the Tamil Nadu Pollution Control Board (TNPCB) Committee Report.



**Figure 1:** Oil spread near Ennore railway bridge



**Figure 2:** Oil contamination in Buckingham Canal

## 2. Mapping the Extent of Oil Contamination

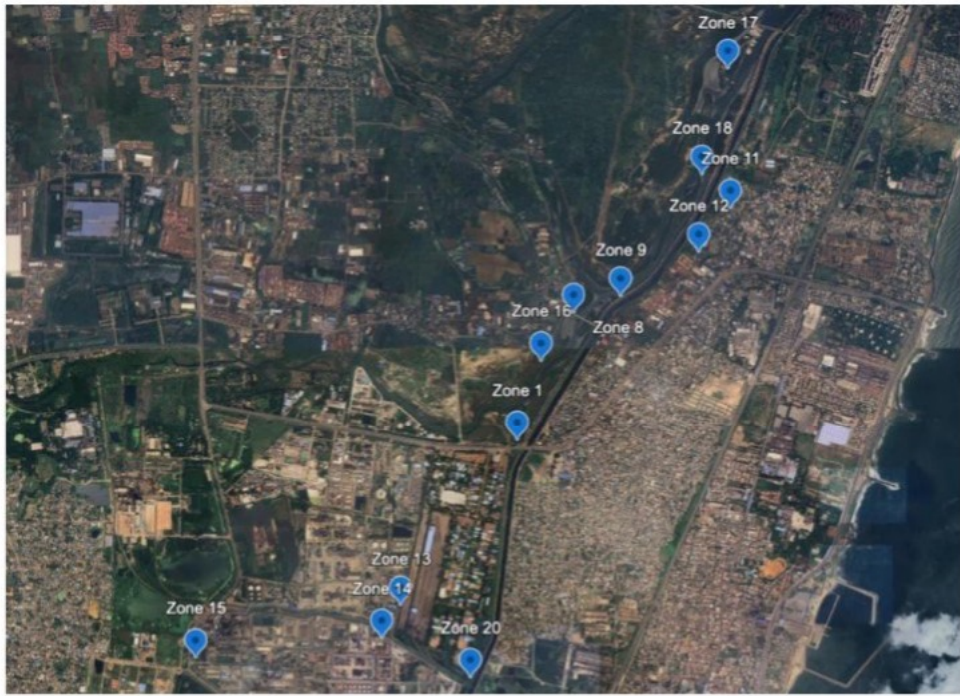
IITM started their on-site investigations after the first response measures undertaken by CPCL. By then, oily sludge of 395 tonnes floating on the river and the banks were contained using booms and removed using skimmers (The Hindu Bureau, 2023). During our physical

survey by boat and by road between 14<sup>th</sup> and 26<sup>th</sup> December 2023, we observed oil marks along the banks of the Kosasthalaiyar River (K River) and the Buckingham Canal (B Canal), identifying 20 zones where oil accumulation was notably high.

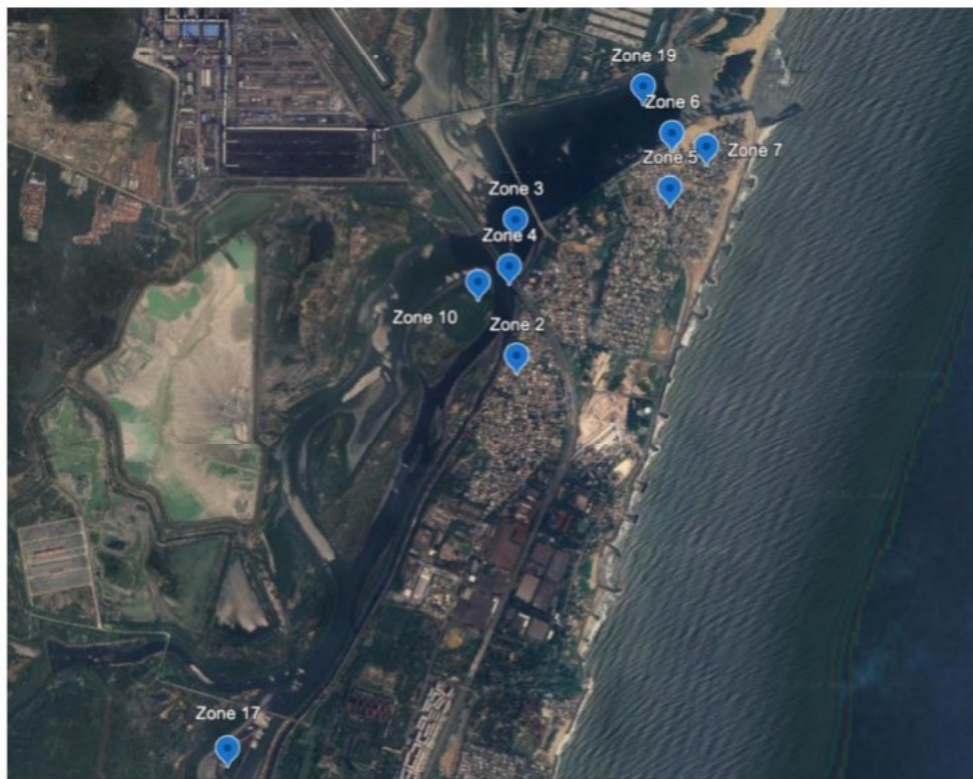
Zone 1: Entry Point 1 - Storm water canal discharge into surplus canal of Kosasthalaiyar River
Zone 2: Kattukuppam
Zone 3: B/w railway and road bridge
Zone 4: Near Ennore railway bridge
Zone 5: Thazhankuppam
Zone 6: Ennorekuppam
Zone 7: Nettukuppam
Zone 8: Bridge pier/island in K River - Sadayankuppam
Zone 9: Oil overflowed along B Canal
Zone 10: In mangrove islands
Zone 11: Ernavoor and Sathyamoorthy Nagar residential area
Zone 12: Ernavoor and Sathyamoorthy Nagar industry/marsh accessible areas
Zone 13: Storm water drain outside M/s CPCL
Zone 14: Storm water drains inside M/s CPCL
Zone 15: Land area within M/s CPCL, IAL, Steel
Zone 16: Oil staining the soil embankment in B Canal and K River
Zone 17: Oil staining the mangroves
Zone 18: River and canal sediments
Zone 19: Marine sediments and oil lost to sea
Zone 20: Entry Point 2 - Storm water discharge outlet at the south-eastern wall of CPCL into the Buckingham Canal

There was a large amount of oil stagnation near Ennore Creek (Zone 19) due to the combination of tidal activity and the river mouth's influence. In this season, the wave and tidal movements tend to carry particles toward the shoreline in a southwest direction. As a result, it takes longer for substances such as oil, to be dispersed back into the ocean. Zone 1 is a hotspot where a large influx of oil came from the storm water drain from M/s CPCL, entering the floodplains of K River, and eventually contaminating the river. In all the

accessible zones we had collected soil, water and some river sediment samples and quantified the oil that had been contaminated.



**Figure 3:** Contamination Zones from CPCL premises to the midstream of Buckingham Canal



**Figure 4:** Contamination Zones from midstream of Buckingham Canal to Ennore Creek

During the flood event, B Canal experienced overflow of oil mixed water, inundating the residential areas of Ernavoor (Zone 11). Lamp posts positioned within the residential vicinity along the B Canal exhibited signs of oil spillage, while flood-affected houses showed oil stains on their walls, reaching heights of 5 to 6 feet. The overflowing oil mixed water adversely affected vegetation, residential buildings, vehicles, and the open wells that serve as sources of groundwater. The field images below provide visual representation of the extent of oil contamination within the residential zones of Ernavoor.



**Figure 5:** Highest oil mixed water level 7.5 feet above normal water level during the cyclone



**Figure 6:** Collection of samples from the oil overflow along the banks of B Canal.



**Figure 7:** Oil marks observed in the residential localities of Ernavoor.

### **Assessment Regions:**

The extensive presence of heavy oil was detected in various locations along our route, indicating a significant spill. IIT Madras team surveyed along the B Canal and K river to identify the extent of the spill along the width and length of the waterways. We have divided the assessment regions to three stretches:

1. Downstream from Ennore Thermal Power Station (ETPS) to Creek:



**Figure 8:** Assessment Region 1 - Downstream from ETPS to Creek Area

The depicted figure illustrates the flow of oil, represented by red arrows, along the B Canal and K River after the floodwaters receded. Dotted lines signify the presence of oil stains along all banks of these water bodies and islands. Hotspots, where substantial oil deposits occurred, are highlighted as red patches along the eastern banks of the Creek, extending from Kattukuppam to Nettukuppam.

2. Midstream from Ennore Thermal Power Station (ETPS) to Manali High Road Bridge:

The midstream stretch of B Canal extending from the junction of K River and surplus canal from Redhills up to ETPS is the crucial area to pay attention. The surplus from Puzhal and Poondi Lakes discharged high quantum of water into the two K River branches which trapped the oil in this mid-stream stretch. The flood water rose to 7 to 9 ft in this section carrying the

oil with it, over the B Canal bank into the adjoining residential and industrial areas of Ernavoor and Sathyamoorthy Nagar. Once the flood water/surplus water receded, the oil must have flown downstream into the Kattukuppam all the way to Nettukuppam.



**Figure 9:** Assessment Region 2 - Midstream From ETPS to Manali High Road Bridge

### 3. Upstream of B Canal from Manali High Road to Kodungaiyur

Two oil discharges from the M/s CPCL stormwater drain have occurred in the locations: one in the south (entry point 2), directly into the B Canal, and another in the north (entry point 1), flowing through the stormwater drain adjacent to India Additives, into the flood plains of K river (Zone 1 indicated by the large red patch). Stormwater drains within M/s CPCL were tracked, revealing breaches in the outlet and walls, with all drains and tanks heavily stained with oil. Numerous open oil-water collection tanks were present at ground level, lacking preventive measures to contain oil during flooding or to prevent its escape from the premises.



**Figure 10:** Assessment Region 3 - Upstream of B Canal from Manali High Road to Kodungaiyur showing the entry point of oil into the Buckingham Canal and Kosasthalaiyar River

The soil samples collected at Zone 1 had oil markings present up to 2m (max.) depth from the surface. This may have long-term impacts on the region as it is mostly an unconfined aquifer where there are possibilities of contamination of the ground water.



**Figure 11:** Drone image of Zone 1



**Figure 12:** Close up view of Zone 1

Verified through drone camera images, the dark patches in the above image signify the presence of oil pools surrounding the stormwater outlets flowing towards the K River. Extensive sampling of soil and water at this contaminated site revealed high oil content. Upstream from this contaminated site, deposits of oil-contaminated sludge are still present, likely resulting from backflow from this leakage point. However, no significant oil spill or sludge deposition was observed beyond 100 meters from this location, indicating that Zone 1 is likely the initial point of oil spillage or the source itself.

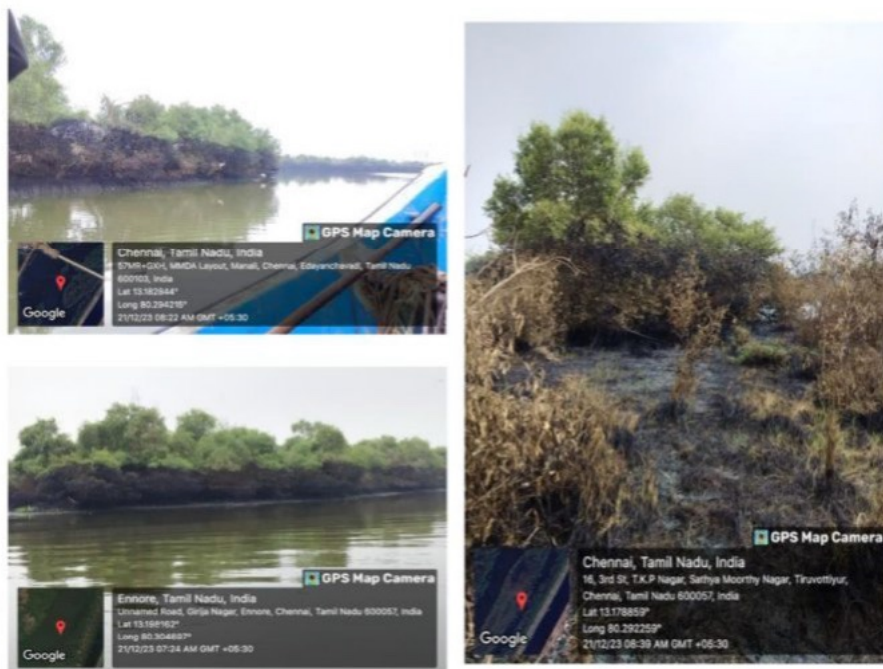


**Figure 13:** Earth moving machinery at the oil spill site



**Figure 14:** B canal possibly breached and oil stain covered.

Numerous earthmoving machines were on-site (Figure 13), along with several laborers tasked with covering the oil stains in the floodplain. Arrows pointing towards the two locations in the Buckingham Canal (Figure 14) distinctly indicate that the bund has been reworked following the oil spill, with one section appearing clean and the other section visibly stained with oil.



**Figure 15:** Mangroves with severe oil contamination



**Figure 16:** Dead birds, crabs, and fishes found in the contaminated site

The oil spill has posed a significant threat to biodiversity (Figure 15 and 16) in the affected area, impacting mangroves and various organisms such as crabs, fishes, and birds.

### 3. Field Assessments and Sampling

Field assessments were conducted along Buckingham Canal utilizing boats and by road in areas inaccessible by boat. Water and sediment samples were systematically collected at 500-meter intervals. Water samples, including any oil present, were obtained from both the top and bottom of the canal using a bailer. The depth of the canal was measured with a staff gauge, and flow velocity was assessed using an ultrasonic flow sensor. Sampling locations along a 12 km stretch from Indian Oil Cooperation Limited (IOCL) in Tondiarpet to Ennore Creek in Buckingham Canal are illustrated in Figure 2. Soil sediments and oil deposits were collected using a grab sampler and analysed in the laboratory for Total Petroleum Hydrocarbon (TPH) via gravimetry and gas-chromatography analysis.

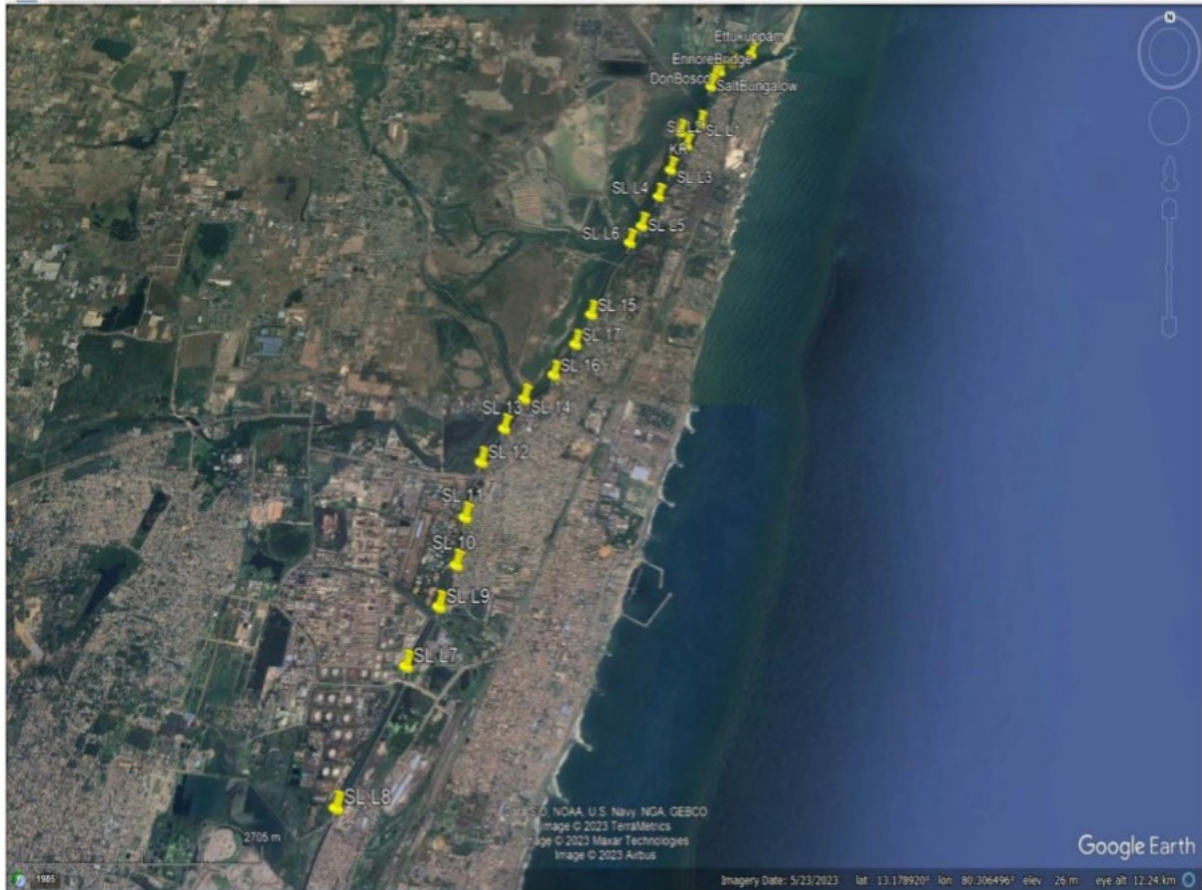


Figure 17: Sampling locations along Buckingham Canal



Figure 18: Collecting sediment samples using a grab sampler



**Figure 19:** Sediment sample collection from midstream and banks



**Figure 20:** Depth measurement



**Figure 21:** Sampling of soil cores



**Figure 22:** Collecting water samples using a bailer

### 3.1 Drone Surveys

A drone survey was carried out to quantify the oil contamination spatially. Drones were employed to capture the hyper-spectral aerial images, that will help us differentiate water from oil. The drone images captured (Figure 24) show the oil sheen floating on B canal and K River.



**Figure 23:** Capturing high-resolution images using drone survey



**Figure 24:** Drone images showing oil contamination in B Canal and K River

### **3.2 Water Characteristics Measured Insitu:**

In-situ water quality measurements, such as pH and total dissolved solids (TDS), were taken using a field probe, revealing pH values ranging from 7.4 to 8.0 and TDS values between 500 and 850 mg/L. The table below shows the insitu-water characteristics of the water samples.

**Table 1:** Insitu- water characteristics

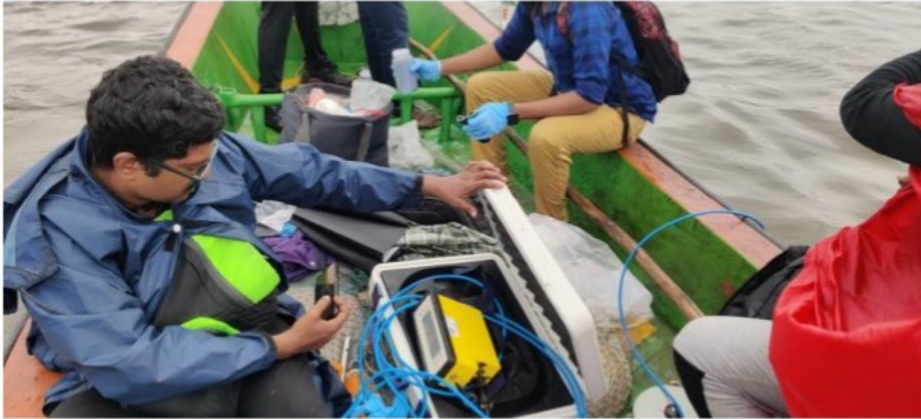
Sample ID	Latitude	Longitude	Water level [m]	pH		TDS [mg/L]	
				Top water	Bottom water	Top water	Bottom water
SL 1	13.2200	80.31833	0.5	7.88	-	842	-
SL 2	13.21666	80.31638	1	7.97	7.80	804	855
SL 3	13.21305	80.31416	1	7.95	8.04	852	845
SL 4	13.20916	80.3125	1	7.92	7.99	844	840
SL 5	13.205	80.31027	1.5	7.88	7.94	824	824
SL 6	13.20217	80.30834	-				
SL 7	13.15433	80.28454	-	7.66	-	671	-
SL 8	13.1415	80.27866	-	7.63	7.73	683	700
SL 9	13.16015	80.2876	-	7.47	7.44	761	795
SL 10	13.16441	80.28916	-	7.7	7.65	740	744
SL 11	13.16938	80.28973	-	7.78	7.67	786	765
SL 12	13.17541	80.29114	-	7.61	7.54	733	752
SL 13	13.17923	80.29366	-	7.51	7.59	732	741
SL 14	13.18276	80.29591	-	7.66	-	634	-
SL 15	13.19324	80.30388	-	7.66	7.62	736	739
SL 16	13.18568	80.29944	-	7.87	7.72	759	751
SL 17	13.18949	80.30199	-	7.81	7.52	770	778
Nettukuppam	13.2311	80.32602	0.9	7.71	7.78	496	758
Thazhankuppam	13.22935	80.32321	0.8	7.77	7.68	581	624
DonBosco	13.22817	80.32137	0.6	7.93	8.00	457	498
EnnoreBridge	13.22726	80.3205	0.5	7.06	7.12	586	560
Salt Bungalow	13.22573	80.31999	0.7	7.04	7.11	536	924

### 3.3 Flow Measurement

Water flow measurements were carried out using an ultrasonic flow measurement device - FLOWFLAT. The velocity values ranged from 0.1 m/s to 0.7 m/s. The measurements were conducted in 10 locations within the B Canal and Ennore Creek at different depths based on the location's available flow depth. The table below summarises the velocity magnitudes in the B Canal and Ennore Creek.

**Table 2:** Velocity values in different locations of B Canal

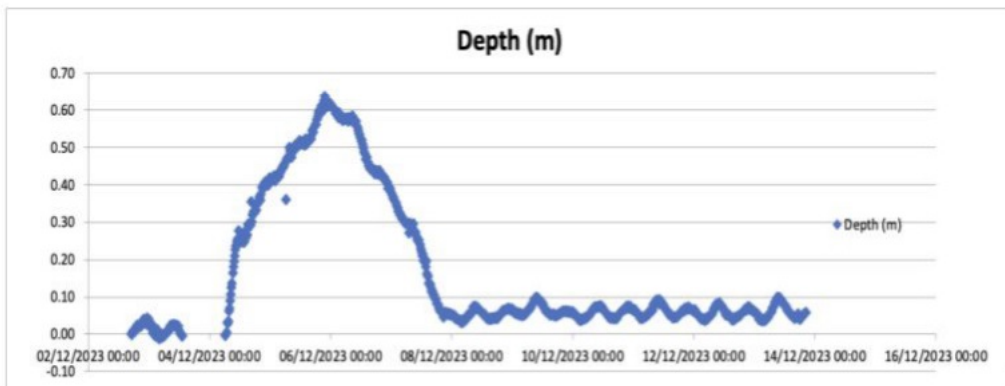
ID	Velocity [m/s]	Depth of flow [m]	Depth of velocity measurement [m]
L2	0.255	0.5	0.15
	0.385		0.40
L3	0.645	1	0.40
	0.734		0.90
L4	0.334	1	0.30
	0.390		0.90
L5	0.400	1.5	0.50
	0.452		1.00
	0.496		1.20
L6	0.214	0.3	0.25
L7	0.308	0.15	0.10
L10	0.104	0.2	0.10
	0.117		0.15
L12	0.150	0.38	0.15
	0.472		0.35
Nettukuppam	0.214	0.9	0.30
	0.243		0.6
Thazhankuppam	0.105	0.8	0.3



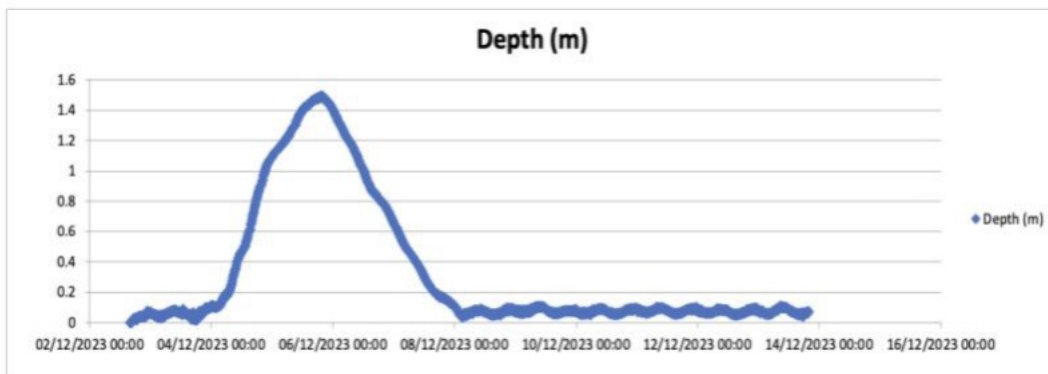
**Figure 25:** Water quality using field probe and flow measurement using FLOWFLAT

**3.4 Flood Water Level Measurement at M/s CPCL Premises**

The installation of water level meters at M/s CPCL by IIT Madras provided valuable data regarding the timing and extent of the peak water level, particularly noting the peak occurring on December 5<sup>th</sup>, 2023. This suggests that a significant influx of water has exacerbated the spread and impact of the oil spill in several ways.



**Figure 26:** Water level metre at M/s CPCL West Gate



**Figure 27:** Water level metre at Bottling plant at CPCL

#### 4. Laboratory Analysis

Oily sludge, a semi-solid waste, contains hazardous hydrocarbon substances and is composed of an emulsion of water, petroleum hydrocarbons, heavy metals, and solid particles. Water and sediment samples collected continuously over a three day period in various locations along the B Canal and Ennore Creek were subjected to analysis for Total Petroleum Hydrocarbon (TPH) utilizing both gravimetric and gas chromatography-mass spectrometry (GC-MS) methods. The TPH content in water ranged from 0.28 to 7.21 grams per litre (g/L), while in sediments, it ranged from 13.6 to 46.55 grams per kilogram (g/kg). These findings indicate the extent of hydrocarbon contamination in both the aquatic environment and sedimentary deposits within the affected areas.

**Table 3:** TPH concentrations in water and sediments/soil

Contaminations in 7 Zones which notably showed a high level of oil contamination		Water	Sediment/Soil
Location	Area [sq.m.]	TPH conc (g/L)	TPH (g/Kg)
Zone 1 Entry Point 1 - Storm water canal discharge into surplus canal of Kosasthalaiyar River	100601	1-2.27	13.6-30.44
Zone 2 (Kattukuppam)	3007	6.195 - 7.21	NA
Zone 3 (B/w railway and road bridge)	3163	5.32-7.13	18-31.8
Zone 4 (Near Ennore railway bridge)	2886	1.02-2.5	15.32-41
Zone 5 (Thazhankuppam)	5139	0.28-0.54	38-40.38
Zone 6 (Ennorekuppam)	3742	sample not collected	sample not collected
Zone 7 (Nettukuppam)	3232	2.45-3.01	46-46.55
Location	Area [sq.m.]	TPH conc (g/L)	TPH (g/Kg)
Buckingham Canal	121765	0.43-3.29	33-110
Kosasthalaiyar River	1032988	0.44-0.97	17-38.9
Residential areas near B Canal (oil pool)	11403	NA	24-120

Gas Chromatography Mass Spectrometry analysis was conducted to determine the type of oil that was spilled during the floods. A total of four samples, specifically the field sample, crude oil, furnace oil, and slop oil, were subjected to analysis using GC- MS. The chromatogram of the field sample was compared with those of crude oil, furnace oil, and slop oil to accurately identify the source of the oil. Upon examination of the chromatogram patterns, a precise retention time match was identified between the field sample and furnace oil. However, upon analysing the individual compounds in each chromatogram (across all four samples) for their m/z fragmentation pattern, it was noted that many compounds in the field sample (such as Decane, Dodecane, Tridecane, Hexadecane, Phytane, etc.) corresponded with those in slop oil and furnace oil. Consequently, it is plausible that the oil present in the flood water originated from either furnace oil or slop oil. To precisely identify the source of the oil type, bio-marker fingerprinting analysis is required.

## **5. Quantification of Oil in the Contaminated Areas**

The total oil present in the major environmental compartments during our sampling events in the 19 zones can be summarized into five categories:

### **a. Oil present in soil:**

The soil contamination extent was surveyed by boat and by road through physical investigation and through drone investigation to identify the impacted zones. The total area of the impacted zones were estimated using Google Earth Pro. The depth of soil contamination varied between 1-2.5 feet in Zone 1 to 8. Estimates referring to the results of laboratory analysis an average oil concentration of 30g/kg was considered for the estimates. The volume of oil that could be entrapped in the soil is within the range of 487 cu.m. to 1623 cu.m.

**Table 4:** Volume of oil estimated in soil

Oil contamination in Soil		Volume of soil contaminated (cu.m.)	Mass of soil contaminated (kg)	Oil measured in soil (concentration ~30g/kg)	Oil in cu.m.	Assuming only 30% of the soil is contaminated
Location	Area (sq.m.)	Upto 1 foot depth cu.m.				Sn = 0.3
Zone 1: Entry Point 1 - Storm water canal discharge into surplus canal of Kosasthalaiyar River	30296	9088.8	24085.32	722.55	903.19	<b>270.95</b>
Zone 2 (Kattukuppam)	3007	902.1	2390.56	71.71	89.64	<b>26.89</b>
Zone 3 (B/w railway and road bridge)	3163	948.9	2514.58	75.43	94.29	<b>28.28</b>
Zone 4 (near Ennore railway bridge)	2886	865.8	2294.37	68.83	86.03	<b>25.81</b>
Zone 5 (Thazhankuppam)	5139	1541.7	4085.50	122.56	153.20	<b>45.96</b>
Zone 6 (Ennorekuppam)	3742	1122.6	2974.89	89.24	111.55	<b>33.46</b>
Zone 7 (Nettukuppam)	3232	969.6	2569.44	77.08	96.35	<b>28.90</b>
Zone 8 (bridge pier/ island in K River near Sadayankuppam)	3000	900	2385	71.55	89.43	<b>26.83</b>
<b>Total volume of oil in cu.m. accounted so far are conservative estimates.</b>					<b>1623.73</b>	<b>487.12</b>



Figure 28: Soil Contamination Zones



Figure 29: Soil Contamination Zones

**b. Oil pools in islands and B Canal overflow:**

Oil was found ponding along the B Canal in the upstream stretch where maximum flood levels had taken the oil above the bank of the canal and into the eastern residential and industrial areas. Oil was also found ponding within the mangrove islands after the flood water receded. Largest oil ponding was observed in Zone 1. Area of the contamination zones for oil pools were estimated using Google Earth Pro. The volume of oil ponded could be anywhere between 31.4 cu.m. to 314 cu.m.

**Table 5:** Volume of oil estimated in oil pools

<b>Oil pools in hotspots</b>	<b>Area (sq.m.)</b>	<b>1 mm ponding depth</b>	<b>5 mm ponding depth</b>	<b>10 mm ponding depth</b>	<b>Lowest Estimate (1mm)</b>
Overflowed along B canal	11403	11.40	57.01	114.03	<b>11.40</b>
In mangrove islands	10000	10	50	100	<b>10</b>
Oil pool near pipelines	10000	10	50	100	<b>10</b>
<b>Total volume of oil in cu.m.</b>		<b>31.40</b>	<b>157.01</b>	<b>314.03</b>	<b>31.40</b>



**Figure 30:** Oil pools on K river flood plain

**c. Oil sheen on B Canal and K River:**

Oil sheen was found on B Canal and K river, where the volume of oil has been calculated for 10 micron and 50 micron sheen thickness. Area of the contamination zones for oil sheen were provided by the coast guard. A conservative estimate would be between 1.21 cu.m. to 10.32 cu.m for 10 micron thickness. It should be noted that CPCL has already removed major part of the oily sludge floating on the river using booms and skimmers amounting to 395 tonnes.

**Table 6:** Volume of oil as oil sheen estimated on B Canal and K River

<b>Oil sheen in water courses from drone</b>				
<b>Location</b>	<b>Area (sq.m)</b>	<b>Sheen thickness - 10 micron</b>	<b>Sheen Thickness - 50 micron</b>	<b>Lowest Estimate (10 micron)</b>
Buckingham Canal	121765	1.21	6.08	<b>1.21</b>
Kosasthalaiyar River	1032988	10.32	51.64	<b>10.32</b>
<b>Total volume of oil in cu.m.</b>			<b>57.73</b>	<b>11.54</b>

**d. Oil present in residential and industrial areas:**

A survey team was deployed to assess the spread of oil in the residential and industrial zone. The team marked the oil level and referenced it with Mean Sea level using DGPS survey at every location. Three levels of inundation with total area inundated and the oil level in each zone was marked in different colours.

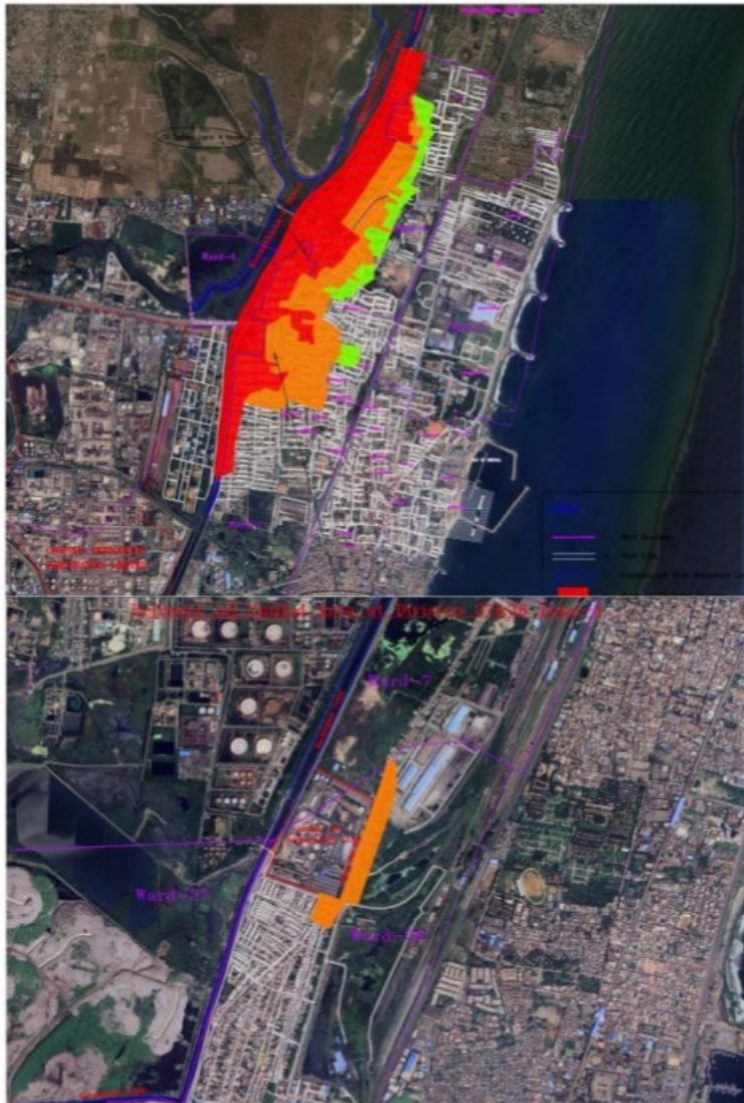
The area under each zone is given below along with presumed depth of oil which was present when the flood water inundated their area. The average quantum of oil inundation is estimated as 117 cu.m. assuming only 0.1 mm of oil.



**Figure 31:** Map showing three levels of inundation

**Table 7:** Volume of oil estimated in residential and industrial areas

Oil mark in the residential areas (physical survey)	Area [sq.m.]	0.1 mm oil layer	0.5 mm oil layer	1 mm oil layer	5 mm oil layer	Lowest Estimate (0.1 mm)
Ernavoor high impact > 1m	452959	45.29	226.47	452.95	2264.79	<b>45.29</b>
Ernavoor medium impact 0.5 to 1.0.m	628017	62.80	314.00	628.01	3140.08	<b>62.80</b>
Ernavoor low impact <0.5 m	31700	3.17	15.85	31.7	158.5	<b>3.17</b>
Behind IOCL	66135	6.61	33.06	66.13	330.67	<b>6.61</b>
<b>Total volume of oil in cu.m.</b>		<b>117.88</b>	<b>589.40</b>	<b>1178.81</b>	<b>5894.05</b>	<b>117.88</b>



**Figure 32:** Close up view of the affected residential and industrial areas

**e. Oil stains on mangroves and river banks:**

Based on the observed length and height of the stains left behind on the banks of the K river and B canal, we estimated the oil on the river banks and mangroves assuming different thicknesses of oil layer starting from 0.01 mm, 0.1 mm and 1 mm. The average volume of oil inundation is conservatively estimated as 0.3849 cu.m. assuming only 0.01 mm of oil was floating on water.



**Figure 33:** Classifying the K river with the height of the oil mark in different stretches

**Table 8:** Volume of oil estimated on mangroves and river bank

Oil stain on banks	Length in km	Height of oil mark in m	0.01 mm	0.1 mm	1 mm	Lowest Estimate (0.01 mm)
Buckingham canal sections	15.1	0.3	0.04	0.45	4.53	<b>0.04</b>
Kosasthalaiyar section 1 (CPCL pipe line to B Canal intersection)	11.4	0.3	0.03	0.34	3.42	<b>0.03</b>
Kosasthalaiyar section 2 (CPCL pipeline to B Canal intersection)	5.8	0.3	0.01	0.17	1.74	<b>0.01</b>
Kosasthalaiyar section 3 (CPCL to Kaatukuppam)	4.7	0.3	0.01	0.14	1.41	<b>0.01</b>
Ennore Creek (Kattukuppam to Kosasthalaiyar River mouth)	1.9	0.3	0.0057	0.057	0.57	<b>0.0057</b>
<b>Oil stain on mangroves</b>						
Kosasthalaiyar section 1, 2ft oil mark	11.4	0.6	0.068	0.68	6.84	<b>0.068</b>
Kosasthalaiyar section 2, 5ft oil mark	5.8	1.5	0.087	0.87	8.7	<b>0.087</b>
Kosasthalaiyar section 3, 8ft oil mark	4.7	2.4	0.11	1.12	11.28	<b>0.11</b>
<b>Total volume of oil in cu.m.</b>			<b>0.38</b>	<b>3.84</b>	<b>38.49</b>	<b>0.38</b>

### Overall Estimates:

The oil present in the environment as observed between December 14<sup>th</sup> TO 24<sup>th</sup>, 2023 and reconfirmed on February 22<sup>nd</sup>, 2024 based on our best possible estimates and accessibility are below:

- a. Oil present in soil – Estimated between 487 to 1623 cu.m. (\*Not including M/s CPCL land area, inaccessible industry areas and marsh areas)
- b. Oil pools in islands and B canal overflow – Estimated between 31.4 cu.m. to 314 cu.m.
- c. Oil sheen on B Canal and K River: Estimated between 11.55cu.m. to 57.74 cu.m.
- d. Oil stains and inundation in residential area – Estimated between 117 to 589 cu.m.
- e. Oil stains on mangroves and river banks – Estimated between 0.3849 to 38.49 cu.m.

*In summary the oil present in the environment is 647 cu.m. or 517 tonnes (most conservative) to 2622 cu.m. or 2097 tonnes (least conservative). The range is provided here considering the uncertainty of the depth of oil in pools, extent of depth and uniformity of soil contamination, film thickness on mangroves and walls of the residential areas.*

*Also these estimates has not been considered:*

1. *Floating oily Sludge removed by CPCL from the surface water and banks of Kosasthalaiyar river and Buckingham canal (395 tonnes as reported in the news media).*
2. *Sediments - Only random samples (Oil concentration: 1000-30,000mg/kg) had been taken and a complete assessment cannot be done due to flowing water. We can take it up in future studies which will be conducted in more detail for impact assessment.*
3. *Water – Variable with time and space due to continuous leaching of oil from banks and soil and sediment. However, it remains relatively minor compared to soil contamination.*
4. *Other upstream locations inside and outside CPCL inundated by high flood where oil was observed.*
5. *Inaccessible islands and marshlands of Kosasthalaiyar River.*
6. *Oil released into sea and coasts beyond Ennore Creek.*

7. CPCL premises – Soil and Storm water drains within premises which were observed to have oil.

6. Oil Estimates in Open Tanks of M/s CPCL

Google Earth images were used to assess the open tanks in M/s CPCL close to the two storm water outlets. The total area of these open tanks are worked out as 95,058 sq.m.



Figure 34: Open tank locations and area in sq.m.

We identified 12 out of 29 tanks containing oil-contaminated water, with six of them discharging into the stormwater drain located north of M/s CPCL (Zone 1), while the remaining six drained into the southern drain of the premises (Zone 20). Table 9 provides an

average estimate of the volume of oil stored in these tanks based on varying oil thicknesses of 1 mm, 5 mm and 10 mm.

**Table 9:** Location and area of open tanks present in M/s CPCL

<b>Tank ID</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Open tank Area sq.m]</b>
0	13.1585	80.2839	3241
1	13.1747	80.278	2547
2	13.159	80.2821	812
3	13.1592	80.2826	1192
4	13.1598	80.2825	8032
5	13.1644	80.274	9008
6	13.1648	80.2809	1599
7	13.1647	80.2814	3473
8	13.1654	80.2816	527
9	13.17	80.2829	9645
10	13.1719	80.2802	6544
11	13.1764	80.2762	3424
12	13.1757	80.281	795
13	13.1754	80.2807	1493
14	13.1723	80.2766	5096
15	13.1714	80.2832	483
16	13.1713	80.2837	129
17	13.1751	80.2836	341
18	13.1749	80.2836	326
19	13.1761	80.2752	509
20	13.1711	80.2819	714
21	13.1717	80.282	491
22	13.1637	80.2716	3241
23	13.1476	80.2802	3820
24	13.1514	80.2821	6529
25	13.1518	80.2813	8236
26	13.1528	80.2826	3799
27	13.1576	80.2836	1454
28	13.1529	80.282	2857
29	13.1541	80.2818	4702

**Table 10:** Volume of oil estimated in the open tanks of M/s CPCL

	<b>Tanks that drain to northern storm water drain</b>	<b>Tanks that drain into southern storm water drain</b>
	6544	3799
	9645	2857
	491	8236
	1599	6529
	3473	4701
	527	3820
<b>Total area of tanks sq.m.</b>	<b>22279</b>	<b>29942</b>
<b>Volume of oil in tanks in cu.m. assuming 1 mm</b>	22.27	29.94
<b>Volume of oil in tanks in cu.m. assuming 5 mm</b>	111.39	149.71
<b>Volume of oil in tanks in cu.m. assuming 10 mm</b>	222.79	299.42

The volume of oil estimated in these exposed tanks amounts to 522 cubic meters or 417 tonnes, representing an oil thickness of 10 mm. The oil estimates from our assessment (517 tonnes) and the oily sludge removed by CPCL (395 tonnes) together sums up to 917 tonnes without including the inaccessible areas and bottom sediments of B Canal and K river. This mismatch suggests that the flood induced release from the open tanks may not have been the sole reason of the oil spill. Other possibilities could be breach of oil from other storage tanks of CPCL premises. Fingerprinting analysis using GC-MS suggests that it could be slop oil or furnace oil or mix of both.

## **7. Coast Guard Assessment:**

On the 14th or 15th of December 2023, an assessment was conducted by the coast guard to estimate the oil spill, ten days after the flooding incident. Despite the passage of time,

remnants of oil and sheen were still detected in both inland water bodies and the sea. Estimates were derived from observations made via their helicopter-mounted camera, revealing approximately 11.6 cubic meters of oil in inland water and 12.4 cubic meters in the sea.

It's important to note that these figures may underestimate the actual volume of oil present, as there could have been higher levels of oil in the intervening days between the spill release and the assessment on December 15th. Additionally, the assessment did not fully account for the oil present in various other environments. This includes oil present in the soil, pooled on land surfaces, present on islands, coating the banks of rivers, and the stains on mangrove forests. The assessment also did not consider oil dispersed within water columns or deposited within sediments. Therefore, the actual extent of the oil contamination may be greater than indicated by the coast guard's estimate. For more detailed information please refer to Appendix A

## **8. Tamil Nadu Pollution Control Board's Survey of M/s CPCL**

### **Premises:**

The Tamil Nadu Pollution Control Board deployed its technical team to conduct an inspection at M/s CPCL, where they identified areas of concern. A Technical Committee Report was subsequently released, evaluating various sections including the stormwater drainage system, petcoke processing area, the ETP area, sludge storage tanks and ponds, sludge bioremediation process area, and crude oil storage area. Numerous observations were documented during the inspection, indicating potential areas of environmental risk.

According to the report, the average quantity of slop oil collected from different sources of the M/s CPCL premises and stored in slop tanks typically ranges between 50 KLD to 150 KLD. However, during the flood, this collection process would likely have been halted, presenting a substantial risk of washout from the ponds and effluent treatment plants. Additionally, the accumulation of oil-bearing sludge in the sludge ponds that occurred due to the maintenance of eight crude oil/sludge storage tanks, also posed a potential risk of overflow into nearby drains and water bodies during the flood. The team estimated that more than 400 KL of slop oil may have been washed away due to rising water levels. Despite

severe weather alerts, M/s CPCL reportedly lacked sufficient precautionary measures to address oil spillage, highlighting a critical gap in disaster preparedness. For more information on quantity of slop oil collected, total quantity of sludge, mass balance etc., please refer to Appendix B.

## **9. Recommendations and Scope for Future Work**

Recommendations for Future Actions:

1. **Conduct Post-Restoration Assessments:** It is imperative to conduct thorough assessments after the restoration efforts of Kosasthalaiyar River, its sediments, islands, mangroves and flood plains at the surplus canal before declaring previously contaminated zones as safe. If oil residues are found restoration activity should be initiated again considering the sensitivity of the ecosystem including soil, water, flora and fauna.
2. **Enhance Storage Infrastructure:** Consider elevating oil sludge and slop oil storage tanks or implementing dykes to contain any potential spills. These measures can help minimize the risk of contamination and mitigate the impact of future accidents.
3. **Prevent Oil Discharge from Stormwater Locations:** Implement measures to prevent the discharge of oil from stormwater locations, such as installing appropriate containment systems or improving drainage infrastructure.
4. **Buckingham Canal Dredging:** Given the heavy siltation and long term contamination of oil in the canal consider dredging the canal to enhance its carrying capacity. This action can help improve water flow and reduce the risk of further contamination but can be more challenging as well.
5. **Prevention of contamination:** Continuous monitoring of the storm water drains in the Ennore industrial area and Buckingham Canal is mandatory to prevent and track contamination from industries and residential areas.

Scope for Future Work:

1. To conduct comprehensive assessments to quantify the level of contamination in water and sediment samples collected from Buckingham Canal and Ennore Creek. This data

will provide more valuable insights into the extent of pollution and aid in planning remediation efforts.

2. To quantify the amount of oil discharged into the sea during the spill event. Accurate measurements will help in assessing the environmental impact accurately.
3. To conduct detailed investigations in inaccessible areas to obtain more accurate estimates of contamination. Utilize advanced technologies and sampling techniques to access remote or challenging locations.
4. To bioremediate excavated soil in covered sheds with proper monitoring, thereby restoring contaminated soil to a healthier state.
5. Environmental Impact Assessment of the spill on water, soil, flora and fauna and Social Impact Assessment of the communities.

These recommendations and future work will contribute to better understanding and management of oil spill impacts in the Ennore region, ultimately leading to improved environmental protection and avoiding future oil spills.

## **10. Conclusion**

The oil spill in Ennore water bodies during the Michaung Cyclone, has led to extensive environmental degradation and socio-economic impacts in the affected regions of North Chennai. This preliminary assessment report underlines the severity and spatial extent of the oil contamination in Buckingham Canal, Kosasthalaiyar River and its surrounding areas.

Field investigations revealed oil accumulation in various zones along the banks, islands and surplus canals of the Kosasthalaiyar River and banks of Buckingham Canal, with significant hotspots identified. The spillage not only contaminated water bodies but also inundated residential areas, causing damage to property, vegetation, and livelihoods. Moreover, the spill has posed a significant threat to biodiversity - affecting mangroves, birds and aquatic organisms. The quantification of the impact will be assessed in Phase 2 of the project.

The field surveys and mapping of the oil spill's aerial extent using drones provided valuable insights into the movement of oil and spatial distribution of contamination. Laboratory analysis of water and sediment samples confirmed widespread total petroleum hydrocarbon

contamination indicating the intensity of the contamination. Flooding of CPCL's open tanks during the flood was suspected as a primary source of the spill by Tamil Nadu Pollution Control Board. The estimates derived from IITM's comprehensive analysis indicates approximately more than 1000 tonnes could have been released to the environment.

Addressing the aftermath of the oil spill requires collaborative efforts from various stakeholders, implementing the recommendations outlined in this report, undertaking further research and continuous monitoring to mitigate the impacts of the oil spill and restore the well-being of affected communities and ecosystems in the Ennore region.

# 11. Appendix

## A. Coast Guard Assessment

**BUCKINGHAM CANAL/ KOSATHALAIYAR RIVER AREA**

Dear Madam,

- Kindly refer to your letter T6/TNPBF.12753/RL/2023 dated 13 Dec 23.
- TNPS vide letter ibid requested assistance of this Headquarters for estimation of quantum of Oil Spill in Ennore Creek, Buckingham Canal and Kosathalaiyar River area. Accordingly, this Headquarters deputed an expert team for quantity assessment of oil spill in the above areas.
- Oil Spill Quantity assessment at Ennore Creek/ Buckingham Canal/ Kosathalaiyar River Area.
  - Oiled Area Measurement:-**

Ser	Name of Canal/River	Area in Sq.Mtr	Oiled Area
(i)	Buckingham canal	6100 x 60 =366000	90% = 329400
(ii)	Kosathalaiyar river	4900 x 260 =1274000	30% = 382200
(iii)	Ennore creek	1550 x 950 =1472500	10% = 147250
  - Appearance Coverage Allocation:-**

Ser	Name of Canal/River	Sheen	Rainbow	Metal
(i)	Buckingham canal	10%	70%	20%
(ii)	Kosathalaiyar river	10%	40%	10%
(iii)	Ennore creek	10%	30%	10%

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- Thickness band of above appearance:-**
  - Sheen : 0.04 µm to 0.3 µm
  - Rainbow : 0.3 µm to 5.0 µm
  - Metal : 5.0 µm to 50 µm
- Minimum Volume of spilled oil calculations:-**

Ser	Name of Canal/River	Sheen (0.04 µm)	Rainbow (0.3 µm)	Metal (5.0 µm)
(i)	Buckingham canal	$(329400 \times 10\%) \times 0.0000004 = 0.0013$	$(329400 \times 70\%) \times 0.0000003 = 0.0692$	$(329400 \times 20\%) \times 0.000005 = 0.3294$
(ii)	Kosathalaiyar river	$(382200 \times 10\%) \times 0.0000004 = 0.0015$	$(382200 \times 70\%) \times 0.0000003 = 0.0803$	$(382200 \times 20\%) \times 0.000005 = 0.3822$
(iii)	Ennore creek	$(147250 \times 10\%) \times 0.0000004 = 0.0006$	$(147250 \times 70\%) \times 0.0000003 = 0.0309$	$(147250 \times 20\%) \times 0.000005 = 0.1473$
<b>Minimum Volume of Spilled Oil</b>				<b>1.043 M<sup>3</sup></b>
- Maximum Volume of spilled oil calculations:-**

Ser	Name of Canal/River	Sheen (0.3 µm)	Rainbow (5.0 µm)	Metal (50 µm)
(i)	Buckingham canal	$(329400 \times 10\%) \times 0.0000003 = 0.009882$	$(329400 \times 70\%) \times 0.000005 = 1.1529$	$(329400 \times 20\%) \times 0.000050 = 3.294$
(ii)	Kosathalaiyar river	$(382200 \times 10\%) \times 0.0000003 = 0.01147$	$(382200 \times 70\%) \times 0.000005 = 1.3377$	$(382200 \times 20\%) \times 0.000050 = 3.822$
(iii)	Ennore creek	$(147250 \times 10\%) \times 0.0000003 = 0.00442$	$(147250 \times 70\%) \times 0.000005 = 0.5154$	$(147250 \times 20\%) \times 0.000050 = 1.4725$
<b>Maximum Volume of Spilled Oil</b>				<b>11.620 KL Appx</b>

Ser	Name of Canal/River	Sheen (0.3 µm)	Rainbow (5.0 µm)	Metal (50 µm)
(i)	Buckingham canal	$(329400 \times 10\%) \times 0.0000003 = 0.009882$	$(329400 \times 70\%) \times 0.000005 = 1.1529$	$(329400 \times 20\%) \times 0.000050 = 3.294$
(ii)	Kosathalaiyar river	$(382200 \times 10\%) \times 0.0000003 = 0.01147$	$(382200 \times 70\%) \times 0.000005 = 1.3377$	$(382200 \times 20\%) \times 0.000050 = 3.822$
(iii)	Ennore creek	$(147250 \times 10\%) \times 0.0000003 = 0.00442$	$(147250 \times 70\%) \times 0.000005 = 0.5154$	$(147250 \times 20\%) \times 0.000050 = 1.4725$
<b>Maximum Volume of Spilled Oil</b>				<b>11.620 KL Appx</b>

4. **Oil Spill Quantity Assessment at Sea.** The assessment of spill at sea was carried out through aerial recce / ships. It was observed that traces of spilled oil were found in appx 20 Sq.Km area from Kasathalaiyar river mouth to Kasimedu Harbour.

Scanned with OKEN Scanner

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Based on the observation, the quantity assessment is as follows:-

- Oiled Area Measurement**
  - Area from Helo data : 20 Sq.Km
  - Area covered with oil : 50%
  - Oiled Area : 20 x 50% = 10 Sq.Km
- Appearance Coverage Allocation**
  - Sheen : 80 %
  - Rainbow : 20%
- Thickness band of above appearance**
  - Sheen : 0.04 µm to 0.3 µm
  - Rainbow : 0.3 µm to 5.0 µm
- Minimum Volume of spilled oil:-**
  - Appearance Sheen : 10 Km<sup>2</sup> x 80% x 0.04 µm = 0.32 M<sup>3</sup>
  - Appearance Rainbow: 10 Km<sup>2</sup> x 20% x 0.3 µm = 0.6 M<sup>3</sup>
  - Minimum Volume: 0.32 M<sup>3</sup> + 0.6 M<sup>3</sup> = 0.92 M<sup>3</sup> (0.92 KL)**
- Maximum Volume of spilled oil:-**
  - Appearance Sheen : 10 Km<sup>2</sup> x 80% x 0.3 µm = 2.4 M<sup>3</sup>
  - Appearance Rainbow: 10 Km<sup>2</sup> x 20% x 5 µm = 10 M<sup>3</sup>
  - Maximum Volume: 2.4 M<sup>3</sup> + 10 M<sup>3</sup> = 12.4 M<sup>3</sup> (12.4 KL)**

Regards,

Your sincerely,

(AS All)  
Commandant  
Regional Ops & Plans Officer  
for Commander  
Coast Guard Region (East)

## B. Tamil Nadu Pollution Control Board's Survey of M/s CPCL Premises

### 6. Findings of the Team based on the information provided by the M/s CPCL:

As per the suggestions of the Team TNPCB requested M/s CPCL to provide certain details viz; quantity of slop oil, O&M details, the mass balance of raw materials, sludge storage, etc. M/s CPCL has submitted the following details vide letter dated 14.12.2023, the details are as below;

SI NO	Information requested	Information provided by CPCL											
i	Oily waste material collected from day to day operations, from all the storm water ponds, ETPs and other sources and its quantity, its storage method and disposals details	<p>Slop Oil quantity collected from storm water ponds, ETPs and other sources for the last three months is furnished below</p> <table border="1"> <thead> <tr> <th>Month</th> <th>Quantity, KL</th> </tr> </thead> <tbody> <tr> <td>September</td> <td>1939</td> </tr> <tr> <td>October</td> <td>4528</td> </tr> <tr> <td>November</td> <td>1238</td> </tr> </tbody> </table> <p>Slop oil is stored in Slop Tanks and reprocessed with Crude.</p>	Month	Quantity, KL	September	1939	October	4528	November	1238			
Month	Quantity, KL												
September	1939												
October	4528												
November	1238												
ii	Whether cleaning operation carried out before Michaug flood, its collection details.	<p>Details of major activities carried out as part of pre monsoon preparedness is furnished below:</p> <ul style="list-style-type: none"> <li>▪ Storm water canal cleaning</li> <li>▪ Building roof cleaning</li> <li>▪ Dewatering pumps checking &amp; availability</li> </ul>											
iii	Whether all the refineries are in operation during the flood, if not details shall be furnished. Further receipt of crude oil from 1st December 2023 to 9th December 2023 shall be furnished	<p>Out of 3 Refineries, only one Refinery was in operation during flood. Other two Refineries were under circulation.</p> <p>Details of Crude Oil Receipt from 01.12.23 to 09.12.23 is furnished below:</p> <table border="1"> <thead> <tr> <th>Date</th> <th>Crude receipt in TMT</th> </tr> </thead> <tbody> <tr> <td>01.12.23</td> <td rowspan="4">No receipt</td> </tr> <tr> <td>02.12.23</td> </tr> <tr> <td>03.12.23</td> </tr> <tr> <td>04.12.23</td> </tr> <tr> <td>05.12.23 20.48 hrs to 07.12.23 06.00 hrs</td> <td>135</td> </tr> <tr> <td>09.12.23 18.54 hrs to 11.12.23 07.12 hrs</td> <td>99</td> </tr> </tbody> </table>	Date	Crude receipt in TMT	01.12.23	No receipt	02.12.23	03.12.23	04.12.23	05.12.23 20.48 hrs to 07.12.23 06.00 hrs	135	09.12.23 18.54 hrs to 11.12.23 07.12 hrs	99
Date	Crude receipt in TMT												
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09.12.23 18.54 hrs to 11.12.23 07.12 hrs	99												
iv	Total quantity of Sludge stored inside the premises and its	Quantity of Sludge Stored in CPCL is 2300 KL in sludge pond. The sludge would be mechanically treated to extract oil and residual material would be											

	method of disposal	bioremediated. Extract oil would be reprocessed thro' crude tanks																																				
v	Frequency of conducting spillage deduction along with details of records maintained.	Spillage Detection & Repair study is carried out yearly once in CPCL and the report is submitted to TNPCB regularly. The latest report is submitted in Jan 23 (Annexure-A)																																				
vi	Mass balance of raw material and product manufactured	<p>Mass balance in Tons/ day furnished below</p> <table border="1"> <tr> <td>Crude through put</td> <td>28.8</td> </tr> <tr> <td>LPG</td> <td>1.0</td> </tr> <tr> <td>Naphtha</td> <td>2.4</td> </tr> <tr> <td>Petrol (M.S)</td> <td>3.0</td> </tr> <tr> <td>ATF</td> <td>3.2</td> </tr> <tr> <td>Diesel</td> <td>15.0</td> </tr> <tr> <td>Lobs/Wax</td> <td>0.8</td> </tr> <tr> <td>Bitumen</td> <td>1.2</td> </tr> <tr> <td>Internal fuel</td> <td>2.2</td> </tr> </table>	Crude through put	28.8	LPG	1.0	Naphtha	2.4	Petrol (M.S)	3.0	ATF	3.2	Diesel	15.0	Lobs/Wax	0.8	Bitumen	1.2	Internal fuel	2.2																		
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vii	<p>Number of unused storage tanks and number of it for maintenance</p> <p>The details of date of clean in progress taken for crude oil tanks, slops storage and other.</p>	<p>Details of idle and M&amp;I tanks is furnished as Tanks released and under Maintenance</p> <table border="1"> <thead> <tr> <th>Sl. No.</th> <th>Tank No.</th> <th>Service</th> <th>Remarks</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>343</td> <td>DWO(HH)</td> <td>Released in Oct 23</td> </tr> <tr> <td>2</td> <td>412</td> <td>SK(LAB)</td> <td>Released in Sep 23</td> </tr> <tr> <td>3</td> <td>418</td> <td>ATF</td> <td>Released in Oct 23</td> </tr> <tr> <td>4</td> <td>107</td> <td>Crude</td> <td>Released in Oct 23</td> </tr> <tr> <td>5</td> <td>820</td> <td>Dry slop</td> <td>Released in Sep 23</td> </tr> <tr> <td>6</td> <td>310</td> <td>HN/DAO</td> <td>Released in Mar'23</td> </tr> <tr> <td>7</td> <td>311</td> <td>IN/HN/DAO</td> <td>Released in Mar'23</td> </tr> <tr> <td>8</td> <td>309</td> <td>Raff</td> <td>Released in Jun'23</td> </tr> </tbody> </table>	Sl. No.	Tank No.	Service	Remarks	1	343	DWO(HH)	Released in Oct 23	2	412	SK(LAB)	Released in Sep 23	3	418	ATF	Released in Oct 23	4	107	Crude	Released in Oct 23	5	820	Dry slop	Released in Sep 23	6	310	HN/DAO	Released in Mar'23	7	311	IN/HN/DAO	Released in Mar'23	8	309	Raff	Released in Jun'23
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		9	201	RFO	Released in Jun'23												
		10	204-D-1	VBU Feed	Released in Jun'23.												
		11	312	IN/HN/DAO	Released in Sep'23												
		12	919	Wax	Released in Oct'23												
		13	345	DWO/RAFF	Released in Sep'23												
		Details of tanks unused tanks:															
		<table border="1"> <thead> <tr> <th>Sl. No.</th> <th>Tank No.</th> <th>Service</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>806</td> <td>Slop Oil</td> </tr> <tr> <td>2</td> <td>383</td> <td>Wax</td> </tr> <tr> <td>3</td> <td>384</td> <td>Wax</td> </tr> </tbody> </table>				Sl. No.	Tank No.	Service	1	806	Slop Oil	2	383	Wax	3	384	Wax
Sl. No.	Tank No.	Service															
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viii	Details of the sludge stored in the open yard	All sludge is stored in concrete pit with impervious layer and is at higher elevation.															
ix	Any operations carried out to protect the refinery to avoid untoward incidents during the flood time	<ul style="list-style-type: none"> <li>➤ One Refinery out of 3 Refineries was operated to maintain product supply to market.</li> <li>➤ Tractors trailers &amp; fire truck were operated to bring Manpower &amp; Material inside Refinery</li> </ul>															
x	The details of Characteristics of waste oil collected from ETPs & storm water collection ponds	<p>Slop oil is a mixture of oil collected from various sources. Slop Oil is reprocessed with crude. Since the qty of slop oil is very minimal, analysis is not required. However as per instruction, one sample was analysed today (14.12.23) and the result is furnished below.</p> <p>a) Density-0.873 gm/cc  b) Sulphur- 2.09 %  c) Flash- 37 Deg C  d) Viscosity @ 40 Deg C- 6.6</p>															
xi	The details of products sent to Manali customers and control mechanism provided to safe guard during no demand period	<table border="1"> <thead> <tr> <th>Industry</th> <th>Products</th> <th>In case of No demand</th> </tr> </thead> <tbody> <tr> <td>TPL</td> <td>LABFS</td> <td>Will be absorbed in Diesel pool / converted to ATF</td> </tr> <tr> <td>MPL</td> <td>Propylene</td> <td>Will be sold as LPG</td> </tr> </tbody> </table>				Industry	Products	In case of No demand	TPL	LABFS	Will be absorbed in Diesel pool / converted to ATF	MPL	Propylene	Will be sold as LPG			
Industry	Products	In case of No demand															
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			<i>KPL</i>	<i>PBFS</i>	
				<i>LPBFS</i>	
			<i>Cetex Petrochemicals</i>	<i>Butene2</i>	
				<i>MEKFS</i>	

From the above information, the Team noticed the following;

- As per the information given at Sl. (i), it is inferred that the average slop oil collected from ETPs and other sources ranges from 50 kld to 150 kld. Due to heavy rain since December 03 and 04, 2023, the collection of slop oil might not be happened, this slop oil might be washed away due to rising of water levels in all ponds since the ponds were just above the ground level. As per this information, the quantity washed away might be more than 400 kl.
- As per the information given at Sl.(iv), it is inferred that 2300 kl oil-bearing sludge is being stored in the sludge pond. The same was observed during the team visit and noticed that the sludge stored was up to the brim level, the oil mixed sludge might be washed away to drain due to the flood which is directly leading to the Buckingham Canal.
- As per the information given at Sl(vii), it is inferred that eight crude oil storage tanks were taken for maintenance during September – October 2023. The oil-bearing sludge required to be separated through centrifugation and the same has to be taken for bio remediation. At least 90 days are required to complete one cycle of bio remediation. Eight tanks were taken for maintenance in the last three months, the oil bearing sludge might be stored in the ponds, due to the flood, these sludge might be washed away. One of the nearby industry namely M/s Indian Additives Ltd, reported to the TNPCB team on 04.12.2023 that the mixture of thick Black oil & water was gushed into their premises. The statement of industry also confirms that the probability of washing of oil-bearing sludge from their storage dykes.
- In spite of sever cyclonic and heavy rain fall alert by IMD and Govt. of Tamil Nadu, the unit is not taken any precautionary measures to contain the oil spillage from

their ponds and ETPs. And also unit is not having either flood management plan or emergency contingency plan to contain oil spillage.

## 12. References

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<https://www.thehindu.com/news/cities/chennai/oil-spill-in-ennore-creek-cpcl-expects-to-finish-cleaning-of-water-in-three-days/article67643161.ece>
6. Wire. (2023, December 15). 20 tonnes of oil-soaked soil, 7000 litres of affected water removed: TN govt on Chennai oil spill. *The Wire*. Retrieved from <https://thewire.in/environment/20-tonnes-of-oil-soaked-soil-7000-litres-of-affected-water-removed-tn-govt-on-chennai-oil-spill>



**Report on  
Impact of Oil Spill in Ennore  
Creek Post Cyclone Michaung**

**Submitted to**  
**Tamil Nadu Pollution Control Board (TNPCB)**

**Submitted by**  
**National Centre for Coastal Research, Chennai**  
**Ministry of Earth Sciences**  
**Government of India**

**February 2024**



## NCCR Team

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5.	<b>Dr. Aiswarya Gopal</b>	<b>Project Scientist II</b>
6.	<b>Dr. P. Karthikeyan</b>	<b>Project Scientist II</b>
7.	<b>Dr. Chinmay Shah</b>	<b>Project Scientist I</b>
8.	<b>Dr. V. Manigandhan</b>	<b>Project Scientist I</b>
9.	<b>Mr. N. Logesh</b>	<b>Project Scientist I</b>
10.	<b>Dr. Anjusha A</b>	<b>Project Scientist I</b>
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## Summary

Impact assessment of oil spill resulting from the flooding caused by Cyclone Mishacung on 4<sup>th</sup> December, 2023 in Ennore Creek was undertaken by the National Centre of Coastal Research (NCCR), Ministry of Earth Sciences (MoES), Chennai, upon the request from the Tamil Nadu Pollution Control Board (TNPCB).

Field sampling was conducted twice a week during the initial phase (December 2023), followed by weekly sampling (January 2024) to assess various physico-chemical and biological parameters at different sectors in and around Ennore Creek. During the initial phase of sampling, the water quality of Ennore Creek was severely affected by high Total Petroleum Hydrocarbon (TPH) levels and reduced biodiversity. However, signs of recovery were observed in the second phase of sampling with reduction in TPH levels and increase in biodiversity.

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## 1. Background

The coastal environment is a dynamic ecosystem where a complex interplay of natural processes and human activities continuously shapes its geomorphological, physical, and biological features. However, this delicate balance is increasingly threatened by anthropogenic disturbances including accidental oil spills, which pose significant challenges to the integrity of coastal environments. Oil spills, whether from maritime accidents, industrial activities, or natural disasters, can have devastating consequences, ranging from immediate harm to marine life to long-term degradation of water quality and ecosystems.

In December 2023, an oil spill occurred in Ennore Creek as a result of flooding during the Cyclone Michaung, a region where refineries and petrochemical industries are situated. The Tamil Nadu Pollution Control Board (TNPCB) formally requested the National Centre for Coastal Research (NCCR), Chennai, to make an impact assessment of the oil spill in Ennore Creek (Figure 1). Accordingly, NCCR carried out a reconnaissance survey with TNPCB officials on 18<sup>th</sup> December 2023. Based on the preliminary assessment it was mutually agreed to monitor 10 locations inside the Ennore Creek (Figure 2) and 8 ground water/bore well locations (Figure 3) in the adjoining residential areas till January 2024. In the month of December 2023, sampling was conducted twice a week followed by weekly sampling in January 2024.

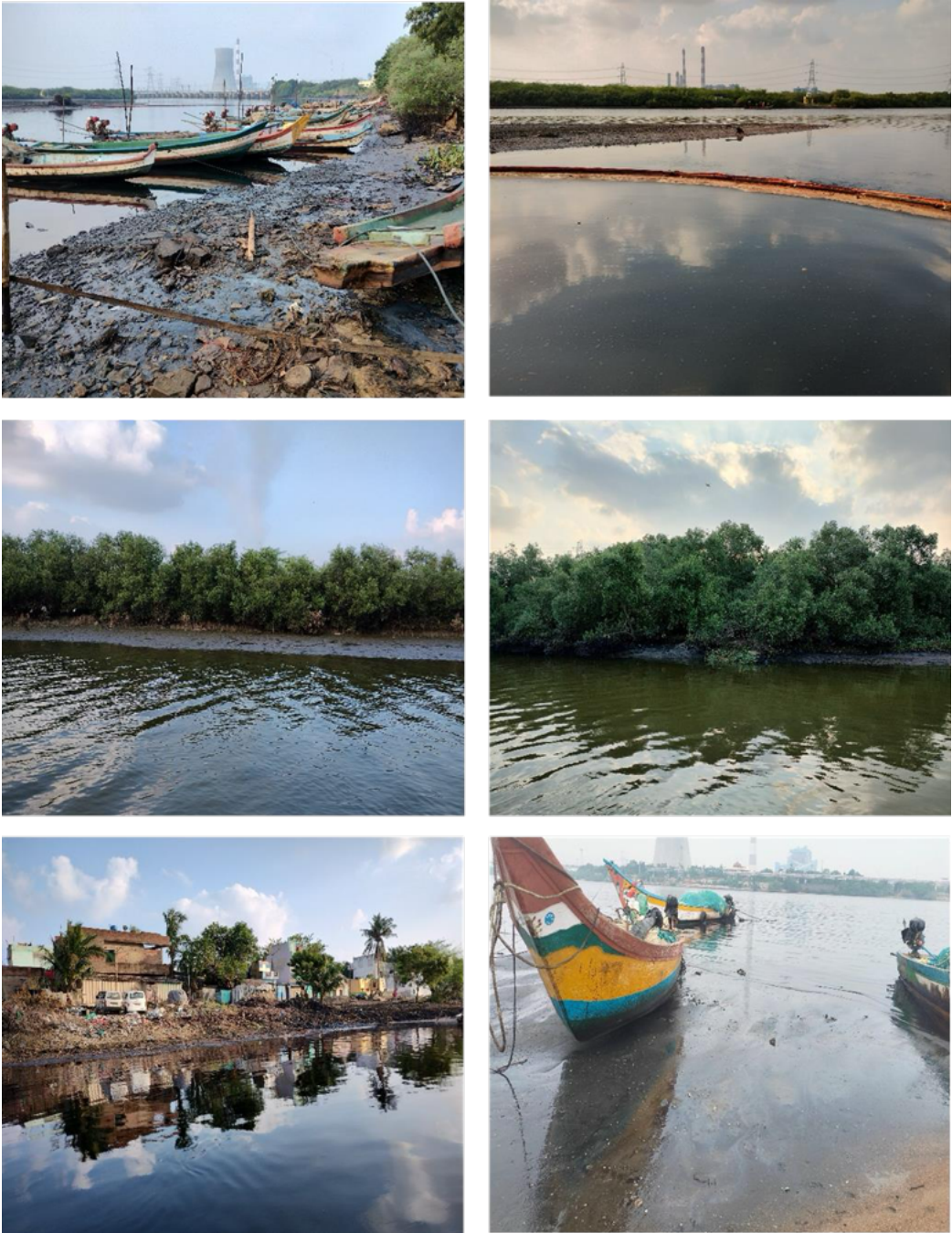


Figure 1. Field photographs taken on 18<sup>th</sup> December, 2023.

## 2. Study Area and Sampling

### 2.1. Study Area

A total of ten stations were selected from various sectors of the Ennore Creek affected by the oil spill (Figure 2). Samples were collected on the following dates (19/12/2023; 22/12/2023; 26/12/2023; 29/12/2023; 02/01/2024; 09/01/2024; 19/01/2024; 25/01/2024; 31/01/2024).



**Figure 2.** Map showing the sampling locations in the Ennore Creek.

Simultaneously, ground water samples at the selected locations (Figure 3) from the adjoining residential areas were collected by TNPCB and handed over to NCCR for analysis.

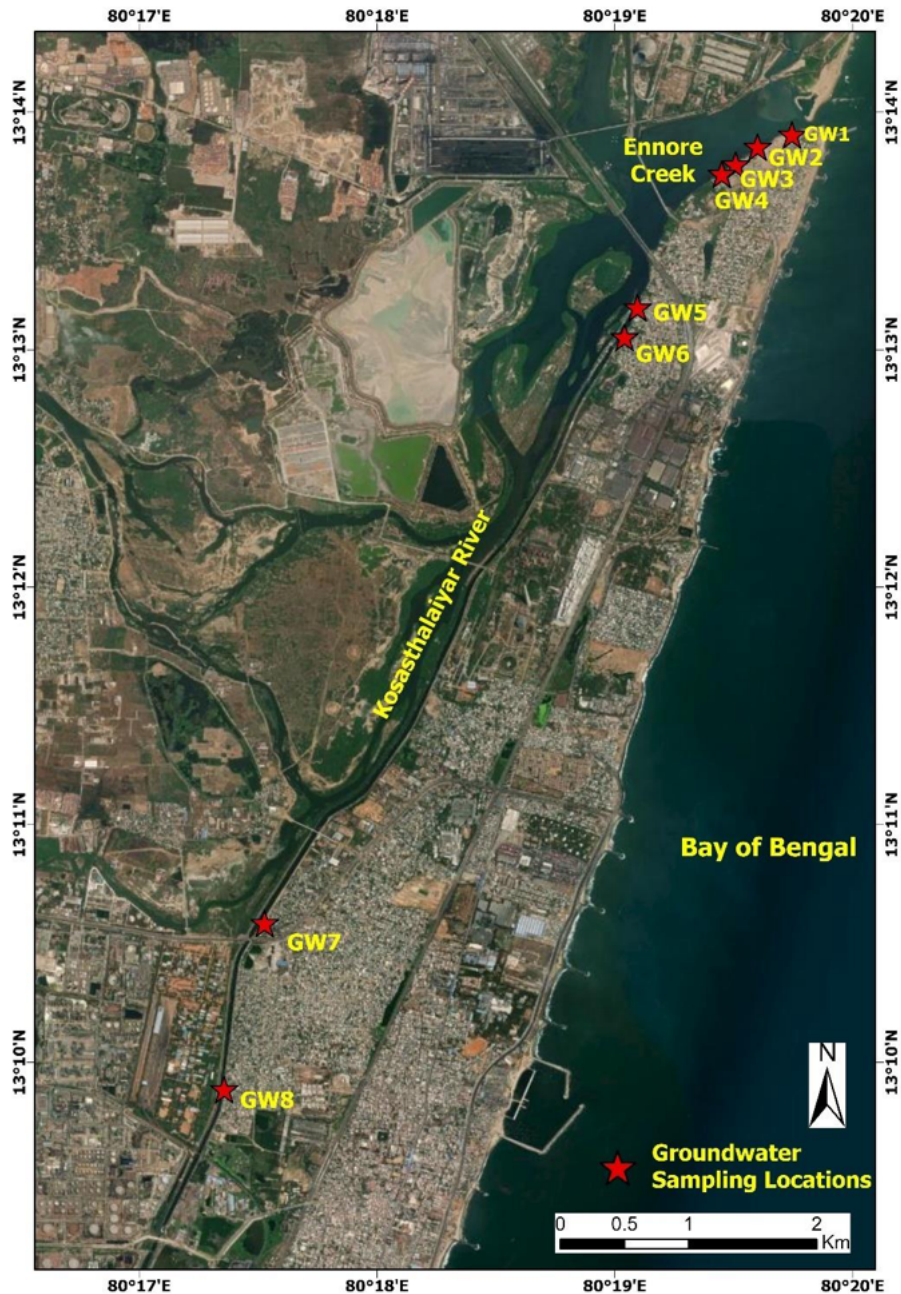


Figure 3. Map showing the ground water sampling locations.

### 2.2. Parameters Analyzed

**Creek Waters:** (Salinity; Temperature; Dissolved Oxygen; Biochemical Oxygen Demand; Chlorophyll; pH; Suspended Particulate Matter; Nutrients (Ammonia, Nitrite, Nitrate, Phosphate, Silicate, Total Nitrogen & Total Phosphorus); Total Petroleum Hydrocarbons; Heavy Metals; Dissolved Organic Carbon; Phytoplankton)

**Ground Waters:** (Heavy Metals; Total Petroleum Hydrocarbons)

**Sediment:** (Total Petroleum Hydrocarbons; Heavy Metals; Macrobenthos)

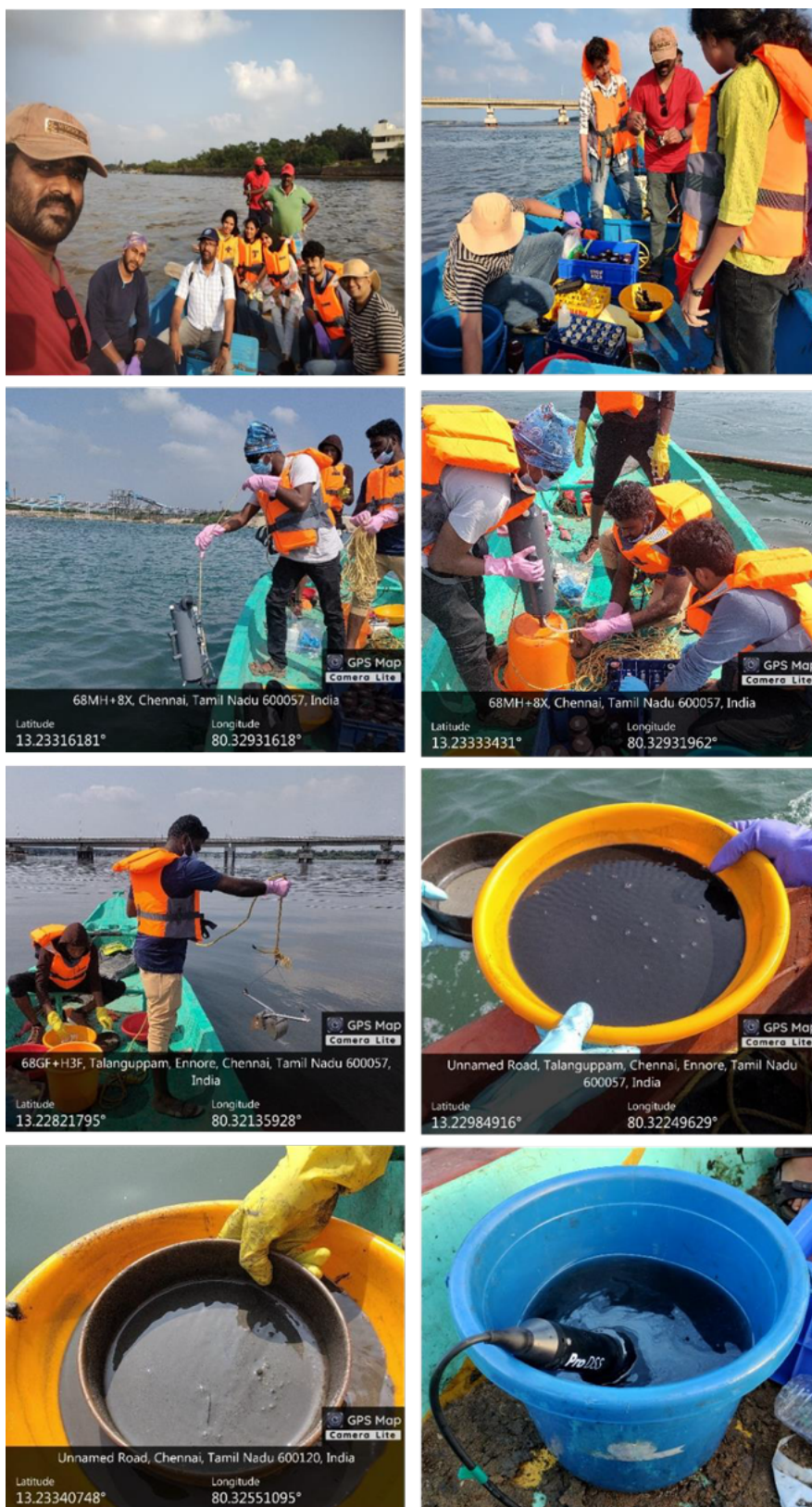
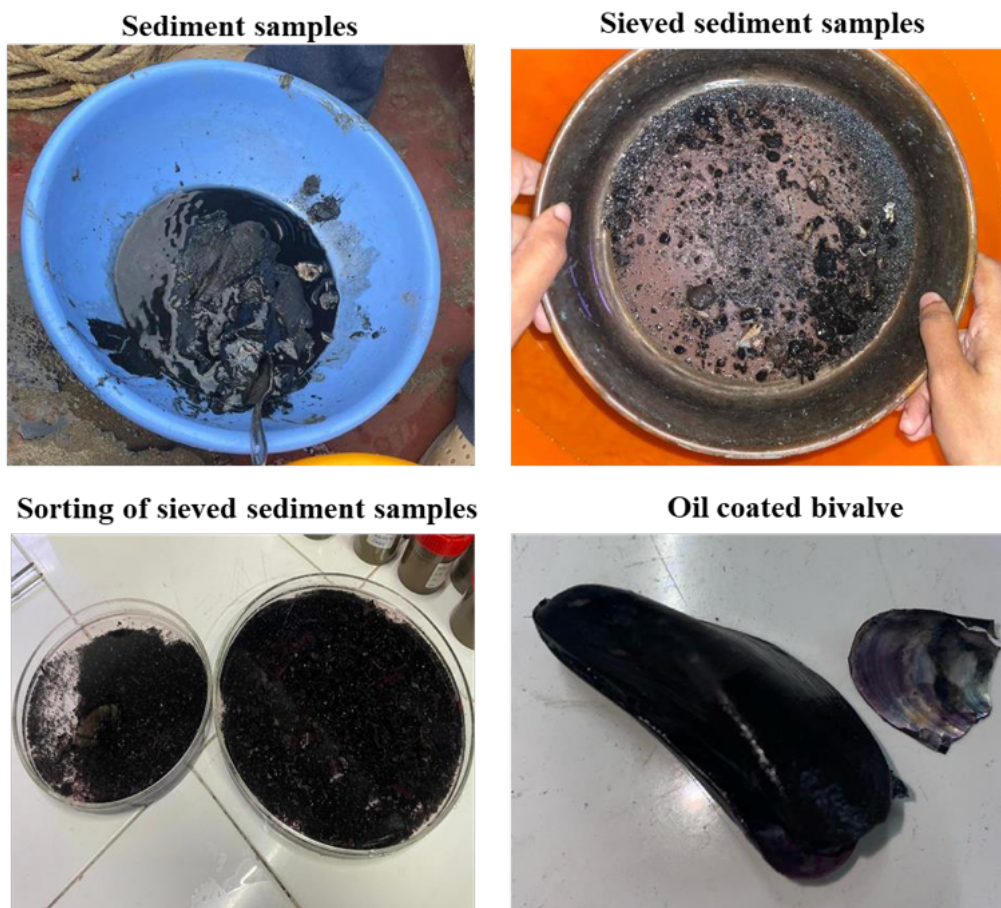


Figure 4. Sampling of water and sediment samples.



Figure 5. Laboratory analysis of collected samples.



**Figure 6.** Discoloration of sediments and benthic fauna due to oil spill.

## 3. Observations

### 3.1. Physicochemical Parameters

Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and pH are crucial parameters to assess and comprehend sea water quality. These indicators offer valuable insights into the suitability of water for sustaining aquatic life. Adequate DO is crucial for the survival of aquatic organisms and the overall health of aquatic ecosystems. Elevated BOD levels suggest the presence of organic pollutants, such as sewage or industrial discharges, depleting oxygen levels and negatively impacting aquatic life. pH levels influence the solubility and availability of metals in water.

*pH:* The spatial and temporal variation of pH at the different locations is shown in Table 1. During the initial day of sampling on 19<sup>th</sup> December 2023, pH levels below 7 were recorded at Buckingham Canal locations (EC-07 and EC-08) indicating acidic conditions. There was a subsequent increase in pH to above 7.5 in January 2024. On 31<sup>st</sup> January 2024, pH levels ranged from 7.42 to 7.84 at all the sampling sites indicating continued improvement in water quality across the Ennore Creek.

**Table 1.** Spatial and temporal variation of pH in Ennore Creek.

Station Id	19/12/23	22/12/23	26/12/23	29/12/23	02/01/24	09/01/24	19/01/24	25/01/24	31/01/24
EC-01	7.95	7.49	7.75	7.93	7.95	7.80	8.01	7.85	7.84
EC-02	7.69	7.35	7.59	7.79	7.91	7.85	7.99	7.64	7.79
EC-03	7.92	6.80	7.82	7.86	7.90	7.85	8.00	7.57	7.79
EC-04	6.91	7.06	7.77	7.73	7.88	7.84	7.95	7.41	7.74
EC-05	7.57	7.31	7.59	7.64	7.74	7.71	7.99	7.61	7.75
EC-06	7.39	7.54	6.88	7.28	7.52	7.09	7.06	7.12	7.60
EC-07	5.78	6.28	6.71	7.35	7.13	7.10	6.93	7.05	7.61
EC-08	6.47	*	*	6.81	6.95	7.15	7.16	7.17	7.43
EC-09	6.67	7.05	7.37	7.45	7.48	7.10	7.54	7.43	7.61
EC-10	6.63	6.57	8.02	7.58	7.62	7.58	7.86	7.62	7.42

\*Sample not collected

*Salinity:* The spatial and temporal variation of salinity at the different locations is shown in Table 2. Markedly low salinity was observed across all the monitoring stations in December 2023. However, in January 2024 a considerable increase in salinity levels across all the sampling stations was observed indicative of the seawater intrusion and subsequent mixing.

**Table 2:** Spatial and temporal variation of salinity in Ennore Creek.

Station Id	19/12/23	22/12/23	26/12/23	29/12/23	02/01/24	09/01/24	19/01/24	25/01/24	31/01/24
EC-01	10.71	3.22	18.00	30.77	31.00	24.20	31.64	32.95	33.75
EC-02	7.79	2.60	15.74	27.30	30.15	26.44	30.79	30.75	32.88
EC-03	5.12	2.23	18.99	29.13	29.83	25.20	31.34	29.71	33.07
EC-04	1.70	1.40	10.69	23.58	29.92	27.30	30.19	25.48	32.43
EC-05	2.08	1.01	9.87	14.53	26.35	21.64	23.60	29.53	32.41
EC-06	0.40	1.01	1.92	8.56	17.95	7.38	25.50	4.59	31.75
EC-07	1.28	1.21	1.44	6.44	3.11	1.18	16.05	2.77	31.12
EC-08	1.09	*	*	3.63	1.36	1.08	7.06	1.78	28.54
EC-09	0.38	0.37	1.54	8.43	14.67	6.89	23.80	12.32	30.61
EC-10	0.40	0.40	7.92	11.94	19.43	16.38	29.26	22.91	30.41

\*Sample not collected

*Dissolved Oxygen:* The spatial and temporal variation of dissolved oxygen at the different locations is shown in Table 3. The near-zero levels of dissolved oxygen at the Buckingham Canal sampling locations (EC-07 and EC-08) indicates severe oxygen depletion, likely resulting from the oil spill event. The variation in dissolved oxygen is also influenced by the tidal cycles. There was an improvement in dissolved oxygen levels on 31<sup>st</sup> January 2024 suggesting that natural processes or the clean-up actions have helped in restoring the oxygen levels to support aquatic life.

**Table 3:** Spatial and temporal variation of dissolved oxygen (mg/l) in Ennore Creek.

Station Id	19/12/23	22/12/23	26/12/23	29/12/23	02/01/24	09/01/24	19/01/24	25/01/24	31/01/24
EC-01	5.29	6.19	6.48	6.83	6.67	6.34	6.56	6.13	6.43
EC-02	5.80	5.69	5.72	5.53	6.67	6.67	6.66	4.07	6.60
EC-03	5.08	3.95	6.18	5.53	6.83	6.83	6.48	2.96	6.39
EC-04	3.00	3.79	4.14	4.23	6.34	6.34	6.20	1.27	6.17
EC-05	5.76	4.88	4.07	5.37	4.72	5.53	6.47	3.40	6.56
EC-06	1.46	0.00	0.00	0.49	1.63	0.65	1.45	1.30	4.62
EC-07	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	4.57
EC-08	0.00	*	*	0.00	0.00	0.00	0.63	0.00	1.99
EC-09	5.13	6.64	0.00	0.65	0.81	1.79	2.40	1.50	4.62
EC-10	4.97	5.13	4.07	3.25	2.93	4.55	5.86	3.30	5.80

\*Sample not collected

*Biochemical Oxygen Demand (BOD):* The analysis of BOD gives further insights into the pollution levels and the subsequent improvement in water quality over time following the oil spill event. Table 4 shows the spatial and temporal variation in BOD levels at the different locations. The elevated BOD levels during the initial sampling period on 19<sup>th</sup> December 2023, indicates high organic pollution load in the water. Organic pollutants such as oil, sewage, or other organic substances introduced by the spill can contribute to increased BOD levels. However, a gradual improvement in the BOD levels was observed by the end of January 2024 suggesting a reduction in organic pollution and the restoration of water quality. This improvement may result from various factors, including natural degradation processes and the remediation efforts. The results of BOD corroborate the trends observed in pH and dissolved oxygen levels, indicating an improvement in water quality conditions over time following the spill event.

**Table 4:** Spatial and temporal variation of Biochemical Oxygen Demand (mg/l) in Ennore Creek.

Station Id	19/12/23	22/12/23	26/12/23	29/12/23	02/01/24	09/01/24	19/01/24	25/01/24	31/01/24
EC-01	4.99	0.49	3.50	6.50	1.63	2.60	2.30	0.89	0.71
EC-03	3.75	1.95	4.07	4.23	3.66	1.87	1.31	2.80	1.81
EC-05	5.13	2.85	2.85	5.37	2.36	2.20	2.51	3.40	2.23

### 3.2. Heavy Metals

*Heavy Metals in Sediments:* Variations in the concentrations of heavy metals were observed in the sediment samples over time, from the initial sampling period to mid-January. These fluctuations may suggest changes in environmental conditions or inputs of heavy metals into the sediment during this timeframe. The heavy metal concentrations in the current study were comparable with the previous studies carried out in Ennore Creek. The heavy metal data from Ennore Creek is presented in Table 5 and provides insight into the levels of various heavy metals within the creek's environment.

*Heavy Metals in Surface and Ground Water:* The heavy metal concentrations in the Ennore Creek waters varied spatially and was comparable to the previously reported values from Ennore Creek.

**Table 5:** Heavy metal concentrations in sediments from Ennore Creek.

Sample Id	Sampling date	Cd (µg/g)	Co (µg/g)	Cr (µg/g)	Cu (µg/g)	Mn (µg/g)	Ni (µg/g)	Pb (µg/g)	V (µg/g)
EC-01	19-12-2023	BDL	BDL	7.66	1.05	33.1	1.52	0.20	4.99
	22-12-2023	BDL	BDL	4.52	0.17	18.3	0.37	BDL	3.19
	26-12-2023	BDL	BDL	8.55	1.79	39.1	1.33	0.46	4.84
	29-12-2023	BDL	0.14	9.90	3.63	37.3	1.76	0.94	7.16
	02-01-2024	1.18	18.4	10.2	50.0	49.3	4.40	3.70	9.06
	09-01-2024	BDL	0.91	13.7	8.03	51.0	3.73	2.23	8.73
EC-02	19-12-2023	5.21	8.30	95.6	90.8	204.9	28.9	20.7	56.3
	22-12-2023	0.82	6.85	50.5	29.5	266.2	17.1	8.74	38.6
	26-12-2023	0.74	2.63	44.4	24.7	84.2	10.8	4.65	35.9
	29-12-2023	1.45	4.23	43.2	34.9	129.4	13.2	8.32	28.6
	02-01-2024	BDL	BDL	47.5	5.67	40.1	2.07	0.57	6.07
	09-01-2024	0.72	1.65	28.8	23.4	58.2	5.93	5.35	16.7
EC-03	19-12-2023	1.35	7.28	61.5	39.6	213.7	21.5	10.4	45.8
	22-12-2023	10.3	8.85	87.8	122.5	266.7	26.4	15.9	52.1
	26-12-2023	BDL	4.30	32.1	15.4	154.2	11.2	4.42	23.9
	29-12-2023	4.57	9.41	76.2	76.6	256.6	28.1	14.2	49.2
	02-01-2024	0.27	5.64	46.5	21.5	201.0	15.0	7.16	35.6
	09-01-2024	1.64	8.15	67.6	44.2	234.1	23.8	12.2	49.9
EC-04	19-12-2023	7.39	10.7	114.5	123.1	205.3	39.4	26.7	67.6
	22-12-2023	3.42	9.19	77.7	65.0	181.0	29.3	15.8	55.2
	26-12-2023	4.75	5.45	65.5	71.2	138.6	18.7	11.3	43.1
	29-12-2023	3.08	3.16	51.9	59.1	96.3	12.6	12.3	26.6
	02-01-2024	4.76	7.21	84.2	80.7	203.5	25.0	15.1	49.2
	09-01-2024	8.57	9.96	117.9	145.3	236.6	34.1	24.7	67.2
EC-05	19-12-2023	3.35	11.7	92.8	76.7	247.7	35.1	18.7	72.2
	22-12-2023	3.90	10.2	83.2	77.9	225.1	30.9	19.9	61.3
	26-12-2023	2.82	8.78	73.1	66.0	195.3	26.3	14.6	52.0
	29-12-2023	3.25	7.58	72.7	74.6	186.6	24.0	17.1	51.7
	02-01-2024	BDL	5.18	32.1	22.2	125.9	12.7	7.80	32.3
EC-06	19-12-2023	BDL	BDL	11.1	8.14	21.7	2.48	1.87	4.22
	22-12-2023	0.10	6.16	70.7	71.0	154.1	22.8	17.0	38.7
	26-12-2023	9.59	9.41	164.6	222.2	241.7	38.5	41.2	56.2
	29-12-2023	4.05	8.09	372.2	353.1	147.3	57.0	67.8	70.2
	02-01-2024	12.0	7.06	189.5	297.6	177.3	37.5	53.0	53.8
	09-01-2024	11.7	7.81	120.3	232.2	155.4	35.7	35.6	51.3
EC-07	19-12-2023	BDL	BDL	29.9	16.7	36.8	3.54	4.08	13.1
	22-12-2023	BDL	BDL	5.66	2.51	16.1	0.84	0.21	2.59
	26-12-2023	BDL	BDL	8.49	3.20	19.4	0.97	0.83	5.22
	29-12-2023	BDL	4.19	38.6	27.4	132.0	11.9	7.70	24.0
	02-01-2024	BDL	BDL	6.47	5.35	20.1	1.30	0.88	4.46
	09-01-2024	BDL	1.70	26.0	17.8	68.0	6.48	4.87	14.3
EC-08	19-12-2023	BDL	BDL	3.61	0.53	10.5	0.33	BDL	1.97
	29-12-2023	12.7	6.35	137.1	211.7	130.7	31.3	42.1	50.4
	02-01-2024	BDL	5.62	31.20	14.2	160.5	13.7	5.54	34.4

	09-01-2024	20.1	6.25	192.6	302.0	171.9	36.1	46.3	54.6
<b>EC-09</b>	19-12-2023	0.44	2.80	67.08	111.1	71.8	17.6	19.9	20.1
	22-12-2023	BDL	BDL	4.08	0.24	34.2	0.51	BDL	1.54
	26-12-2023	BDL	0.82	24.9	24.7	46.1	4.83	5.22	7.52
	29-12-2023	BDL	BDL	5.53	1.38	19.3	1.67	0.22	2.84
	02-01-2024	BDL	1.04	25.9	40.3	38.3	6.98	8.57	10.4
<b>EC-10</b>	19-12-2023	BDL	1.03	12.0	3.57	70.3	2.41	2.19	9.20
	22-12-2023	3.32	6.48	61.9	63.0	131.3	21.0	13.3	39.2
	26-12-2023	BDL	0.74	8.84	1.39	36.7	1.83	0.65	6.37
	29-12-2023	BDL	0.30	6.78	2.31	26.5	1.91	0.42	3.70
	02-01-2024	BDL	0.79	8.78	1.57	45.4	1.73	1.81	7.29

BDL: Below Detection Limit

**Table 6:** Heavy metal concentrations in surface waters from Ennore Creek.

Sampling date	Sample ID	Cd (µg/l)	Co (µg/l)	Cr (µg/l)	Cu (µg/l)	Mn (µg/l)	Ni (µg/l)	Pb (µg/l)	V (µg/l)
<b>19-12-2023</b>	EC-01	0.04	0.08	0.21	2.82	1.18	1.96	0.38	1.66
	EC-02	0.05	0.14	0.24	2.16	1.63	2.22	0.58	1.90
	EC-03	0.03	0.02	0.15	0.61	0.65	0.57	0.21	0.28
	EC-04	0.19	0.20	0.27	2.13	8.47	2.79	0.58	2.14
<b>22-12-2023</b>	EC-01	0.15	0.22	0.34	3.45	3.70	3.79	1.23	2.68
	EC-03	0.10	0.24	0.38	4.35	7.75	3.44	0.76	2.89
	EC-05	0.17	0.18	0.35	1.96	9.19	2.72	1.06	1.95
	EC-09	0.09	0.09	0.29	1.32	3.13	1.90	0.67	0.95
<b>26-12-2023</b>	EC-01	0.12	0.10	0.35	2.72	1.54	2.09	0.56	2.05
	EC-03	0.31	0.25	0.22	2.55	5.12	2.32	0.88	3.28
	EC-05	0.08	0.12	0.18	2.25	1.21	0.46	0.43	2.02
	EC-07	0.20	0.16	0.27	1.50	5.22	2.28	0.92	0.91
	EC-09	0.02	0.01	0.19	1.56	1.24	0.24	0.52	0.25
<b>29-12-2023</b>	EC-01	0.09	0.15	0.29	2.69	3.81	0.92	0.85	1.61
	EC-03	0.10	0.23	0.18	7.86	2.12	1.11	1.87	2.33
	EC-05	0.08	0.15	0.54	5.42	3.21	2.71	1.20	2.98
	EC-07	0.06	0.25	0.25	2.12	2.04	1.69	0.98	0.99
	EC-09	0.08	0.34	0.23	3.02	2.74	2.73	1.41	2.51
<b>02-01-2024</b>	EC-01	0.04	0.51	0.38	2.67	1.14	0.94	0.94	2.27
	EC-03	0.04	0.20	0.26	1.72	1.05	1.08	0.78	2.13
	EC-05	0.02	0.08	0.20	1.97	1.74	1.15	0.52	1.55
	EC-07	0.17	0.30	0.32	2.93	13.14	4.08	1.28	1.69
	EC-09	0.05	0.17	0.18	1.95	4.12	2.50	0.84	2.56
<b>09-01-2024</b>	EC-01	0.03	0.07	0.23	--	1.42	1.56	1.14	2.13
	EC-03	0.03	0.09	0.28	4.67	3.26	1.99	1.27	2.26
	EC-05	0.03	0.06	0.21	2.88	1.67	1.52	0.54	1.56
	EC-07	0.14	0.15	0.37	2.01	10.04	3.93	1.15	1.48
	EC-09	0.07	0.10	0.27	1.68	4.14	1.60	0.64	0.96

<b>19-01-2024</b>	EC-03	0.02	0.03	0.16	1.20	1.00	0.23	0.12	0.59
	EC-05	0.01	0.00	0.09	2.08	0.21	0.33	0.12	0.50
	EC-07	0.09	0.07	0.13	1.12	3.18	2.05	1.61	0.33
	EC-09	0.06	0.12	0.12	5.87	1.43	2.96	1.21	2.15
<b>25-01-2024</b>	EC-03	0.15	0.07	0.39	3.16	0.86	1.86	0.63	2.16
	EC-05	0.01	0.05	0.12	1.38	0.52	0.97	0.12	1.43
	EC-07	0.21	0.13	0.37	4.12	13.62	4.28	1.01	1.55
	EC-09	0.06	0.20	0.26	2.29	6.84	3.42	1.05	3.69
<b>31-01-2024</b>	EC-01	0.11	0.03	0.14	1.32	0.36	0.48	0.19	0.89
	EC-03	0.02	0.04	0.16	3.63	0.42	1.15	3.98	1.31
	EC-05	0.01	0.04	0.13	1.81	0.50	0.52	0.24	1.11
	EC-07	0.03	0.08	0.14	1.59	1.22	1.18	0.53	1.70
	EC-09	0.02	0.04	0.18	2.13	1.21	0.76	0.34	0.94

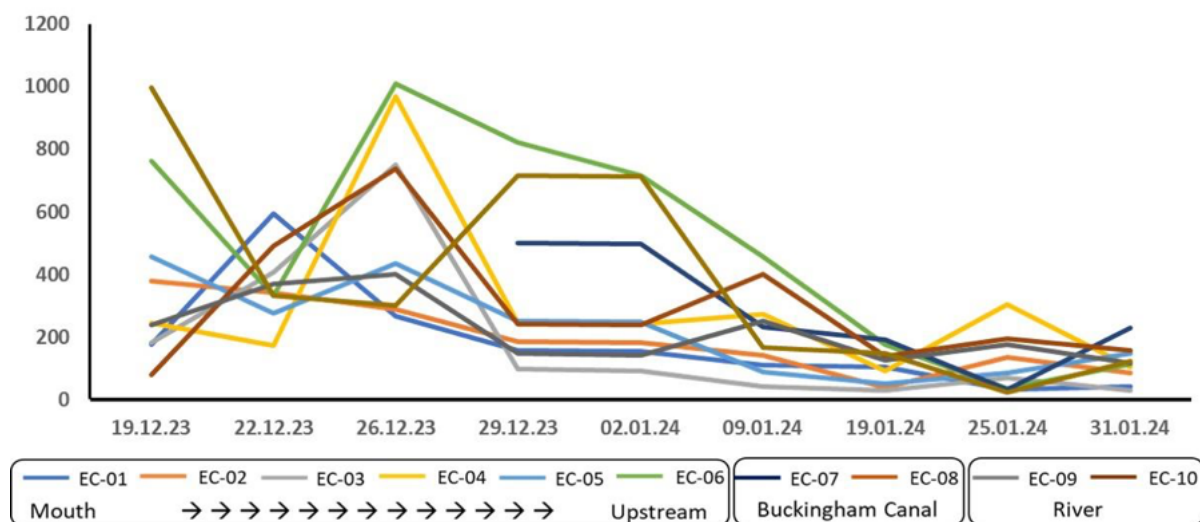
**Table 7:** Concentrations of heavy metals in ground water samples adjacent to Ennore Creek.

Sampling Date	Sample ID	Cd (µg/l)	Co (µg/l)	Cr (µg/l)	Cu (µg/l)	Mn (µg/l)	Ni (µg/l)	Pb (µg/l)	V (µg/l)
<b>19-12-2023</b>	GW-01	0.08	0.04	0.15	1.38	2.34	1.16	0.43	1.97
	GW-02	0.04	0.12	0.07	4.50	1.95	1.59	0.25	1.95
	GW-03	0.08	0.02	0.07	3.96	1.45	1.61	0.27	5.49
	GW-05	0.08	0.12	0.17	2.93	2.73	3.33	0.43	--
	GW-06	0.16	0.04	0.42	--	0.89	2.10	0.91	2.53
	GW-07	0.25	0.10	0.20	2.85	5.26	3.08	0.45	6.40
	GW-08	0.26	0.20	0.31	9.97	3.25	5.27	1.59	--
	<b>22-12-2023</b>	GW-01	0.11	0.03	0.54	3.10	1.87	1.93	0.74
GW-02		0.11	0.02	0.18	--	1.30	2.08	1.02	2.63
GW-03		0.02	0.01	0.30	0.90	1.07	0.56	0.85	0.28
GW-04		0.09	0.14	0.20	2.23	4.19	3.07	0.58	4.29
GW-05		0.07	0.09	0.23	6.67	--	1.86	1.40	0.50
GW-06		0.16	0.03	0.34	9.64	1.22	1.95	0.70	10.59
GW-07		0.29	0.07	0.21	4.37	4.23	2.13	0.59	6.17
GW-08		0.52	0.24	0.24	3.06	8.28	--	0.56	5.12
<b>26-12-2023</b>	GW-01	0.43	0.04	0.48	--	1.17	1.58	0.69	6.55
	GW-02	0.15	0.02	0.32	5.97	1.49	1.14	1.38	1.96
	GW-03	0.34	0.11	0.16	12.53	0.94	2.30	0.77	4.58
	GW-04	0.09	0.18	0.38	3.21	2.07	1.53	1.77	5.20
	GW-05	0.07	0.16	0.17	1.17	4.09	0.39	0.77	0.79
	GW-06	0.07	0.24	0.25	1.87	1.33	1.94	1.23	14.58
	GW-07	0.20	1.60	0.24	2.75	--	2.54	3.49	7.51
	GW-08	0.15	1.25	0.28	2.65	1.44	2.48	2.38	10.38
<b>29-12-2023</b>	GW-01	0.15	0.18	0.22	1.68	3.58	0.98	0.81	2.16
	GW-02	0.10	0.36	0.23	2.33	--	1.26	2.14	3.19
	GW-03	0.10	0.36	0.19	4.71	6.71	1.23	1.38	8.74
	GW-04	0.04	0.22	0.21	--	1.90	1.63	1.41	1.14

	GW-05	0.18	0.33	0.23	1.49	--	2.63	0.90	4.96
	GW-06	0.14	0.24	0.26	3.11	1.88	1.82	1.20	3.17
	GW-07	0.15	0.85	0.24	1.54	--	2.24	1.75	4.73
	GW-08	0.09	0.79	0.18	1.63	1.55	1.74	1.74	--
<b>02-01-2024</b>	GW-01	0.03	0.03	0.12	0.66	1.27	0.45	0.32	1.10
	GW-02	0.08	0.21	0.13	6.03	8.40	1.50	0.88	2.79
	GW-03	0.05	0.03	0.16	4.02	2.64	1.35	0.62	5.13
	GW-04	0.04	0.07	0.13	--	3.18	2.71	1.25	1.97
	GW-05	0.04	0.08	0.28	0.85	8.56	1.81	0.67	2.16
	GW-06	0.09	0.04	0.19	1.98	2.88	2.32	0.98	4.59
	GW-07	0.06	0.07	0.21	1.95	3.50	2.99	0.90	6.15
	GW-08	0.12	0.33	0.27	4.94	--	6.43	2.41	--
<b>09-01-2024</b>	GW-01	0.06	0.01	0.23	0.89	2.49	0.95	0.62	1.08
	GW-02	0.04	0.04	0.11	0.55	9.85	1.46	0.29	0.41
	GW-03	0.07	0.09	0.07	--	8.48	2.80	1.84	2.79
	GW-04	0.04	0.02	0.08	3.62	2.85	1.22	0.34	4.45
	GW-05	0.05	0.20	0.26	0.56	--	1.99	0.58	1.44
	GW-06	0.09	0.04	0.06	2.38	2.43	1.47	0.91	4.67
	GW-07	0.43	0.05	0.21	1.88	4.21	1.96	0.89	5.79
<b>19-01-2024</b>	GW-01	0.16	0.25	0.77	2.78	--	1.76	3.96	5.32
	GW-02	0.09	0.02	0.09	0.89	3.88	0.86	0.34	1.77
	GW-03	0.04	0.10	0.11	0.65	2.50	2.02	0.25	0.90
	GW-04	0.06	0.10	0.21	1.62	4.13	2.50	0.79	0.95
	GW-05	0.04	0.05	0.17	2.28	4.61	1.26	0.54	1.81
	GW-06	2.56	0.04	0.14	--	4.89	1.43	1.80	4.72
	GW-07	0.09	0.05	0.08	1.88	5.26	2.58	0.72	3.78
	GW-08	0.13	0.09	0.20	2.53	6.48	2.18	1.66	9.74
<b>25-01-2024</b>	GW-01	0.19	0.03	0.20	1.34	4.71	1.23	0.36	2.75
	GW-02	0.11	0.10	0.07	1.91	--	1.43	0.65	3.36
	GW-03	0.06	0.02	0.08	4.57	2.00	1.24	0.30	5.84
	GW-04	0.07	0.05	0.09	--	3.71	3.12	1.65	1.84
	GW-05	0.12	0.32	0.25	3.03	--	3.38	0.54	3.55
	GW-06	0.16	0.01	0.06	1.95	1.58	1.75	0.53	3.80
	GW-07	0.07	0.04	0.06	1.08	2.59	1.35	0.30	2.07
	GW-08	0.01	0.01	0.05	0.27	0.09	0.23	0.05	0.04
<b>31-01-2024</b>	GW-01	0.03	0.01	0.22	0.59	1.62	0.87	0.45	1.76
	GW-02	0.05	0.13	0.12	8.15	4.06	1.22	0.65	2.70
	GW-03	0.03	0.02	0.35	2.17	1.57	0.33	0.90	2.19
	GW-04	0.01	0.04	0.04	21.61	1.20	1.29	1.36	0.82
	GW-04A	0.08	0.72	0.23	9.94	--	3.57	0.93	4.95
	GW-05	0.06	0.20	0.06	2.03	--	1.38	0.45	1.22
	GW-06	0.05	0.04	0.13	3.24	3.87	0.64	0.71	0.95
	GW-07	0.07	0.06	0.08	2.13	8.47	1.85	0.90	6.32
GW-08	0.05	0.16	0.24	0.92	9.44	3.17	0.70	6.80	

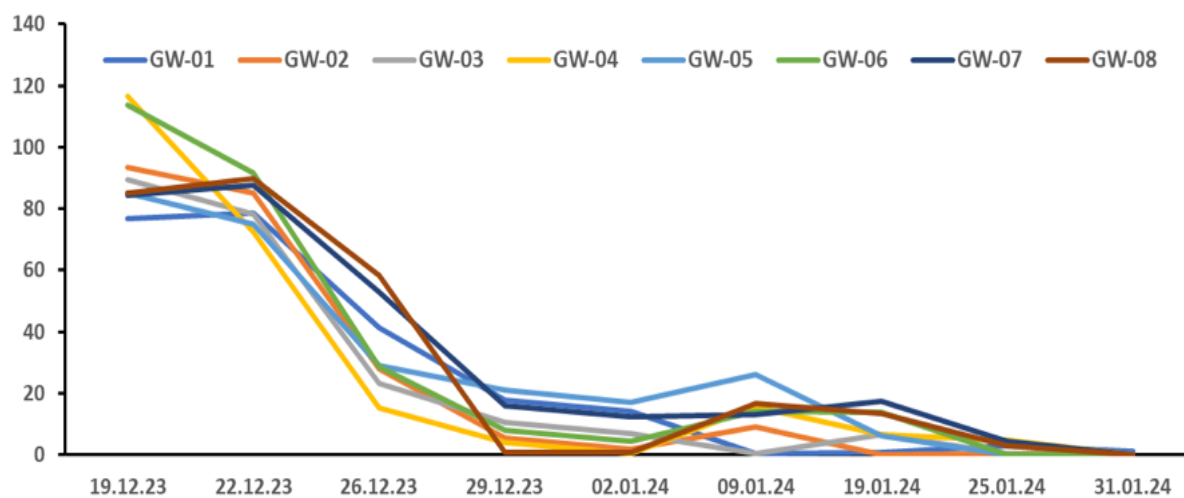
### 3.3. Total Petroleum Hydrocarbons

The TPH concentrations in the surface waters of Ennore Creek were found ranging from 28.77 µg/l – 1008 µg/l (Figure 7). Higher concentrations of TPH were found in the Buckingham canal and neighboring stations in the Ennore creek. Over the period of sampling, the TPH concentrations, were observed to reduce at all the sampling points and may further decrease by natural weathering.

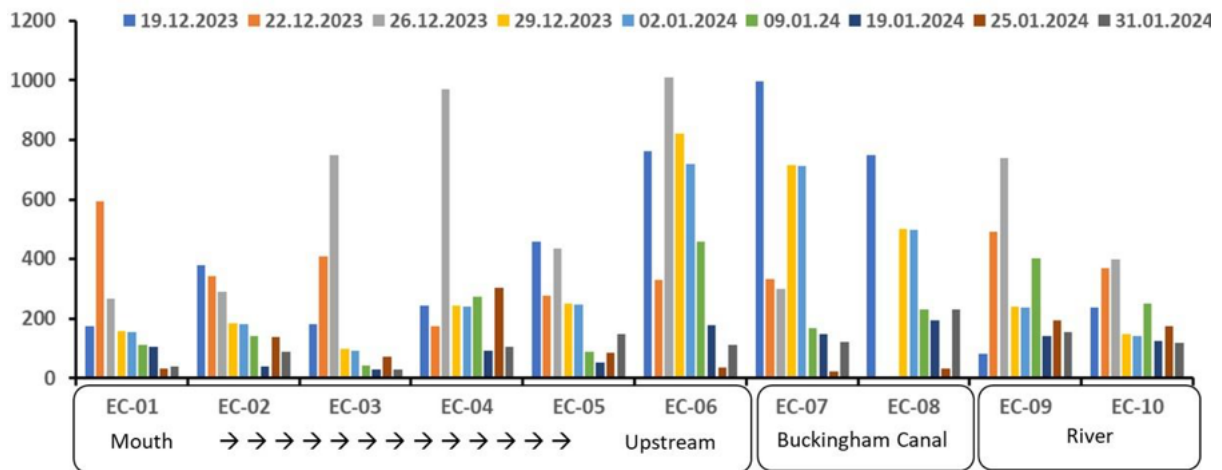


**Figure 7.** Distribution of Total Petroleum Hydrocarbons (µg/l) in the surface waters.

The TPH concentrations in the ground waters were found ranging from BDL – 116 µg/l (Figure 8). Higher concentrations were observed in all the ground water samples in the initial days of sampling and gradually reduced over the period of sampling.



**Figure 8.** Distribution of Total Petroleum Hydrocarbons (µg/l) in ground waters.



**Figure 9.** Distribution of Total Petroleum Hydrocarbons ( $\mu\text{g/g}$ ) in the sediments.

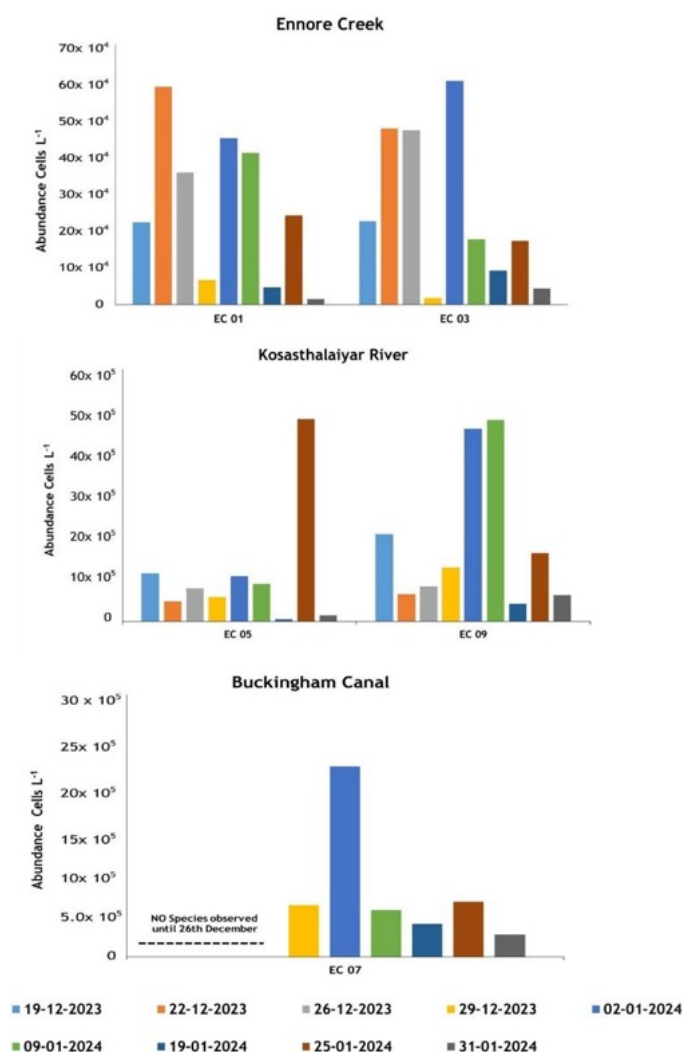
The concentrations of TPH in sediment samples is shown in Figure 9. Higher concentrations were observed in the Buckingham canal and neighboring stations. The concentrations of TPH in sediments did not show any decreasing pattern as observed for the surface water samples. The variations observed in the TPH concentrations in the sediments over the period of sampling might be due to the continuous dredging in the upstream and Buckingham canal during salvage operations.

### 3.4. Phytoplankton species composition and abundance

**Phytoplankton abundance:** Phytoplankton samples were collected from five designated stations, mouth of Ennore creek (EC-01; EC-03), Kosasthalaiyar River (EC-05; EC-09) and Buckingham Canal (EC-07) from 19<sup>th</sup> December 2023 to 31<sup>st</sup> January 2024 to evaluate the spatial distribution and temporal variations in the phytoplankton community due to the oil spill. Totally, 78 species belonging to 10 classes: *viz.*, Bacillariophyceae, Chlorellaceae, Chlorophyceae, Chrysophyceae, Cryptophyceae, Cyanophyceae, Dinophyceae, Euglenoidea, Trebouxiophyceae and Zygnematophyceae were observed. Of these 10 classes, Bacillariophyceae was recorded as dominant group with 37 species, followed by Chlorophyceae (12) and Cyanophyceae (10).

Quantitative analysis of phytoplankton revealed gradual increase in the abundance of phytoplankton following the oil spill event (Figure 10). The highest population density of  $48.12 \times 10^5$  and  $47.85 \times 10^5$  cells  $\text{L}^{-1}$  was observed on 25<sup>th</sup> and 9<sup>th</sup> January, 2024, respectively, at stations EC-05 and EC-09 (Kosasthalaiyar river; Figure 10). The high abundance observed is due to the freshwater green algae *viz.*, *Chlorella* sp., *Chroococcus* sp., *Thalassiosira* sp., *Scenedesmus* sp., *Navicula* sp., and *Anabaena* sp.

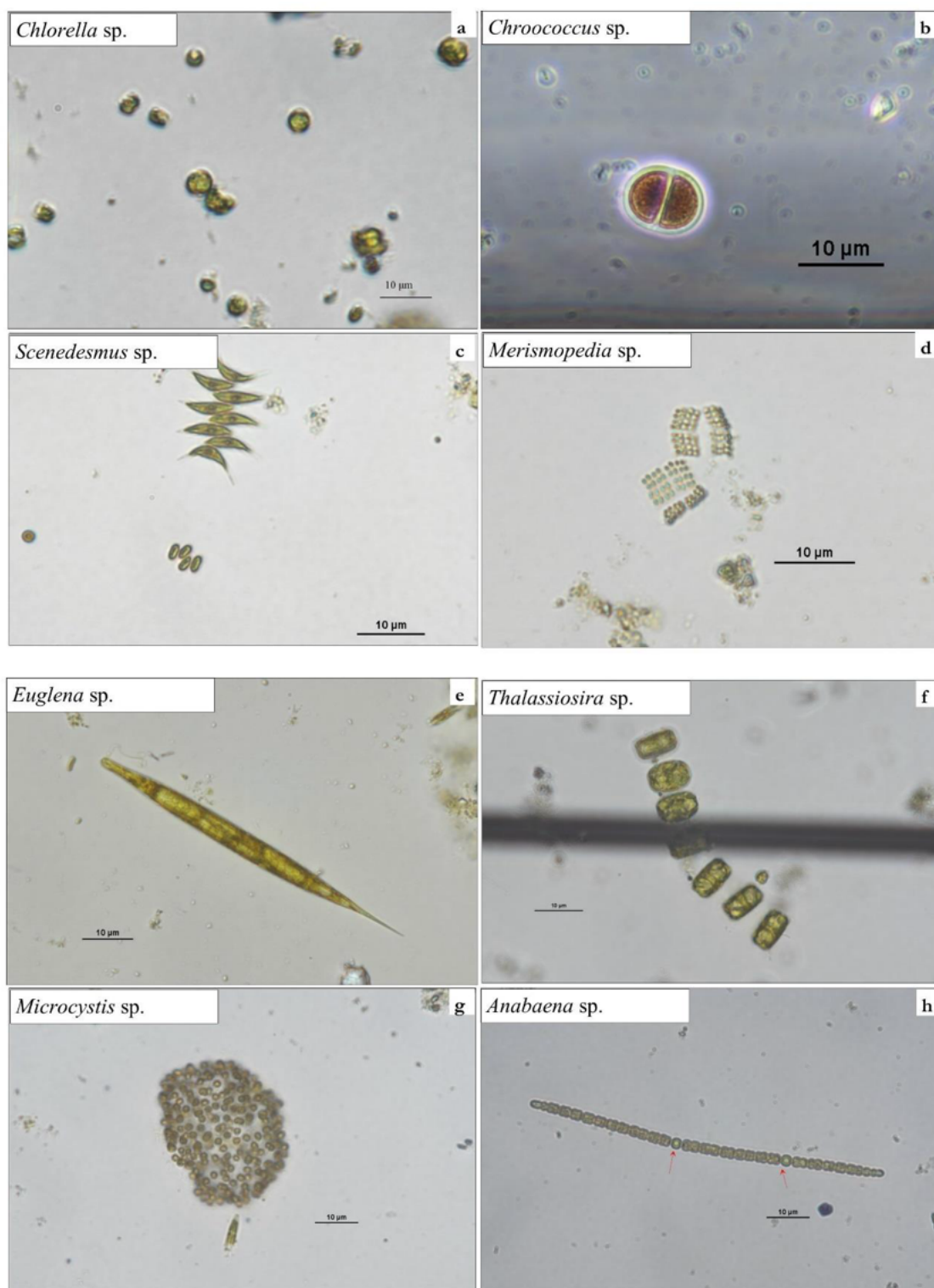
At EC-07 (Buckingham canal) station, which had been highly polluted by the oil spill and sewage, was studied to observe the recovery process. Initially, no presence of phytoplankton was observed until 26<sup>th</sup> December 2023. However, a gradual increase in phytoplankton species was noted from 29<sup>th</sup> December 2023 onwards (Figure 10). The highest population density at EC-07 was observed on 2<sup>nd</sup> January 2024 with an abundance of  $21.80 \times 10^5$  cells L<sup>-1</sup>. The high density observed was primarily due to the presence of the freshwater cyanobacterium *Pseudanabaena* sp. (Figure 11).



**Figure 10.** Temporal and spatial variation in phytoplankton abundance.

*Phytoplankton species composition:* Changes in species composition was noted during the analysis, following the oil spill event till 31<sup>st</sup> January 2024. During the initial period, phytoplankton species composition was predominantly contributed by freshwater algae belonging to classes Chlorophyceae, Trebouxiophyceae, Cyanophyceae and Bacillariophyceae. The dominant freshwater genera (Figure 11) observed during the study were

*Actinastrum* sp., *Anabaena* sp., *Chroococcus* sp., *Chlorella* sp., *Cyclotella* sp., *Euglena* sp., *Merismopedia* sp., *Microcystis* sp., *Monoraphidium* sp., *Navicula* sp., *Oocystis* sp., *Stephanodiscus* sp., and *Thalassiosira* sp., which exhibited consistent presence until 19<sup>th</sup> January 2024. However, a notable shift in species composition was observed on 25<sup>th</sup> and 31<sup>st</sup> January 2024 with estuarine phytoplankton species (genera such as *Chaetoceros* sp., *Tripos furca*, *Cylindrotheca* sp., *Nitzschia* sp., *Pleurosigma* sp., and *Skeletonema* sp.) becoming more prevalent (Figure 12). The noticeable shift in phytoplankton species composition towards estuarine genera such as *Chaetoceros* sp., *Cylindrotheca* sp., *Nitzschia* sp., *Pleurosigma* sp., *Skeletonema* sp. and *Tripos* sp., indicates a transition towards estuarine community structure. Additionally, the observation of a high abundance of freshwater cyanobacterium (*Pseudoanabaena* sp.), known as a pollution indicator in freshwater environments, on 2<sup>nd</sup> January 2024 suggests an elevated pollution level at Buckingham Canal (EC-07). However, from 9<sup>th</sup> January 2024 onwards, there was a gradual increase in phytoplankton diversity, characterized by the presence of various freshwater green algae (Figure 13). This shift indicates a transition in the recovery of the freshwater ecosystem in Buckingham Canal (EC-07).



**Figure 11.** Dominant freshwater phytoplankton species (a-h) observed.

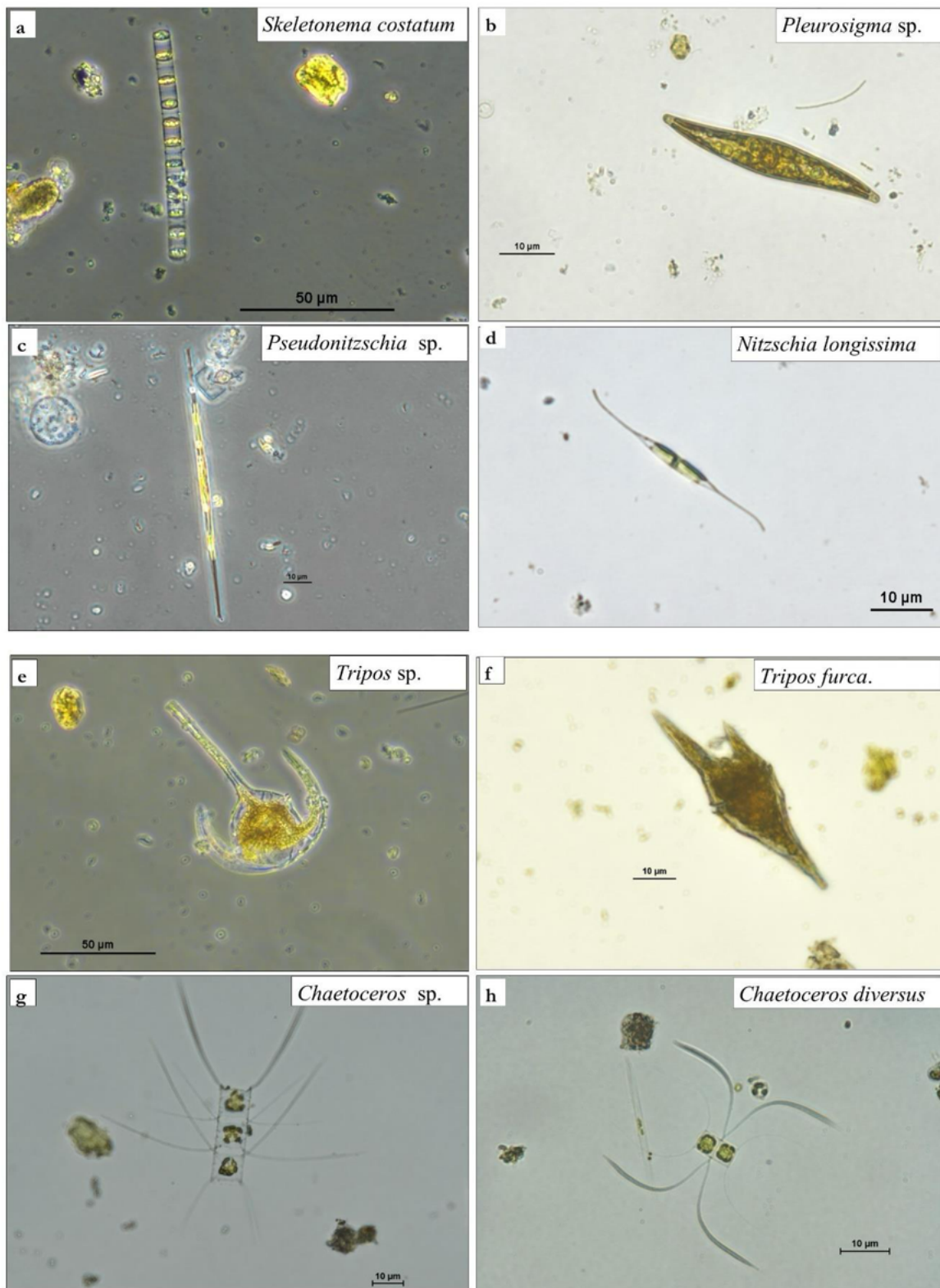
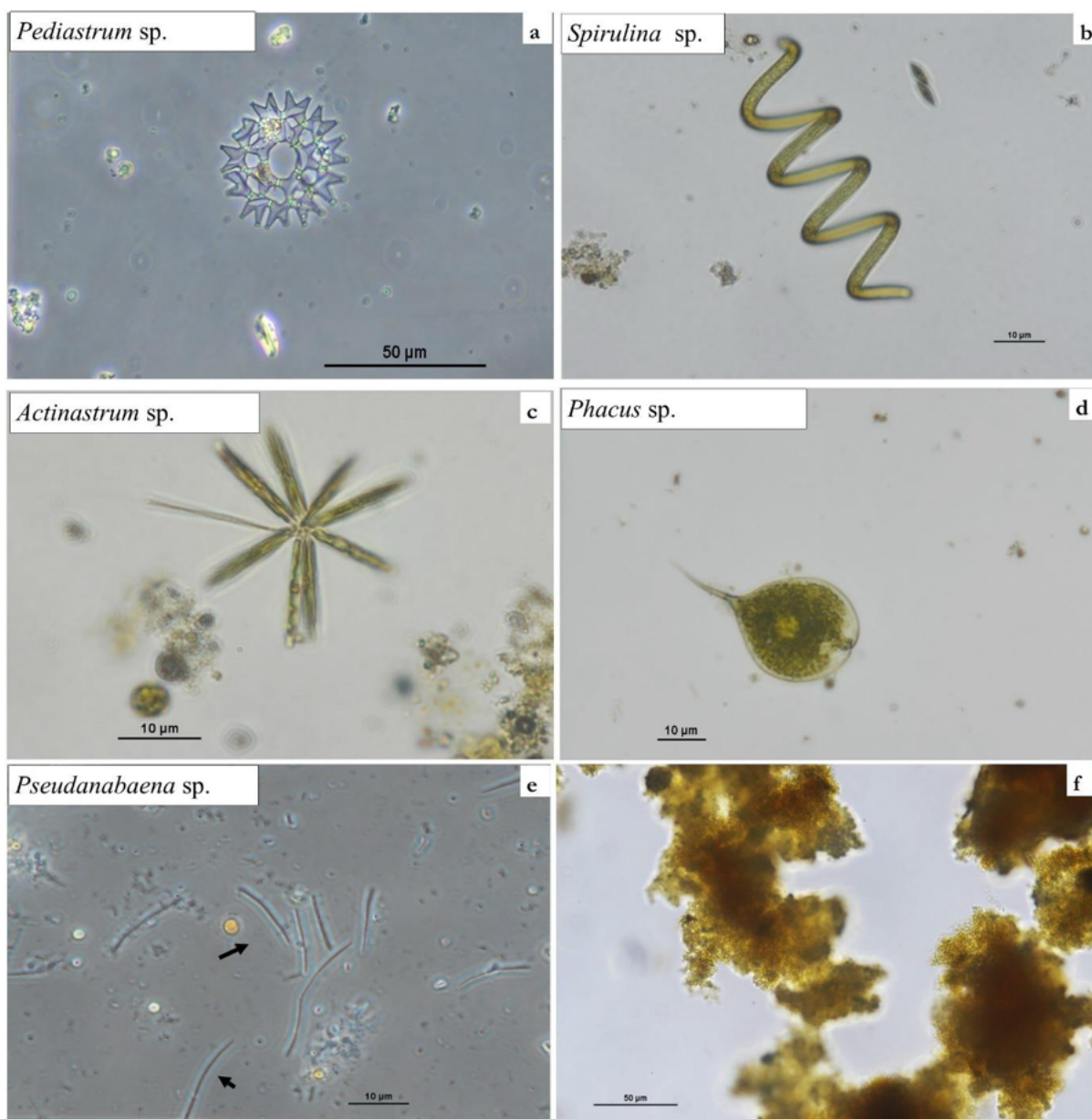


Figure 12. Estuarine phytoplankton species (a-h) observed on the 25<sup>th</sup> and 31<sup>st</sup> January 2024.



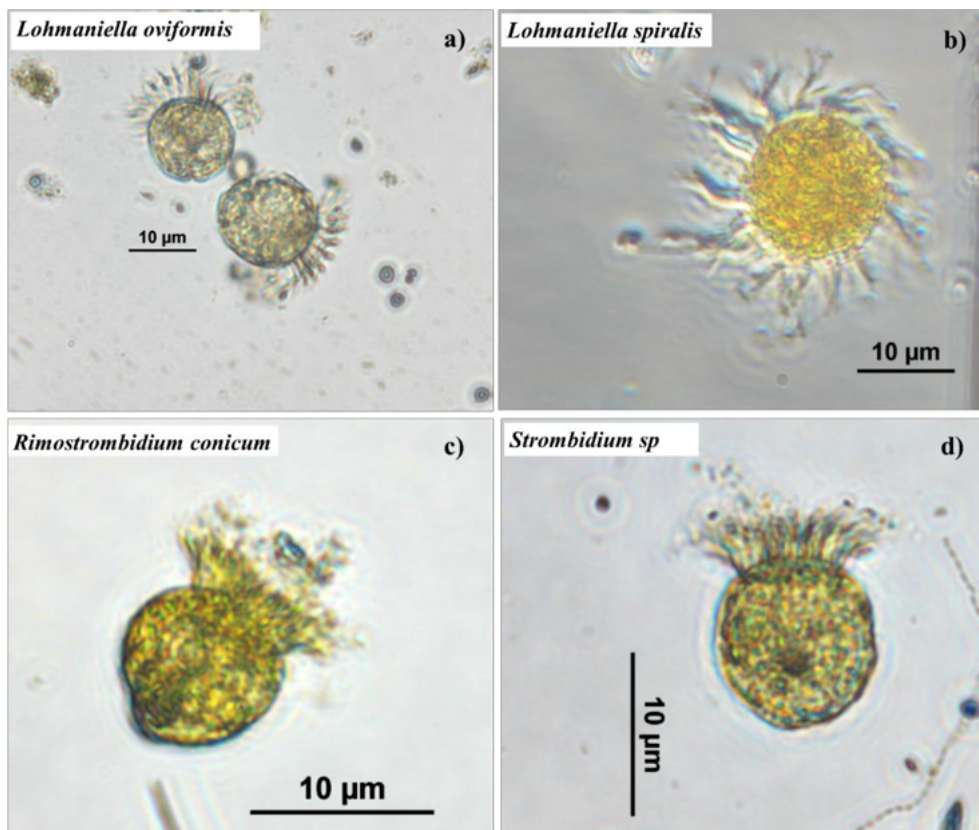
**Figure 13.** The freshwater phytoplankton species (a-e) observed in Buckingham Canal (EC-07) after 26<sup>th</sup> December, 2023 and suspended particles (f) observed during the first phase of sampling.

### 3.5. Microzooplankton

Microzooplankton play a key role in marine food web dynamics, biogeochemical cycling and fish recruitment. With their short life cycle and delicate external membranes, they may react more quickly to environmental changes than any other eukaryotic organisms.

*Microzooplankton composition and community structure:*

Protozoans dominated the microzooplankton community in the samples analyzed. Among protozoans, ciliates were the most abundant group, in which aloricate ciliates contributed substantially (up to 100%) to the total density of microzooplankton irrespective of the sampling dates. A total of 34 species of microzooplankton were reported, of which 32 were ciliates and 2 were rotifers. Among ciliates, 24 species were aloricate and 8 species were loricate ciliates. Smaller aloricate ciliates like *Lohmaniella oviformis*, *L. spiralis*, *Strombidinopsis minima*, *Rimostrombidium conicum*, *Strombidinopsis chesrii* were dominant. The tintinnid ciliates like *Tintinnidium primitivum*, *Tintinnopsis directa*, *T. beroidea* and *Codonellopsis ostenfeldii* and *Helicostomella subtula* were present in the Ennore creek and Kosasthalayar River, however, were completely absent in the Buckingham canal. Figure 14 represents some of the dominant microzooplankton observed in the study.



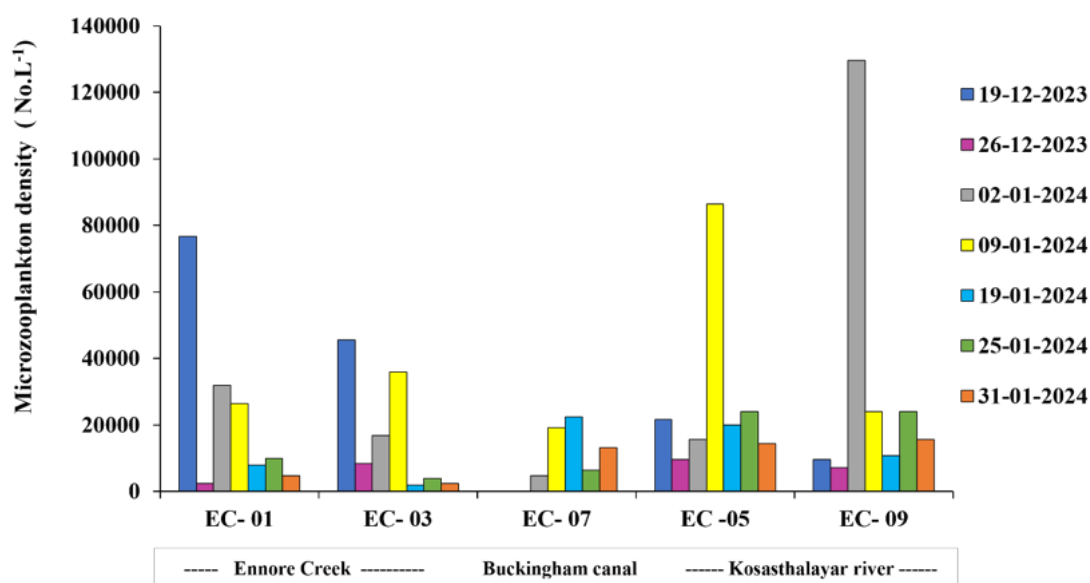
**Figure 14.** Dominant microzooplankton observed.

*Microzooplankton density*

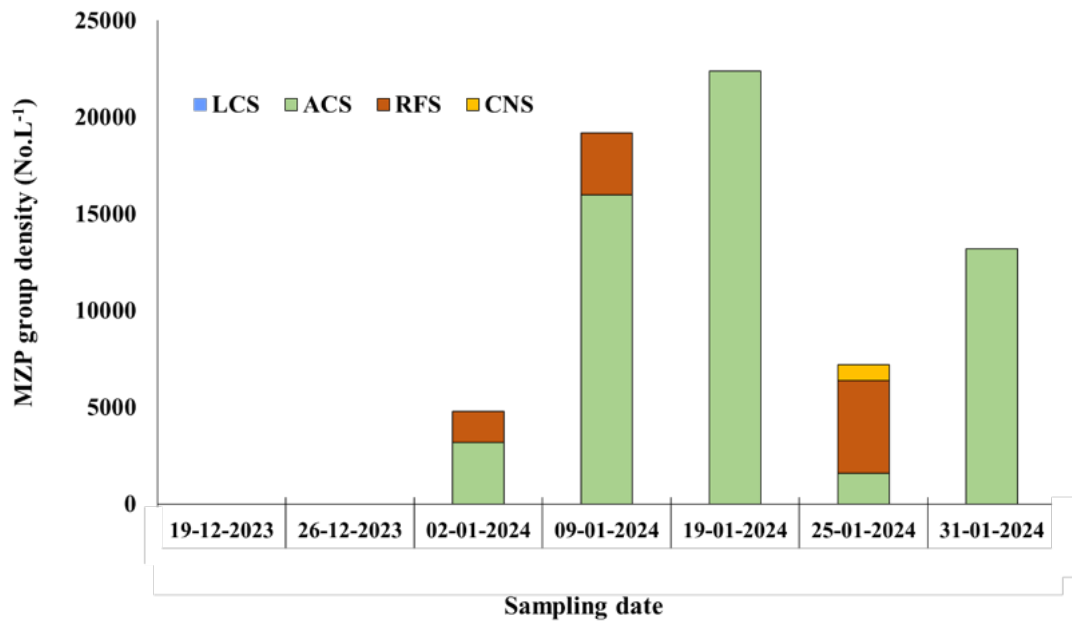
Microzooplankton density showed temporal and spatial variations (Figure 15). Density of microzooplankton varied from 2000 - 129600 No. L<sup>-1</sup>. High density of microzooplankton were observed at locations in Kosasthalayar River (EC-09) and Ennore creek (EC- 01).

Maximum density (129600 No. L<sup>-1</sup>) was observed in Kosasthalayar River (EC-09) on 02/01/2024 and was associated with dominance of the small aloricate ciliate *Lohmaniella oviformis*. Similarly, dominance of aloricate ciliates *L. spiralis* and *Strombidium minimum* in the Ennore creek (EC-01) contributed towards the high density (76800 No. L<sup>-1</sup>) on 19/12/2023. The microzooplankton were absent at Buckingham canal region during the initial stages of the sampling (Figure 15 and 16). From 2<sup>nd</sup> January 2024 the microzooplankton density at the Buckingham canal location demonstrated an increasing trend, which indicates the revival of the microzooplankton at the oil spill site.

The microzooplankton community responded to oil pollution by regulating the density and community structure of its taxa, resulting in variations in their temporal distribution, especially at the Buckingham canal. Even though the oil spill had affected the microzooplankton at the oil spill site, the system eventually displayed signs of recovery.



**Figure 15.** Microzooplankton density (No. L<sup>-1</sup>) at the different stations in Ennore Creek.



**Figure 16.** Temporal variation in the density of major groups of microzooplankton community at Buckingham canal location. Abbreviations MZP- Microzooplankton, LCS- loricate ciliates, ACS- aloricate ciliates, RFS- rotifers, CNS- crustacean nauplii.

### 3.6. Macrobenthos

Benthic organisms which are present in the sediments are used as indicators of oil pollution especially the dominant fauna polychaetes. Polychaete indicator species have been widely used to determine the bioavailability of pollutants and to identify the ecological risks. During incidents like oil spill, the sensitive polychaete species are wiped out while the opportunistic species dominate. The presence and their abundance can be used in monitoring the impacts of oil pollution.

#### *Abundance and diversity of macrobenthos*

The oil spill in the Ennore Creek had impacted the macrobenthic fauna. In the initial surveys (from 19/12/23 to 29/12/23, Figure 17), the abundance of macrobenthic organisms was higher along the Ennore Creek mouth (EC-01; EC-03), while decreased in abundance towards the riverine region (EC-05, EC-09), while organisms were completely absent in the Buckingham canal (EC-07). The macrobenthic organisms were fairly present in the reference station (EC-10). The abundance ranged from nil (EC-07; EC-09) to 8200 ind. /m<sup>2</sup> (EC-05). Polychaetes, crustaceans and oligochaetes were the major taxa observed in the region, with polychaetes being the dominant group (Figure 18). Dead gastropod and bivalve shells were present in the sediment samples. Among polychaetes, only *Prionospio* sp. belonging to family Spionidae were present in the sediment samples whereas crustaceans, amphipods were the only

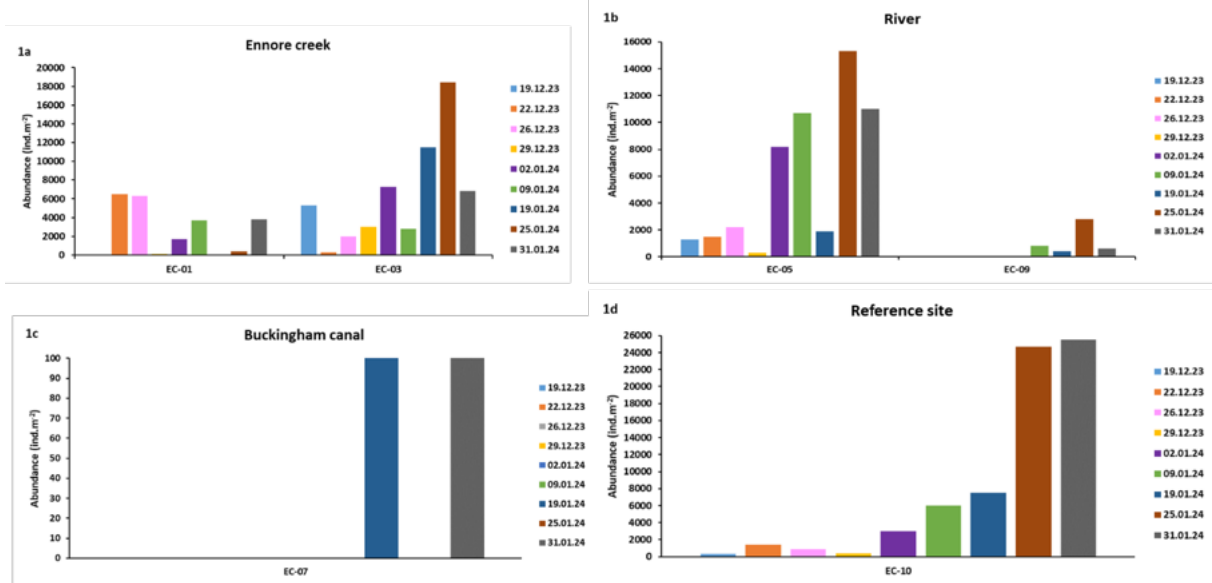
group represented. On an average, half of the samples collected, were devoid of life forms representing the Buckingham canal (EC-07) and in Kosasthalaiyar river (EC-09) and there were no signs of recovery in these two sites.

After 20 days of initial sampling (09/01/24), there was a recovery of polychaetes in one of the sites in the Kosasthalaiyar River region (EC-09, Figure 17), while fauna was completely absent in Buckingham canal (EC-07). In the other sites, from Ennore Creek mouth to upstream (EC-01; EC-03; EC-05), where spionids only dominated till 20 days of initial sampling, another family of polychaete capitellidae showed their presence. After 30 days of initial sampling (19/01/24), the presence of polychaetes were observed in Buckingham canal (EC-07, Figure 17). The abundance of macrobenthic fauna (100 ind.m<sup>-2</sup>) in the Buckingham canal was relatively less compared to creek mouth and riverine sites. The diversity of polychaete fauna increased in the Ennore creek mouth, with maximum diversity in EC-03. Seven families (Eunicidae, Onuphidae, Pilargidae, Opheliidae, Capitellidae, Spionidae, Sabellidae) of polychaetes were observed exclusively in EC-03 (Figure 18). Although the recovery of polychaete communities were rapid, there were no signs of recovery of sensitive fauna like benthic crustaceans, molluscs and echinoderms in the Ennore Creek mouth. The abundance of macrofauna in the reference site (EC-10, Figure 17) showed a three-fold increase in abundance.

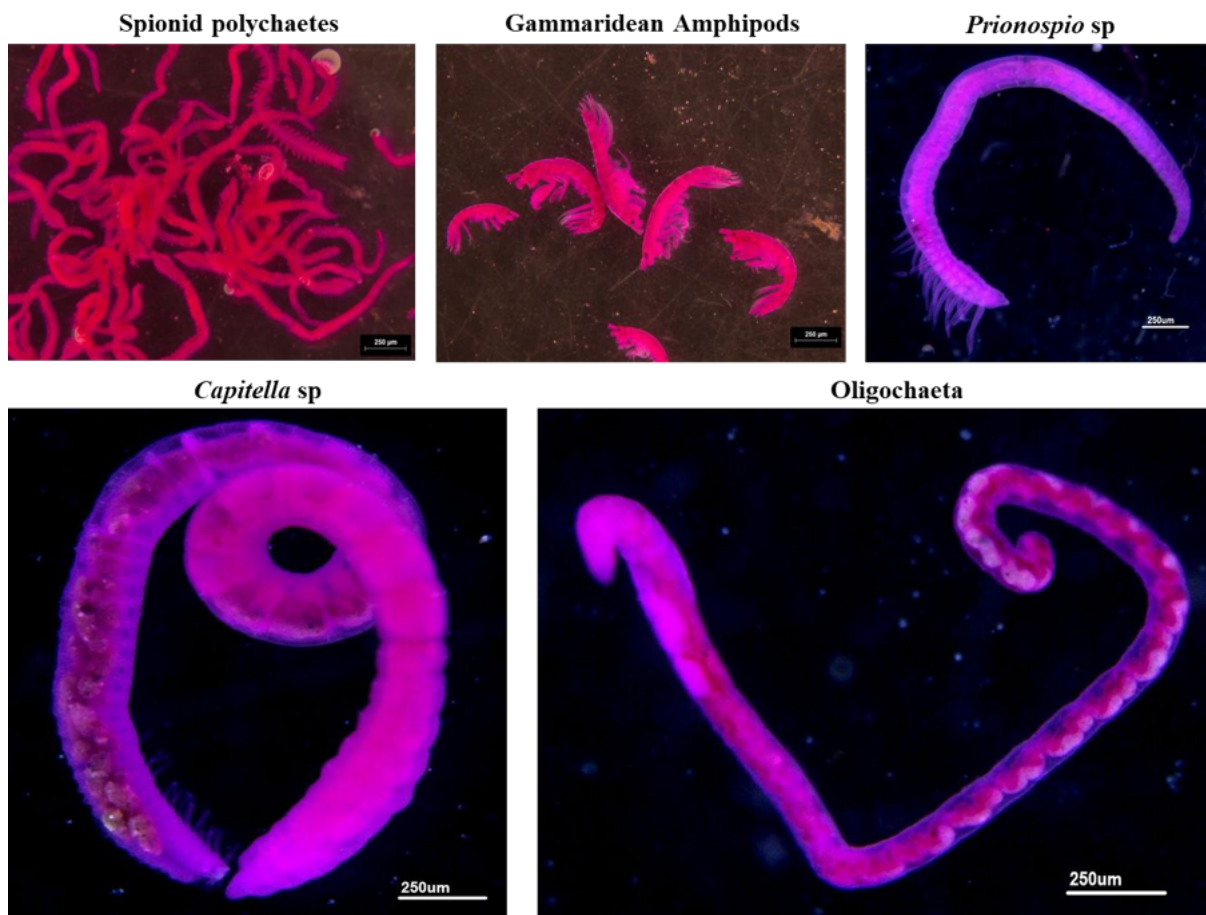
Although all sites of Ennore Creek was impacted by the oil spill, the Buckingham Canal was heavily impacted and no macrobenthic fauna was found during the initial sampling. The results suggest that spionid polychaetes can be used as indicator species for oil spill incidents as certain species of polychaetes (mainly the opportunistic species) are able to withstand the adverse conditions in the ecosystem. The results also reveal that partial recovery of benthic fauna requires a minimum time period of 60 days.

**Table 8.** Macrofaunal abundance (ind m<sup>-2</sup>) in the sampling sites.

Sampling dates	Ennore Creek mouth		Buckingham Canal	Kosasthalaiyar River		Reference site
	EC-01	EC-03	EC-07	EC-05	EC-09	EC-10
19.12.23	0	5300	0	1300	0	300
22.12.23	6500	300	0	1500	0	1400
26.12.23	6300	2000	0	2200	0	900
29.12.23	100	3000	0	300	0	400
02.01.24	1700	7300	0	8200	0	3000
09.01.24	3700	2800	0	10700	800	6000
19.01.24	0	11500	100	1900	400	7500
25.01.24	400	18400	0	15300	2800	24700
31.01.24	3800	6800	100	11000	600	25500



**Figure 17.** Temporal and spatial variation in the abundance of macrobenthic fauna.



**Figure 18.** Common macrobenthos fauna observed in the sediment samples.

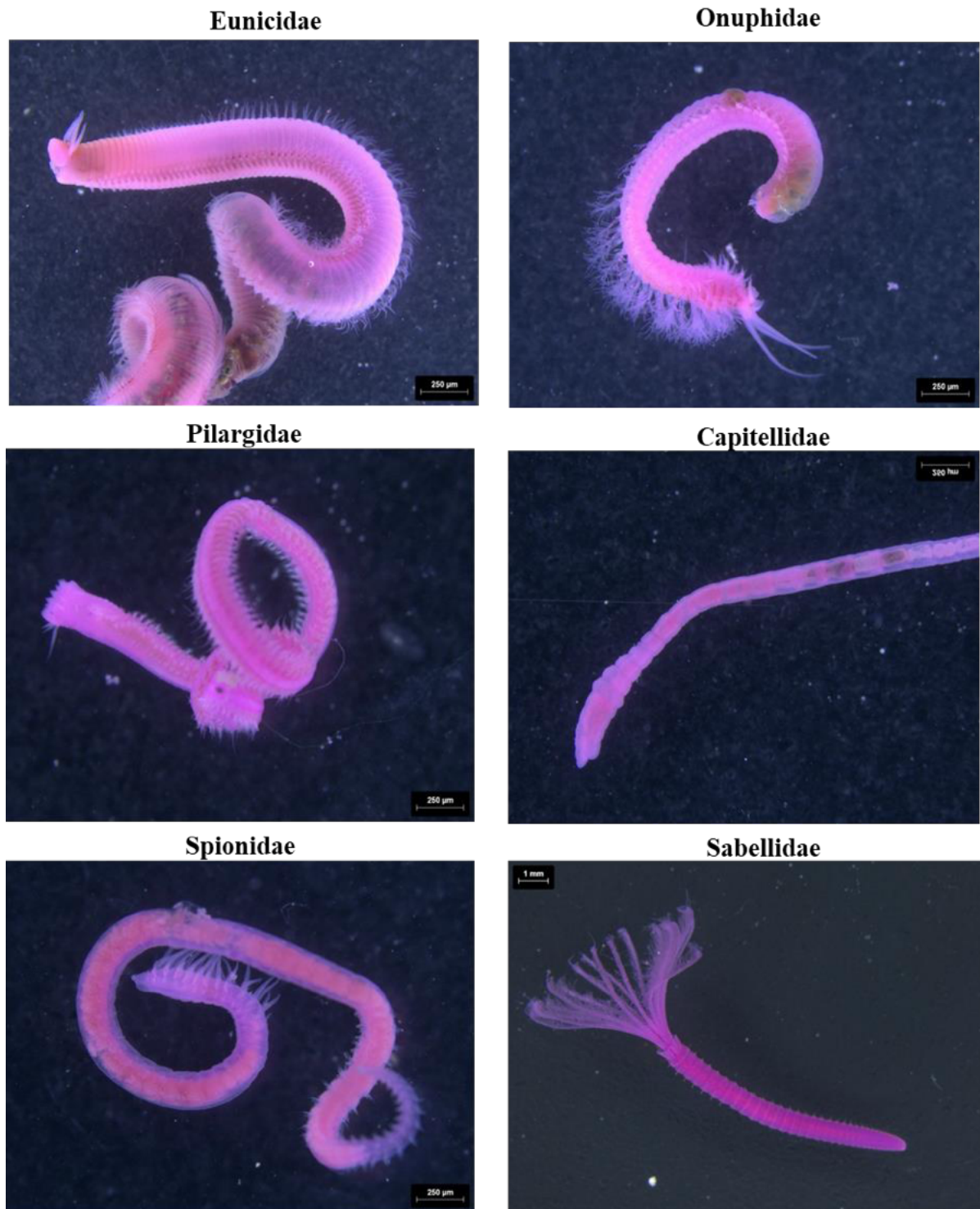
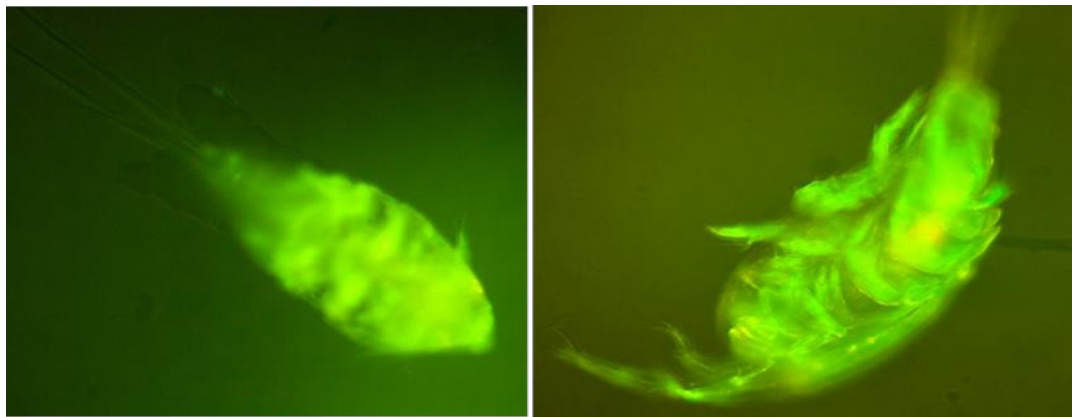


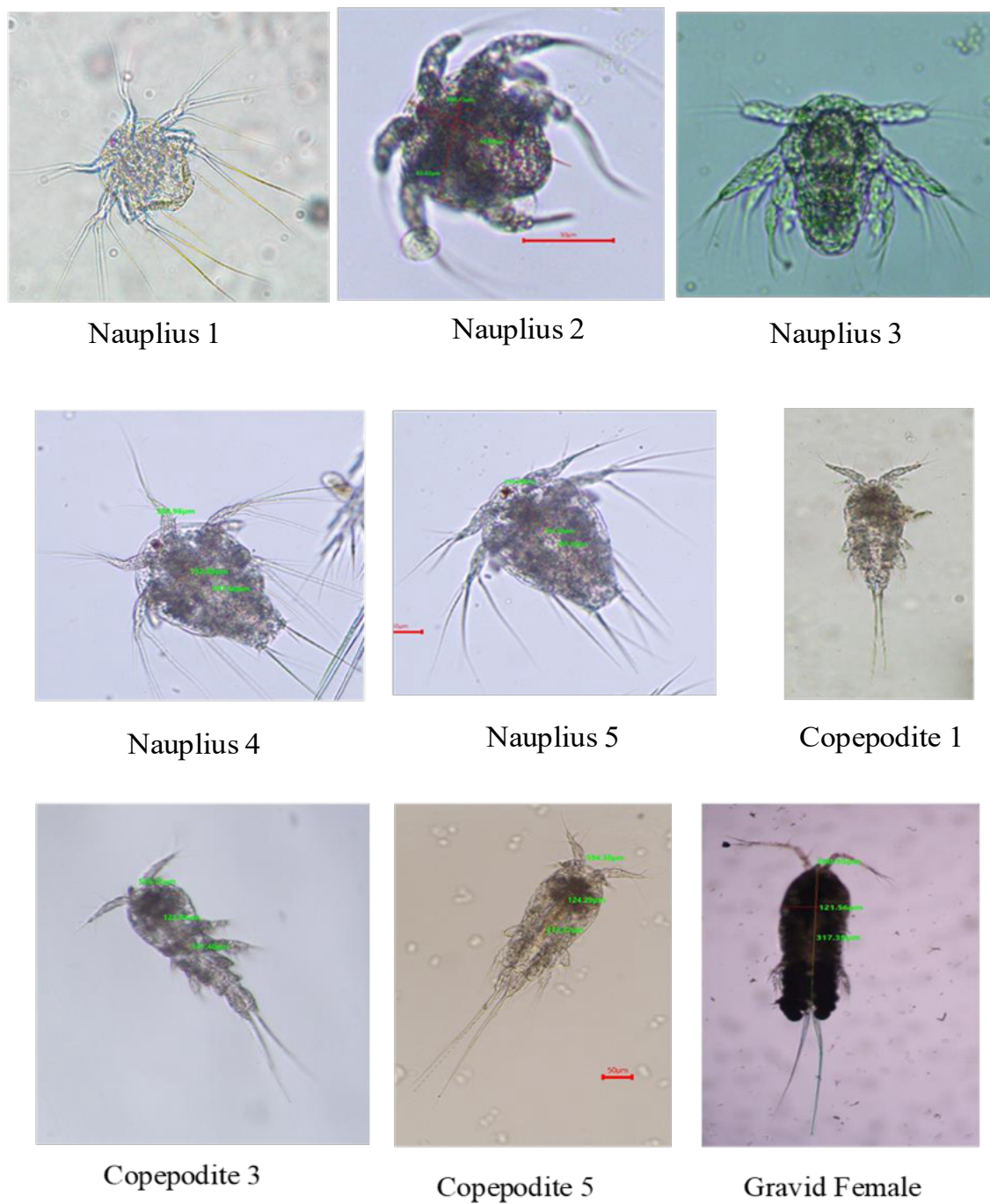
Figure 19. Dominant families of polychaetes found in the mouth of Ennore Creek.

### 3.7. Impact Assessment of Ennore Oil Spill through in-vivo Microassay on Copepods

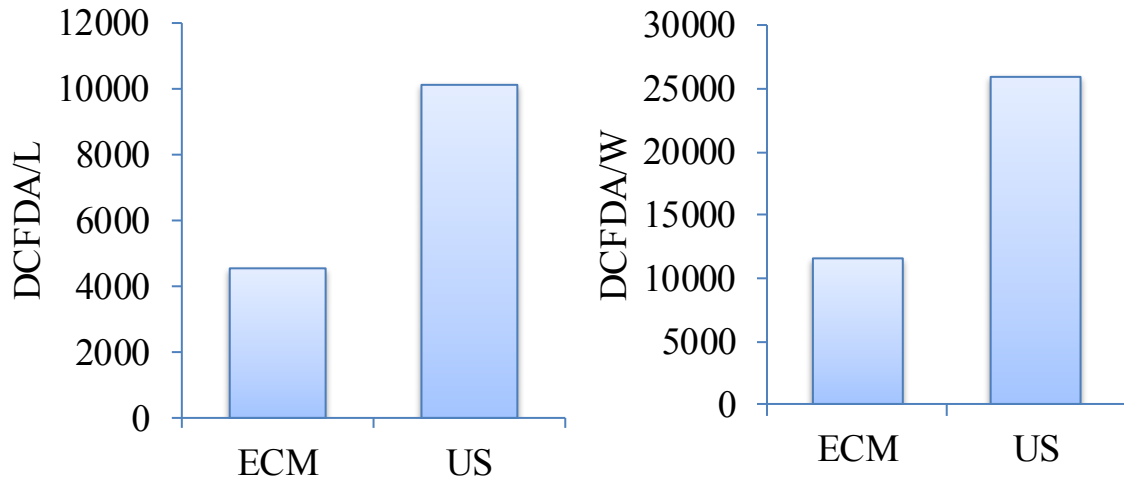
The direct impact of contaminants on marine organisms can be measured through toxicity bioassays. Copepods are sensitive to environmental contaminants and widely applied for toxicity bioassays. Therefore, a rapid short-term toxicity bioassay was conducted on meiobenthic harpacticoid copepod *Tisbe furcata* to assess the impact of oil spill after one month. Biological responses of copepod were measured by hydrolysis of Fluorescein diacetate (FDA) and Dichlorofluorescein diacetate (DC-FDA). FDA and DCFDA hydrolysis by different life stages of the copepod were measured in control and surface waters from Ennore Creek (Figure 20 and 21). The surface water samples were collected from the mouth of Ennore Creek (ECM) and 1km upstream (US) after one month from the incident of oil spill. Significantly higher hydrolytic activity of DCFDA by nauplius larvae was observed in water from US than ECM (Figure 22). Slightly higher hydrolysis of FDA and DCFDA in US water by adult and subadult copepods was observed than the water from ECM. Overall, the toxicity bioassay result indicates that the post-oil spill impact on adult and subadult copepods is lesser than the naupliar larval stages. This study infers that the impact of oil-spill after one month is reduced however further improvement is required to protect the sensitive larval stages from the stress.



**Figure 20.** Emission of green fluorescence by live copepod observed under epifluorescence microscope.



**Figure 21.** Different life-stages of the copepod observed under light microscope.



**Figure 22.** Ratio of size and DCFDA hydrolysis by the nauplius larvae of harpacticoid copepod, *Tisbe furcata* on 30 min exposure to seawater collected from Ennore estuary after the oil spill event (L: length; W: width; ECM: Ennore Creek Mouth; US: Upstream)

## 4. Salient Observations

For the assessment of oil spill in Ennore Creek post Cyclone Michaung, surface water and sediment samples were collected from ten different locations in Ennore Creek covering the different sectors like (mouth of Ennore Creek, Buckingham Canal & Kosasthalaiyar River from 19<sup>th</sup> December 2023 to 31<sup>st</sup> January 2024 for the analysis of different physicochemical and biological parameters. Additionally, groundwater samples from eight open and bore wells in the residential areas in and around the Ennore Creek were analyzed to understand the impact of the seepage of TPH into the ground waters.

**Water Quality:** There was a subsequent increase in pH at all the sampling sites (ranging from 7.42 to 7.84) indicating continued improvement in water quality across the Ennore Creek. There was an improvement in dissolved oxygen and BOD levels in the last week of January 2024 suggesting that natural processes or the clean-up actions have helped in restoring the oxygen levels to support aquatic life.

**Heavy metals:** The concentrations of heavy metals in the sediment and surface water samples from Ennore Creek were comparable to the values reported earlier from Ennore Creek.

**Total Petroleum Hydrocarbons:** Over the period of sampling from 19<sup>th</sup> December 2023 to 31<sup>st</sup> January 2024 the TPH concentrations in surface waters of Ennore Creek were observed to reduce at all the sampling locations and may further decrease by natural weathering. Higher concentrations of TPH were observed in all the ground water samples in the initial days of sampling and gradually reduced over the period of sampling. However, the concentrations of TPH in sediments did not show any decreasing pattern as observed for the surface water samples of the Ennore Creek and ground water samples.

**Phytoplankton:** A gradual increase in phytoplankton diversity was observed in many of the sampling locations suggesting improvement of the water quality.

**Microzooplankton:** The Buckingham canal location was severely affected by the oil spill. However, by the end of January 2024 the microzooplankton density demonstrated an increasing trend, which indicates the revival of the microzooplankton at the oil spill site.

**Macrobenthos:** The macrobenthic community demonstrated recovery within 60 days following the oil spill incident.

**Toxicity bioassay:** The toxicity bioassay result indicates that the post-oil spill impact on adult and subadult copepods is lesser than the naupliar larval stages. The study infers that the impact of oil-spill after one month is reduced however further improvement is required to protect the sensitive larval stages from the stress.

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**Final Report**


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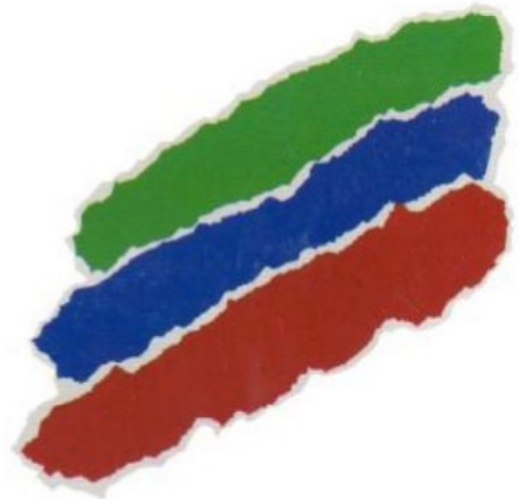
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**SSP3585**

**Pilot Studies for assessing Environmental Benefits for cleaning/bioremediation of oil spillage at designated locations in the Ennore Creek, Buckingham Canal, and Kosasthalaiyar River through the application of Biodispersant Comprising of Alkyl poly glucosides, Fatty Acids, & Botanical Extracts**

**For**  
**Chennai Petroleum Corporation Limited**  
**Chennai- 600 032**

**Through**  
**TNPCB, Chennai**

**August, 2024**



 <p>सीएसआईआर CSIR भारत का नवाचार इंजन The Innovation Engine of India</p>	<p>सीएसआईआर – राष्ट्रीयसमुद्रविज्ञानसंस्थान CSIR-NATIONAL INSTITUTE OF OCEANOGRAPHY (वैज्ञानिकतथाऔद्योगिकअनुसंधानपरिषद) (COUNCIL OF SCIENTIFIC &amp; INDUSTRIAL RESEARCH) दोनापावला, गोवा, भारत /DONA PAULA, GOA - 403004 INDIA फ़ोन/Tel : 91(0)832-2450450/ 2450327 फैक्स /Fax: 91(0)832-2450602 इ-मेल/E-mail : <a href="mailto:ocean@nio.org">ocean@nio.org</a> बसाईट/Website: <a href="http://www.nio.org">www.nio.org</a></p>	 <p>सीएसआईआर - राष्ट्रीयसमुद्रविज्ञानसंस्थान CSIR - National Institute of Oceanography</p>
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## **1. Background**

Humanity has always needed various energy resources to develop civilization and make life more comfortable. Exploration of energy resources has played an essential role in generating and sustaining individual development and economic growth. Increased importance is presently given to the exploration and development of conventional energy resources like oil and natural gas, locally referred to as refinery outputs. The society's dependence on oil and gas has been increasing at an alarming rate.

Oil is a major pollutant in the ocean, and the spill of marine oil is one of the major threats to fragile marine life. Whatever the reason, oil spills are a significant source of hydrocarbons into the oceans and are considered a major form of pollution that adversely affects aquatic life. The purpose of any oil spill response is to minimize the environmental damage that the spill could cause.

### **1.1. Genesis**

In the aftermath of floods due to cyclone Michaung on 04 December 2023, a massive oil spill was observed at Ennore Creek, Chennai, Tamil Nadu. The storm induced flooding ultimately spread the spill to the entire Ennore Creek and adjoining areas. As a consequence of this oil spill event, the State's Environment Department has undertaken emergency oil recovery initiatives with the engagement of many agencies to restore the environment quality on a war footing basis.

To address the concerns of oil pollution on the estuarine and coastal ecosystem, the Tamil Nadu Pollution Control Board (TNPCB) also requested the CSIR-National Institute of

Oceanography (CSIR-NIO), Goa, vide letter No. T6/TNPCB/F.12753/RL/2023 dt. 16/12/2023 to assist in perambulating the affected areas of Ennore Creek, Buckingham Canal, Kosasthalaiyar River, and other adjoining water bodies and to suggest possible bioremediation measures to mitigate the effects of oil spill on the fragile ecosystem on an immediate basis after the completion of manual and mechanical cleaning of the above-mentioned affected sites.

In response to the request of TNPCB, a Team of two scientists from CSIR-National Institute of Oceanography (CSIR-NIO), Goa (Dr. Suneel Vasimalla, Senior Scientist and Mr. R. A. Sreepada, former senior principal Scientist) visited those oil spill affected sites during 20-22 December 2023, to assess the overall situation arising out of oil spill. After a thorough reconnaissance survey of the affected areas, discussions were also held with concerned officials of TNPCB, the State Forest Department, the Environment Department, the Wetland Authority and other stakeholders. After a comprehensive assessment of the situation during the field-based survey and considering the damage to the marine ecosystem arising out of oil contamination, the CSIR-NIO team suggested applying biodispersants in the affected water bodies as an effective bioremedial measure for conserving the sensitive ecological niches.

CSIR-NIO is an authorized agency for testing and approving oil spill dispersants and related bioremediation products to combat oil spills along the Indian coast. CSIR-NIO is actively evaluating a few bio-dispersants, specifically Nano Botanical Formulations comprising Alkyl-poly glucosides, Fatty acids, and Botanical extracts, for their effectiveness in bioremediating the oil spilled areas. These “green” dispersants are preferred because they are non-toxic, made from naturally available or renewable materials, and are non-volatile. Hence, ‘Green Dispersants (Biodispersants) serve as environmentally benign alternatives to traditional synthetic chemical dispersants, specifically for bioremediating oil spills in ecosystems to achieve maximum environmental benefits. To date, the results obtained from a wide range of

laboratory tests carried out by CSIR-NIO have shown that such bio-dispersants have a high degree of oil dispersion potentials due to their characteristic in forming a reasonably stable oil emulsions for different varieties of crude oil at different salinity levels (10 to 30 ppt) with low toxicity profile. Furthermore, these biodispersants have shown significantly high bioremediation potentials in rapidly depleting the levels of total petroleum hydrocarbons within a short time frame in oil-contaminated soils (NIO/TSP-xxx/2024; TSP3241).

After a careful assessment of the affected sites and local aquatic ecosystems of the intertidal areas, mangrove belts, wetlands, etc., a suggestion was made to TNPCB to apply such bio-dispersants to bioremediate oil-contaminated sites on a trial basis. With the approval of the concerned authorities, 10 litres of one such concentrated Biodispersant comprising of Alkyl-poly glucosides, Fatty acids, and Botanical extracts were sprayed at a few selective oil-spill affected areas after being diluted 10 times with seawater) on a trial basis on 20 December 2023 in the presence of TNPCB and CPCL officials.

After witnessing the results of the trial application of biodispersant and follow-up extensive discussions with the concerned officials, the Chairperson, TNPCB, requested CSIR-NIO vide letter Nos T6/TNPCB/F.12753/RL/2023 dt. 22/12/2023 & T6/TNPCB/F.12753/RL/2023-1 dt. 22/12/2023 to submit the work proposal for the application of biodispersant products at 04 designated locations in the oil spill contaminated area. It has also been decided that 03 sites in the oil-affected area would be allowed for systematic application of Biodispersant, and 01 site would serve as a control (with no Biodispersant application) on an emergent basis. The geographic locations of 03 Treatment Sites (T1, T2 and T3) and the Control Site (C) are presented in Table 1 and depicted in Fig 2.

Following the request from TNPCB, CSIR-NIO was proposed to conduct post-treatment monitoring works (over a certain period of time) to assess the effectiveness of the herbal Nanotech Bio-dispersant. Thus, the scope of the proposed work includes (a) the application of dispersants at the designated sites identified by TNPCB for the treatment of the oil spillage, (b) the assessment of specific environmental parameters, including the quantification of Total Petroleum Hydrocarbons (TPHC) in Ennore Creek Water surficial sediment at fixed intervals (b) to impart training of TNPCB officials at CSIR-NIO.

## **2. Scope of the proposed study**

The primary purpose of the proposed study is to conduct a comparative assessment of seawater and sediment quality parameters at 04 sites before and after bio-dispersant treatment. The results of these field-based studies would help evaluate the effectiveness of 'Herbal Nanotech Biodispersant' in bioremediating oil spillage areas with maximum environmental benefits. The following parameters were studied to monitor the water and sediment qualities during pre- and post-treatment sessions at both control (Site 'C') and treatment sites (T1, T2 & T3).

### **Water quality parameters:**

1. Total Petroleum Hydrocarbons (TPH)
2. Dissolved Oxygen (DO.)
3. Biochemical Oxygen Demand (BOD)
4. Chlorophyll-*a*
5. Total Bacterial Counts (TBC)
6. Total Viable Counts (TVC)

### **Sediment quality parameters:**

1. Total Petroleum Hydrocarbons (TPH)

2. Total Bacterial Counts (TBC)

3. Total Viable Counts (TVC)

## ***2.2. Objectives of the proposed work***

The overall objectives of the proposed work are:

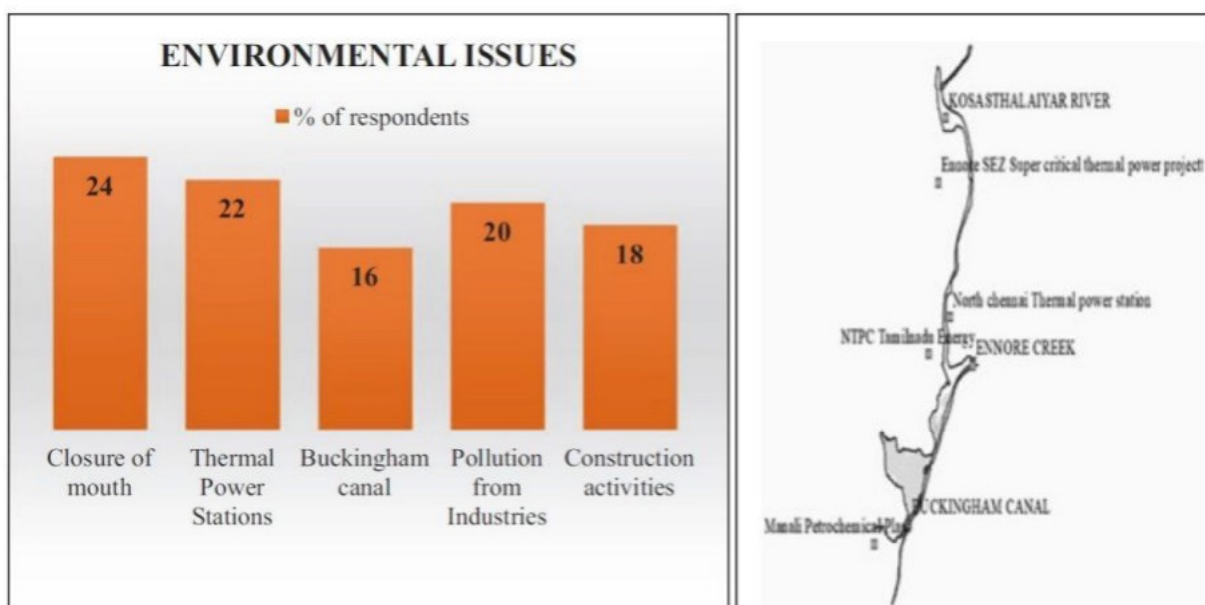
- (i) To carry out a comparative assessment of the environmental benefits of Herbal Nanotech Biodispersant Treated and Control sites by regular monitoring of key water and sediment quality parameters and quantification of total petroleum hydrocarbons (TPH).
- (ii) To train 03 TNPCB scientists/officials on water quality analysis, quantification of bulk petroleum hydrocarbons, bacteriology, oil spills and their management etc.

## **3. Methodology**

### ***3.1. Description of study area***

Ennore Creek is located on the northeast coast of Chennai, Tamil Nadu, India. It is located between 13°16' and 13°26'N latitudes and between 80°24' and 80°35'E longitudes. The southern branch of the Creek is well-developed with industries, utilities, residential areas and fishing hamlets. The Creek supports the livelihood of thousands of fishermen's families in the adjacent villages and sustains the traditional fishermen's community (Krishnaveni et al., 2023). The northern section of the Creek or Kosastalaiyar backwater is connected to the Ennore Thermal Power Station (ETPS), Ennore Port and Petrochemical industries (Kannan et al. 2007). The Creek is highly polluted due to mixing domestic sewage, various industrial effluents from the industrial belt, and coolant water discharge from the ETPS (Krishnaveni et al. 2023). The magnitude of various environmental issues affecting the Creek ecosystem highlighted by Krishnaveni et al. (2023) are depicted in Fig. 1. It is almost 800m long and elongated in a NE-SW direction. Ennore Creek merges with the backwater bodies and the north-south trending

channels connecting to Pulicat Lake in the north and to the tributaries of Kortalaiyar River in the south (Jayaprakash et al. 2014).



**Figure 1.** Various Environmental Issues affecting Ennore Creek based on a survey. (Picture courtesy: Krishnaveni et al. 2023).

### 3.2 Environmental settings of the study region

The meteorological conditions around Ennore Creek exhibit minimum air temperatures ranging between 20°C and 28°C, and maximum temperatures vary within the range of 28°C and 37°C. The Creek is also influenced by strong winds during the southwest (SW) and northeast (NE) monsoons. This region mainly receives rainfall from the NE monsoons during October-November. The Creek was once endowed with rich biodiversity, but in due course, it has been reduced drastically due to the impacts of the release of untreated/partially treated effluents from thermal power plants and petrochemical industries into the Creek ecosystem (Subathra et al. 2013). The Creek is also connected to the Buckingham Canal (part of the National Waterway 4 (NW-4), which originates in the Godavari district of Andhra Pradesh and runs parallel to the coastline up to Villupuram District of Tamil Nadu.

### 3.2. Sampling strategies

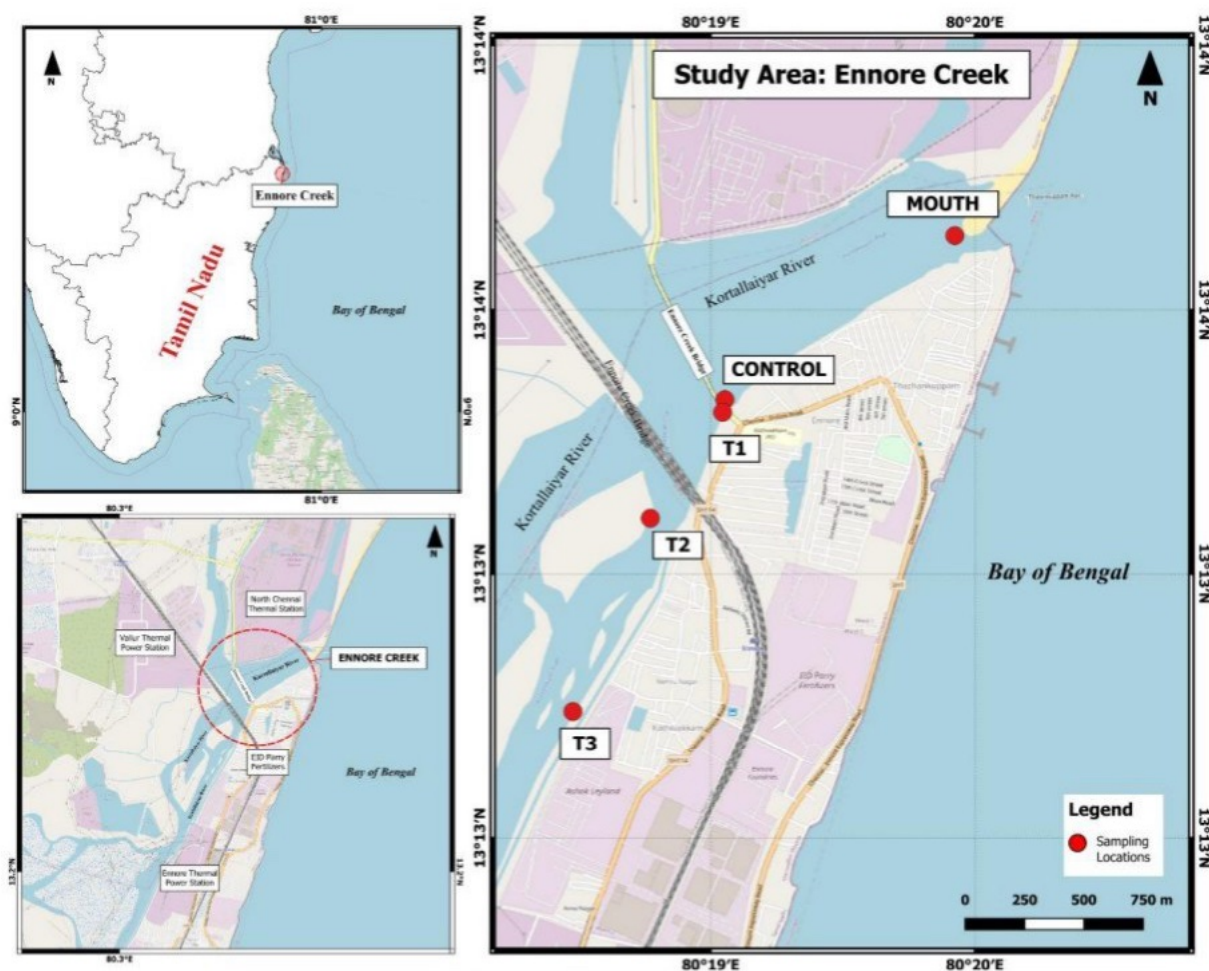
For this pilot study, 04 oil contaminated sites were identified (Table. 1 and Fig. 2) to collect water and sediment samples. At those stations, the first set of field sampling (i.e., pre-treatment sampling) was undertaken by the collaborative team comprising members from CSIR-NIO, TNPCB and Chennai Petroleum Corporation Limited (CPCL) between 09 and 11 January 2024 before applying any dispersant. Then CPCL facilitated the procurement of a 1000-litre Concentrated Herbal Nanotech bio-dispersant that was applied after proper dilutions at 03 treatment sites (e.g. T1:300 Lt, T2:300 Lt and T3:400 Lt) on 10 January 2024 (Fig. 3). One of those 04 contaminated stations was designated as the Control station (Table 1 and Fig. 2) where no dispersant was applied. After the application of biodispersant through a fine jet spray, 03 more sets of post-treatment samplings for water and sediment quality assessment was carried out at 05 sampling sites (3 treatment sites, 01 control and Mouth) at the time intervals of 10, 25 and 40 days post Biodispersant application. The details of those sampling stations are mentioned in Table 1. During each sampling occasion, the surface seawater and surface sediment at those 05 designated sites (e.g. Mouth (M), Control (C), T1, T2, and T3) (Fig. 3) was collected by following the standard methods.

**Table 1.** Locations of sampling stations and dates of 4 sampling sessions

Sampling sites	Latitude	Longitude	Sampling1	Sampling2	Sampling3	Sampling4
	(N)	(E)	BDA	ADA		
Mouth (M)	13°23' 28.75"	80° 32' 92.26"	09.01.24	20.01.24	05.02.24	20.02.24
Control (C)	13°13' 35.74"	80° 19' 13.93"	09.01.24	20.01.24	05.02.24	20.02.24
T1	13°13' 58.10"	80° 19' 45.27"	09.01.24	20.01.24	05.02.24	20.02.24
T2	13°13' 19.59"	80° 19' 04.76"	09.01.24	20.01.24	05.02.24	20.02.24

T3	13°12' 52.99"	80° 18' 52.58"	09.01.24	20.01.24	05.02.24	20.02.24
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*BDA: Before the Dispersant Application; ADA: After the Dispersant Application*



*Figure 2. Map showing the study area and sampling stations along Ennore Creek.*

Water samples were collected by using a pre-cleaned Niskin water sampler, while sediment samples were collected with a mini-core sampler. All sample collections were performed from a fishing dinghy provided by CPCL, Chennai. Figure 4 shows a few glimpses of the sampling activities at different sites along Ennore Creek. The complete details of the field sampling have been mentioned in the following section.

### 3.3. Field data collection, subsampling and preservation of water samples

#### 3.3.1. Sensor-based monitoring of physiochemical parameters in surface water

At each sampling site, initially, measurements of key water quality parameters were made using an electronic sensor-based Water Quality Analyser attached to a probe fitted with multiple sensors (Model: U53/HORIBA). A key physiochemical parameters such as temperature, salinity, turbidity, pH and total dissolved solids were measured *in situ* by deploying that probe in the surface water. After sensor-based measurements, the water samples for other analytical parameters were collected.



**Figure 3.** Application of bio-dispersant at selected sites at T1, T2, & T3 on 10 January 2024.



**Figure 4.** Collection of water and sediment samples at different stations by the CSIR-NIO team and TNPCB & CPCL officials.

### ***3.3.2. Dissolved Oxygen (DO)***

For analyses of dissolved oxygen (DO), water samples from the Creek were collected in 100 ml pre-cleaned DO bottles and onboard immediately fixed with Winkler's A (Manganese chloride) and Winkler's B (alkaline potassium iodide) reagents. Immediately, the sample bottles were carefully stopped to prevent the introduction of air and thoroughly mixed. Later, standard iodometric titration with sodium thiosulfate was carried out for subsequent analysis in the laboratory.

### ***3.3.3. Chlorophyll-a in surface water***

A known volume (1000 mL) of surface seawater was collected in sterilized PP bottles and immediately filtered through GF/F filter papers (pore size, 0.7 $\mu$ m). After filtration, the filter papers were stored at 4.0°C in amber-colored tubes till further analysis. In the laboratory, chlorophyll *a* was extracted from filters after overnight extraction in 90% acetone in the dark at 4°C and Chl-*a* was estimated spectrophotometrically following the methods described by Parsons et al. (1984).

### ***3.3.4. Microbiological aspects***

Marine microorganisms occupy the base of the food web and form food for protozoa, invertebrate larvae and many large zooplankton and regenerate dissolved nutrients for marine photosynthesis and the formation of newer organic biomass.

The microorganisms, particularly heterotrophic bacteria, contribute substantially to the ecosystem's productivity. Identifying the role of the bacteria in biogeochemical cycles relies on the simultaneous assessment of their phylogenetic identity and ecological function. Considering that bacteria have significant links to many biological and non-biological events

in the oceans, studies on various groups of bacteria were included in the present study. Surface water samples for microbiological analyses were collected in sterilized PP bottles at each sampling location. All the water samples for microbiological analysis were stored in ice and then transported to the laboratory in an insulated ice box for further analysis.

### ***3.3.5. Total Petroleum Hydrocarbons (TPH)***

Altogether, 19 water samples were collected from five sampling stations (T1, T2, T3, Control and Mouth, Fig. 2) during each sampling occasion at Ennore Creek to analyze water quality parameters, including TPH. Creek water samples from the surface (< 0.5 m) were collected by using a Niskin's water sampler and transferred the sample to the pre-cleaned (with distilled water followed by the methanol, acetone and hexane) and oven-dried (50 °C) 1.0 Lt amber coloured glass bottles. Then, collected samples were fixed with 1.0 ml of HPLC grade n-hexane on-site and stored at 4°C till further processing. In the laboratory, TPH from water samples were extracted within 7 days after collection.

### ***3.4. Sampling of surficial sediment***

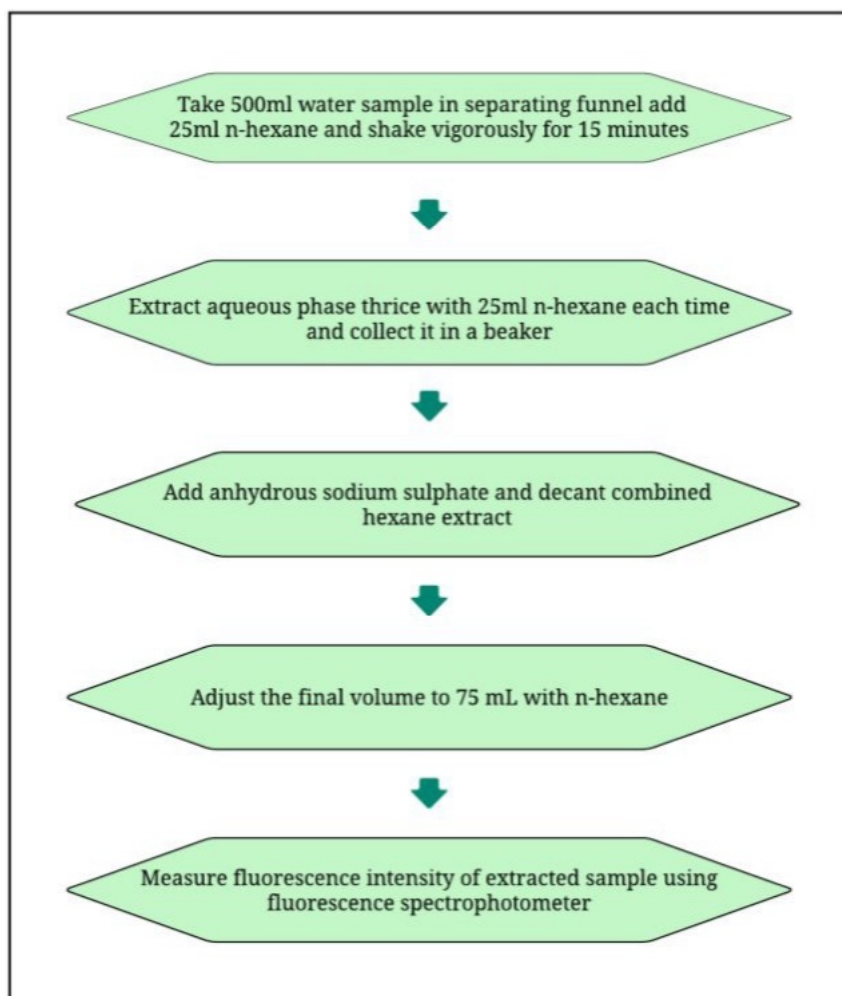
Altogether, 20 surficial sediment samples (top 2.0 cm layer of sediment ) were collected at sites T1, T2, T3 and C using a mini acrylic core sampler during the course of the study. The sediment samples at a relatively deeper site, M, were collected using a van Veen Grab. Immediately after collection, a small portion of each sediment sample was aseptically transferred into fresh polythene bags using a sterile spatula before sediment samples were collected for other analyses.

Then, the rest of each sediment sample was carefully transferred into separate zip-locked polythene bags and stored at 4.0°C for TPH analyses. All these sediment samples were processed within 10 days of collection. Immediately after collection, a part of each sediment sample was stored in ice in an insulated icebox. Those samples were transported to the laboratory for analyses of microbiological and other parameters.

### *3.5. Processing of sediment samples and laboratory analyses*

#### *3.5.1. TPH content in the water sample*

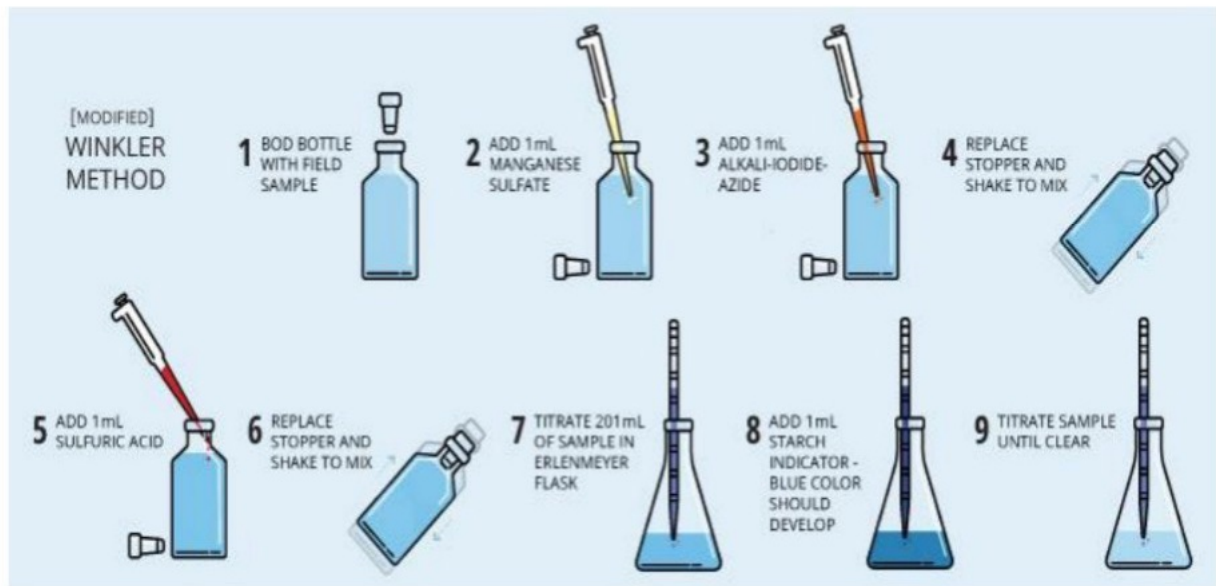
The total petroleum hydrocarbon content in the water samples was extracted in triplicates with HPLC grade n-hexane following the standard method described in IOC-UNESCO (1984). Briefly, 500 mL of each water sample was taken in a glass separating funnel, and then 25 mL of HPLC grade n-hexane was added. The mixture was vigorously shaken for 15 minutes and allowed to stand for 10 minutes. After that, the organic phase was separated out in a pre-cleaned glass beaker. A similar extraction process was repeated two more times. In the combined n-hexane extracts (organic phase), anhydrous sodium sulfate was added to absorb the residual moisture. The petroleum hydrocarbon concentrations in those extracted samples were determined using fluorescence spectroscopy (Model: Shimadzu, RF5301PC). The fluorescence of the samples was measured at an emission wavelength of 360 nm (excitation wavelength 310 nm). All blanks, standards and samples were measured in a Teflon-capped 1cm silica fluorescence cell under identical instrumental settings and conditions. Fluorescence of Chrysene calibration standards was measured similarly to quantify the TPH in the samples, and the TPH data in water samples were expressed in terms of Chrysene equivalents. The fluorescence of HPLC grade n-hexane was almost negligible, and the same was used for blank corrections. All fluorescence readings were taken in three replicates, and the average values were used to estimate the TPH concentration. The complete methodology is illustrated in the flow chart shown in Fig. 5.



*Figure 5: Flowchart illustrating the steps involved in the estimation of TPH in water samples.*

### ***3.5.2. Dissolved Oxygen in water sample***

The water sample's dissolved Oxygen (DO) content was analyzed using Winkler's titration method. In the laboratory, the fixed DO sample of each bottle was dissolved by adding 2.0 ml of concentrated sulfuric acid. The sample bottle is then resealed with the stopper and thoroughly mixed to dissolve the precipitate completely. Then 100 ml of dissolved sample was pipetted in a flask and titrated against 0.025(N) standardized sodium thiosulfate solution using starch solution as indicator. The DO values in water samples are presented in terms of mg/L.



**Figure 6:** Schematic Diagram of the Steps in the Winkler's Method for DO analysis (Picture courtesy: Internet)

### 3.5.3. Chlorophyll-a in the water sample

In the laboratory, to estimate the total chlorophyll, 10 ml of 90% acetone is initially added to the tubes containing filter papers and then extracted at 4.0°C in the dark overnight. After incubation, the samples were centrifuged at 5000 rpm to remove the remains of filter paper from the sample and get a clear solution. The photometric absorbances of solutions were measured at 664, 647, and 630nm wavelengths using a spectrophotometer. Based on absorbance values, the chlorophyll-a content in seawater samples was estimated by using the following empirical relations (Parsons et al., 1984).

$$\text{Chl-a } (\mu\text{g/L}) = (11.85 \times E_{664}) - (1.54 \times E_{647}) - (0.08 \times E_{630})$$

$$\text{Chlorophyll-a in seawater (mg/L)} = [\text{Chl-a} \times 10] / 1000 \times L$$

In which:

L = Light path of cuvette, cm

E<sub>664</sub> = Value of absorbance at wavelength 664 nm

E<sub>647</sub> = Value of absorbance at wavelength 647 nm

E<sub>630</sub> = Value of absorbance at wavelength 630 nm

### **3.5.4. Total Bacterial Counts (TBC)**

#### **(A) Water Samples**

For estimation of total bacterial counts (TBC), 50 ml of the water sample was collected in a scintillation vial, and 1.0 ml of filtered sterilized formalin was added to each scintillation vial to preserve the sample (Hobbie et al., 1977). Then, the vials were stored at 4.0°C. Later in the laboratory, samples were stained with a DNA staining fluorochrome dye 4, 6 - diamidino-2-phenylindole (DAPI) at a 1.0 mg/ml concentration for 20 minutes. After that, using a UV filter set, an Olympus Epifluorescence Microscope was used to count those fluorochrome-stained bacterial cells at an excitation wavelength of 365 nm. The bacterial counts in water samples were expressed in the number of cells/ml.

#### **(B) Sediment samples**

1.0 gm of sediment samples were taken and fixed with formalin in the vial. Then, the vials with preserved sediment were stored at 4.0°C, and later, using the same method explained above, they were analyzed for TBC in the laboratory.

### **3.5.5. Total Viable Counts (TVC)**

#### **(A) Water Samples**

For viable bacterial counts, samples were diluted as per requirement, and then those samples were spread-plated (0.1 ml) on Zobell Marine Agar (Hi-media) media. Those media were incubated at (30 ±2°C) for 1-2 days. The bacterial colonies developed within that media were counted, and the final results were presented in cells/ml.

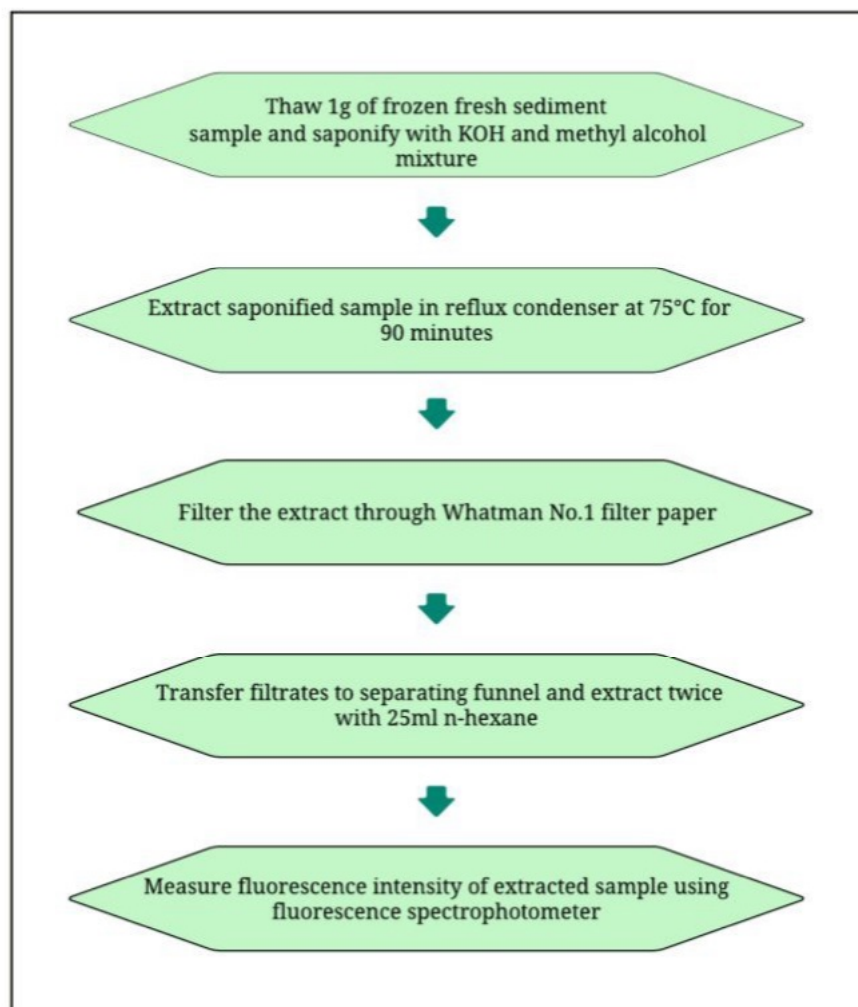
#### **(B) Sediment Samples**

1.0 gm of the sediment sample was suspended in 9.0ml of autoclaved seawater using a sterile 5.0 ml syringe. The suspension was vortexed for two minutes. The sediment was then allowed

to settle, and serial dilutions were carried out by serially transferring 1 ml of the sample to 9.0 ml autoclaved seawater. Then 0.1 ml of the sample was spread plated onto Zobell marine agar plates and incubated at  $(30 \pm 2^\circ\text{C})$  for 1-2 days.

### 3.5.6. TPH in the sediment sample

Samples were extracted, purified, and analyzed according to the methods established by IOC-UNESCO (1984). Thawed frozen fresh 1g of sediment samples were saponified using a KOH-methanol mixture. The resulting saponified samples were extracted in a reflux condenser at  $75^\circ\text{C}$  for 90 minutes, then by cooling to room temperature and filtration through Whatman No. 1 filter paper.



**Figure 7:** *Flowchart illustrating the steps involved in the extraction and estimation of TPH in sediment samples*

The filtrates were transferred to a separating funnel and extracted twice with 25 mL of n-hexane. Subsequently, the fluorescence intensity of the extracted sample was measured using a fluorescence spectrophotometer with emission at 360 nm and excitation at 310 nm. The n-Hexane was used as the solvent blank, and chrysene was employed as the calibration standard, resulting in the expression of the results in terms of chrysene equivalents.

## 4. Results

### 4.1. Key water quality parameters

All the water quality data measured with the water quality probe are presented in Table 2. The key water quality measurements made by sensor-based on showed that parameters like salinity, turbidity, and TDS showed large variations during each sampling session at different sampling sites. Irrespective of sampling sessions, the salinity showed higher values at the Mouth station (up to 32 ppt), which gradually dropped at other stations towards upstream (up to <1.0 ppt) (Table 2). Likewise, the TDS values showed similar trends along those sampling stations with higher values towards the Mouth station (M). This indicates a substantial flux of low-saline wastewater (flowing through Bakinkham Canal and Ennore Creek) mixed with high-saline coastal water in the study area. Such an extensive mixing process was further supported by a relative increase of pH in water towards the Mouth. In contrast, the spatial distribution of turbidity showed an opposite trend, with lower values recorded towards downstream, indicating more suspended matter load in the Canal and Creek waters. All these trends in measured water quality parameters were consistent during all sampling sessions.

**Table 2:** Data on key water quality parameters measured using water quality during different sampling sessions.

	<b>Location</b>	<b>Temperature (°C)</b>	<b>pH</b>	<b>TDS (g/L)</b>	<b>Salinity (ppt)</b>
<b>Sampling - 1</b>	<b>C</b>	30.9	8.05	9.03	8.34
	<b>M</b>	28	7.5	10.1	10
	<b>T3</b>	29.99	6.26	0.655	0.60
<b>Sampling - 2</b>	<i>Probe data is not available</i>				
<b>Sampling - 3</b>	<b>C</b>	33.5	7.83	14.8	14.37
	<b>M</b>	35.75	8.45	30.1	32.233
	<b>T1</b>	31.83	7.87	13.1	12.65
	<b>T3</b>	33.06	7.92	6.68	6.04
<b>Sampling - 4</b>	<b>C</b>	33.37	8.01	21.0	21.60
	<b>M</b>	35.73	8.26	28.6	30.4
	<b>T1</b>	34.47	7.69	18.7	19.01
	<b>T3</b>	33.96	8.95	10.2	9.58

Dissolved oxygen refers to the amount of oxygen dissolved in water, which is vital for the survival of aquatic organisms. Generally, the DO value in coastal waters varies depending on temperature, salinity, pressure, productivity, degree of contamination etc. In our present study, the estimated DO values in surface water at different stations of the study area were widely variable, ranging from almost below the detection level to 8.0 mg/l (Table 3). Similar to other water quality parameters, spatial variation of DO during each sampling session could be attributed to the magnitude of wastewater influx (through the Backinhagm canal) into the study area during the sampling period. A higher influx of dark-coloured sewage during low tides causes extreme depletion of DO, demarking hypoxic conditions, while it reverts back to an oxic condition when the site gets flooded with more seawater during high tides.

**Table 3:** Variation of Dissolved Oxygen in surface water around the study area.

Sampling site	Dissolved oxygen (mg/L)			
	Sampling 1	Sampling 2	Sampling 3	Sampling 4
<b>C</b>	2.29	2.84	1.08	NA
<b>M</b>	0.95	6.75	8.09	NA
<b>T1</b>	0.54	6.75	1.05	NA
<b>T2</b>	2.16	BD*	0.12	NA
<b>T3</b>	4.46	4.73	0.51	NA

\*BD: Below detection; NA: Not Analysed

Finally, it has been noticed that most of the above-mentioned measured water quality parameters, particularly pH, DO, and turbidity, vary within specific ranges in surface water and have not altered much before or after bio-dispersant treatments. Therefore, it can be presumed that the application of Bio-dispersants had no negative impacts on key water quality in the study area impacted by the oil spill.

The concentration of chlorophyll-*a* in the water samples collected from the 05 stations during different sampling sessions is presented in Table 4. The chlorophyll-*a* concentrations, as indicative of primary productivity, showed ranges of 1.33 to 5.87 mg/m<sup>3</sup> (date), 2.54 to 10.30 mg/m<sup>3</sup> 14.54 to 23.93 mg/m<sup>3</sup> (date), and 0.82 to 5.16 mg/m<sup>3</sup> (date). The measured chlorophyll-*a* concentrations were significantly increased progressively during post-treatment sessions (ADA) (i.e., sampling 2 and 3) at stations T1, T2, and T3 compared to those found at the control station. The significant increase in chlorophyll levels at stations T1, T2, and T3 during samplings 2 and 3 with the progressive samplings ADA compared to the control station indicates the enhanced phytoplankton activity, likely driven by favourable environmental conditions and possibly a reduction in TPH levels. This suggests that these stations provided favourable environmental conditions supporting phytoplankton proliferation and growth during the observation period. This is again a positive sign that the environment is recovering after the application of Biodispersant.

**Table 4:** Variation of chlorophyll-*a* (mg/m<sup>3</sup>) in surface water around the study area.

Stations	Sampling 1	Sampling 2	Sampling 3	Sampling 4
<b>C</b>	5.87	6.86	14.54	2.71
<b>M</b>	4.80	2.54	23.93	0.82
<b>T1</b>	2.80	7.69	16.97	3.56
<b>T2</b>	1.39	2.86	17.45	1.71
<b>T3</b>	1.33	10.30	18.45	5.17

#### 4.2. Variation of microbiological parameters in surface waters

Bacterial abundance measured in terms of Total Bacterial Count (TBC) and Total Viable Count (TVC) are commonly used to assess the microbial load in environmental samples. Monitoring TBC and TVC in any polluted water body provides critical information on the abundance of microbial species.

##### 4.2.1. Total Bacterial Counts (TBC)

The total bacterial counts of bacteria in the surface waters ranged from 1.22 to  $5.67 \times 10^5$  during sampling-1 before the dispersant application (BDA). However, the TBC ranged from 1.72 to  $4.31 \times 10^5$ , 1.67 to  $4.39 \times 10^5$ , and 1.44 to  $5.20 \times 10^5$  during 2, 3, and 4 samplings (ADA), respectively, indicating a slight increase in the lower limit of the count ADA. This increase is also seen in the control station, wherein the counts have increased nearly 2.5 times more than those at sampling 1 to 3, suggesting a natural increase. Whereas in sediments, the counts ranged from 0.85 to  $1.145 \times 10^7$  during sampling-1 before the dispersant application (BDA). The counting ranges for samplings 2, 3, and 4 are 0.65 to  $1.67 \times 10^7$ , 0.70 to  $1.36 \times 10^7$ , and 0.81 to  $1.49 \times 10^7$  respectively, indicating that the sediment recorded higher TBC compared to the sampling 1 (BDA) (Table 2). Though a slight increase is observed in the control station, the increase in counts in the stations T1, T2, and T3 are more significant (Table 2).

The observations from the sampling data suggest a relationship between bacterial load and Total Petroleum Hydrocarbons (TPH) levels at the T3 station. Here's a refined explanation of the findings: During sampling 2, the T3 station exhibited a higher bacterial abundance. This bacterial abundance then decreased in sampling 3, only to rise again in sampling 4. This fluctuation in bacterial populations may correlate with the observed reduction in TPH levels at the T3 station. The plausible explanation is that conditions became more favourable for bacterial growth due to the reduction in TPH levels post-application of Biodispersant. It has been documented that petroleum hydrocarbons can be toxic or inhibitory to many bacterial species; thus, a reduction in TPH could lower toxicity and provide an improved environment for the proliferation of bacterial communities. Additionally, certain bacteria can utilize hydrocarbons as a carbon source, indirectly contributing to the degradation of TPH, and as TPH levels drop, these bacteria might flourish due to the increased availability of other nutrients or reduced competition.

In summary, the data suggests that the decline in TPH at the T3 station likely created conditions conducive to bacterial growth, leading to the observed fluctuations in bacterial load across different samplings. This indicates a dynamic interaction between TPH levels and microbial populations, where the reduction of TPH possibly facilitated an environment that supported bacterial proliferation. Thus, the results suggest that sediments might have recovered from the oil spillage ADA. Such results are not seen in the water sample counts. The counts in the water samples are relatively less than the sediment counts. This may be because the surface waters are more dynamic due to the influence of flood and ebb tide in Ennore Creek.

**Table 5:** Variations of Total Bacterial Counts (TBC) in surface water

Sampling sessions	Stations	Total bacterial Count of Bacteria (TBC)	
		Seawater ( $\times 10^5$ CFU/ml)	Sediment ( $\times 10^7$ CFU/g of dry wt.)

Sampling 1	C	1.63	1.01
	M	1.22	-
	T1	5.67	1.14
	T2	2.35	0.84
	T3	2.30	0.13
Sampling 2	C	4.31	0.90
	M	2.83	-
	T1	1.72	0.65
	T2	1.86	1.41
	T3	2.17	1.67
Sampling 3	C	4.39	1.36
	M	2.84	-
	T1	1.67	0.93
	T2	1.85	1.10
	T3	2.17	0.70
Sampling 4	C	1.44	1.49
	M	5.20	-NA
	T1	1.45	1.16
	T2	2.67	0.81
	T3	Sample lost	1.43

#### 4.2.2. Total Viable Colony Counts (TVC)

Total Viable Counts (TVC) in the seawater and sediment samples collected from the 5 stations in the study region are presented in Table 3. Total counts in the surface waters ranged from 0.0001 to  $0.003 \times 10^5$  during sampling 1 (BDA) and ranged from 0.0014 to  $0.04 \times 10^5$ , 0.0179 to  $0.97 \times 10^5$  CFU/ml, 0.0002 to 0.0029 during samplings 2, 3 and 4, respectively. Whereas in sediment, the counts ranged from 0.37 to  $9.40 \times 10^5$  during sampling 1, in which the control station contained the highest  $9.40 \times 10^5$  CFU/ml. But the counts ranged from 4.90 to  $13.40 \times 10^5$ , 0.154 to  $0.209 \times 10^5$ , 0.59 to  $1 \times 10^5$  CFU/g of dry wt., respectively, for samplings 2, 3, and 4, indicating that the counts are significantly lower than the control station during samplings 3 and 4 (ADA). However, a significant increase in counts was observed during sampling 2, ten

days post dispersant application at stations T1 and T3. This increase in counts is a clear indication of ecosystem recovery. Overall, the TVC counts in the sediments were relatively higher in the 1-2 order magnitude than those retrieved from the water column.

**Table 6:** Variations of Total Viable Counts (TVC) in surface water

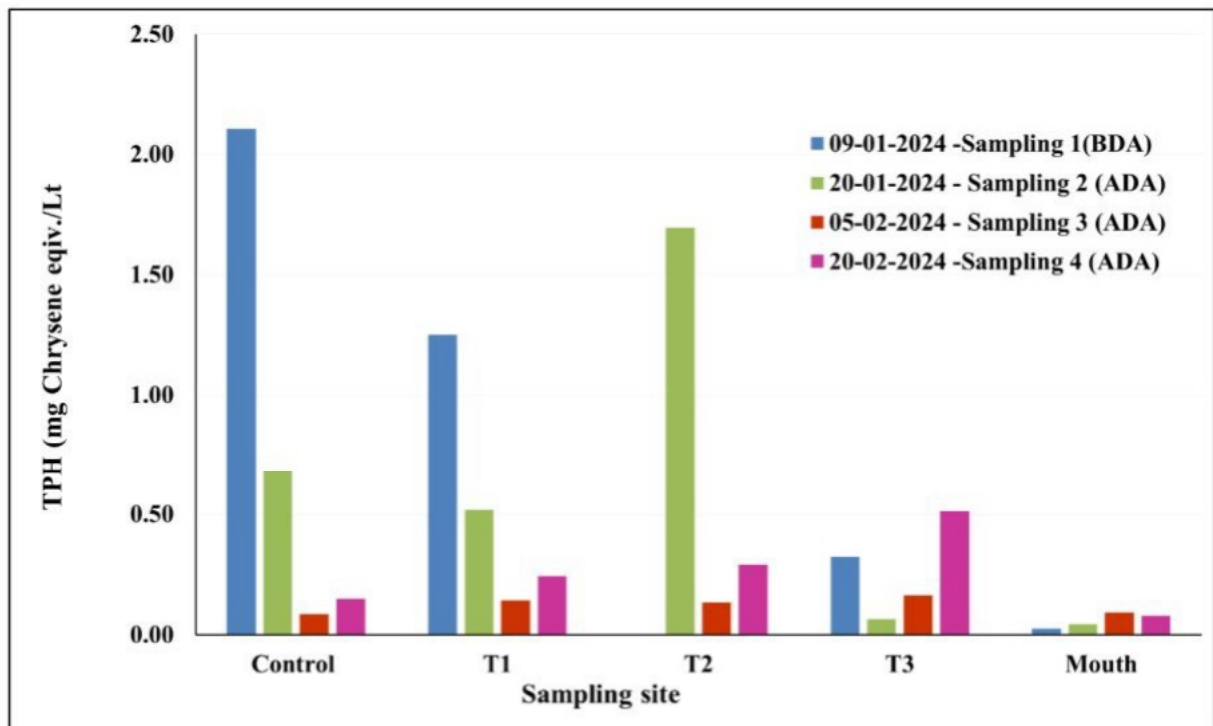
Sampling sessions	Stations	Total Viable Count (TVC)	
		Seawater ( $\times 10^5$ CFU/ml)	Sediment ( $\times 10^5$ CFU/g of dry wt.)
Sampling 1	C	0.0016	9.10
	M	0.003	-
	T1	0.0001	0.37
	T2	0.0017	0.45
	T3	0.00231	9.40
Sampling 2	C	0.0198	13.10
	M	0.04	-
	T1	0.0014	13.40
	T2	0.0253	4.90
	T3	0.0264	11.70
Sampling 3	C	0.097	0.154
	M	0.061	-
	T1	0.022	0.209
	T2	0.0179	0.158
	T3	0.071	0.207
Sampling 4	C	0.0002	NA
	M	0.0004	-
	T1	0.0014	0.61
	T2	0.0029	0.79
	T3	0.0011	0.59

TVC in the range from  $1.0 \times 10^1$  to  $17.9 \times 10^3$  CFU/ml in water sample and from  $0.154 \times 10^5$  to  $13.40 \times 10^5$  CFU/gm/dry wt. in sediments were recorded during the present study. The counts recorded in the present study are within the normal values recorded for similar coastal waters along the east and west coast of India.

### 4.3. Total Petroleum Hydrocarbons (TPHs)

Petroleum hydrocarbons are complex mixtures of aliphatic and aromatic compounds and the major constituents of gasoline, crude oil, lubricating oils, fuel oils, mineral oils, solvents, and mineral spirits. Among those organic compounds in petroleum hydrocarbons, some are highly toxic and may produce deleterious impacts on living organisms. They degrade very slowly in the natural environment; therefore, any such petroleum products are considered pollutants of potential concern in the environment (Kostka et al., 2020).

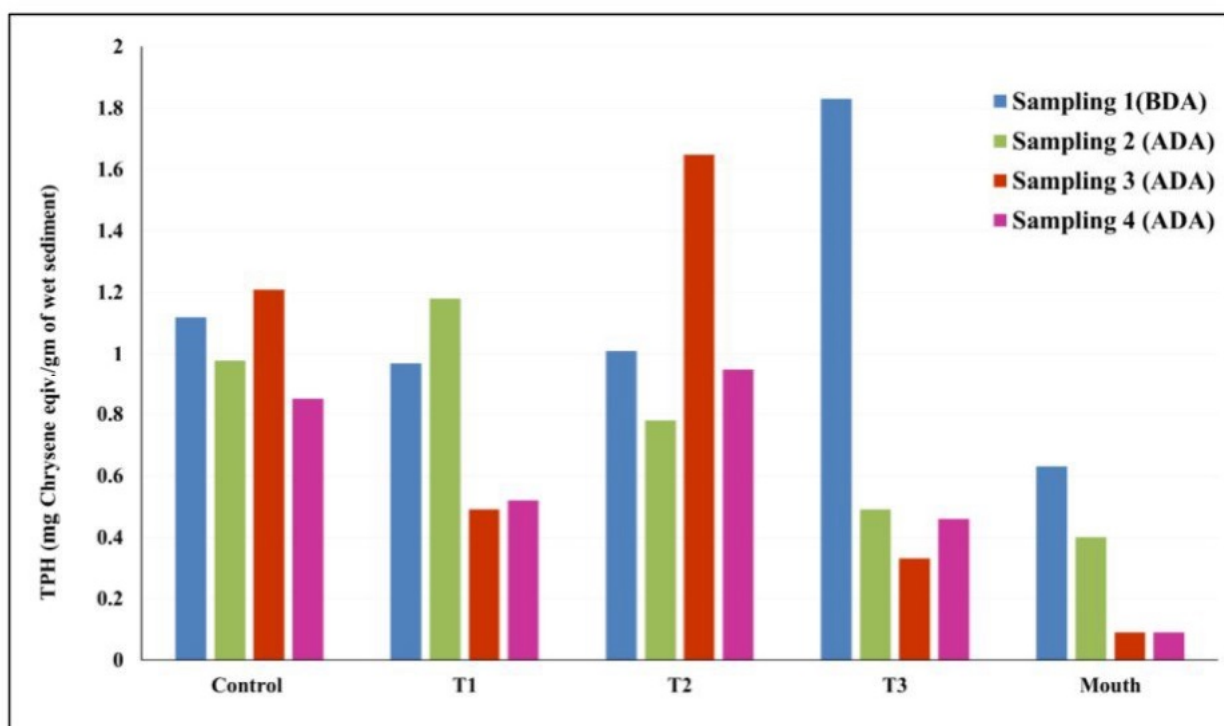
During the first sampling (i.e., before the application of the dispersant), the estimated TPHs in the surface water samples around the study area were 2.11 mg/L, 1.25 mg/L, 0.32 mg/L, and 0.025 mg/L at C, T1, T3, and M stations, respectively (Fig. 8). No samples were collected at T2 due to extreme low tide during the first sampling.



**Figure 8.** Distribution of TPH in water samples of 05 sampling sites during four consecutive field samplings.

The water in the control and T1 stations was slightly more contaminated than at stations T3 and Mouth before the dispersant application. Whereas during the post-treatment session during sampling 2 (i.e., after application of dispersant on the sediment), the degree of oil contamination among all the stations dropped down to the range between 0.044-1.69 mg/L during sampling 2; 0.09-0.16 mg/L during sampling 3 and 0.07-0.51 mg/L during sampling 4 (Fig. 8).

Like the TPHs in water, the estimated bulk petroleum hydrocarbon contents in the sediment samples collected from oil spilled sites showed a wide range of values ranging from 0.63 to 1.83 mg/g (Fig. 9) before applying the Biodispersant. The highest oil accumulation on surface sediment was recorded at station T3, followed by control site C. During sampling sessions 2, 3, and 4, after the Biodispersant application, the TPH values ranged from 0.4 – 1.18 mg/g, 0.09 – 1.65 mg/g, 0.09 – 0.95 mg/g respectively (Fig. 9).



**Figure 9.** Distribution of TPHs in surficial sediment of 05 sampling sites during 04 sampling sessions.

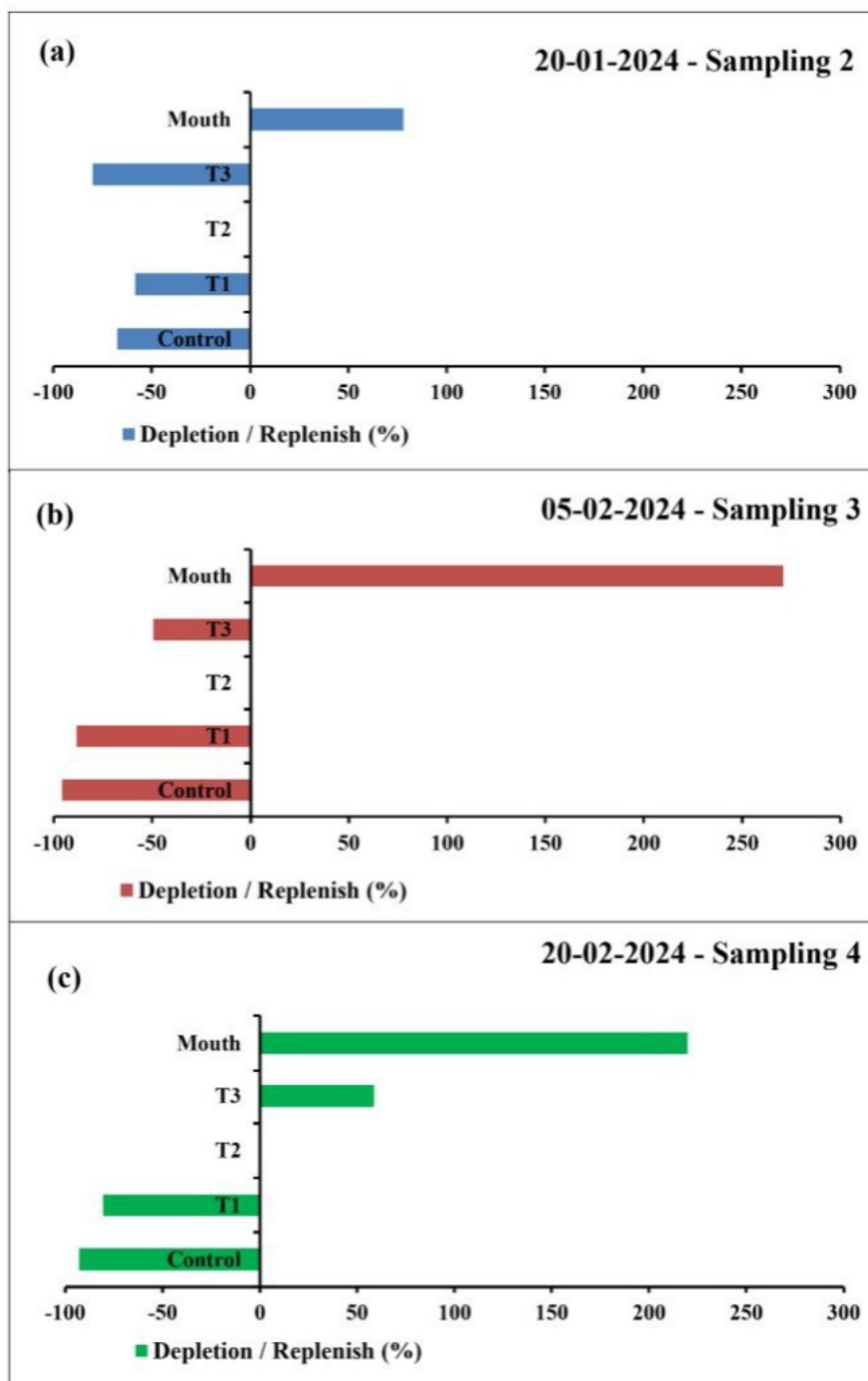
#### *4.4. Relative percentage depletion of TPHs in water and sediment with time*

For a better understanding of the influence impacts of Biodispersant on the degradation of petroleum hydrocarbons, the relative depletion of TPHs (in percentage) has been evaluated from the concentrations of TPH recorded for results found during sampling sessions 2, 3, and 4 (i.e., after application of dispersant) with reference to the value of the concentration recorded prior to application of before applying Biodispersant (during sampling 1). Sampling 2 corresponds to 10 days after the application of Biodispersant. Similarly, Samplings 3 and 4 correspond to after 25 days and 40 days post-application of Biodispersant, respectively. Both water and sediment samples were collected from those same locations during each sampling session.

##### *4.4.1. Relative depletion of TPH in water samples*

The status of TPHs 10 days post application of Biodispersant (sampling 2), seems to have reduced by 67%, as depicted in the water samples of the control station. Such a significant drop in the concentration of TPHs in surface water at the control site could be due to the effects of natural processes, including dispersion, dilution, and precipitation of oil components, over the period. However, the TPHs of the water sample at station T1 (58%) do not show a depletion percentage as high as the control station, indicating that the applied Biodispersant does not seem to have an efficient impact on the TPH content in water. Meanwhile, the TPHs at station T3 depleted by 80%, which is 13% higher than the natural dispersion of the control site. This data suggests that the higher depletion at the T3 station could be attributed to Biodispersant application. However, very surprisingly, during the next two samplings, means sampling 3 and sampling 4, the TPHs were naturally depleted by 92-95% at the control station (C), but no such high depletions were recorded for stations T1 and T3. This 92-95% depletion in TPH concentrations at the control site may be largely due to the tidal influence of the fresh seawater,

which was found to get fully submerged during the high tide (due to proximity of site C to the Mouth compared to the other stations) and thus regular washing off Site C might have contributed to significantly higher depletion in TPH levels.



*Figure 10. Depletion/replenish percentage of TPHs in water samples*

Thus, the Biodispersant sprayed onto the sediments exposed during the low tide apparently did not produce any prominent effects on the oil dispersed in water samples. This is quite possible as the locations T1, T2, T3, and control stations are not far from the river mouth, and robust semidiurnal tides flush the Ennore Creek every 6 hrs intervals. Concomitantly, the dynamic nature of water also discharges increased volumes of pollutants, including oil, from upstream into the study sites as the tide recedes. As discussed in the introduction, the Creek water is getting contaminated with untreated or partially treated domestic sewage, industrial effluents from the industrial belt, coolant water discharge from the ETPS, and various other industrial effluents (Krishnaveni et al., 2023). In addition to these pollutants, the waste oil released into the Buckingham Canal might have increased the overall pollution levels in the water samples, whose impact could have dominated overwhelmingly the positive impacts of the applied Bio dispersant. In addition, the designated areas where Biodispersant was sprayed were not adequately contained by the booms throughout the study, though the booms were installed. Due to the tidal influence, the waters of Biodispersant sprayed areas continuously mixed up with the surrounding waters.

#### ***4.4.2. Relative depletion of TPH in sediment samples***

The TPH depletion percentage among the sediment samples collected during four samplings is illustrated in Fig. 11. It is evident from the second sampling at the control station that the TPHs were naturally depleted by 12.5% within 10 days after the dispersant application. But stations T2 and T3 showed 23% and 73% depletion percentages, respectively. This, in turn, shows a 10% and 60% higher depletion than the control station, indicating that the Biodispersant might have played a role in the higher degree of depletion of TPHs. However, such depletions were not shown in the T1 location. Exciting results were seen in the third sampling (Fig. 11b). The figure shows that the TPHs increased by 8% in the control station.

However, T1 and T3 (dispersant-applied locations) showed a depletion of 49% and 81%, respectively. During the fourth sampling, 40 days after the Biodispersant application, the control station showed only a 24% depletion. Meanwhile, stations T1, T2, and T3 showed 46%, 6%, and 74% depletion in TPH.

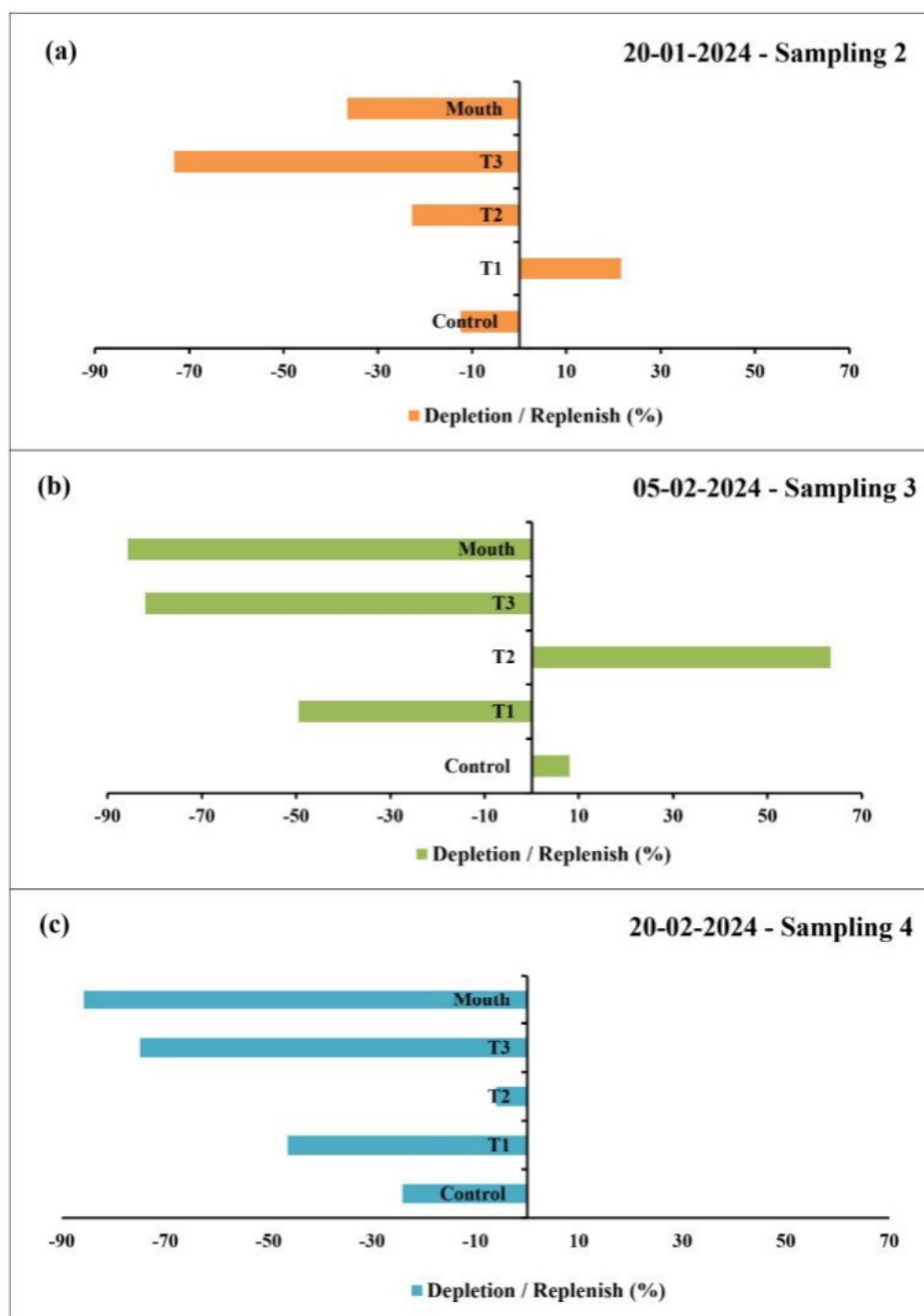


Figure 12. Depletion percentage of TPHs in sediment samples.

Overall, the Biodispersant application at the T2 location did not show any positive impact on the surficial sediments over there. The plausible reason could be that this location is near the Buckingham Canal, from which fresh domestic sewage and other industrial pollutants are continuously entering, which might have further increased the TPH levels in addition to the spilled oil.

### **5. Training on water quality parameters to TNPCB officials**

The TNPCB officials Dr Vasudevan, Dr Venkatesan Perumal and Mrs Rosina Begam visited CSIR-NIO from 12 to 16 March 2024 to attend a training programme. On the first day of the 03-day training programme (i.e., on 13 March 2024), the details of sample processing and analytical techniques for microbial parameters like TVC and TBC were presented at the Biological Oceanography Division.

The second day (14 March 2024) was about the sample processing (water and sediment) and analysis of TPH in water and sediment in the Environmental Forensics Laboratory.

Hands-on training was also provided to quantify the TPH using the Spectrofluorometer. Additionally, training was given on microplastic analysis in water and sediment samples. On the last day, on 15 March 2024, an exclusive training on oil spills, impacts of oil spills on the coastal marine environment, mitigation of oil spills, application of dispersants and bioremediation agents and testing procedures of oil spill dispersants and bio-remediation agents was imparted.

The glimpses of these three days of training are depicted in Fig. 13.



*Figure 13. The snapshots of the TNPCB training programme at CSIR-NIO during 13-15 March 2024.*

## 6. Conclusions

- The CSIR-NIO has undertaken the pilot study. A total of four field samplings were conducted to collect surface water and sediment samples from the select locations. The first sampling was before the application of the bio dispersant (09/01/2024), followed

by samplings after 10 days (20/01/2024), 25 days (05/02/2024) and 40 days (20/02/2024) of post-application.

- The results reveal that the TPHs in water samples initially were in the range of 0.025 to 2.11 mg/L and reduced to 0.07 to 0.51 mg/L by fourth field sampling, i.e. 40 days after the biodispersant is applied.
- The TPH at station T3 reduced from 0.3 mg/L (Before Dispersant Application (BDA)) to 0.06 mg/L (After Dispersant Application (ADA)) during the second sampling, depleted 13% higher than the natural dispersion, which could be due to dispersant application. However, very surprisingly, during the next two samplings, means sampling 3 and sampling 4, the TPHs were naturally depleted by 92-95% at the control station, which could be due to the mixing of fresh seawater due to the tidal actions as this location faces the sea, and may not be due to the natural depletion. It is also possible that due to the continuous cleaning activity in the Creek area, jointly organised by CPCL and TNPCB.
- Overall, the dispersant application seems to have had no significant positive impact on the TPHs present in water samples other than at the T3 location. This is possible since the tidal influence exists every 6 hrs due to the rising and falling of high and low tides in Ennore Creek. Water is dynamic due to tidal influence; freshly added pollutants may enter the water every time, and fresh sea water may cleanse the water during every tidal cycle. Therefore, it is complicated to rely on the results of the water samples.
- Interestingly, the TPHs present in the sediment samples have shown different ranges. Initially the TPH was in the range of 0.63 to 1.83 mg/g (BDA) and reduced to the range of 0.09 to 0.95 mg/g, within 40 days after the biodispersant application. Stations T1 and

T3 showed the highest depletion of 49% and 81%, respectively, on 05 February 2024, 25 days after the dispersant application. The TPH at T1 reduced from 0.97 mg/g (BDA) to 0.49 mg/g (ADA). Similarly at T3 reduced from 1.83 mg/g (BDA) to 0.33 mg/g (ADA).

- During the fourth sampling, 40 days after the dispersant application, the control station showed only a 24% depletion. Meanwhile, the T1, T2, and T3 stations showed 46%, 6%, and 74% depletion. The TPHs at T1 reduced from 0.97 mg/g (BDA) to 0.52 mg/g (ADA). Similarly at T3 reduced from 1.83 mg/g (BDA) to 0.46 mg/g (ADA). Station T2 has shown very little depletion, reducing from 1.01 to 0.95 mg/g ADA.
- The maximum depletion of TPHs (81%) in sediments was observed at the T3 location. The reason could be that an additional 100 litres of dispersant were sprayed at this location. Therefore, even the TPHs of water at this location have shown a significant depletion (13%), but only during sampling 2, immediately after the 10 days of the dispersant application.
- No TPH depletion was observed in the sediments at the T2 location. One plausible reason could be that this station is near the Buckingham Canal, through which domestic and other industrial waste is continuously released into Ennore Creek.
- Based on the observed data for Total Viable Count (TVC), Total Bacterial Count (TBC), and chlorophyll levels, it appears that the reduction in Total Petroleum Hydrocarbons (TPH) has indeed created more favourable conditions for microbial and phytoplankton activity. Additionally, the application of biosurfactants likely played a significant role in aiding the ecosystem's recovery from the oil spillage.

- Overall, biodispersant application has a significant positive impact, especially on sediments. If the proper dilution and dosage of spraying are made, excellent results can be expected. In this study, we roughly sprayed the dispersant only once, with 300 L at T1 and T2 and 400 L at the T3 location.
- As proposed, the training for TNPCB officials was conducted at NIO Goa from 13 to 16 March 2024. Three officers from TNPCB have attended the training course.

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**Assessment of environmental quality of oil spill  
contaminated sites in and around Buckingham Canal to  
the Ennore Creek aftermath of floods due to Cyclone  
Michaung**

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## 1. Executive summary

Chennai Petroleum Corporation Limited (CPCL), formerly known as Madras Refineries limited (MRL), was formed in 1965 by the Government of India (GOI), American Oil Company (AMOCO) and National Iranian Oil Company (NIOC) as a Joint Venture undertaking. Chennai Petroleum Corporation Limited (CPCL) is one of the leading downstream petroleum industries, refining crude oil to produce and supply various petroleum products. CPCL is situated in Manali Village in Chennai, Tamil Nadu, in an industrial zone. CPCL Manali Refinery was originally established with an installed capacity of 2.5 Million Tonnes Per Annum (MMTPA). The present refining capacity is 10.5 Million Tonnes Per Annum (MMTPA). CPCL has captive generation power plants, Effluent Treatment Plants, Sewage Reclamation & Zero Discharge units and Desalination units to meet its power and water requirements.

Cyclone Michaung was a strong tropical cyclone that formed in the Bay of Bengal during the year 2023 . Michaung originated as a low-pressure area in the Gulf of Thailand, became a deep depression on 2<sup>nd</sup> December 2023 and developed into a cyclonic storm.

Heavy rains and strong winds seriously affected the coastal areas. Persistent rains caused flooding and inundation in Chennai, the capital of Tamilnadu. Major rivers in Chennai, including Cooum river, Buckingham canal and Adyar River, overflowed, causing havoc in low-lying areas along the banks. Water intruded into many residential and surrounding industrial areas and created serious havoc.

Flood water also intruded into most of the surrounding industrial areas, like Ambattur, Manali, Thiruvattiyur, and Ennore. In Manali & Ennore, large-scale industries are located, which include Ennore Thermal Power Plant, CPCL, Madras Fertilizers Ltd (MFL), Tamil Nadu Petroproducts, CETEX, MPL, Indian Additives Ltd, Supreme Petrochemicals, Raj Lubricants, JSW Toshiba, IOCL & BPCL marketing terminals, North Chennai Thermal Power Station, Ashok Leyland, Kamarajar Port Ltd, Kattupalli, IOCL LNG Pvt Ltd, Ennore Tank Terminal Pvt Ltd, CPCL Desalination Plant, NTPC Tamil Nadu Energy, Kothari Chemicals, Gulf Oil Lubricants, etc. Almost all the industries in Manali & Ennore are located close to the shore of the Bay of Bengal. Flood water intruded into these industries, which would have carried surface oil and reached the Ennore Creek.

Based on the report that an oil slick had formed near the Ennore Creek, CPCL in alignment with the Tamilnadu Pollution Control Board and the State authorities quickly mobilized resources to contain the oil slick and swiftly removed the oil traces at Ennore Creek. The following oil slick removal activities at Ennore Creek were carried out by CPCL. 1.

Containment booms of around 1500m were installed in the creek and canal locations. 2. 6 nos. of oil skimmers were in operation along with the help of 8 nos. of oil booms for removal of trapped oil. 3. A fleet of heavy machinery was deployed for oil removal along the creek area from Kaatukuppam area. 4. The clean-up activities at Ennore creek by four professional agencies ( M/s. Viraj Clean Sea Enterprises, Mumbai M/s. Sea Care Marine Services, Mumbai, M/s. Neo Will Win India, Chennai & M/s. Vens HydroLuft, Chennai) removed the oil content in the shortest possible time frame. Absorbent booms, pads and socks were effectively used to sweep the residual oil traces from the water.

After necessary clean-up activities were carried out by CPCL in the Ennore creek, CPCL invited TERI to undertake the environmental assessment study of the impacted area. The field reconnaissance survey of surrounding areas was carried out with the scope of an environmental damage assessment study. TERI had undertaken environmental assessment and sampling activities from 28<sup>th</sup> December, 2023 to 29<sup>th</sup> December 2023. The water, sediment, plant and fish samples were collected from Buckingham canal, Ennore creek, including backwater of the Kosasthalaiyar river. Before sampling, the team identified 25 sampling locations in coordination with stakeholders. A total of 25 water samples, 25 sediment samples were collected, two plants and 4 fish and prawn samples were also collected for the analysis of petroleum hydrocarbons and its associated pollutants, including heavy metals. The summary of the findings is furnished below:

- The site investigation findings showed that there was no significant oil slick or visible contamination in and around the Study area.
- The sample analysis revealed that there is no accumulation of petroleum hydrocarbons in water, sediment, plants and fish
  - The physico-chemical analysis of water, sediment, plant and fish samples collected from Buckingham canal, Ennore Creek and Kosasthalaiyar river revealed that the anthropogenic sources like sewage wastewater and solid waste dumps contributed in the occurrence of pollution in the water and sediment quality.
  - The reported contamination of various pollutants in water and sediments is mainly from domestic wastewater released into Buckingham canal over a period of time

**This conclusion is based on the following findings:**

- The water samples analysis results showed that oil and grease concentration of <10 mg/L was observed in samples collected from the Ennore Creek area. The sample collected from upstream of CPCL in the Buckingham Canal was slightly higher than the standard limit (10 mg/L), indicating high domestic waste water and effluent influence on the Buckingham canal.
- The water sample collected upstream of Buckingham canal region (before CPCL premises) showed the Total Petroleum Hydrocarbon (TPH) in the range of 1.51 to 2.2 mg/L. In the downstream region (after CPCL premises) region of Buckingham canal to Ennore creek, the TPH was recorded in the range of 0.2 to 3.9 mg/L. Among 25 samples, 21 samples showed the TPH within the guideline limit of 0.1 to 2.0 mg/L. These results revealed that the TPH in the water samples are due to different anthropogenic activities and the flow of domestic wastewater in Buckingham canal. It was observed that the various sewage streams are joined in Buckingham canal.
- The Poly Aromatic Hydrocarbon in all 25 samples water samples are Below the Limit of Quantification (BLQ).
- The results indicate severe oxygen depletion in the Buckingham Canal, with average DO levels well below the minimum water quality standards of 3-4 mg/L to support aquatic life. The extremely low DO suggests high pollution loads from sewage and organic waste effluents entering these water bodies.
- The BOD was observed to be in the range of 6.1 mg/L to 52 mg/L. This suggests high pollution loads from sewage, organic waste and surrounding industrial effluents entering these water bodies. Aerobic decomposition of these oxygen-demanding wastes is likely responsible for the observed oxygen depletion. The high BOD level observed before CPCL premises revealed the domestic wastewater influence on the water quality of Buckingham Canal.

- The detected concentrations for total petroleum hydrocarbons in all 25 sediments samples were lower than guideline values for ecological risk which is 280 mg/Kg (Sediment quality guideline threshold value from the Australian and New Zealand Environment and Conservation Council (ANZECC)).
- The PAH level in the sediment samples is in the range of Below the limit of Quantification (BLQ) to 0.174 mg/Kg, which is below 10 mg/Kg of sediment quality guideline threshold value from the Australian and New Zealand Environment and Conservation Council (ANZECC).
- The analysis results from plant, fish samples showed that the PAHs compounds were below the limit of quantification. It revealed that there is no significant accumulation of PAHs in biotic organisms in the study area.

## **2. INTRODUCTION**

### **2.1 Chennai Petroleum Corporation Limited (CPCL)**

CPCL is one of the leading downstream petroleum companies, refining crude oil to produce and supply various petroleum products. Chennai Petroleum Corporation Limited (CPCL), formerly known as Madras Refineries Limited (MRL) was formed in 1965 by the Government of India (GOI), American Oil Company (AMOCO) and National Iranian Oil Company (NIOC) as a Joint Venture. Subsequent to GOI's disinvestment in 2001, CPCL became a subsidiary company of Indian Oil Corporation Limited (IOCL). CPCL is located in Manali Village in Chennai, Tamilnadu. CPCL Manali Refinery was set up with an installed capacity of 2.5 Million Tonnes Per Annum (MMTPA). The present refining capacity is 10.5 Million Tonnes Per Annum (MMTPA).

CPCL Manali Refinery is one of the most -important refineries in India. Manali refinery operates three primary refining units viz Refinery I, Refinery II & Refinery III and other secondary processing units which includes Once Through Hydrocracker, Fluidised Catalytic Cracking Unit, Delayed Coker Unit, Continuous Catalytic Reforming Unit, Hydrogen Generation Unit, Diesel Hydro-desulphurisation Unit, Naphtha Isomerisation Unit, Kerosene Hydro-desulphurisation Unit, and Delayed Coker unit to produce value added petroleum products like LPG, Motor Spirit, Superior Kerosene, Aviation Turbine Fuel, High Speed Diesel, Naphtha, Bitumen, Lube Base Stocks, Paraffin Wax, Fuel Oil, Pet Coke, Hexane and Petrochemical feed stocks. Also, CPCL supplies feed stocks to the neighbouring industries in the Manali industrial belt.

Besides this, CPCL has captive generation power plants, Effluent Treatment Plants, Sewage Reclamation & Zero Discharge units and desalination units to meet its power and water requirements. CPCL also pioneered key initiatives in several areas such as process optimisation, technology absorption, energy conservation, Net Zero Activities and Environment management. CPCL Manali Refinery is also accredited with ISO-9001:2015, ISO-14001:2015 and OHSAS 45001: 2018.

### **2.2 Major Neighbouring Industries**

The Manali & Ennore region, is a hub of petrochemical industries and an Eco-sensitive zone. The Manali and surrounding industrial area includes a range of industries, mainly thermal power stations, fertilizer factories, surrounding industrial ports and coal yards. The major industries include the following

Name Of the Industry	Manufacturing Products
➤ Madras Fertilizers Limited:	Urea & DAP
➤ TamilNadu Petro Products Limited:	Linear Alkyl Benzene (LAB) & Propylene Oxide (PO)
➤ Kothari Petrochemicals:	Poly Butylene
➤ Manali Petrochemicals:	Polyol & Propylene Glycol
➤ Cetex Petrochemicals:	Methyl Ethyl Ketone
➤ Indian Additives Limited:	Lube Additives

### 2.3 Cyclone MICHAUNG

Cyclone Michaung was a strong tropical cyclone that formed in the Bay of Bengal during the year 2023. Michaung originated as a low-pressure area in the Gulf of Thailand, became a deep depression on 2<sup>nd</sup> December 2023 and further developed into a Cyclone on 03<sup>rd</sup> December 2023.

Heavy rains and strong winds seriously affect the coastal areas. Persistent rains caused flooding and inundation in Chennai, the capital of Tamil Nadu (Fig. 1 and 2). Major rivers in Chennai, including Cooum, Buckingham canal and Adyar River, overflowed, causing havoc in low-lying areas along the banks. Water intruded into many of the residential & surrounding industrial areas and created serious havoc. Nearly 30,000 people were evacuated in Tamil Nadu and temporarily relocated to safer places.

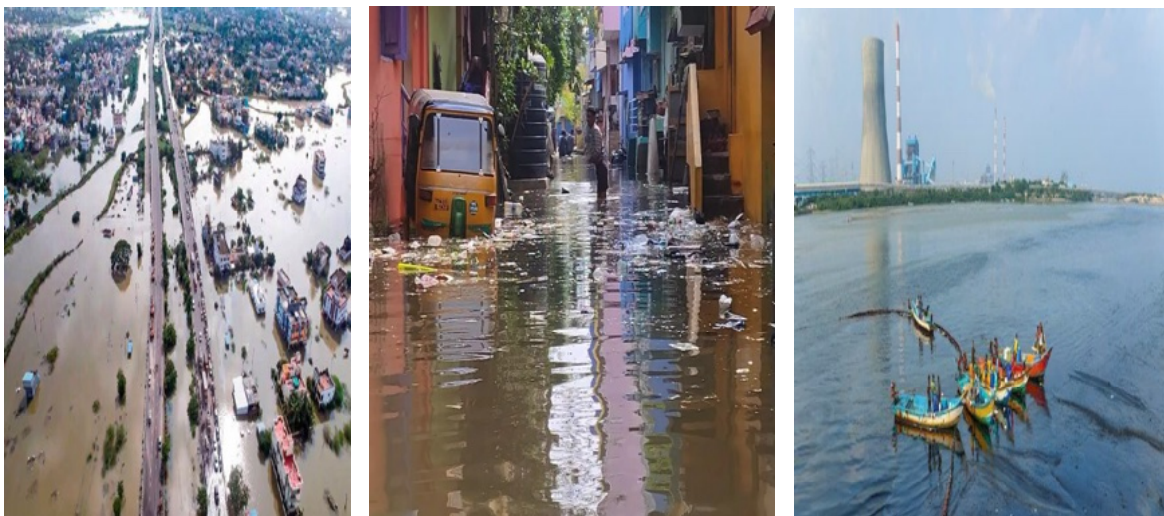
Flood water also entered into most of the surrounding industrial areas, like Ambattur, Manali, Thiruvottiyur, and Ennore. In Manali & Ennore, large-scale industries are available, which include Ennore Thermal Power Plant, CPCL, Madras Fertilizers Ltd (MFL), Tamil Nadu Petroproducts, CETEX, MPL, Indian Additives Ltd, Supreme Petrochemical, Raj Lubricants, JSW Toshiba, IOC & BPCL marketing terminals, North Chennai Thermal Power Station, Ashok Leyland, Kamarajar Port Ltd, Tamil Nadu Desalination Plant, Kattupalli, IOCL LNG Pvt Ltd, Ennore Tank Terminal Pvt Ltd, CPCL Desalination Plant, NTPC Tamil Nadu Energy, Kothari Fertilisers, Gulf Oil Lubricants, etc.

### 2.4 Oil spill Contamination

Almost all the industries in Manali & Ennore are located near to the shore of the Bay of Bengal. Flood water intruded into industries, which subsequently carried away the surface oil and reached the Ennore Creek.



**Fig. 1 Severe Cyclonic Storm causes rampage across Tamil Nadu and Andhra Pradesh coast**



**Fig.2 A drone visual shows an area that is flooded after the landfall of Cyclone Michaung, in Chennai on December. 6, 2023**

### **2.5 Oil slick removal activities in Buckingham Canal, Kosasthalaiyar River and Ennore creek**

Based on the report that an oil slick had formed near Ennore Creek, CPCL in coordination with the Tamilnadu Pollution Control Board and State authorities quickly mobilized resources to contain the oil slick and swiftly removed the oil traces

at Ennore Creek. The following oil slick removal activities at Ennore Creek were carried out by CPCL (Fig. 3):

1. Containment booms of around 500 m were installed in the creek and Buckingham canal. Containment booms were installed to prevent further movement of oil into the sea.
2. 6 nos. of oil skimmers were in operation along with the help of 8 nos. of oil booms for removal of trapped oil.
3. Sufficient boats and manpower were deployed for oil removal activities at Ennore Creek, Kaatukuppam area, Buckingham canal and Kosasthalaiyar river mouth. Mechanized cleaning efforts successfully removed the majority of the oil slick under Ennore Road Bridge.
4. A fleet of heavy machinery was deployed for oil removal along the creek area from Kaatukuppam area. This includes 128 boats with 512 people, 8 Gully Suckers, 7 JCBs, 6 Poclain machines, 15 Dumpers, 2 Tractor Trailers, 28,000 nos. of Absorbent pads, 3 Hydra, along with a team of 4 export agencies with 250 trained manpower ensuring strict PPE compliance and safety measures.
5. The clean-up activities at Ennore creek by the four professional agencies ( M/s. Viraj Clean Sea Enterprises, Mumbai M/s. Sea Care Marine Services, Mumbai, M/s. Neo Will Win India, Chennai & M/s.Vens HydroLuft,Chennai) removed the oil content in the shortest possible time frame. Absorbent booms, pads and socks were effectively used to sweep the residual oil traces from the water.
6. Housekeeping of affected areas with required manpower was carried out. Hydro jetting machines, Wet and dry Vacuum Machines were employed to expedite the clean-up works.
7. To address the health needs of the workers and communities, three mobile medical units with requisite medicines, doctors and paramedics teams were stationed by CPCL in Ennore Creek and nearby villages, benefiting more than 2743 individuals. Kits including essential items like Rice, Dhotis, Bed sheets, Mosquito Coils and sarees were handed over to the State Nodal Officer, for the welfare of the people.

The above actions taken on war footing basis removed the oil content in the water in shorter span of time



**Fig.3 Oil removal activities carried out in Ennore Creek Region**

### 3. Project description

A detailed environmental assessment study was undertaken to ascertain the effectiveness of cleaning and actual environmental damage, if any. The assessment was carried out during 28-12-2023 and 29.12.2023. The environmental contamination status of the affected area has been focused on assessing the accumulation of possible contaminants, including petroleum hydrocarbons, poly-aromatic hydrocarbons and heavy metals. The water, sediment, plant and fish samples were collected in the entire stretch of Buckingham canal, the Kosasthalaiyar river and Ennore Creek. Hence, TERI has undertaken the present study to assess the status of water, coastal and surrounding biodiversity status following the reported oil slick.

### 4. Scope of study

The proposed specific objectives are

- a. To undertake a field visit and survey the field for contamination
- b. Collection and analysis of water samples from Buckingham canal up to Ennore Creek, including backwater of the Kosasthalaiyar river.
- c. Collection and analysis of sediment samples and biotic organisms in the study area including fish, aquatic plants, algae and plankton's from Buckingham canal up to Ennore Creek including backwater area of the Kosasthalaiyar river

- d. Analyze the water, sediment and biotic organism for the different chemical characteristics
- e. Submit the detailed report on the status of the environmental quality of Buckingham canal up to Ennore Creek, including the backwater of the Kosasthalaiyar river with recommendations.

## 5. Study Area

The sampling has been carried out on Buckingham Canal, Kosasthalaiyar River and Ennore Creek from a) Nettukuppam to Ennore bridge, b) Ennore bridge to Railway Bridge c) Railway Bridge to the entrance of Buckingham Canal, d) Buckingham Canal to Sathyamoorthy Nagar, and e) Upstream of CPCL.

### Brief description about the study area.

#### 5.1 Buckingham Canal

- It runs parallel to the coastline of Chennai city for about 55 km before emptying into the Ennore Creek.
- It receives domestic sewage, surrounding industrial treated effluents, and runoff as it flows through densely populated areas of Chennai.
- Considered as heavily polluted with high levels of bacteria, suspended solids, and reduced dissolved oxygen.
- A significant source of contamination in Ennore Creek and the Kosasthalaiyar River.

#### 5.2 Kosasthalaiyar River

- Originates in the Poondi reservoir and flows through Thiruvallur district before emptying into Ennore Creek.
- Major tributaries include the Cooum and Araniyar Rivers.
- Used for irrigation, surrounding industrial purposes, and sand mining activities along its banks.
- Faced with reduced water flow and pollution from agricultural runoff and surrounding industrial effluents.

#### 5.3 Ennore Creek

- Formed by the confluence of the Kosasthalaiyar River and Buckingham Canal north of Chennai city.

- Joins with the Bay of Bengal, providing harbor access to the Ennore port.
- Surrounded by thermal power plants, petrochemical industries and coastal urbanization.
- Prone to contamination from surrounding industrial discharges and wastes entering from the Kosasthalaiar River and Buckingham Canal.

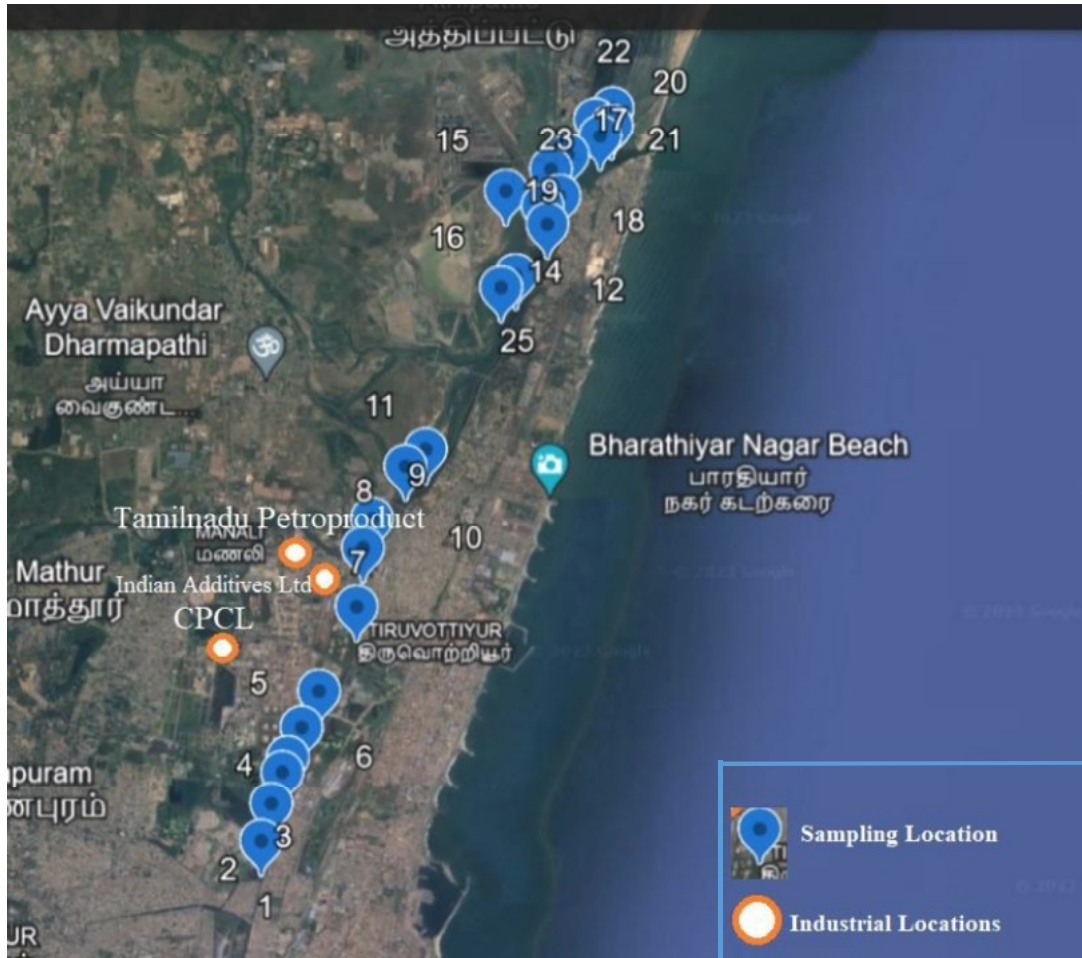
## **6. Methodology**

### **6.1 On-site investigations**

The detailed site investigation has been carried out starting from the Buckingham Canal upstream of M/s CPCL till Ennore Creek. The initial site visit was carried out along with CPCL officials from the upstream area of Buckingham canal (Elilnagar, Tondiarpet) followed by mid stream (Sathyamoorti Bridge) and downstream (Ennore Creek) areas. Subsequently, water, sediment and fish & prawn samples were collected. The general information from the local stakeholders was that oil was observed in the water-bodies., observation of oil slicks and oil accumulation, odour and colour resembles the nature of waste water and municipal entry into the study area has been observed during the visit. The study area covers the following stretches as mentioned in figure 4.

- 1) Nettukuppam to Ennore bridge
- 2) Ennore bridge to Railway Bridge
- 3) Railway Bridge to entrance of Buckingham Canal
- 4) Buckingham Canal to Sathyamoorthy Nagar
- 5) Upstream of CPCL

The GPS coordinates were used to locate the specific sampling point for water, sediment and fish samples.



**Fig. 4** Water, sediment, plant and fish sampling locations from Buckingham canal to Ennore creek

## 6.2 Sampling

The technical team from TERI walked through entire stretches of Buckingham canal (upstream of CPCL) to Ennore Creek and prepared the sampling plan. The TERI sampling team has selected the sampling location based on initial site visit, discussion with stakeholders and CPCL. The water, sediment, plant and fish samples were collected in selected locations along Buckingham canal to Ennore Creek, including the backwater area of Kosasthalaiyar river for the detailed investigation.

A total of 25 water samples, 25 sediment samples, 2 plant samples, 4 fish and prawn samples were collected from the study area. The physico, chemical quality of water was analyzed in water and sediment samples. Also, the accumulation of petroleum hydrocarbon products and its associated pollutants such as heavy metals and poly aromatic hydrocarbons in the samples were analyzed. In order to know the toxicity and accumulation of pollutants released during water flood, plant, fish and prawn samples were collected from different selected locations of

Buckingham canal to Ennore Creek. The status and quality of aquatic organisms, including photosynthesizing phytoplankton, Zooplankton, other organisms such as fishes and water-dependent organisms has been monitored and sampled for further analysis. Table 1, 2 and 3 shows the sample details with analysis parameters.

A total of 25 water samples from upstream of Buckingham canal before CPCL facility upto Ennore creek were collected. The sediment, plants and fish samples have been collected in the following five stretches:

- 1) Nettukuppam to Ennore bridge
- 2) Ennore bridge to Railway Bridge
- 3) Railway Bridge to entrance of Buckingham Canal
- 4) Buckingham Canal to Sathyamoorthy Nagar
- 5) Upstream of CPCL

All the samples were transported to a NABL accredited laboratory for further analysis.

The water and sediment samples were collected from Tondiarpet, Eliznagar of Buckingham canal, which is upstream of CPCL, followed by the midstream area in which Buckingham canal mixes with Kosasthaliyar river and finally merges in Bay of Bengal at Ennore Creek. The water, sediment and fish and prawn samples have been collected as per the standard procedures.

### **6.3 Water and sediment sampling**

The sampling team approached the Buckingham canal from bund wall side and samples were collected. The Buckingham canal is clogged with public sewage wastewater containing plastic waste, sewage, rubber and other wastes. There are different domestic wastewater streams that enter into Buckingham canal and mix with the Kosasthaliyar river. The water and sediment samples have been collected along entire stretches from Buckingham canal at Tondiarpet to Ennore creek. The details of water and sediment sampling locations and analysis parameters are presented in tables 1 and 2.

Then the sampling was carried out on the complete stretch of Buckingham canal to Ennore creek. The water and sediment sample was started from upstream of CPCL including Elil nagar (1.2 km upstream of CPCL) followed by Patel nagar, Tondiarpet and IOCL Gate followed by New bridge, Kargil Nagar, Sathiyamoorthi bridge, Jyothi Nagar and Sivanpadaikuppam and Kammalamma Nagar (2.5 Km from Sivanpadaikuppam-middle

location of study area). Further samples were collected up Ennore creek covering the junction of Kosasthaliya river and Buckingham canal, Thallakuppam and Nettukuppam.

**Table 1. Water sampling locations and its analysis parameters**

S.No.	Sample ID- Water	Sampling Location	Sampling date and submitted to the lab	Test Parameters
1	CP51003019W1	Elilnagar, Tondiarpet	28-12-23	pH, Oil and Grease, MBAS (Surfactants), Phenolic compounds, Total Organic carbon, SAR and Electrical conductivity, BOD, COD, Cadmium, Lead, Mercury, Nickel, Hexavalent Chromium, Zinc, Copper Polynuclear Aromatic Hydrocarbons: Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Anthracene, Phenanthrene, Fluoranthene, Pyrene, Benz[A]Anthracene, Chrysene, Benzo[K]Fluoranthene, Benzo[A]Pyrene, Benzo[ghi]Perylene, Dibenzo[ah]Anthracene, Indeno[1,2,3-cd]Pyrene, Benzo[B]Fluoranthene, Total Petroleum Hydrocarbon and Fractionated Hydrocarbons (C5 - C40) BTEX
2	CP09173586W2	Patel Nagar, Tondiarpet	28-12-23	
3	CP25824137W3	CPCL Tondiarpet (Near Government Fertilizer Unit)	28-12-23	
4	CP35004445W4	IOCL Gate (Chinnasekkadu)	28-12-23	
5	CP48375100W5	Near New Bridge (Buckingham Canal)	28-12-23	
6	CP18730675W6	East side of CPCL, Buckingham Canal	28-12-23	
7	CP48562059W7	Kargil Nagar	28-12-23	
8	CP20852454W8	Near CMDA Steel Yard, Tiruvottiyur	28-12-23	
9	CP32592746W9	Sathyamoorti Bridge	28-12-23	
10	CP58675459W10	Sadyanguppam Bridge	28-12-23	
11	CP08745794W11	Jyothi Nagar -Between Sadyanguppam and Kattukuppam bridge	28-12-23	
12	CP01570001W12	Sivanpachaikuppam	29-12-23	
13	CP15100635W13	Junction of Manali and Kosasthaliyar river	29-12-23	
14	CP09615714W14	Buckingham canal and Kosasthaliya river confluence	29-12-23	
15	CP29693748W15	Buckingham canal and Kosasthaliya river (East side of Temple area)	29-12-23	
16	CP29340251W16	Buckingham canal -Railway bridge	29-12-23	
17	CP35850279W17	Kattukuppam	29-12-23	
18	CP36941099W18	Under Ennore bridge	29-12-23	
19	CP39331517W19	Ennore Bridge - Near Don-Bosco School, Kattukuppam	29-12-23	
20	CP48102631W20	Thallakuppam Mouth of Ennore Creek	29-12-23	
21	CP57554482W21	Nettukuppam - Mouth of Ennore Creek	29-12-23	
22	CP59563762W22	NTPC Side- Ennore Creek (Opp. Nettukuppam)	29-12-23	
23	CP57372400W23	NTPC Side -Ennore Creek	29-12-23	
24	CP43821087W24	Between Ennore bridge and Ennore Creek	29-12-23	
25	CP34274619W25	(Kamalamma Nagar) Buckingham canal	29-12-23	

**Table 2. Sediment sampling locations and its analysis parameters**

S.No.	Sample ID	Sampling Locations	Sampling date and submitted to the lab	Test Parameters
1	CP51003019S1	Elilnagar, Tondiarpet	28-12-23	pH, Oil and Grease, MBAS (Surfactants), Phenolic Compounds, Total Organic carbon, SAR, Electrical conductivity, Cadmium, Lead, Mercury, Nickel, Hexavalent Chromium, Zinc and Copper. Polynuclear Aromatic Hydrocarbons: Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Anthracene, Phenanthrene, Fluoranthene, Pyrene, Benz[A]Anthracene, Chrysene, Benzo[K]Fluoranthene, Benzo[A]Pyrene, Benzo[ghi]Perylene, Dibenz[ah]Anthracene, Indeno[1,2,3-cd]Pyrene, Benzo[B]Fluoranthene. Total Petroleum Hydrocarbon and Fractionated Hydrocarbons (C5-C40). BTEX.
2	CP09173586S2	Patel Nagar, Tondiarpet	28-12-23	
3	CP25824137S3	CPCL Tondiarpet (Near Government Fertilizer Unit)	28-12-23	
4	CP35004445S4	IOCL Gate (Chinnasekkadu)	28-12-23	
5	CP48375100S5	Near New Bridge (Buckingham Canal)	28-12-23	
6	CP18730675S6	East side of CPCL, Buckingham Canal	28-12-23	
7	CP48562059S7	Kargil Nagar	28-12-23	
8	CP20852454S8	Near CMDA Steel Yard, Tiruvottiyur	28-12-23	
9	CP32592746S9	Sathyamoorti Bridge	28-12-23	
10	CP58675459S10	Sadyanguppam Bridge	28-12-23	
11	CP08745794S11	Jyothi Nagar -Between Sadyanguppam and Kattukuppam bridge	28-12-23	
12	CP01570001S12	Sivanpadaikuppam	29-12-23	
13	CP15100635S13	Junction of Manali and Kosasthaliyar river	29-12-23	
14	CP09615714S14	Buckingham canal and Kosasthaliya river confluence	29-12-23	
15	CP29693748S15	Buckingham canal and Kosasthaliya river (East side of Temple area)	29-12-23	
16	CP29340251S16	Buckingham canal -Railway bridge	29-12-23	
17	CP35850279S17	Kattukuppam	29-12-23	
18	CP36941099S18	Under Ennore bridge	29-12-23	
19	CP39331517S19	Ennore Bridge - Near Don-Bosco School, Kattukuppam	29-12-23	
20	CP48102631S20	Thallakuppam Mouth of Ennore Creek	29-12-23	
21	CP57554482S21	Nettukuppam - Mouth of Ennore Creek	29-12-23	
22	CP59563762S22	NTPC Side- Ennore Creek (Opp. Nettukuppam)	29-12-23	
23	CP57372400S23	NTPC Side -Ennore Creek	29-12-23	
24	CP43821087S24	Between Ennore bridge and Ennore Creek	29-12-23	
25	CP34274619W25	(Kamalamma Nagar) Buckingham canal	29-12-23	

## 6.4 Fish and plant samples

Due to the domestic wastewater flow, there were no fish samples and plant sample available in Buckingham canal. The fish samples were collected from the Kosasthaliyar river and Ennore creek. The plant samples were collected from the mangrove area of Kosasthaliyar river. The table 3 shows the sample details and analysis parameters.

**Table 3. Plant, fish and prawn sampling locations and its analysis parameters**

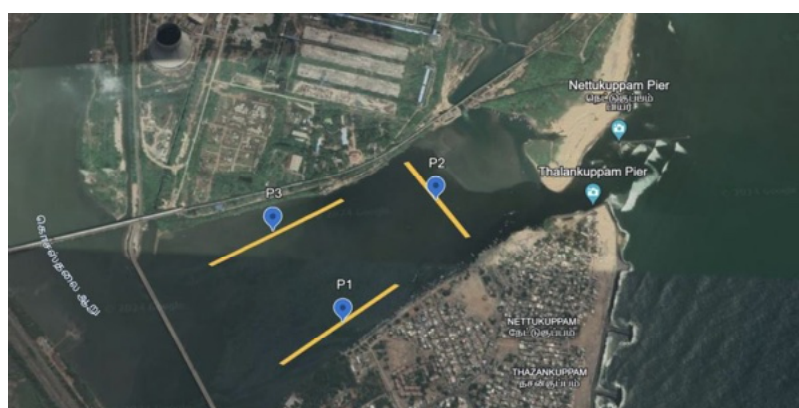
S.No	Sample ID	Sampling Locations	Sampling date	Parameters to be tested
<b>Plant samples</b>				
1	CP01475004P1	Kosasthaliyar river	29-12-23	Cadmium, Lead, Mercury, Nickel, Hexavalent Chromium, Zinc, Copper.
2	CP35850279P2	Kattukuppam Bridge	29-12-23	
<b>Fish &amp; Prawn</b>				
1	CP35850279F1	Under Ennore railway bridge	29-12-23	Cadmium, Lead, Mercury, Nickel, Hexavalent Chromium, Zinc, Copper.
2	CP39331517F2	Kattukuppam -Ennore Creek	29-12-23	
3	CP57554482F3	Nettukuppam -Ennore Creek	29-12-23	Polynuclear Aromatic Hydrocarbons: Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Anthracene, Phenanthrene, Fluoranthene, Pyrene, Benz[A]Anthracene, Chrysene, Benzo[K]Fluoranthene, Benzo[A]Pyrene, Benzo[ghi]Perylene, Dibenz[ah]Anthracene, Indeno[1,2,3-cd]Pyrene, Benzo[B]Fluoranthene.
4	CP59563762F4	Under Ennore Bridge	29-12-23	

## 6.5. Plankton Survey

Oil spills associated contamination can have significant detrimental impacts on marine plankton communities and diversity. Plankton, including both phytoplankton and zooplankton, are critical early life stages of many aquatic species and form the base of marine food webs. Even small amounts of oil can cause harm to these sensitive organisms. Light oils can form a thin sheen on the water surface, inhibiting gas exchange and light penetration that phytoplankton require for photosynthesis. Heavier oils can physically smother both phytoplankton and zooplankton when droplets get adhered to bodies and clog feeding apparatus. The toxicity of petroleum hydrocarbons also negatively affects zooplankton survival and impairs phytoplankton growth. Exposure during early life stages can have lasting impacts on the plankton population. Plankton diversity often declines in oil-contaminated waters. Certain species and groups of phytoplankton and zooplankton are more susceptible to oil pollution than others. Spills selectively target sensitive species, allowing more tolerant organisms to dominate. Shifts in competitive balance alter food web dynamics. Loss of

diversity can compromise ecosystem function and stability. This report summarizes an environmental impact assessment conducted on plankton populations following an oil spill in a coastal marine environment. The goal was to determine the extent of diverse changes to the plankton community resulting from water contamination. Both phytoplankton and zooplankton were evaluated through field sampling, laboratory analyses, and ecological surveys (fig.5).

1. A plankton net with a size of 500  $\mu\text{m}$  mesh for zooplankton and 63  $\mu\text{m}$  mesh for phytoplankton with a collection cup was towed from a boat at low speed for 10 minutes through the water's surface in the oil contaminated region.
2. Towing was conducted following a standard plankton tow procedure, maintaining the net at a 45-degree angle and towing against the current to maximize zooplankton & phytoplankton capture.
3. The GPS start and end points were recorded to determine the total volume of water filtered through the net using the net mouth area and distance towed.
4. After the 10-minute tow, the collection cup was detached and the concentrated phytoplankton & zooplankton sample was preserved in 5% buffered formalin.
5. Sampling was conducted during daytime hours to target phytoplankton & zooplankton that migrate upwards in the water column.
6. Multiple 10-minute tows were conducted to collect sufficient phytoplankton & zooplankton biomass for diversity analysis.



**Fig. 5 Plankton sampling area**

## 7. Quality Assurance and Quality Control

The Quality Assurance and Control Sampling (QA/QC) has been followed as mentioned above. It includes codification of samples, use of standard sampling and analysis procedures. For the water and sediment quality parameters analysis, the samples have been collected as

per prescribed standards for sample collections, preservation and transportation. At the end of the sampling day, samples were delivered to NABL accredited laboratories.

## **8. Results and Discussion**

### **8.1 Field observations**

TERI sampling and expert team has prepared a field sampling data sheet to collect the information about the sampling sites and information from stakeholders in the study area. Stakeholders informed that that the Buckingham canal receives surrounding industrial and domestic wastewater throughout the year. CPCL and other authorities responded immediately and oil slick removal activities were carried out to prevent the spread of oil slicks. The oil slick removal activities were carried-out immediately using containment booms, absorption pads, absorbent booms and oil skimmers. Different agencies were engaged in the complete removal of trapped oil spills from Buckingham canal to Ennore creek, including an ecologically sensitive zone mangrove area.

The present environmental assessment study was carried out during 28-12-2023 and 29.12.2023. During that time, oil spill was removed and transported to a safe site for disposal. Hence, the study team found the areas free of oil spills in residential and forest region from Buckingham canal/ Kosasthalaiyar river to Ennore region. The severe pollution and flow of wastewater from domestic and surrounding industrial sources was observed in the Buckingham canal. The domestic wastewater based odour like hydrogen sulfide was very commonly observed in Buckingham canal wastewater due to mixing of wastewater with Buckingham water. Some of the wastewater outlets from municipal corporations were entering into different parts of Buckingham canal. The movement of animals like buffaloes and birds were seen in Buckingham canal and the mangroves region. The wet land of Manali-Ennore region also witnessed the birds' movement during field observations which is 12 km from CPCL, Manali. The appearance of flora, fauna, any physical appearance of contaminants in the sampling site was noted. The sampling and site investigation findings showed that there was no significant visible contamination in and around the sampling site. Also, there was no oily odour in the sampling site. The field data sheet is presented in Annexure -1.

### **8.2 Water quality status of Buckingham canal to Ennore creek after Michaung cyclone and followup clean activities by CPCL**

A total of 25 water samples were collected starting from Buckingham canal at Tondiarpet to Ennore creek. The total distance of 13.5 km has been covered from CPCL to Ennore creek to know the impact of floods Michaung influenced contamination in the study area. The

physico-chemical parameters were analyzed and presented below. The laboratory analysis report is presented in annexure - II. The major analysis parameters include oil and grease, Total petroleum hydrocarbons (TPH), Poly Aromatic Hydrocarbons (PAH), phenolic compounds and heavy metals.

### **8.2.1 Oil and Grease and Total petroleum Hydrocarbons**

The water samples analysis results showed that the oil and grease concentration of <10 mg/L was observed in samples collected from the Ennore Creek area. The sample collected from upstream of CPCL in Buckingham Canal, showed slightly higher than the standard limit (10 mg/L) indicating the high domestic and surrounding industrial wastewater influences on the Buckingham canal pollution (table 4).

The water sample collected upstream of Buckingham canal region (before CPCL premises) showed the Total Petroleum Hydrocarbon (TPH) in the range of 2.2 to 1.51 mg/L. Along and downstream region of CPCL premises, from Buckingham canal up to Ennore creek, the TPH was recorded in the range of 0.2 to 3.9 mg/L. Among 25 samples, 21 samples showed the TPH within the guidelines limit of 0.1 to 2.0 mg/L. These results revealed that the TPH in the water samples are due to different anthropogenic activities and the flow of domestic wastewater in Buckingham canal. ( table 6).

**Table 4: Chemical quality parameters (General Parameters) in Water Samples**

Samp le No.	Sampling Location	pH	Oil and Grease	MBAS (Surfact ants)  mg/L	Phenolic compoun dsmg/L	Total Organi c carbon mg/L	SAR	Electri cal conduc tivity  µs/cm	BOD  mg/ L	COD  mg/L
1	Elilnagar, Tondiarpet	6.75	14.6	0.65	0.034	79	6.93	2240	52	211
2	Patel Nagar, Tondiarpet	6.93	6	0.7	0.048	55	6.39	1952	39	146
3	CPCL Tondiarpet (Near Government Fertilizer Unit)	6.9	7.2	1.4	0.044	59	6.03	1824	42	158
4	IOCL Gate (Chinnasekkadu)	7.33	7.2	0.08	0.036	56	8.15	2550	40	150
5	Near New Bridge (Buckingham Canal)	7.36	12.5	BDL(DL :0.05)	0.088	37	18	9000	13	100
6	East side of CPCL, Buckingham Canal	7.26	6.5	0.42	0.036	51	7.56	2750	38	138
7	Kargil Nagar	6.87	7.2	0.58	0.016	67	6.96	2430	38	145
8	Near CMDA Steel Yard, Tiruvottiyur	6.99	9.5	0.36	0.005	82	5.88	2480	26	196
9	Sathyamoorti Bridge	7.16	5.9	1.8	0.03	43	7.16	2580	29	114
10	Sadyanguppam Bridge	7.11	6	1.2	0.07	42	6.29	2900	29	165
11	Jyothi Nagar -Between Sadyanguppam and Kattukuppam bridge	6.54	7.9	0.123	0.07	86	6.37	3310	42	296
12	Sivanpadaikuppam	7.18	7.2	0.35	0.026	56	6.48	2510	41	150
13	Junction of Manali and Kosasthaliyar river	6.92	BDL(DL:4. 0)	0.45	0.044	30	8.77	2940	21	81
14	Buckingham canal and Kosasthaliya river confluence	7.04	BDL	0.6	0.044	25	13.1	4650	37	150
15	Buckingham canal and Kosasthaliya river (East side of Temple area)	7.03	BDL(DL:4. 0)	0.58	0.05	11.2	25.4	6090	8.2	30
16	Buckingham canal - Railway bridge	7.06	BDL(DL:4. 0)	BDL(DL :0.05)	0.03	8.3	5.22	7443	6.1	22

17	Kattukuppam	7.1	BDL(DL:4.0)	BDL(DL:0.05)	0.05	22.9	23.6	8370	7.2	61
18	Under Ennore bridge	6.86	BDL(DL:4.0)	0.16	BDL(DL:0.001)	39	26	10260	6.9	104
19	Ennore Bridge - Near Don-Bosco School, Kattukuppam	6.96	7	0.38	0.06	28	23.6	8010	6.9	74
20	Thallakuppam Mouth of Ennore Creek	6.77	BDL(DL:4.0)	0.81	0.002	16.1	23.8	7220	11.4	43
21	Nettukuppam - Mouth of Ennore Creek	6.88	BDL(DL:4.0)	0.06	0.02	24	30.6	11830	18.6	65
22	NTPC Side- Ennore Creek (Opp. Nettukuppam)	6.92	BDL(DL:4.0)	0.1	0.042	33	35.9	16540	25	87
23	NTPC Side -Ennore Creek	6.89	BDL(DL:4.0)	BDL(DL:0.05)	0.004	23	38.3	12500	17.7	61
24	Between Ennore bridge and Ennore Creek	6.88	BDL(DL:4.0)	0.06	0.056	18	33.4	13550	12.9	48
25	(Kamalamma Nagar) Buckingham canal	6.89	BDL(DL:4.0)	0.05	0.067	19.5	38	14580	14.7	52

**Table 5: Heavy metal concentrations in water**

Sample No.	Sampling Location	Nickel as Ni, (mg/L)	Copper as Cu, (mg/L)	Zinc as Zn, (mg/L)	Cadmium as Cd, (mg/L)	Mercury as Hg, (mg/L)	Lead as Pb, (mg/L)	Hexavalent Chromium(mg/L)
1	Elinagar, Tondiarpet	0.010	0.102	0.116	BLQ[LOQ:0.005]	BLQ[LOQ:0.0005]	0.011	BDL(DL:0.01)
2	Patel Nagar, Tondiarpet	0.011	0.062	0.104	BLQ[LOQ:0.005]	BLQ[LOQ:0.0005]	0.016	BDL(DL:0.01)
3	CPCL Tondiarpet (Near Government Fertilizer Unit)	0.011	0.048	0.082	BLQ[LOQ:0.005]	BLQ[LOQ:0.0005]	0.01	BDL(DL:0.01)
4	IOCL Gate (Chinnasekkadu)	0.013	0.049	0.083	BLQ[LOQ:0.005]	BLQ[LOQ:0.0005]	0.011	BDL(DL:0.01)
5	Near New Bridge (Buckingham Canal)	0.016	0.053	1.175	0.006	0.0061	0.017	BDL(DL:0.01)
6	East side of CPCL, Buckingham Canal	0.011	0.017	0.021	BLQ[LOQ:0.005]	BLQ[LOQ:0.0005]	0.007	BDL(DL:0.01)
7	Kargil Nagar	0.012	0.063	0.18	0.009	0.0038	0.036	BDL(DL:0.01)
8	Near CMDA Steel	0.082	0.2	1.055	0.053	BLQ[LOQ:0.0005]	0.05-0.1	BDL(DL:0.01)

	Yard, Tiruvottiyur					0005]		
9	Sathyamoorti Bridge	0.01	0.01	0.038	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	0.009	BDL(DL:0.01)
10	Sadyanguppam Bridge	0.059	0.358	1.03	0.031	BLQ[LOQ:0. 0005]	0.074	BDL(DL:0.01)
11	Jyothi Nagar -Between Sadyanguppam and Kattukuppam bridge	0.2	0.06	1.7	0.382	0.0108	0.1	BDL(DL:0.01)
12	Sivanpadaikuppam	0.024	0.068	0.833	0.005	BLQ[LOQ:0. 0005]	0.023	BDL(DL:0.01)
13	Junction of Manali and Kosasthaliyar river	0.011	0.038	1.111	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	0.007	BDL(DL:0.01)
14	Buckingham canal and Kosasthaliya river confluence	0.017	BLQ[LOQ: 0.005]	0.235	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	BLQ[LOQ: 0.005]	BDL(DL:0.01)
15	Buckingham canal and Kosasthaliya river (East side of Temple area)	0.007	0.011	0.013	BLQ[LOQ: 0.005]	0.0026	BLQ[LOQ: 0.005]	BDL(DL:0.01)
16	Buckingham canal - Railway bridge	0.006	BLQ[LOQ: 0.005]	0.015	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	BLQ[LOQ: 0.005]	BDL(DL:0.01)
17	Kattukuppam	BLQ[LOQ :0.005]	BLQ[LOQ: 0.005]	0.044	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	BLQ[LOQ: 0.005]	BDL(DL:0.01)
18	Under Ennore bridge	BLQ[LOQ :0.005]	0.007	0.037	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	0.008	BDL(DL:0.01)
19	Ennore Bridge - Near Don-Bosco School, Kattukuppam	0.006	BLQ[LOQ: 0.005]	0.433	BLQ[LOQ: 0.005]	0.0006	0.01	BDL(DL:0.01)
20	Thallakuppam Mouth of Ennore Creek	BLQ[LOQ :0.005]	BLQ[LOQ: 0.005]	0.104	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	0.006	BDL(DL:0.01)
21	Nettukuppam - Mouth of Ennore Creek	BLQ[LOQ :0.005]	BLQ[LOQ: 0.005]	0.065	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	0.027	BDL(DL:0.01)
22	NTPC Side- Ennore Creek (Opp. Nettukuppam)	BLQ[LOQ :0.005]	BLQ[LOQ: 0.005]	0.029	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	0.018	BDL(DL:0.01)
23	NTPC Side -Ennore Creek	BLQ[LOQ :0.005]	BLQ[LOQ: 0.005]	0.041	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	BLQ[LOQ: 0.005]	BDL(DL:0.01)
24	Between Ennore bridge and Ennore Creek	BLQ[LOQ :0.005]	0.046	0.028	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	BLQ[LOQ: 0.005]	BDL(DL:0.01)
25	(Kamalamma Nagar) Buckingham canal	BLQ[LOQ :0.005]	BLQ[LOQ: 0.005]	0.022	BLQ[LOQ: 0.005]	BLQ[LOQ:0. 0005]	BLQ[LOQ: 0.005]	BDL(DL:0.01)

**Table 6. Total Petroleum Hydrocarbons and BTEX concentration in different water**

Sample No.	Sampling Location	Total Petroleum Hydrocarbon mg/L	BTEX, mg/L
1	Elilnagar, Tondiarpet	2.21	1.46
2	Patel Nagar, Tondiarpet	1.98	0.76
3	CPCL Tondiarpet (Near Government Fertilizer Unit)	1.47	0.76
4	IOCL Gate (Chinnasekkadu)	1.51	0.78
5	Near New Bridge (Buckingham Canal)	2.93	0.84
6	East side of CPCL, Buckingham Canal	1.38	0.8
7	Kargil Nagar	1.51	0.82
8	Near CMDA Steel Yard, Tiruvottiyur	1.96	0.85
9	Sathyamoorti Bridge	1.81	0.99
10	Sadyanguppam Bridge	1.65	1.09
11	Jyothi Nagar -Between Sadyanguppam and Kattukuppam bridge	1.44	0.87
12	Sivanpadaikuppam	1.34	0.7
13	Junction of Manali and Kosasthaliyar river	1.19	0.83
14	Buckingham canal and Kosasthaliya river confluence	BLQ(LOQ:0.1)	BLQ(LOQ:0.1)
15	Buckingham canal and Kosasthaliya river (East side of Temple area)	BLQ(LOQ:0.1)	BLQ(LOQ:0.1)
16	Buckingham canal -Railway bridge	BLQ(LOQ:0.1)	BLQ(LOQ:0.1)
17	Kattukuppam	0.2	BLQ
18	Under Ennore bridge	0.2	BLQ
19	Ennore Bridge - Near Don-Bosco School, Kattukuppam	0.2	0.1
20	Thallakuppam Mouth of Ennore Creek	2.3	0.3
21	Nettukuppam - Mouth of Ennore Creek	0.2	0.1
22	NTPC Side- Ennore Creek (Opp. Nettukuppam)	1.3	0.3
23	NTPC Side -Ennore Creek	0.2	BLQ
24	Between Ennore bridge and Ennore Creek	BLQ	BLQ
25	(Kamalamma Nagar) Buckingham canal	0.2	0.14

### 8.2.2. The Poly Aromatic Hydrocarbon

The Polycyclic aromatic hydrocarbons (PAHs) are a class of organic compounds that are produced by incomplete combustion. The Poly Aromatic Hydrocarbons in all 25 samples of collected water samples are below the Limit of quantification (BLQ). The absence of PAH in water samples shows the lower oil pollution footprints in the study area.

### 8.2.3. Other water quality indicators

The dissolved oxygen (DO) levels measured across the 13 sampling sites (figure 6) along the Buckingham Canal ranged from 0.05 to 0.6 mg/L, with an average of 0.216 mg/L. All Buckingham canal sites had extremely low DO levels below 1 mg/L. The 5 sites sampled along the Kosasthalaiyar River close to Buckingham canal had slightly higher but still depleted DO levels ranging from 0.023 to 0.045 mg/L, averaging 0.031 mg/L. The 3 Ennore Creek sites showed higher DO levels between 1.34 and 4.76 mg/L, with an average of 3.32 mg/L (table 7).

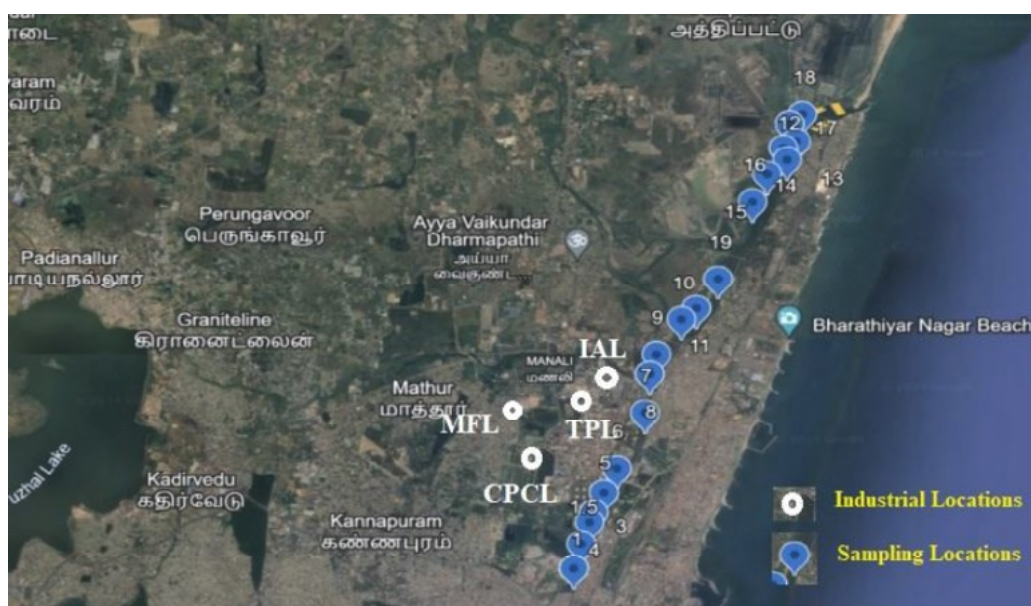
The results indicate severe oxygen depletion in the Buckingham Canal, with average DO levels well below the minimum water quality standards of 3-4 mg/L to support aquatic life. The extremely low DO suggests high pollution loads from sewage, organic waste and surrounding industrial effluents entering these waterbodies.

Aerobic decomposition of these oxygen-demanding wastes is likely responsible for the observed oxygen depletion. In contrast, the Ennore Creek sites had moderately higher DO levels, indicating the positive influence of tidal flushing. The low oxygen observed in the creek's inner reaches suggests migration of oxygen-depleted waters from the adjoining canal and river.

Overall, the low DO throughout the study area provides evidence of degradation of water quality. The degradation would have taken place over a period of time due sewage, organic waste and surrounding industrial effluents entering these water bodies, and cannot be attributed to the oil slick. Remediation efforts should focus on reducing contaminant loads entering the Buckingham Canal to curb oxygen depletion. Continued monitoring will be required to assess the ecosystem impacts of chronic low oxygen levels in these surface waters.

**Table 7. Dissolved oxygen (DO) level in water samples**

Sampling Locations	DO (mg/L)	Site	DO (mg/L)
1	0.12	12	0.35
2	0.23	13	0.45
3	0.43	14	0.023
4	0.04	15	0.023
5	0.54	16	0.023
6	0.14	17	0.023
7	0.60	18	0.023
8	0.08	P1	1.34
9	0.05	P2	4.76
10	0.53	P3	3.87
11	0.46		

**Fig. 6 Location showing on-site dissolved oxygen measured**

BOD was in the range of 6.1 mg/L to 52 mg/L in the study area. This suggests high pollution loads from sewage, organic waste and surrounding industrial effluents entering these water bodies. Aerobic decomposition of these oxygen-demanding wastes is likely responsible for the observed oxygen depletion. The high BOD level was observed upstream of CPCL premises, indicating that domestic sewage wastewater influenced the water quality of the Buckingham Canal ( table 4).

The COD concentrations observed in surface water resources typically range from 20 mg/L or less in unpolluted waters to greater than 200 mg/L in waters receiving effluents. In the present

study, the highest COD of 296 mg/L was observed in Buckingham Canal-Sadyanguppam Bridge followed by 211 mg/L in sample collected from Upstream-Elilnagar, Tondiarpet. The lowest COD of 22 mg/L was recorded in Kosasthaliya river - Mangroove Area. The results revealed that the Buckingham canal is more loaded with organic content from domestic sewage and surrounding industrial effluents (table 4).

The other pollutants like MBAS surfactant was in the range of 0.08 to 1.8 mg/L in the water samples. Among 25 samples, the maximum concentration of MBAS was observed in the midstream location of the Buckingham Canal-near CMDA Steel yard, Thiruvotiyur. The second highest concentration of 1.4 mg/L was observed in Upstream of CPCL (Tondiarpet) which showed that the miscellaneous sources contributed to the MBAS present in the study area. Ninety percentage (90%) of the collected samples showed (Limit value for surface water is 1 mg/L of the surfactants -EU standards) values within European standard limits (table 4).

In water samples, the heavy-metals were observed in the range of 0.01 to 0.2 mg/L (Ni), 0.01 to 0.2 mg/L (Cu), 0.02 to 1.7 mg/L (Zn), BLQ to 0.38 mg/L (Cd), 0.006 to 0.027 mg/L (Pb) in 25 samples collected from Buckingham canal to Ennore creek. The mercury was observed in the range of 0.0038 to 0.010 mg/L in three different samples collected from the upstream, midstream and downstream study area (table 5). The different study conducted to assess the water quality of Buckingham canal showed the presence of various heavy metal concentrations such as 0.006 to 0.012 mg/L (Cr), 1.04 to 1.34 (Cu), 0.23 to 1.75 (Fe), 0.013 to 0.035 (Pd) and 0.125 to 1.6 (Zn) in the year 2012 (Kumar *et al.*, 2018). Many reports evidence that pre-occurrence of various pollutants including heavymetals in the study area including Buckingham canal and Ennore creek (NEERI Report, 1995).

## **8.2.4 Plankton study**

### **8.2.4.1 Phytoplankton**

The phytoplankton community was assessed on Buckingham canal and Ennore creek, covering 3 sampling areas covering Nettukuppam area of Ennore Creek (P1), Thalankuppam peer towards Ennore creek (P2) and Ennore creek NCTPS side covering the entire area of Ennore creek.

The phytoplankton community at the impacted P1 site showed the lower diversity, with only 4 taxa and 5585 individuals observed. Dominance was high (0.7472) and evenness was low (0.4262) at P1, indicating uneven distribution where a few taxa make up the majority of individuals (table 8).

P2 had moderate phytoplankton diversity with 7 taxa and 4728 individuals counted. The community was also highly uneven and dominated (0.7933) by a couple taxa. Shannon diversity (0.4787) and evenness (0.2306) were somewhat higher than P1 but still indicated an imbalanced community structure. The P3 site showed the highest phytoplankton diversity, with 9 taxa and 3936 individuals. Dominance (0.7514) and evenness (0.2022) were comparable to the other sites. All diversity indices were highest at P3 - Shannon (0.5988), Brillouin (0.5926), Margalef (0.9664). The low diversity and high dominance at P1 suggests the domestic wastewater severely affects phytoplankton communities. Sensitive species were likely inhibited or killed off, allowing a few pollution-tolerant taxa to dominate. P3 showed healthier phytoplankton diversity, indicating reduced oil effects further from the spill site.

Phytoplankton	P1	P2	P3
<i>Asterionellopsis sp</i>	0	1	4
<i>Ceratium sp</i>	0	1	0
<i>Chlorella sp</i>	400	200	100
<i>Chaetoceros sp</i>	0	0	6
<i>Ditylum sp</i>	0	6	13
<i>Pediastrum sp</i>	480 0	4200	3400
<i>Scenedesmus sp</i>	60	200	130
<i>Skeletonema sp</i>	0	0	45
<i>Thalassionema sp</i>	325	120	230
<i>Triceratium sp.</i>	0	0	8

**Table 8. Phytoplankton Diversity**

Phytoplankton Indices	P1	P2	P3
Taxa_S	4	7	9
Individuals	5585	4728	3936
Dominance_D	0.7472	0.7933	0.7514
Simpson_1-D	0.2528	0.2067	0.2486
Shannon_H	0.5335	0.4787	0.5988
Evenness_e^H/S	0.4262	0.2306	0.2022
Brillouin	0.5313	0.4751	0.5926
Menhinick	0.05352	0.1018	0.1435
Margalef	0.3477	0.7091	0.9664
Equitability_J	0.3848	0.246	0.2725
Fisher_alpha	0.4214	0.8068	1.1
Berger-Parker	0.8594	0.8883	0.8638
Chao-1	4	8	9
iChao-1	4	8	9
ACE	4	11.05	9

### 8.2.4.2 Zooplankton

Zooplankton diversity was lowest at P1, with 7 taxa making up a total of 7797 individuals. Dominance was high (0.533) and evenness was moderate (0.4045). All diversity indices were lowest. The low diversity and high dominance at P1 suggests the domestic wastewater severely affects zooplankton communities. (table 9). These observation revealed that the anthropogenic sources contributed in quality of water in the study area.

Slightly higher diversity was observed at P2, with 9 taxa and 5984 individuals counted. Community dominance (0.457) and evenness (0.3482) were also fairly uneven. Shannon diversity increased to 1.142.

P3 showed the most diverse zooplankton community with 13 taxa comprising 9265 individuals. All diversity metrics were highest at P3, including lower dominance (0.3187), higher evenness (0.3088), and Shannon diversity of 1.39.

Zooplankton	P1	P2	P3
<i>Acartia</i> sp.	0	12	53
<i>Euterpina</i> sp.	320	32	54
<i>Paracalanus</i> sp.	0	4	12
<i>Pseudodiaptomus</i> sp.	0	0	3
<i>Copepod Nauplii</i>	5600	3880	4300
<i>Cladoceran</i>	0	0	3
<i>Mysis</i>	0	0	7
<i>Polychaete larvae</i>	0	0	3
<i>Pontella</i> sp.	7	56	210
<i>Oithona spp.</i>	650	400	1300
<i>Harpactoid</i>	520	120	600
<i>Nitokra</i> sp.	300	600	120
<i>Oithona brevicornis</i>	400	880	2600

Zooplankton Indices	P1	P2	P3
Taxa_S	7	9	13
Individuals	7797	5984	9265
Dominance_D	0.533	0.457	0.3187
Simpson_1-D	0.467	0.543	0.6813
Shannon_H	1.041	1.142	1.39
Evenness_e^H/S	0.4045	0.3482	0.3088
Brillouin	1.038	1.138	1.385
Menhinick	0.07927	0.1163	0.1351
Margalef	0.6695	0.9199	1.314
Equitability_J	0.5349	0.5199	0.5419
Fisher_alpha	0.7576	1.039	1.488
Berger-Parker	0.7182	0.6484	0.4641
Chao-1	7	9	13
iChao-1	7	9	13
ACE	7	9	13

**Table 9. Zooplankton diversity in study area**

Zooplankton were likely affected both by oil and indirect food web effects of reduced phytoplankton. This demonstrates a cascading effect due to domestic wastewater influence across multiple plankton trophic levels. The P3 site reflects a healthier baseline community further from the impact zone.

Higher diversity was observed at the P3 site, though still showing some degradation. Severely depleted dissolved oxygen was measured throughout the Buckingham Canal. The lack of oxygen is likely due to other organic pollutants, creating hypoxic conditions unable to support aquatic life.

The findings of water analysis reveals the influence of anthropogenic sources including mixture of domestic sewage wastewater and surrounding industrial wastewater from different parts of Chennai Manali-Ennore region contribute to the pollution load in Buckingham canal-Ennore creek region.

### **8.3 Sediment quality status of Buckingham canal to Ennore creek after Michaung cyclone and followup clean activities by CPCL**

The 25 different bottom sediment samples were collected from Buckingham canal at Tondiarpet to Ennore creek. The total distance of 13.5 km has been covered from CPCL to Ennore creek to know the impact of floods Michaung influenced contamination in the study area. The physico-chemical parameters were analyzed and presented below table. The major analysis parameters include oil and grease, Total petroleum hydrocarbons (TPH), Poly Aromatic Hydrocarbons (PAH), phenolic compounds and heavy metals. The laboratory analysis report is enclosed in annexure - III.

#### **8.3.1 Total Petroleum Hydrocarbons and BTEX**

Total Petroleum Hydrocarbons – Oil Range (TPH-o) are larger hydrocarbons that don't evaporate and don't burn very well. They are commonly used to make lubricants and greases. BTEX is mixture of benzene, toluene, ethylbenzene, and xylene. These are four specific compounds found in the TPH-g category. The total petroleum hydrocarbons showed a value of 5.84 to 47.34 mg/Kg for sediment samples collected from Buckingham canal, Kosasthliyar river, Ennore wetland mangroves. The detected concentrations for total petroleum hydrocarbons in all 25 sediments samples were lower than guideline values for ecological risk which is 280 mg/Kg (Sediment quality guideline threshold value from the Australian and New Zealand Environment and Conservation Council (ANZECC)). The data analysis results reveal that the oil spill was removed from the contaminated area effectively and the TPH concentration was within the safe ecological risk limit (table 13).

Table 10. Oil and Grease, Surfactant, TOC, SAR and EC concentrations in sediment samples

S.No.	Locations	pH	Oil and Grease (mg/kg)	MBAS (Surfactants) (mg/kg)	Phenolic compound s (mg/kg)	Total Organic carbon %	SAR	Electrical conductivity (µs/cm)
1	Elilnagar, Tondiarpet	7.29	238	316	3.6	6	1.24	2230
2	Patel Nagar, Tondiarpet	7.44	239	339	BDL(DL: 0.05)	2.37	1.55	1598
3	CPCL Tondiarpet (Near Government Fertilizer Unit)	7.22	155	152	1.5	1.89	1.99	1554
4	-IOCL Gate	7.51	196	194	2.4	4.47	8.17	2890
5	Buckingham Canal ( inbetween CISF bridge and Manali New Bridge)	7.93	273	390	0.5	1.93	3.08	2170
6	Manali Near New Bridge	7.92	198	278	1.4	3.06	2.88	6160
7	Eastside of CPCL	7.39	250	426	1.3	8.27	3.21	4320
8	Kargil Nagar	7.13	255	200	1.5	9	1.35	18050
9	Near CMDS Steel yard, Thiruvetriyoor	8.03	180	930	1.9	1.51	1.6	1336
10	Sathyamoorti Bridge	7.75	220	219	0.9	1.48	0.9	3340
11	Sadyanguppam Bridge	8.02	220	301	2.3	8.91	3.05	7250
12	Jyothi Nagar - Between Sadyanguppam and Kattubakkam bridge	7.84	157	165	0.7	1.47	2.62	3180
13	Sivanpadai Kuppam Bridge	7.51	185	405	3	2.61	5.15	4290
14	Manali-Junction of Buckingham canal and Kosasthaliya river	8.03	97	BDL(DL:5)	BDL(DL: 0.05)	BDL(D L:0.2)	3.17	1245
15	Buckingham canal and Kosasthaliya river	6.13	BDL(DL:1 0.0)	BDL(DL:5)	BDL(DL: 0.05)	BDL(D L:0.2)	8.68	3860
16	Kosasthaliya river - Mangroove Area	4.43	BDL(DL:1 0.0)	BDL(DL:5)	BDL(DL: 0.05)	BDL(D L:0.2)	4.45	1087
17	attukuppam Railway Bridge	7.21	35	298	0.9	2.34	10.7	12680
18	Kattukuppam - After railway Bridge	8.01	26	42	1.2	0.57	3.93	5130
19	Under Ennore Bridge	7.66	BDL(DL:1 0.0)	31	0.1	BDL(D L:0.2)	6.1	6340
20	Ennore Bridge -Near Don Bosco School	7.69	18	12..	0.08	3.46	11.3	17320
21	Thallakuppam Mouth of Ennore Creek	7.4	35	45	5.7	3	10.7	26600

22	Nettukuppam - Mouth of Ennore Creek	8.49	BDL(DL:10.0)	BDL(DL:5)	BDL(DL:0.05)	BDL(DL:0.2)	3.33	4140
23	Nettukuppam - Mouth of Ennore Creek	7.69	BDL(DL:10.0)	BDL(DL:5)	BDL(DL:0.05)	BDL(DL:0.2)	3.6	3900
24	NTPC Side- Ennore Creek (Opp. Nettukuppam)	8.04	BLQ	26	BDL(DL:0.05)	1.18	6.7	14830
25	Between Ennore Creek and Ennore Bridge	7.76	BDL(DL:0.05)	38	BDL(DL:0.05)	1.57	10.7	15160

**Table 11. Different heavy metal concentration in sediment samples**

S. No.	Locations	Nickel as Ni,(mg/kg)	Copper as Cu,(mg/kg)	Zinc as Zn,(mg/kg)	Cadmium as Cd,(mg/kg)	Mercury as Hg,(mg/kg)	Lead as Pb,(mg/kg)	Hexavalent Chromium(mg/kg)
1	Elilnagar, Tondiarpet	27.93	235.52	341.77	7.89	BLQ[L OQ:2.0]	48.02	BDL(DL:5.0)
2	Patel Nagar, Tondiarpet	27.2	154.43	224.47	5.97	BLQ[L OQ:2.0]	42.09	BDL(DL:5.0)
3	CPCL Tondiarpet (Near Government Fertilizer Unit)	17.91	102.49	132.98	8.61	BLQ[L OQ:2.0]	23.15	BDL(DL:5.0)
4	IOCL Gate	17.14	95.92	152.91	5.93	BLQ[L OQ:2.0]	25.91	BDL(DL:5.0)
5	Buckingham Canal (inbetween CISF bridge and Manali New Bridge)	22.23	95.33	23	11.37	BLQ[L OQ:2.0]	16.19	BDL(DL:5.0)
6	Manali Near New Bridge	13.48	63.15	99.58	3.77	BLQ[L OQ:2.0]	16.62	BDL(DL:5.0)
7	Eastside of CPCL	30.95	187.95	357.04	11.85	BLQ	47.84	BDL(DL:5.0)
8	Kargil Nagar	20.11	225.51	210	28.83	BLQ[L OQ:2.0]	28.74	BDL(DL:5.0)
9	Near CMDS Steel yard, Thiruvetriyoor	16.05	114.91	327.94	10.51	BLQ[L OQ:2.0]	19.29	BDL(DL:5.0)
10	Sathyamoorti Bridge	13.15	40.72	195.43	4.88	BLQ[L OQ:2.0]	14.04	BDL(DL:5.0)
11	Sadyanguppam Bridge	24.38	185.61	180	18.58	BLQ[L OQ:2.0]	26	BDL(DL:5.0)
12	Jyothi Nagar - Between Sadyanguppam and Kattubakkam bridge	14.08	35.83	174.9	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	11.83	BDL(DL:5.0)

13	Sivanpadai Kuppam Bridge	13.52	99.47	350	8.83	BLQ[L OQ:2.0]	16.87	BDL(DL:5.0)
14	Manali-Junction of Buckingham canal and Kosasthaliya river	17.66	49.33	772.35	4.1	BLQ[L OQ:2.0]	8.34	BDL(DL:5.0)
15	Buckingham canal and Kosasthaliya river	3.57	3.53	10.45	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	BLQ[L OQ:2.0]	BDL(DL:5.0)
16	Kosasthaliya river - Mangroove Area	4.39	BLQ[L OQ:2.0]	6.7	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	BLQ[L OQ:2.0]	BDL(DL:5.0)
17	attukuppam Railway Bridge	11..5	16	25	8.57	BLQ[L OQ:2.0]	19.77	BDL(DL:5.0)
18	Kattukuppam - After railway Bridge	7.02	8.65	63.8	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	3.8	BDL(DL:5.0)
19	Under Ennore Bridge	3.95	5.47	34.21	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	BLQ[L OQ:2.0]	BDL(DL:5.0)
20	Ennore Bridge - Near Don Bosco School	19.71	18	19.71..	9.17	BLQ[L OQ:2.0]	18.09	BDL(DL:5.0)
21	Thallakuppam Mouth of Ennore Creek	22.26	23	18..	4.88	BLQ[L OQ:2.0]	17.63	BDL(DL:5.0)
22	Nettukuppam - Mouth of Ennore Creek	3.93	BLQ[L OQ:2.0]	7.52	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	BLQ[L OQ:2.0]	BDL(DL:5.0)
23	Nettukuppam - Mouth of Ennore Creek	3.11	BLQ[L OQ:2.0]	6.8	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	BLQ[L OQ:2.0]	BDL(DL:5.0)
24	NTPC Side-Ennore Creek (Opp. Nettukuppam)	11.77	16.79	99.1	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	6.42	BDL(DL:5.0)
25	Between Ennore Creek and Ennore Bridge	15.18	30.92	23	BLQ[LOQ:2.0]	BLQ[L OQ:2.0]	10.74	BDL(DL:5.0)

**Table 12. Poly Aromatic Hydrocarbons (PAH's) in sediment**

S.No.	Locations	Naphthalene (mg/kg)	Acenaphthylene (mg/kg)	Acenaphthene (mg/kg)	Fluorene (mg/kg)	Anthracene (mg/kg)	Phenanthrene (mg/kg)	pyrene (mg/kg)	Fluoranthene (mg/kg)	Benzo(a)anthracene (mg/kg)	Chrysene (mg/kg)	Benzo(b)fluoranthene (mg/kg)	Benzo(k)fluoranthene (mg/kg)	Benzo(a)pyrene (mg/kg)	Indeno(1,2,3-CD)pyrene (mg/kg)	Dibenz(a,h)Anthracene (mg/kg)	Benzo(g,h,i)perylene (mg/kg)	Total PAH
1	Elitnagar, Tondiarpet	0.01	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.014	0.052	0.008	0.037	0.03	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.174
2	Patel Nagar, Tondiarpet	0.01	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.018	BLQ(LOQ 0.05)	0.015	0.013	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.065
3	CPCL Tondiarpet (Near govt. Fertilizer unit)	0.064	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.067
4	-IOCL Gate	0.012	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.017	BLQ(LOQ 0.05)	0.009	0.008	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.053
5	Buckingham Canal (inbetween CJSF bridge and Manali New Bridge)	0.021	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.015	0.015	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.051
6	Manali Near New Bridge	0.051	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.056	0.046	0.008	0.013	0.04	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.231
7	Eastside of CPCL	0.031	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.021	0.047	0.007	0.019	0.023	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.163
8	Kargil Nagar	0.015	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.056	0.059	0.011	0.003	0.01	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.177
9	Near CMDS Steel yard, Thiruvetriyoor	0.014	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.012	0.012	BLQ(LOQ 0.05)	0.006	0.006	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.05
10	Sathyamoorti Bridge	0.027	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.007	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.034
11	Sadyangappam Bridge	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)
12	Jyothi Nagar - Between Sadyangappam and Kathubakkam bridge	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.004	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.004
13	Sivanpadi Kuppam Bridge	0.01	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.003	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.003
14	Manali Junction of Buckingham canal and Kosasthaliya river	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)
15	Buckingham canal and Kosasthaliya river	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)
16	Kosasthaliya river -Mangroove Area	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)
17	attukuppam Railway Bridge	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	0.001	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(LOQ 0.05)

18	Kattukuppam - After railway Bridge	BLQ( LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	0.001	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(L OQ:0.05 )
19	Under Ennore Bridge	BLQ( LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	0.002	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(L OQ:0.05 )
20	Ennore Bridge - Near Don Bosco School	BLQ( LOQ 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	0.002	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(L OQ:0.05 )
21	Thalakkuppam Mouth of Ennore Creek	0.005	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(L OQ:0.05 )
22	Nettukuppam - Mouth of Ennore Creek	0.005	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(L OQ:0.05 )
23	Nettukuppam - Mouth of Ennore Creek	0.005	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(L OQ:0.05 )
24	NTPC Side- Ennore Creek (Opp. Nettukuppam)	0.005	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(L OQ:0.05 )
25	Between Ennore Creek and Ennore Bridge	0.005	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ( LOQ 0.05)	BLQ(L OQ 0.05)	BLQ(L OQ 0.05)	BLQ(LO Q 0.05)	BLQ(L OQ:0.05 )

### 8.3.2. Oil and Grease and Phenolic compounds

Oil and grease (O&G) and total petroleum hydrocarbons (TPH) are both contaminants found in different water and sediments. TPHs are chemical compounds derived from petroleum. Oil and grease includes fatty oily substances that commonly come from cooking oils and animal fats. Oil and grease are generally contributed from anthropogenic sources, as Buckingham canal receives a large quantity of municipal sewage wastewater. The oil and grease level in the sediment was observed in the range of below the limit of Quantification (BLQ) to 273 mg/Kg which is below the standard limit (280 mg/Kg) specified by Australian and New Zealand Environment and Conservation Council (ANZECC). The phenolic compound in the sediment was in the range of 0.9 to 5.7 mg/Kg (table -10).

### 8. 3.3.Poly Aromatic Hydrocarbon

A polycyclic aromatic hydrocarbon (PAH) is a organic compounds that is composed of multiple aromatic rings and formed in coal and in oil deposits, and are also produced by the incomplete combustion of organic matter. The PAH level in the sediment samples is in the range of below the limit of Quantification (BLQ) to 0.174 mg/Kg which is below 10 mg/Kg of sediment quality guideline threshold value (table 12) from the Australian and New Zealand Environment and Conservation Council (ANZECC).

Table 13. TPH and BTEX in sediment

S.No.	Locations	TPH (mg/kg)	BTEX (mg/kg)
1	Elilnagar, Tondiarpet	18.17	2.28
2	Patel Nagar, Tondiarpet	12.02	2.35
3	CPCL Tondiarpet (Near Government Fertilizer Unit)	11.46	2.14
4	-IOCL Gate	8.99	2.22
5	Buckingham Canal ( inbetween CISF bridge and Manali New Bridge)	22.05	2.43
6	Manali Near New Bridge	47.34	2.12
7	Eastside of CPCL	13.71	2.47
8	Kargil Nagar	23.21	2.95
9	Near CMDS Steel yard, Thiruvetriyoor	30.74	1.42
10	Sathyamoorti Bridge	25.56	2.24
11	Sadyanguppam Bridge	18.38	1.92
12	Jyothi Nagar -Between Sadyanguppam and Kattubakkam bridge	7.18	2.03
13	Sivanpadai Kuppam Bridge	18.65	2.2
14	Manali-Junction of Buckingham canal and Kosasthaliya river	16.62	2.18
15	Buckingham canal and Kosasthaliya river	21.98	1.53
16	Kosasthaliya river -Mangroove Area	4.97	1.74
17	attukuppam Railway Bridge	18.8	2.17
18	Kattukuppam - After railway Bridge	19.85	1.79
19	Under Ennore Bridge	6.97	2.02
20	Ennore Bridge -Near Don Bosco School	16..	0.9
21	Thallakuppam Mouth of Ennore Creek	14.93	0.6
22	Nettukuppam - Mouth of Ennore Creek	5.84	BLQ
23	Nettukuppam - Mouth of Ennore Creek	5.74	0.1
24	NTPC Side- Ennore Creek (Opp. Nettukuppam)	17.59	0.7
25	Between Ennore Creek and Ennore Bridge	15.6	0.1

#### 8.3.4. Heavy metal Contamination

Ennore Creek is a vital water body that plays a significant role in the ecological and environmental landscape of the region. There are several research findings show that the detection of a high concentration of heavy metals in the Ennore estuaries. Ennore estuary is contaminated with Cd, Pb, Cu and sources identified as anthropogenic sources (Karthikeyan *et al.*, 2020). In the study area, heavy metal copper was found in the range of 3.53 to 235 mg/kg, Nickel was in the range of 3.1 to 30.95 mg/Kg, Zink was in the range of 6.7 to 341 mg/Kg was found in the sediments, showed the high contamination of heavy metal from different anthropogenic sources. The cadmium was observed in the range of 4.8 to 28.83

mg/Kg. Lead concentration of 3.8 to 48 mg/Kg was observed in different locations from Buckingham canal to Ennore creek (table 11). Due to high surrounding industrial and domestic wastewater entry into the Buckingham canal, Kosasthliyar river and Ennore creek, the higher concentration of heavy metal accumulation in sediment was observed. The mercury value was below the limit of Quantification (BLQ).

### 8. 3.5. Bioaccumulation of pollutants in plant, fish and prawn communities

The flora and fauna of the ecosystem are changing both quantitatively and qualitatively, mainly due to the natural process and anthropogenic influences. Bioaccumulation is the gradual accumulation of toxic heavy metals, mainly occurs through roots with limited upward translocation. The different partitioning and uptake capability of heavy metals in the tissues of various mangrove species have been shown by the translocation and bioaccumulation factors of heavy metals by mangroves. The laboratory analysis results of plant and fish sample are enclosed in annexure - IV.

**Table 14. Different heavy metals in plant samples collected from Kosasthaliyar river-Ennore creek**

S.No	Parameters	Sample No.1 Ennore railway bridge- Kosasthliyar Bridge	Sample No.2 Near Kattukuppam
1	Nickel as Ni (mg/kg)	2.12	2.83
2	Copper as Cu (mg/kg)	3.98	4.29
3	Zinc as Zn (mg/kg)	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]
4	Cadmium as Cd (mg/kg)	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]
5	Mercury as Hg (mg/kg)	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]
6	Lead as Pb (mg/kg)	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]
7	Hexavalent Chromium(mg/kg)	BDL(DL:5.0)	BDL(DL:5.0)

Metals tend to adsorb from water onto surfaces of particles and they are settled into the sediment and further accumulate in the tissues of marine organisms from the water, sediment, suspended particulate materials. Several studies have demonstrated metal contamination in river water, seawater, sediments and bio-accumulation in coastal and estuaries ecosystems of India. In the present study, the common heavy metals were analyzed in plants samples collected from the Buckingham canal and Kosasthaliyar river junction point and found a nickel concentration of 2.12 to 2.83 mg/Kg and copper concentration of 4 - 4.3 mg/Kg was observed and other metals like Zinc, Cadmium, Mercury, Lead and Hexavalent Chromium were below the limit of quantification (Table 14). The heavy-metal accumulation in plant is from the different anthropogenic sources like municipal wastewater and surrounding industrial wastewater.

**Table 15. Different heavy metals in fish samples collected from Kosasthaliyar river-Ennore creek area**

S.No	Locations	Fish sample 1 Ennore Railway Bridge and Kosasthalayar Bridge	Fish Sample 2 Nettukuppam and Ennore Creek	Fish Sample 3 Ennore Creek NCTPS Side	Fish Sample 4 Ennore Bridge and Ennore Creek
1	Nickel as Ni (mg/kg)	0.57	0.66	0.61	0.53
2	Copper as Cu (mg/kg)	BLQ	BLQ	BLQ	BLQ
3	Zinc as Zn (mg/kg)	BLQ	BLQ	BLQ	BLQ
4	Cadmium as Cd (mg/kg)	BLQ[LOQ:0.5]	BLQ[LOQ:0.5]	BLQ[LOQ:0.5]	BLQ[LOQ:0.5]
5	Mercury as Hg (mg/kg)	BLQ[LOQ:0.5]	BLQ[LOQ:0.5]	BLQ[LOQ:0.5]	BLQ[LOQ:0.5]
6	Lead as Pb (mg/kg)	BLQ	BLQ	BLQ	BLQ
7	Hexavalent Chromium(mg/kg)	BDL(DL:5.0)	BDL(DL:5.0)	BDL(DL:5.0)	BDL(DL:5.0)

The different heavy metals were analyzed in fish samples collected from Ennore creek area and analysis results showed that the metal concentration of 0.53 to 0.66 mg/kg of Nickel and other analyzed heavy metals like copper, zinc, cadmium, mercury, lead, and hexavalent chromium was found in the study area (table 15). This similar type of bioaccumulation in fish *M.cephalus* in Ennore estuary was observed for higher bioaccumulation of Cr, Cd, Pb and Ni (Karthikeyan et al., 2020). The data revealed from the present study demonstrate the contamination of Ennore region by metals due to anthropogenic activities. The PAH concentration in all four fish samples was below the limit of the quantification.

## 9. Conclusion

CPCL is situated in the surrounding industrial zone of Manali, Chennai, Tamilnadu which is closer to Ennore the wetland ecosystem. The nearby Buckingham canal runs parallel to the Coromandel Coast, connecting natural backwater areas along the coast to the Chennai port. Due to rapid urbanization and surrounding industrialization, the water ecosystem has been affected due to release of untreated municipal wastewater and surrounding industrial effluents. Generally, coastal environments like Ennore creeks are characterized by high biological

productivity. The present study data also shows the contribution of anthropogenic sources of pollution in the Buckingham canal to Ennore creek.

Due to effective immediate operation and removal of oil contamination, the TPH and its associated pollutants in the study area were within the standard limits.

The summary of the findings is furnished below:

- The site investigation findings showed that there were no significant oil slick or visible contamination in and around the study area.
- Based on the overall water, sediment, plant and fish quality analysis of study area, it is inferred that the anthropogenic sources of pollutants contributed to water and sediment quality of study area from Buckingham canal up to Ennore Creek, including backwater of the Kosasthalaiyar river.
- The reported level of contamination of various pollutants in water and sediments is mainly from domestic wastewater released into Buckingham canal, over a period of time.
- The sample analysis revealed that there is no significant deposition accumulation of petroleum hydrocarbons in water, sediment, plants and fish.
- The reported oil slick has not had any significant impact on the bio-diversity of the waterbodies and nearby areas.

## References

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Kumar S. V., Sultana M., Pascal L. F., Tennyson S., Pandeewari M., Dhinamala K., Persis D., Raveen R., Arivoli S., Meeran M. "Analysis of a few heavy metals in Buckingham Canal water, Chennai, Tamil Nadu, India". *International Journal of Zoology Studies*, Volume 3, Issue 1, 2018, Pages 232-235.

NEERI (1995) Coastal aquaculture, Report. p: 7.

their ponds and ETPs. And also unit is not having either flood management plan or emergency contingency plan to contain oil spillage.

## **7. Monitoring of Water and Air Quality**

### **7.1 Variation of Oil & Grease level in water bodies**

The presence of 828 mg/L of Oil & Grease and 48.4 mg/L Total Phenolic Compounds in the sample collected at Ennore Creek Bridge on 05/12/2023 as against the standards of 10 mg/L and 1.0 mg/L clearly indicates the high oil content in the water bodies. (Annexure 2).

On 07.12.2023, five samples were collected along the Buckingham Canal stretch and near CPCL campus and the Oil & Grease value was varying from 28 mg/L at the B' Canal, near IOCL gate, Tondiarpet to 158 mg/L at Ennore creek. This report clearly indicates that Oil & Grease value in the B' Canal in the upstream of CPCL was lower compared to its level in Ennore creek which is in the downstream of CPCL. The Oil & Grease value was 230 mg/L in the sample collected in the stagnant water in the storm water drain near south gate of CPCL. The high Oil & Grease value in B' Canal in the downstream of CPCL and in the stagnant water in the storm water drain near south gate of CPCL clearly indicate oil spillage from CPCL.

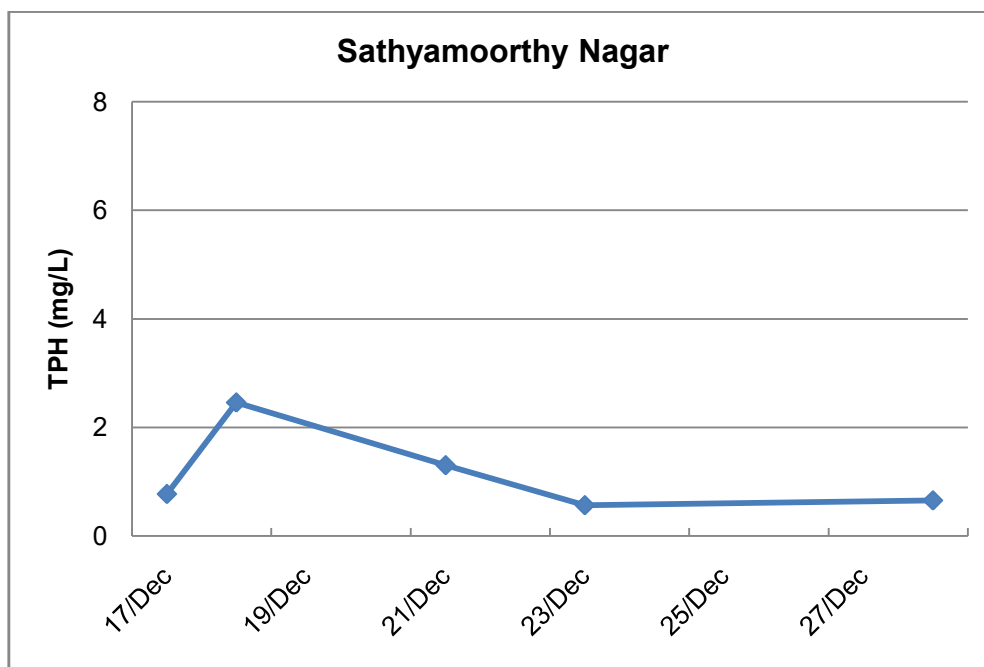
The Oil & Grease value in the samples collected on 09/12/2023 from storm water ponds inside the CPCL premises ranges from 46 mg/L to 96 mg/L indicates clearly that Oil & Grease got mixed with storm water in the unit of CPCL.

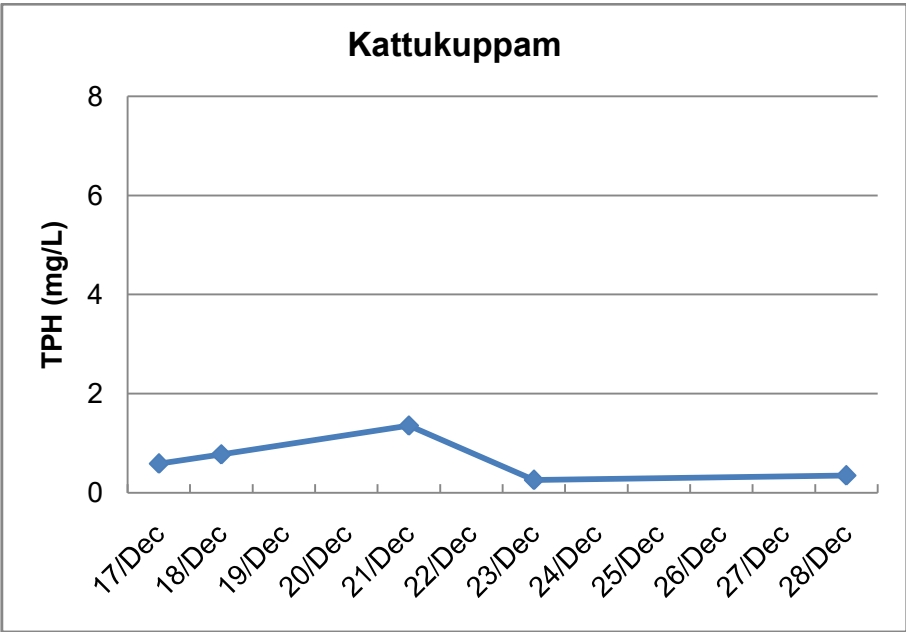
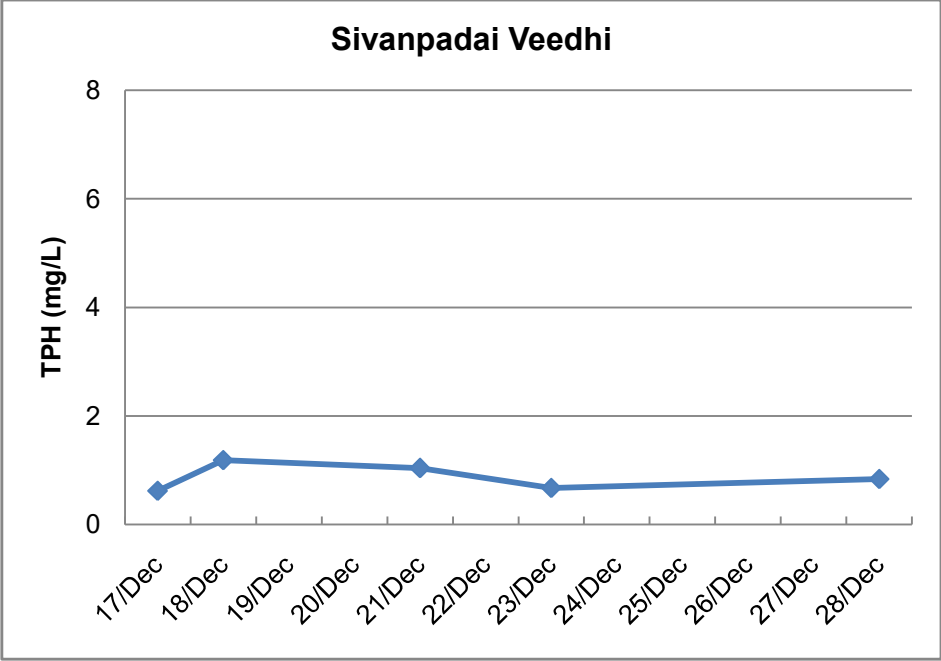
### **7.2 Variation of Total Petroleum Hydrocarbons (TPH) level in water bodies**

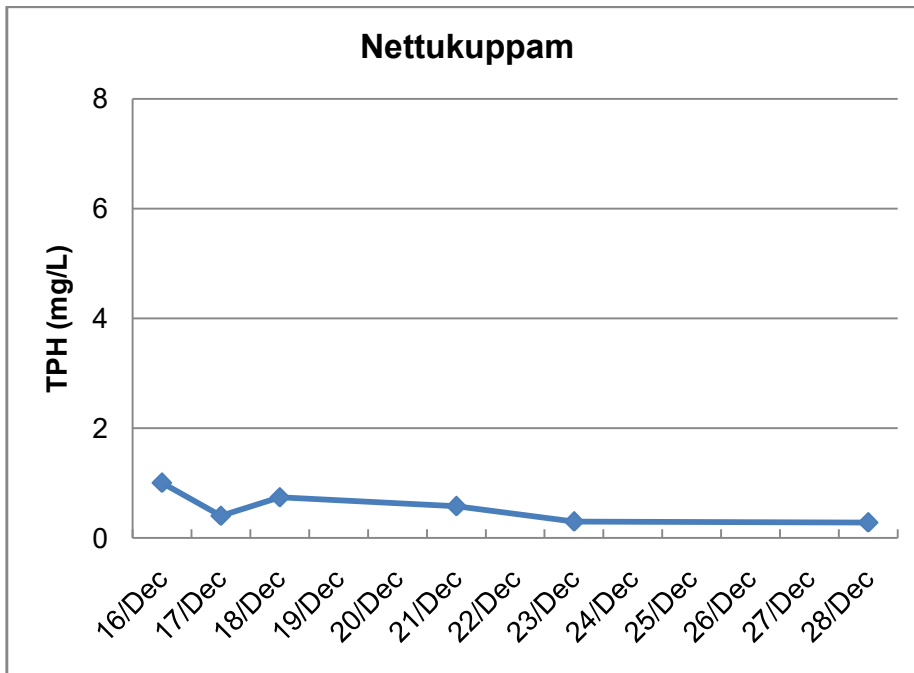
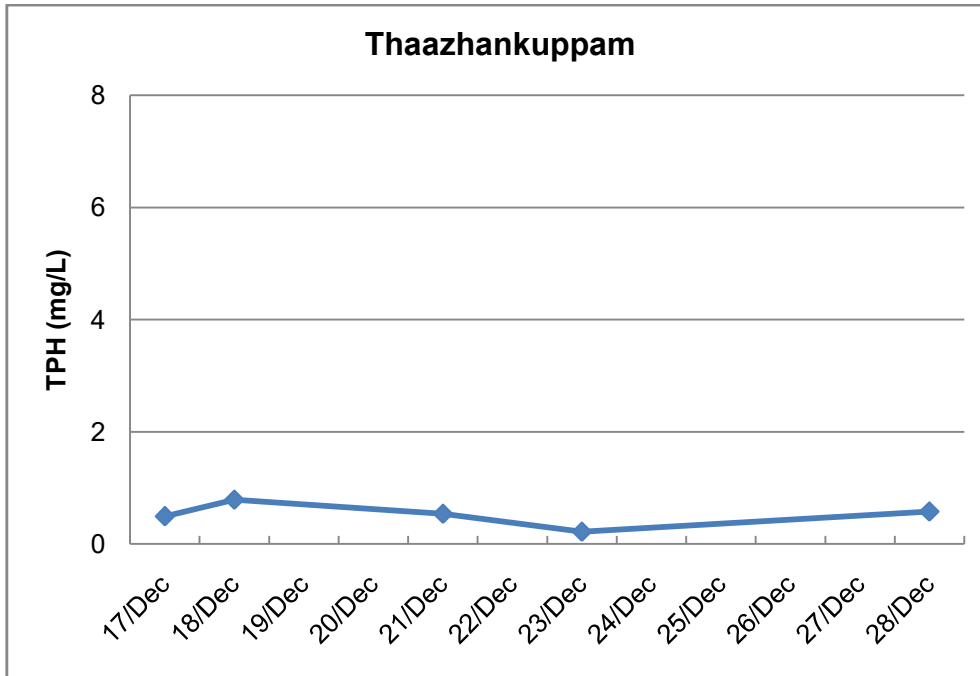
Surface water samples were collected by TNPCB officials and analysed at a NABL accredited private laboratory post the oil spillage and cleaning activities carried out across Ennore and Neighbouring coastal areas (17-12-2023 to 28-12-2023). Samples were analysed for Total Petroleum Hydrocarbons (TPH) and the results are tabulated below. The decreasing trend of TPH value from 17/12/2023 to 23/12/2023 in most of the locations and the flat graph of the same from 23/12/2023 probably indicates that no fresh contamination of B' Canal is occurring from CPCL which is the

major contributor of TPH. The cleaning and remediation activities is responsible for reduction of TPH initially.

Sampling Location	17.12.2023	18.12.2023	21.12.2023	23.12.2023	28.12.2023
Sathyamoorthy Nagar	0.772	2.458	1.302	0.565	0.653
SivanpadaiVeedhi	0.619	1.185	1.034	0.672	0.837
Kattukuppam	0.584	0.775	1.355	0.253	0.344
Thaazhankuppam	0.488	0.787	0.536	0.217	0.576
Nettukuppam	0.402	0.74	0.573	0.294	0.277







Graphs showing the variation of TPH value at various sampling locations

**REPORT ON  
OIL SPILL ASSESSMENT IN NORTH CHENNAI DURING  
CYCLONE MICHAUNG**

CLIENT



**CHENNAI PETROLEUM CORPORATION LIMITED  
CHENNAI-600018**

CONSULTANT



**DEPARTMENT OF OCEAN ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY MADRAS  
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04 MARCH 2025

## Executive Summary

Cyclone Michaung in 2023 caused significant disruption in coastal areas with heavy rainfall and strong winds, particularly impacting Chennai. The persistent rainfall led to widespread flooding and inundation, intensified by the release of excess water from the Poondi and Puzhal Lakes. The floodwaters inundated industrial zones including Manali, Tiruvottiyur, and Ennore and led to the oil spill in the Buckingham Canal and Ennore Creek.


To estimate the quantity of oil in the Buckingham Canal and the Kosasthalaiyar River, CPCL entrusted the task to the Department of Ocean Engineering at IIT Madras (IITM). IITM was chosen for its access to advanced and sophisticated technology, offering a significant advantage over conventional methodologies traditionally used for such assessments.

IITM developed a model to estimate the total oil spilled in the Buckingham Canal and Kosasthalaiyar River using high-resolution PlanetScope satellite data. This advanced approach enabled precise detection and quantification of the oil spill, highlighting the effectiveness of modern remote sensing technology in oil spill monitoring and assessment.

Also, as part of the scope defined, sediment and soil samples were analyzed to assess the concentration of total petroleum hydrocarbons (TPH) in it. The samples from six locations, spanning from the Buckingham Canal to Ennore Creek, are collected.

Flow from the Puzhal and Poondi Lakes were estimated using the Hydrologic Modeling System (HMS), River Analysis system (RAS) model and satellite data during the Michaung Cyclonic event (02-06 Dec 2023).

A flood inundation map was generated using the RAS model, incorporating flow contributions from the Puzhal and Poondi Lakes along with the precipitation across the study area.

  
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The salient observations are as under:

1. The image acquired on 19th November 2023, prior to the oil spill, was analysed to establish baseline conditions of the study area. This pre-spill image (Refer page no: 13), showed no traces of oil contamination, with natural features such as water bodies and surrounding vegetation appearing in their typical spectral characteristics.
2. Satellite observations on 7<sup>th</sup> Dec, 2023 image revealed the oil spill quantity from Manali industrial area to Ennore creek including the residential / adjacent area is 20.53 M<sup>3</sup> (16.4 T). (Refer page no: 15). **The oil volume was calculated by multiplying the oil thickness in each pixel by the pixel's coverage area. The combination of oil fraction, thickness, and volume maps offers a comprehensive understanding of the spill's magnitude and distribution, enabling informed decision-making for mitigation and remediation efforts.**
3. The 26<sup>th</sup> Dec, 2023 post-mitigation image was examined to evaluate the effectiveness of the clean-up operations. The oil volume image (Refer page no: 16) showed no visible traces of oil, suggesting successful removal.
4. Oil typically floats on water due to its lower density, and when an oil spill occurs, the oil tends to remain on the water surface rather than settling down to the channel bed and requires longer period for settling.
5. The TPH estimates from the ground based discrete sediment samples are highly biased. Extrapolation of such TPH values from discrete samples to arrive oil quantity for the entire area would lead to erroneous results.
6. Present sediment analysis at upstream of Manali Industrial area reveals TPH concentration in the range of 1-5 mg/Kg and downstream is 1 to 30 mg/Kg (Refer page no: 35 and 36). This is in line with similar study submitted by Barath kumar et al., in Aug 2023 & NCCR (Annexure).
7. The persistent presence of TPH in the channel bed sediments is likely due to the continuous discharge of urban runoff, municipal waste, oil releases from fishing boats and commercial/industrial discharges into the Buckingham Canal and Ennore creek.
8. No visible oil traces were observed on the water surface during the field survey.
9. The flood inundation map was generated during the cyclonic rainfall event, with flow contributions from the Puzhal and Poondi Lakes, in addition to precipitation across the region.
  - The entire catchment area experienced continuous precipitation and runoff flows, resulting in flow depths significantly exceeding the capacity of the Kosasthalaiyar river.
  - This caused the overflow of the water from the canal to the adjoining areas and led to the reverse flow of water in the canal segments during high tide.
  - The continuous precipitation, surface runoff and flows coming from Poondi and Puzhal Lakes increased the water volume and depth in the river and canal, leading to the reversal and overflow of water from the canal to the adjoining areas (70000 cusec approx. in K-river).

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## 1. Outline of the study

The study aims to assess the oil spill using satellite-based data, with a focus on detecting oil on water surfaces. It will involve conducting in situ experiments to analyze the spectral signatures of oil compounds and estimating their fraction in sediments/soils. Additionally, the study will utilize flow estimation models and satellite data to understand the dispersion and movement of oil, providing a comprehensive analysis of oil spill.

## 2. Scope of Work

- Satellite based assessment of oil spill in Chennai.
- In-situ experiments and spectral analysis of oil compounds.
- Sediment/soil sample analysis for oil fraction estimation.
- Flow estimation using model/satellite data.

### 3. **Introduction**

Cyclones are among the most devastating natural disasters that significantly impact coastal regions, causing severe damage to infrastructure, livelihoods, and the environment. The Bay of Bengal is known for its frequent cyclonic activity, often resulting in heavy rainfall, storm surges, and flooding in adjacent areas. One such severe cyclonic storm, named "MICHAUNG," formed over the Bay of Bengal in late 2023, leaving a trail of destruction in its wake. This extreme weather event particularly affected the coastal districts of North Tamil Nadu and South Andhra Pradesh, where exceptionally heavy rainfall inundated low-lying areas. Chennai city experienced unprecedented rainfall during this period, with the Nungambakkam Meteorological Station recording a staggering 530 mm of rainfall between December 2 and 4, 2023.

The heavy rainfall not only inundated vast stretches of land but also led to the excessive discharge of water from major lakes, including the Poondi and Puzhal Lakes. This sudden and voluminous river discharge overwhelmed the Kosasthalaiyar River and nearby waterways, intensifying flooding in low-lying areas and contributing to significant ecological and infrastructural damage. The additional water flow compounded the challenges faced by the affected communities, disrupting livelihoods and displacing many residents. Among the areas hit hardest was Manali and Ennore, a key industrial hub in Chennai known for its extensive petrochemical and petroleum industries.

To assess the extent and severity of the oil spill, a comprehensive post-disaster assessment was undertaken. The investigation covered a range of activities, including:

- Flow and flood inundation analysis in the Buckingham Canal (pre- and post-cyclone).
- Collection of sediment samples for laboratory analysis to determine contamination levels.
- Mapping the spread of oil, focusing on estimating oil thickness and volume using satellite remote sensing data.

The findings from this assessment provide critical insights comparing conditions before and after the oil spill. The report also highlights the importance of integrating field investigations, laboratory studies, and satellite data analysis to understand

### 4. **Study area**

This study investigates the oil spill regions resulting from flood inundation caused by Cyclone Michaung in the northern part of Chennai, located on the south-eastern coast of India. The region's geographical coordinates are approximately 13° 4' 2.78" N and 80° 14' 15.42" E. Leveraging PlanetScope satellite data, the study examines the spatial extent and impact of oil spills, particularly in industrial areas prone to environmental hazards during extreme weather events.



**Figure 1.** Geographic representation of the study area in Northern Chennai.

The study area focuses on the part of Northern Chennai, covering the Ennore Creek, Kosasthalaiyar River, Buckingham Canal, and the Manali Industrial Area, a central hub for industrial and economic activity. Situated along the East Coast, this region is characterized by a mix of industrial and urban landscapes, making it a vital yet vulnerable area. The Manali Industrial Area, located approximately 20 km north of Chennai at 13°10'4" N latitude and 80°15'43" E longitude, is an extensive industrial hub. It hosts a diverse range of industries,

including oil refining, petrochemicals, pharmaceuticals, engineering, and chemicals. The area is essential to India's petrochemical and energy sectors, providing raw materials critical for various industries. Adjacent to the Manali Complex lies the Ennore Industrial Area, which houses thermal power plants, oil terminals and large-scale chemical and fertilizer units, forming an integrated industrial hub. The region is intersected by numerous water bodies, including the Kosasthalaiyar River, Buckingham Canal, and the Ennore Creek. Despite the presence of these water systems, the area is prone to frequent flooding. This vulnerability is exacerbated by the absence of a comprehensive drainage master plan, encroachments on natural watercourses, inadequate storm water drainage infrastructure etc. During Cyclone Michaung, floodwaters inundated industrial zones, intensifying the risks of oil spills and chemical contamination. This study's investigation of oil spill impacts, using advanced satellite data, provides valuable insights into assessing the oil spillage during extreme weather events.

## 5. Satellite based oil volume estimation

### 5.1 Data used

The PlanetScope satellites are a part of the SuperDove constellation, provides enhanced spectral capabilities along with high spatial and temporal (daily) resolution. It consists of numerous small, low-cost Cube satellites designed to capture multispectral imagery across eight spectral bands: Coastal Blue (444 nm), Blue (492 nm), Green I (533 nm), Green II (566 nm), Yellow (612 nm), Red (666 nm), Red Edge (704 nm), and Near-Infrared (866 nm). The satellite imagery has a swath width of approximately 24 km and a pixel size of 3-4 meters, with a daily revisit period. PlanetScope satellite imageries were purchased from the Planet Labs Inc. through the web portal (<https://www.planet.com/explorer/>). The top-of-atmosphere radiance products (bundle named analytic\_8b\_udm2) covering the Chennai coastal region were acquired for specific periods before, during, and after the cyclone Michaung event in December 2023 (Refer Table 1).

**Table 1.** PlanetScope satellite data used in this study

S. No	Date	Description
1	19 November 2023	Before the Oil Spill
2	07 December 2023	After the Oil Spill
3	26 December 2023	After Mitigation

### 5.2 Linear spectral unmixing model

Linear Spectral Unmixing Models (LSUM) are widely utilized in remote sensing to unmix mixed pixels and quantify the proportion of different materials in a pixel. This model assumes that the observed spectrum of a pixel is a linear combination of the spectra of endmembers, which represent the pure components in the scene. LSUM is especially effective in scenarios involving fractional abundances of materials with distinct spectral characteristics, such as oil spills and water bodies. LSUM has been extensively applied in various environmental monitoring tasks, including vegetation analysis, urban mapping, and marine applications. LSUM is particularly useful for oil spill detection because it can decompose the

spectral signature of mixed pixels containing oil, water, and other constituents. By leveraging high-resolution multispectral or hyperspectral data, LSUM enables the estimation of oil thickness and spatial distribution over water surfaces. The application of LSUM for oil spill estimation is a robust and versatile approach for remote sensing-based environmental monitoring. By incorporating known oil thickness endmembers and addressing the challenges associated with mixed spectra, LSUM provides accurate quantification of oil spills.

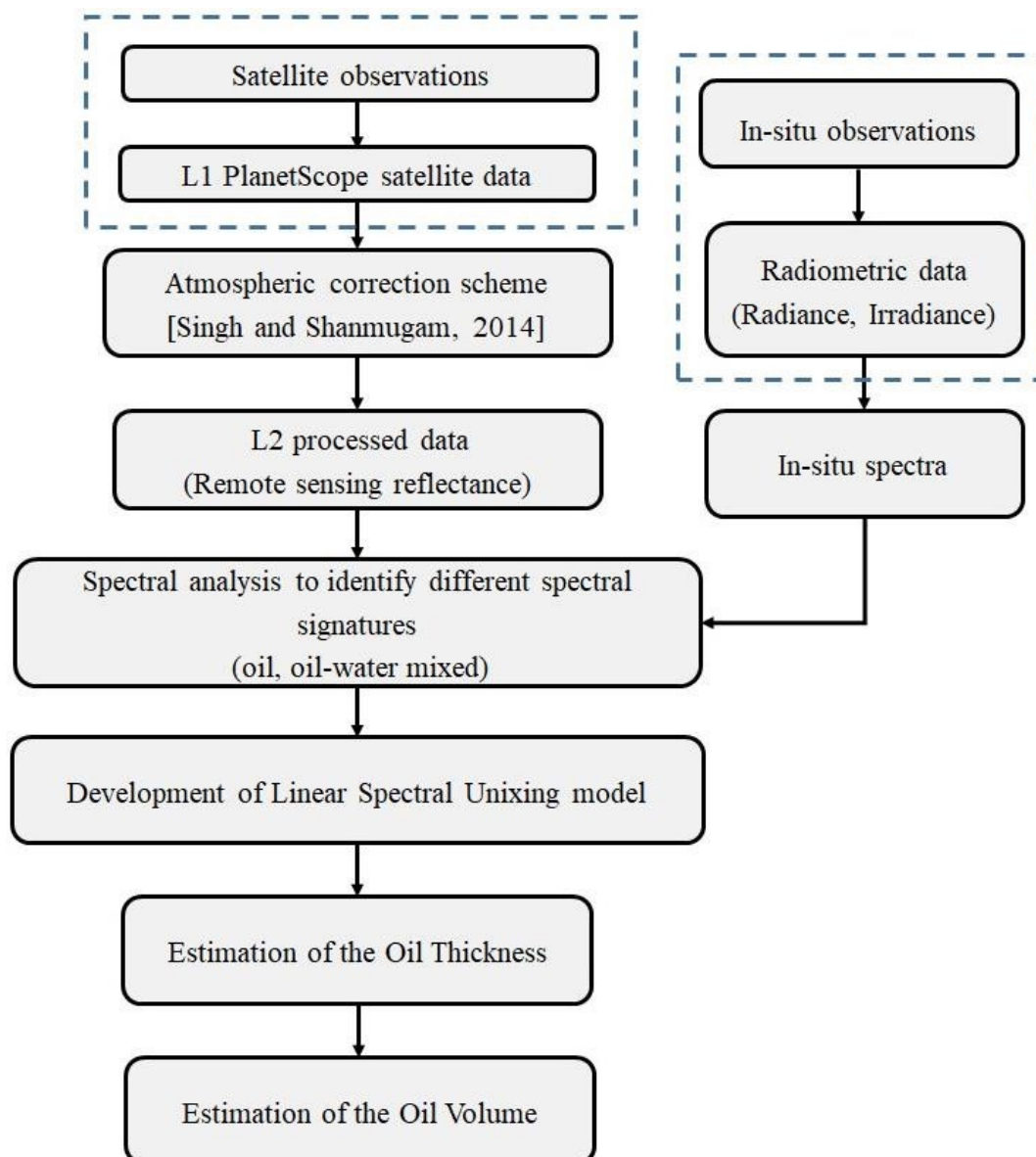
### 5.3 Methodology

The top-of-atmosphere radiance products from the PlanetScope sensor were acquired for the Chennai coastal region. Banerjee and Shanmugam (2021) further refined the above described SS14 atmospheric correction scheme and validated it using MSI sensor data from the Sentinel-2 satellite, which has a 10 m resolution. In this study, the refined atmospheric correction scheme was applied to PlanetScope data to produce realistic  $R_{rs}$  values. The processed PlanetScope image offers a detailed and high-resolution view of the study area affected by the oil spill. This date was particularly crucial because it was the only day during the observation period when the satellite data was completely free of cloud cover, ensuring clear and unobstructed imagery of the spill site. The image was pre-processed to correct for atmospheric and geometric distortions, ensuring its accuracy for further analysis. A true colour composite image was generated using remote sensing reflectance ( $R_{rs}$ ) products, specifically the red ( $R_{rs\_666}$ ), green ( $R_{rs\_566}$ ), and blue ( $R_{rs\_492}$ ) spectral bands. This combination mimics how the human eye perceives the Earth, providing a realistic and visually interpretable representation of the oil spill and its surrounding environment. The true colour image highlights the contrast between the oil spill and the natural features of the area, such as water bodies and vegetation, making it easier to identify the extent of the spill.

In-situ observations during field experiments were systematically conducted to study the spectral characteristics of oil and their direct correspondence to its thickness. Radiometric data, including both radiance and irradiance measurements, were collected under natural environmental conditions to capture the optical properties of the oil. The in-situ spectra of oil with varying thicknesses were accurately recorded, revealing distinct spectral signatures that correlated with specific thickness ranges. These spectral variations were analysed to identify key wavelengths and patterns that could be used to differentiate between thin sheen and thicker oil layers. To quantify the oil spill, a technique called linear spectral unmixing was employed. This method uses the spectral signatures of pure oil and water as endmembers to decompose mixed pixels into their constituent components. By analysing the reflectance properties of these endmembers, the proportion of oil in each pixel was estimated, with values ranging from 0 (indicating no oil) to 1 (indicating pure oil). This process provided a detailed map of the oil fraction across the study area, revealing the spatial distribution of the spill. Using the known thickness of the oil spectra endmember, the oil thickness was then estimated by correlating it with the oil fraction results. A colour-coded map was created to visually represent the oil thickness, with darker or more intense colours indicating thicker oil layers. This visualization helps identify areas with the highest oil concentrations, which is critical for prioritizing clean-up efforts and assessing the environmental impact of the spill.

**Finally, the oil volume was calculated by multiplying the oil thickness in each pixel by the pixel's coverage area.** Since the PlanetScope imagery has a resolution of  $3 \times 3$  meters, each pixel represents an area of 9 square meters. The oil volume map, accompanied by a colour bar, illustrates the spatial distribution of the oil volume across the study area. This map provides valuable insights into the total amount of oil spilled, highlighting hotspots where the volume is the highest. **The combination of oil fraction, thickness, and volume maps offers a**

**comprehensive understanding of the spill's magnitude and distribution, enabling informed decision-making for mitigation and remediation efforts.** This detailed analysis underscores the importance of remote sensing and spectral techniques in monitoring and managing environmental disasters like oil spills, providing critical data for effective response strategies.



**Figure 2.** Flowchart representing the methodology followed to estimate the oil volume.

#### 5.4 Results and discussion:

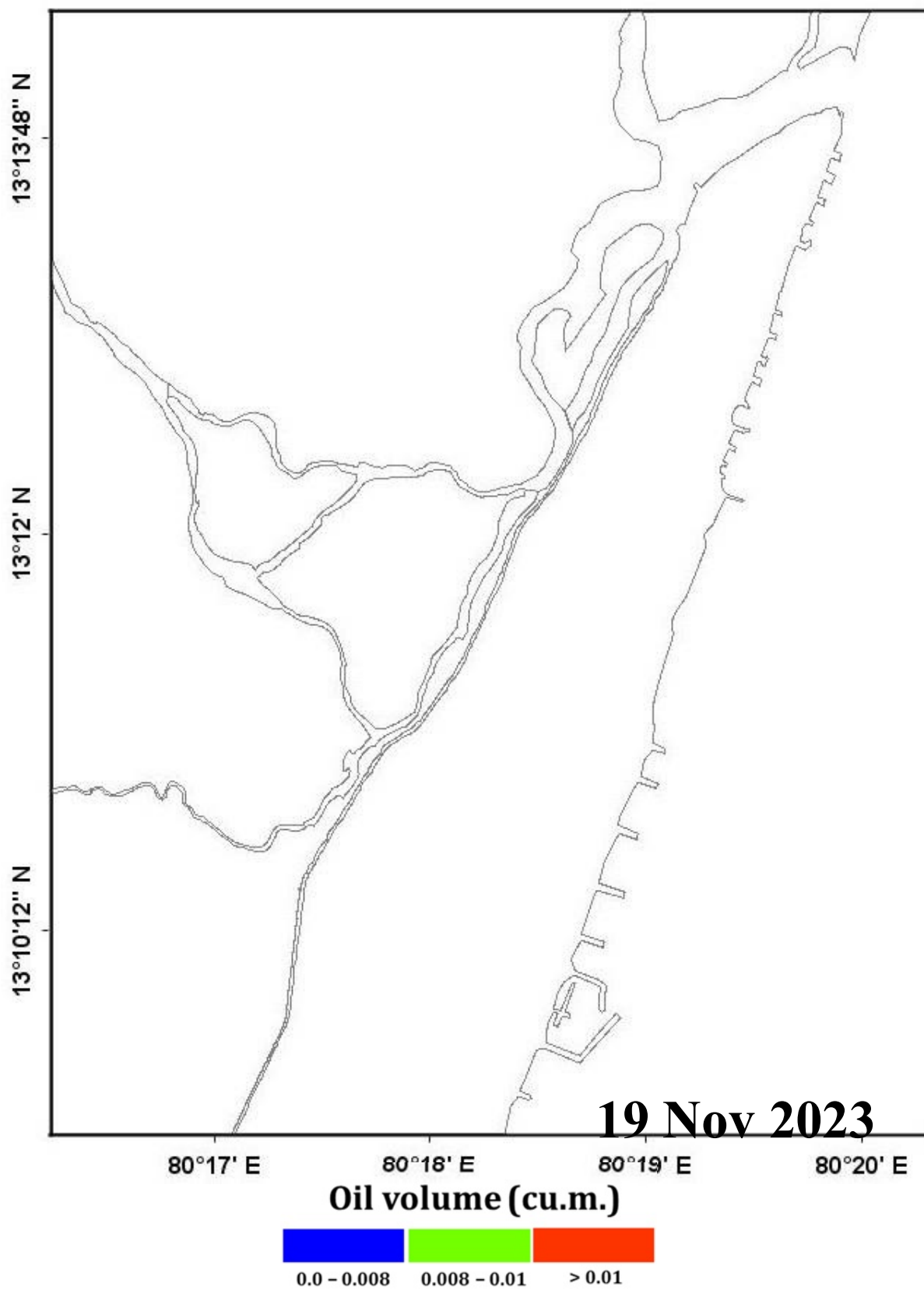
The analysis of the PlanetScope imagery before, during, and after the oil spill event provides a comprehensive understanding of the spill's impact and mitigation effectiveness. The image acquired on 19<sup>th</sup> November 2023, prior to the oil spill, was analysed to establish baseline conditions of the study area. This pre-spill image (Fig. 3, page no: 13), showed no traces of oil contamination, with natural features such as water bodies and surrounding vegetation appearing in their typical spectral characteristics. The absence of any spectral anomalies or deviations in reflectance values validated that no oil contamination was present before the event.

Following the oil spill, the 7<sup>th</sup> December 2023 image (Fig. 4 and 5, page no: 14 and 15) was analysed to estimate the extent and severity of the contamination. Using the linear spectral unmixing technique, the oil fraction image was generated, illustrating the proportion of oil within each pixel. To further assess the impact, an oil thickness image was created by correlating the oil fraction with known oil thickness values derived from in-situ spectral measurements. The thickness map provided a clear representation of the variations in oil layer densities, distinguishing between thin oil sheens and thicker accumulations.

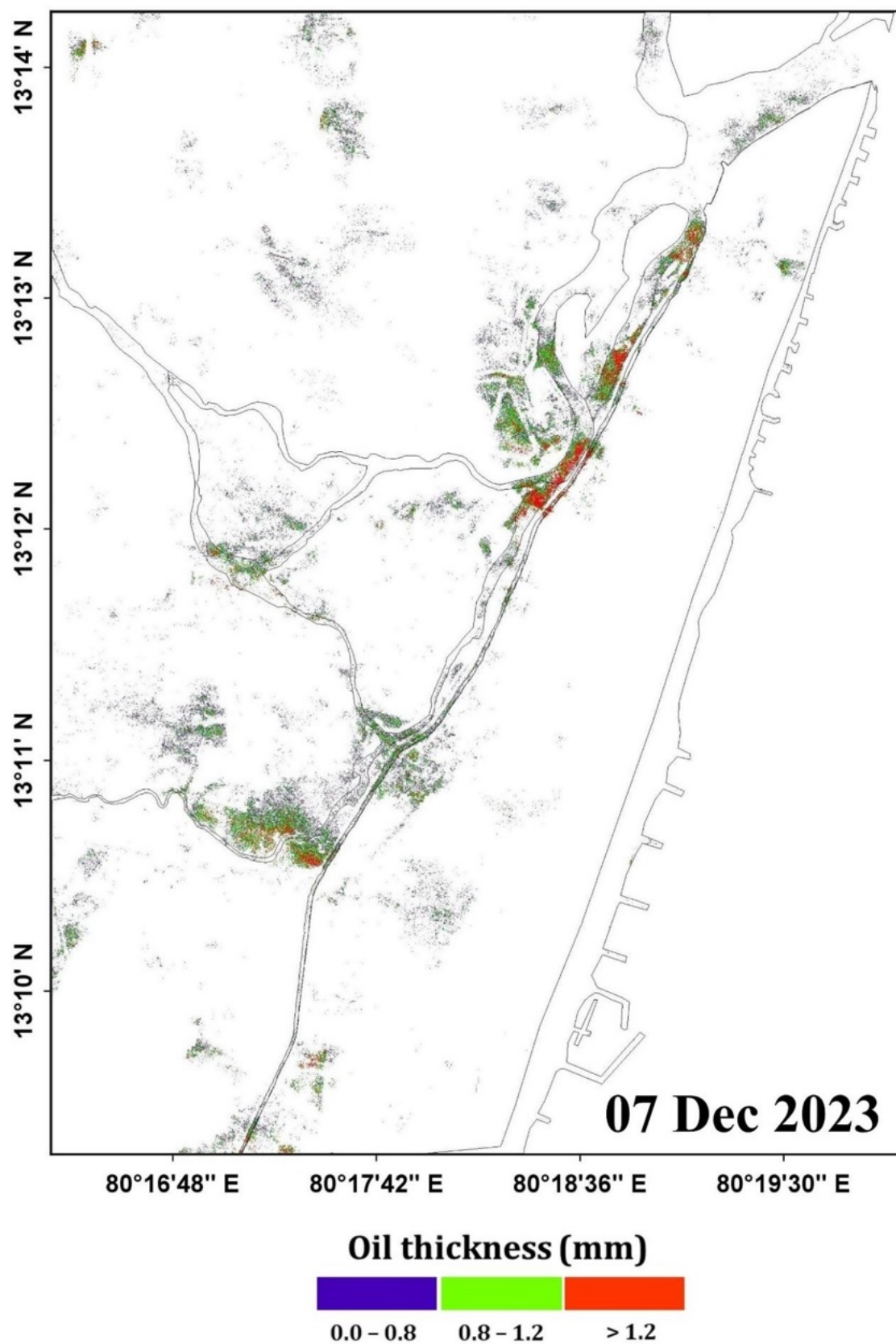
The oil volume map, along with thickness maps (Fig. 4 and 5, page no: 14 and 15), provided a detailed spatial representation of the contamination. Satellite observations revealed the oil spill quantity from Manali industrial area to Ennore creek including the residential / adjacent area is 20.53 M<sup>3</sup> (16.4 Tons).

The 26<sup>th</sup> December 2023 post-mitigation image was examined to evaluate the effectiveness of the clean-up operations. The oil volume of this image (Fig. 6, page no: 16) showed no visible traces of oil, suggesting successful removal or dispersion of the spilled oil. A spectral analysis confirmed that the reflectance properties of the water had returned to pre-spill conditions, with no significant deviations indicating residual contamination. The absence of oil signatures in the results (Fig. 6, page no: 16), further supported this conclusion, demonstrating that the remediation efforts had effectively restored the environmental conditions of the study area.

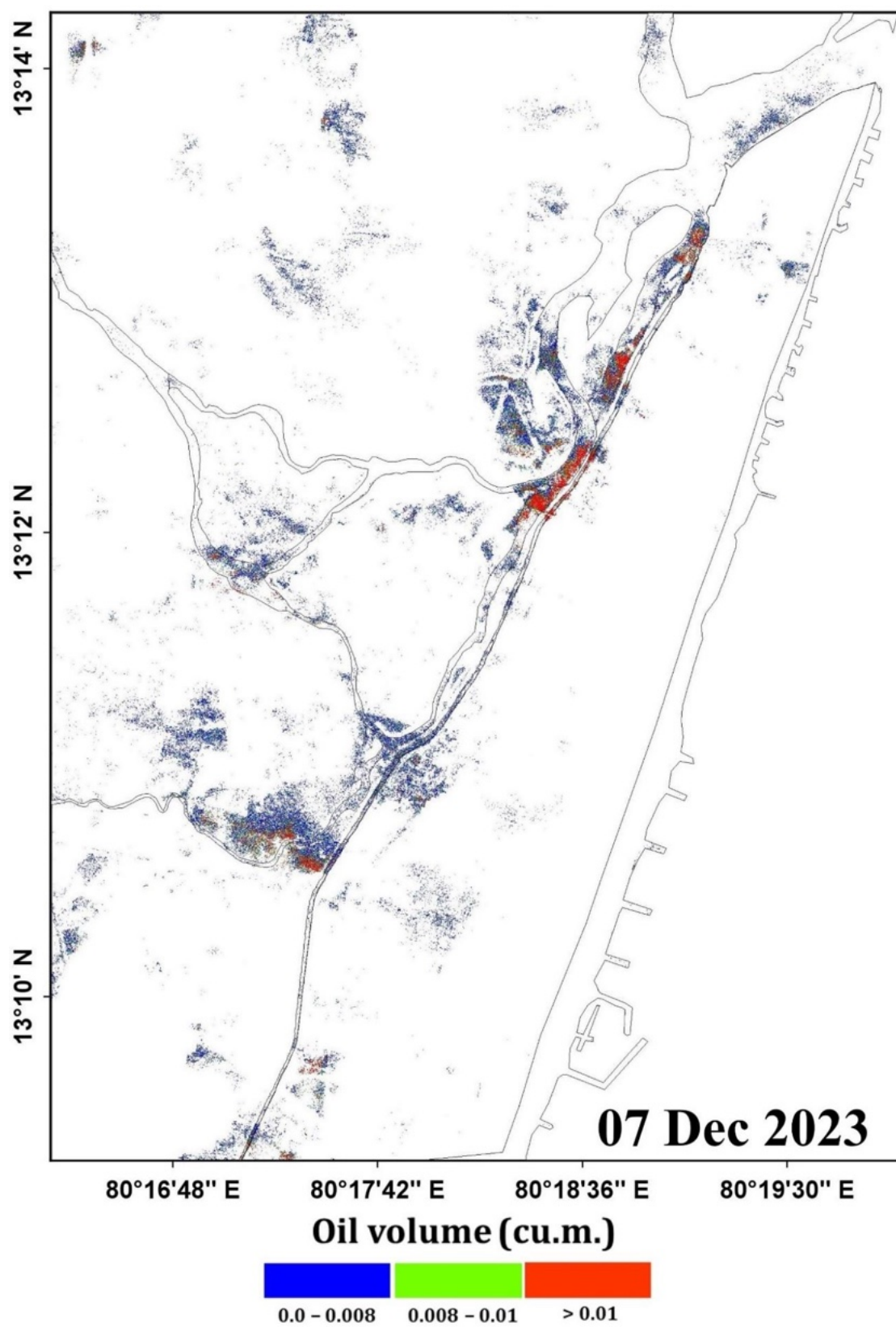
The comparison of pre-spill, post-spill, and post-mitigation images highlights the effectiveness of remote sensing techniques in monitoring oil spill incidents. The integration of high-resolution PlanetScope imagery, in-situ spectral data, and advanced image analysis methods provided an accurate and reliable assessment of the spill's extent, severity, and subsequent mitigation. The study highlights the critical role of satellite-based monitoring in environmental disaster response, enabling timely decision-making and targeted intervention strategies. By leveraging remote sensing for oil spill assessment, authorities can enhance their ability to detect, quantify, and mitigate oil spills, minimizing ecological and economic damages associated with such environmental hazards.



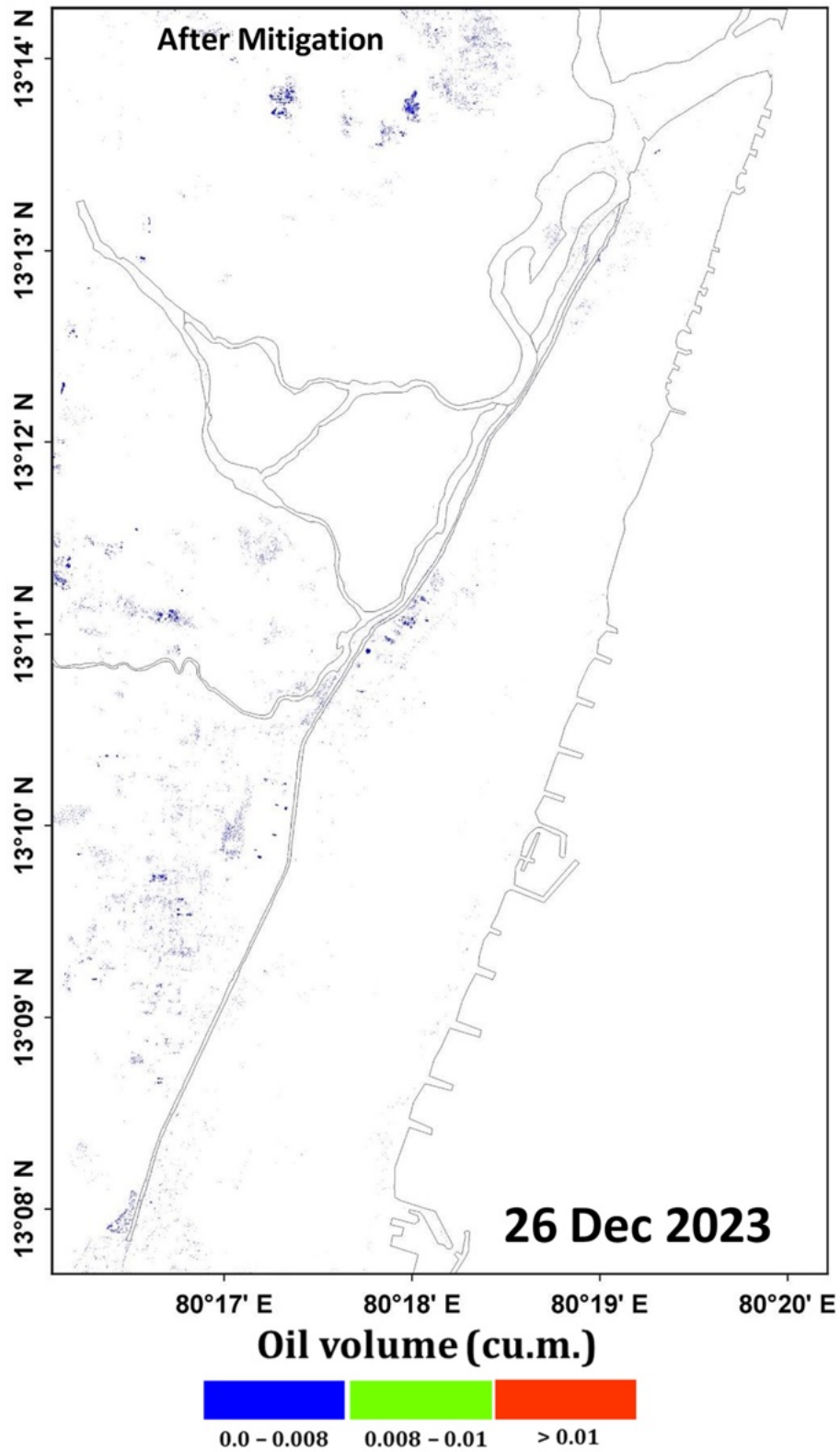
**Figure 3.** Map showing oil volume image derived from the PlanetScope data of the Chennai coast, on 19 November 2023 (no oil patches were observed in this image).



**Figure 4.** Map showing oil thickness from the PlanetScope data of the Chennai coast, on 07 December 2023.



**Figure 5.** Map showing oil volume from the PlanetScope data of the Chennai coast, on 07 December 2023.



**Figure 6.** Map showing oil volume image derived from the PlanetScope data of the Chennai coast, on 26 December 2023 (no oil patches were observed in this image).

## **6. Flow analysis using hydrological models**

### **6.1 Data**

#### **6.1.1 Digital elevation model (DEM)**

A Digital Elevation Model (DEM) is a crucial geospatial dataset that provides a three-dimensional representation of the Earth's surface by showing its terrain elevation at specific intervals, free from vegetation, buildings, and other surface features. DEMs are foundational for numerous geospatial and hydrological applications, as they enable the analysis of landform characteristics such as slope, aspect, drainage patterns, and elevation differences. These models were useful for hydrological studies, as they useful for watershed and sub-basin delineation, slope computation, flow direction and accumulation analysis, flood modelling, and river/channel network identification. The accuracy and resolution of a DEM significantly influence the precision of the hydrological and hydraulic models.

For this study, two high-resolution DEM datasets were acquired: the Shuttle Radar Topography Mission (SRTM) DEM with a spatial resolution of 30 m (Fig. 7, page no: 18) and the Cartosat DEM with a finer resolution of 2.5 m (Fig. 8, page no: 19), both covering the Chennai region. The SRTM DEM (<https://earthexplorer.usgs.gov/>), derived from radar interferometry, provides global coverage and was widely used for regional-scale studies due to its consistent quality. The Cartosat DEM (<https://bhuvan-app3.nrsc.gov.in/>), generated from stereo images captured by the Cartosat-1 satellite, offers higher spatial detail, making it suitable for localized studies requiring detailed terrain information. These DEM datasets were reprocessed using Geographic Information System (GIS) tools to ensure compatibility with the study area, defined by the Chennai boundary shapefiles.

The DEM preprocessing involved clipping the terrain data to the study area boundary, removing any sinks (depressions) to ensure accurate flow direction and accumulation modelling, and aligning the projection to the World Geodetic System, 1984 (WGS84). WGS84, a globally recognized reference system, ensures consistency in spatial referencing for hydrological modelling. The study area, located in the 43° Northern Hemisphere zone, was assigned this coordinate system to the DEM to ensure compatibility and alignment with other geospatial data products used as inputs to this hydrological modelling.

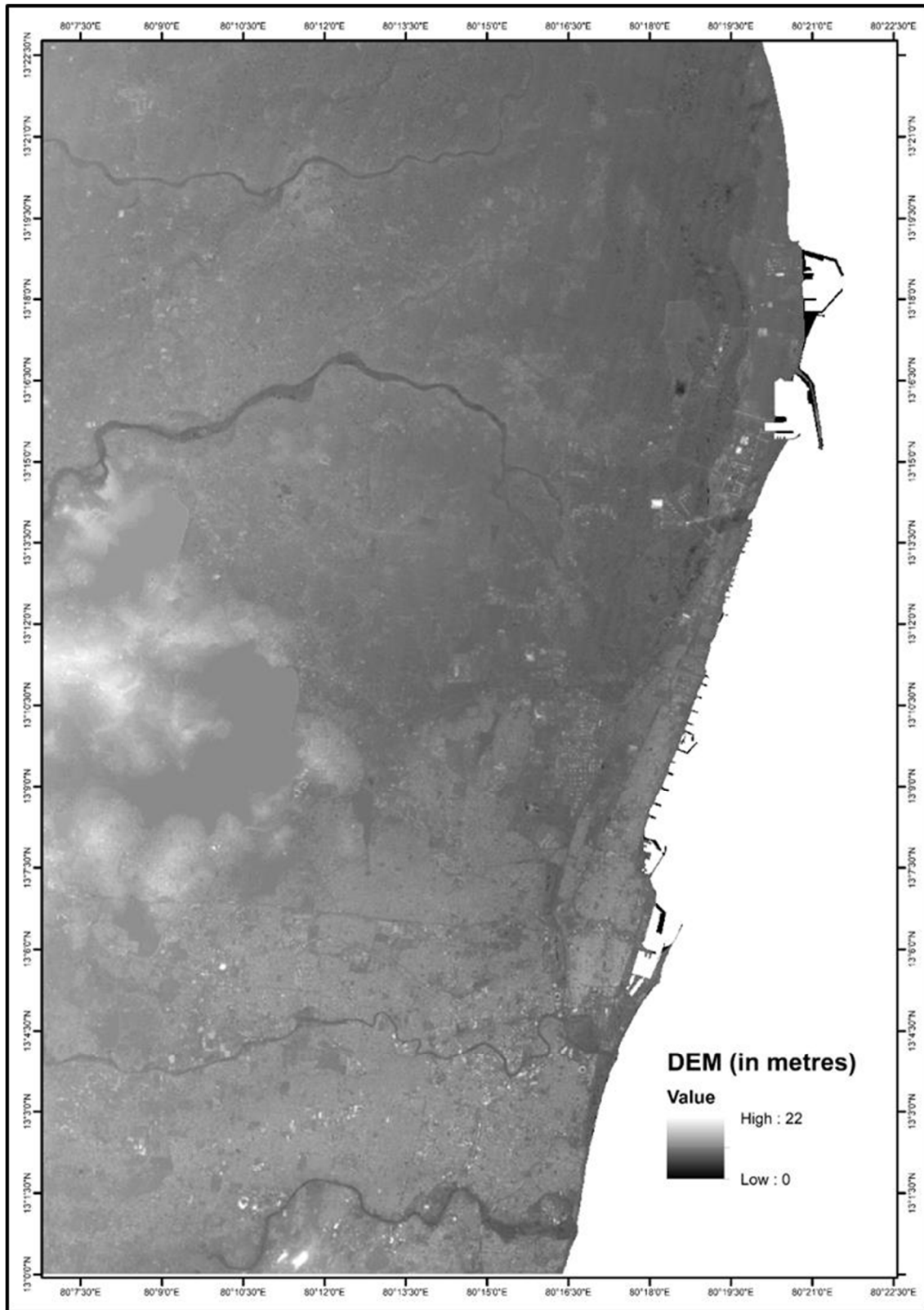
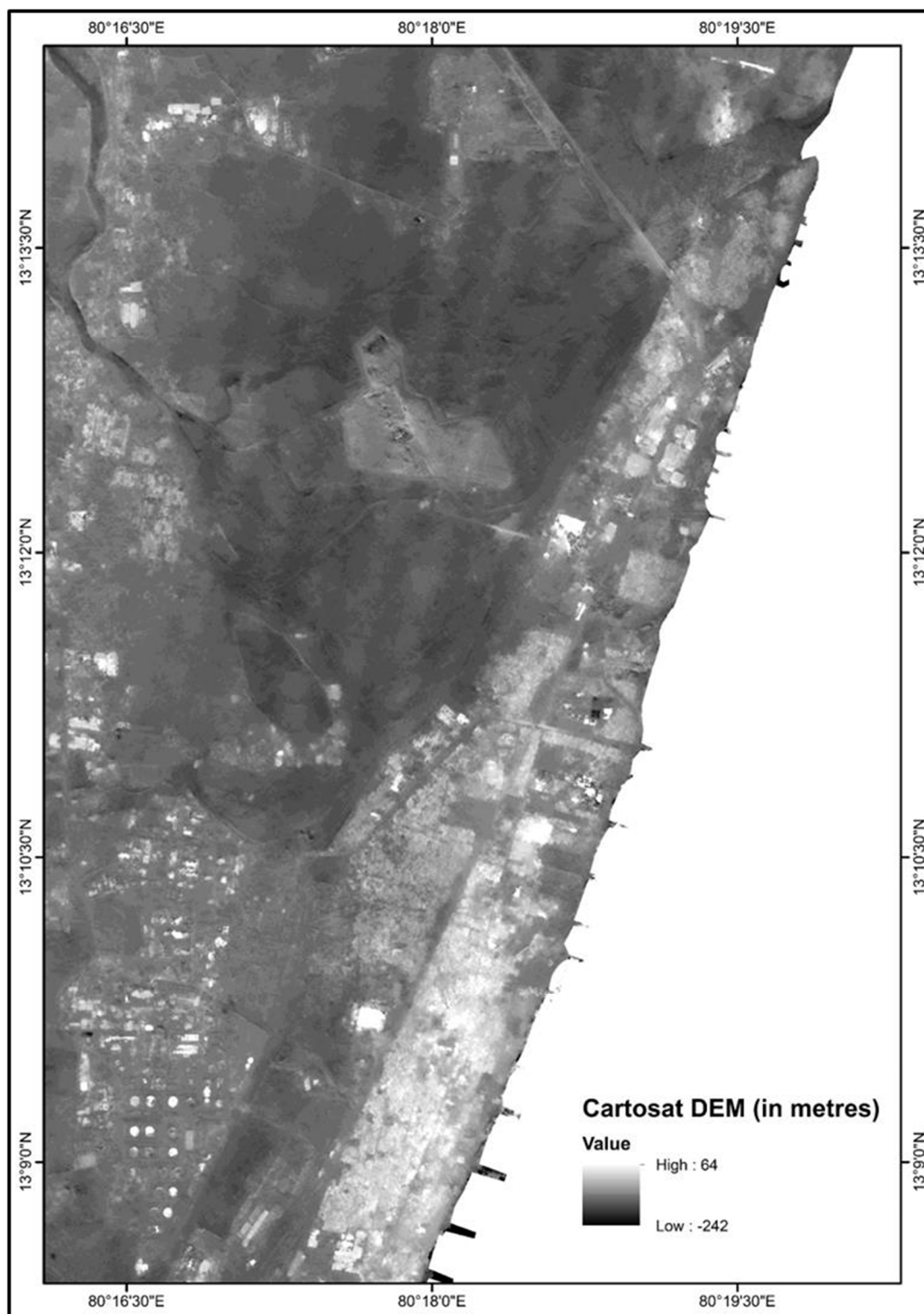


Figure. 7 The SRTM DEM with a resolution of 30 m.



**Figure. 8** The Cartosat DEM with a resolution of 2.5 m.

### 6.1.2 Land use/cover

Land use (LU) refers to the way land and its resources were utilized to fulfill various human needs, including agriculture, urban development, forestry, recreation, or industrial activities. On the other hand, land cover (LC) describes the physical and biological characteristics of the Earth's surface, encompassing features such as vegetation, water bodies, barren land, and built-up areas. In this study, satellite imagery was utilized to identify various LC types, providing a high-resolution view of the physical surface features of the region. The acquired LU/LC maps were digitized within ArcGIS (10.1 version), allowing for precise delineation of different land cover classes, such as urban areas, agricultural fields, forests, and water bodies. Additionally, the software was used to calculate the spatial extent of each LC type, enabling a quantitative assessment of land distribution in the study area. The LU/LC data maps (Fig. 9, page no: 21) were further integrated with hydrological models to analyse their impact on surface runoff, infiltration, and flood dynamics. The urbanized areas with impervious surfaces tend to reduce infiltration and increase surface runoff, whereas vegetated areas promote water retention and groundwater recharge. This information was critical for urban planning, watershed management, and implementing strategies to mitigate flood risks. By comparing historical and current satellite imagery, trends such as urban sprawl, loss of vegetation cover, or expansion of water bodies can be analysed to inform decision-making processes for sustainable development. This integration of satellite data and GIS analysis provides for monitoring and managing land resources effectively.

### 6.1.3 Soil data

Soil data (<https://indiawris.gov.in/wris/#/soil>) plays a significant role in hydrological modelling by providing essential information on soil types, texture, infiltration rates, and hydrological soil groups. These parameters are crucial for estimating water losses, such as infiltration and percolation, which significantly impact surface runoff generation and overall watershed hydrology. Understanding the soil's physical and hydrological properties helps the model how water interacts with the land surface, affecting processes like runoff, infiltration, and groundwater recharge. In the present study, soil classification maps are used to identify the dominant soil type in the region, which is found to be primarily clayey, shale and sandstone. The clayey soils are characterized by fine particles, low permeability, and high-water retention capacity. These properties influence hydrological behaviour by reducing infiltration rates and increasing surface runoff, particularly during intense rainfall events. The classification of soils into hydrological groups, based on their infiltration and drainage characteristics, provides valuable inputs for hydrological models. The clayey soils generally fall into hydrological groups with low infiltration rates, which are critical for estimating runoff volumes and peak discharges.

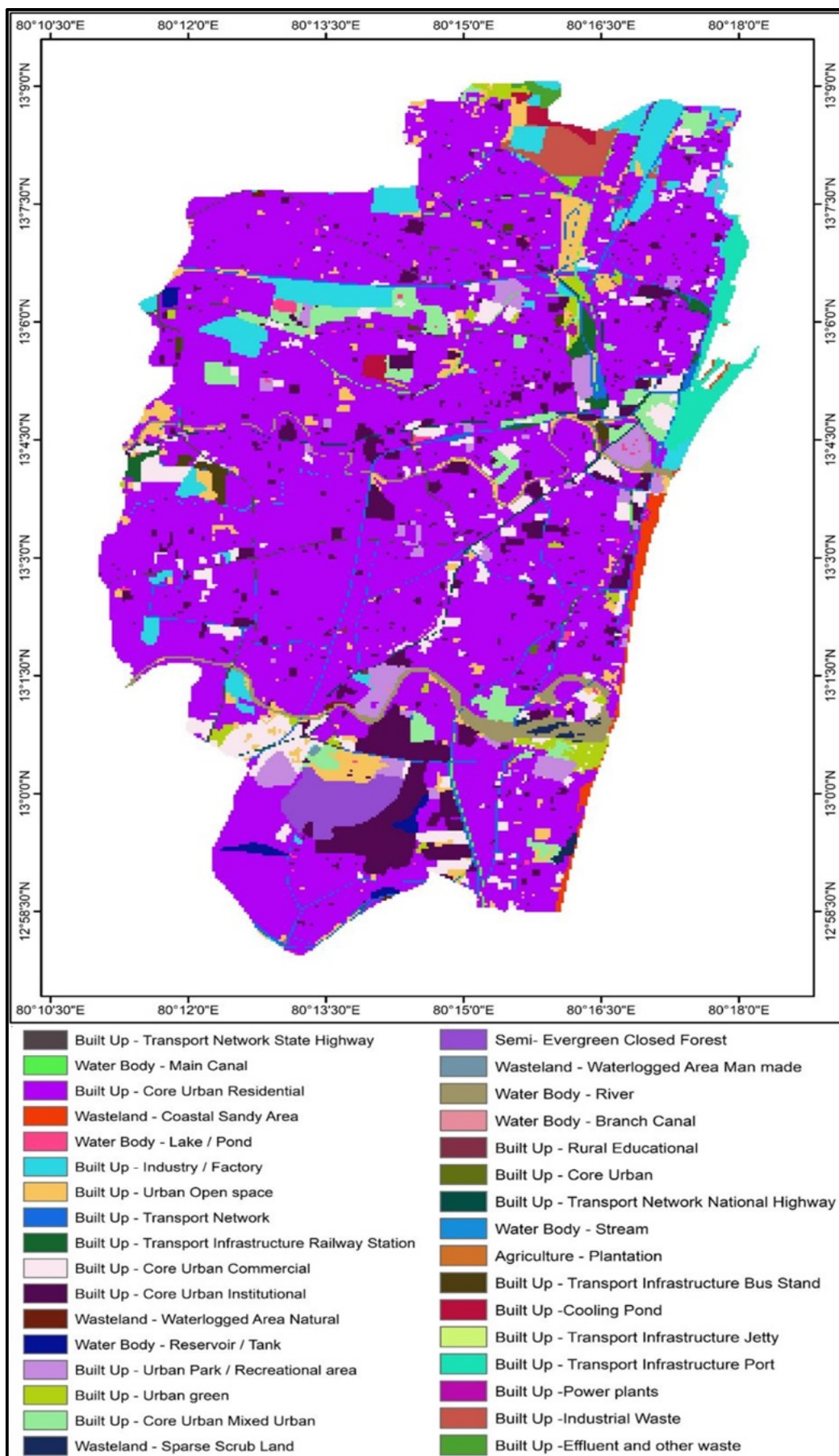
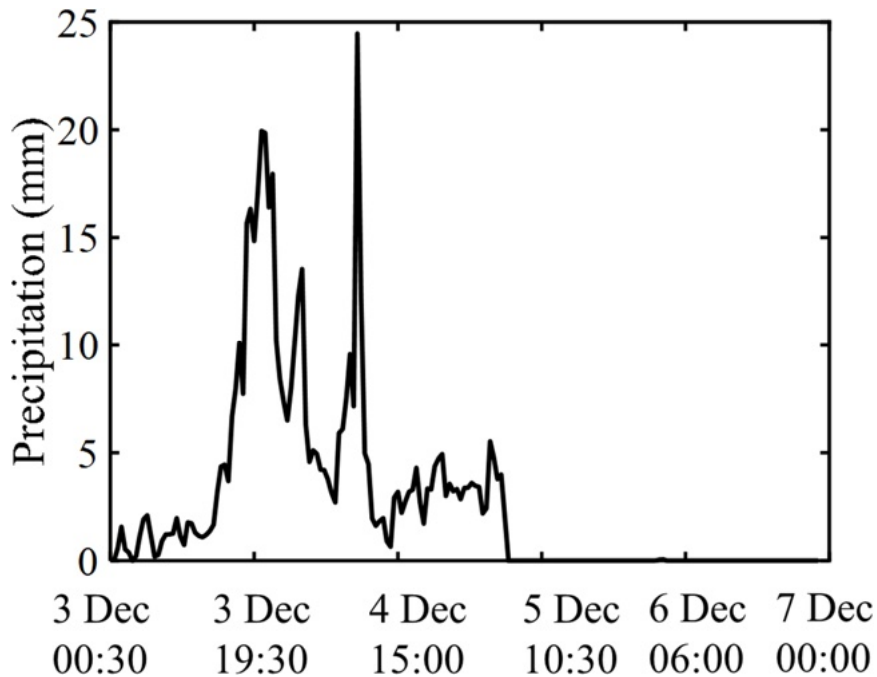


Figure. 9 Land use/cover map of Chennai region.

#### 6.1.4 Precipitation data

Precipitation is a critical hydrological parameter that represents the intensity, amount, and spatial-temporal distribution of rainfall over a given area. It serves as the primary input for hydrological models to simulate runoff, infiltration, and other water cycle components. Accurate precipitation data is essential for understanding and predicting the hydrological response of a catchment, especially during extreme weather events such as cyclones. For this study, precipitation data was obtained from satellite-derived datasets, specifically the Integrated Multi-satellite Retrievals for GPM (IMERG). The IMERG dataset, a product of NASA's Global Precipitation Measurement (GPM) mission, provides high-resolution precipitation estimates derived from multiple satellite observations. This data is particularly valuable for areas with limited ground-based rain gauge networks, as it ensures continuous spatial and temporal coverage. The IMERG data was downloaded with a temporal resolution of 30 minutes to capture the dynamic rainfall patterns during the MICHAUNG cyclonic event (December 3 to December 6, 2023). This timeframe allowed for detailed monitoring of the rainfall distribution and intensity during the peak of the cyclone (Fig. 10, page no: 22).

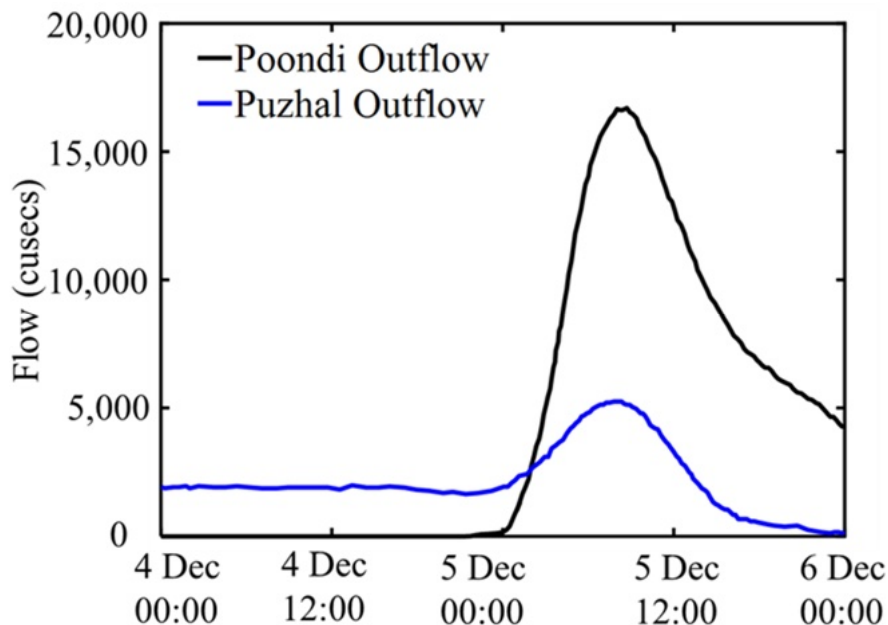


**Figure. 10** Precipitation data downloaded from the IMERG for the Chennai region from 3 to 7 Dec 2023.

#### 6.1.5 Discharge data

Poondi Lake, also known as Sathyamoorthy sagar, is a major water resource formed across the Kosasthalaiyar River to enhance the water supply for Chennai City. It serves as a critical source of water for the Kosasthalaiyar river and plays a significant role in meeting the city's water demands. Additionally, Puzhal Lake, another prominent Lake in the region, also contributes to the flow in the Kosasthalaiyar river. Together, these water bodies significantly influence the hydrology of the region, particularly during extreme weather events. For this study, the discharge from the Lakes the data was attained from the literature (Radhakrishnan et al., 2024). The Poondi Lake and other connected water bodies discharged substantial volumes

of floodwaters during the MICHAUNG cyclone in December 2023. The data used for this study corresponds to the period from 4 to 7 December, 2023, which coincides with the peak of the cyclonic event. This period was chosen to capture the Poondi and Puzhal Lakes response to the intense rainfall and its contribution to downstream flooding. Figure 11 shows the flow from the Poondi and Puzhal Lakes.



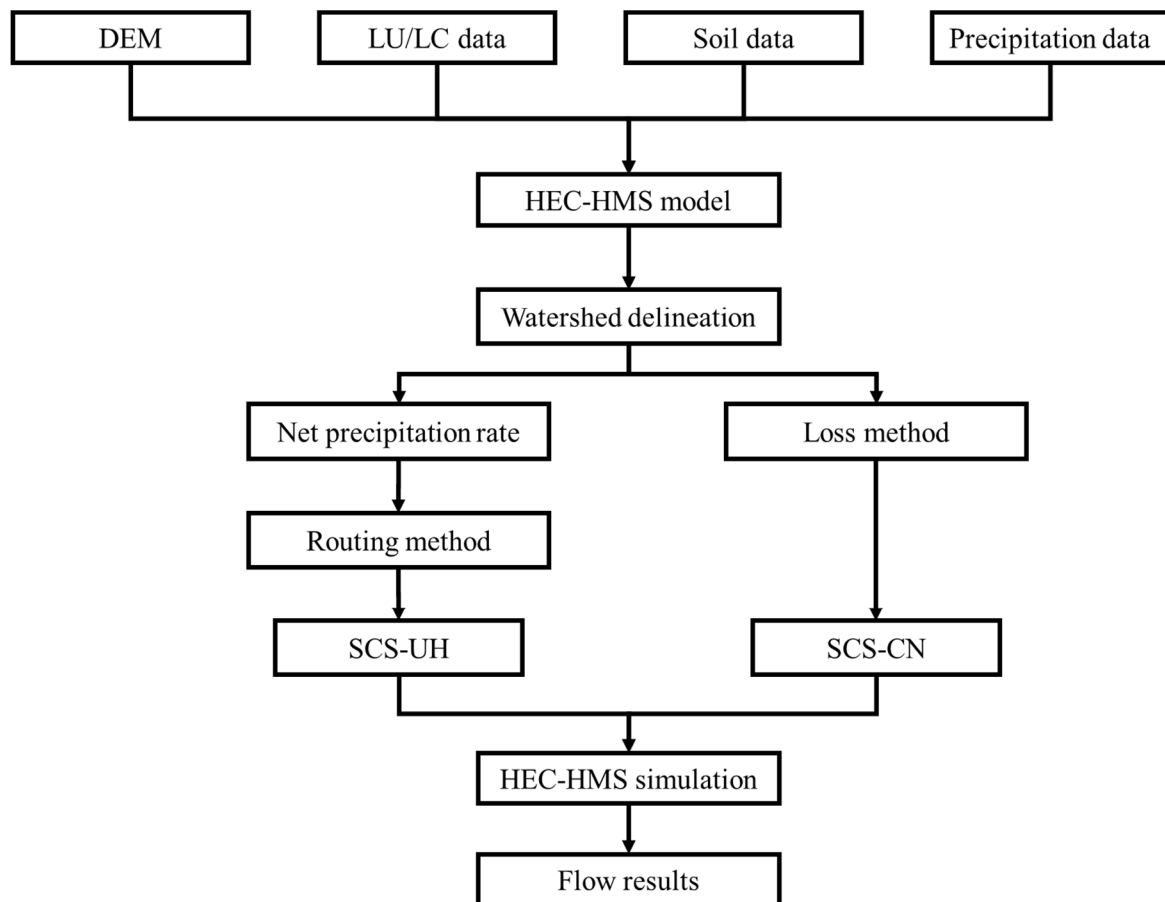
**Figure. 11** The outflow release data of Poondi and Puzhal Lakes for the Chennai region from 4 to 7 Dec 2023.

## 6.2 Methodology

There were numerous models available for hydrological modelling. The choice of model is contingent upon the specific characteristics of the basin as well as the intended purpose of the hydrological forecasting within that particular basin (Ocio et al., 2020). This study utilized a semi-distributed hydrologic model, the Hydrologic Engineering Center- Hydrologic Modelling System (HEC-HMS), to model the rainfall-runoff process in the Kosasthalaiyar River and Buckingham canal. The HEC-HMS model was created by the US Army Corps of Engineers (Chu and Steinman, 2009) and is suitable for various hydrological simulations. HEC-HMS was a hydrologic modelling that contains an integrated tool for modelling the hydrologic processes of dendritic watershed systems (Chu and Steinman, 2009). Moreover, it has been widely used in many hydrological studies due to its simplicity and capability (Halwatura and Najim, 2013; Jayanti et al., 2020; Sahu et al., 2023). The widespread adoption of HEC-HMS in hydrology is attributed to its capacity to simulate runoff in various event durations, ease of use, and utilization of standard methods (Oleyblo and Li, 2010).

The HEC-HMS model has been used to generate the flow data for the study area. The HEC-HMS model integrates spatial, hydrological, and meteorological data to simulate rainfall-runoff processes accurately (Fig. 12, page no: 24). The input parameters are the DEM, LU/LC, soil data, precipitation data in the region, and the outflow data. HEC-HMS model has been widely embraced in numerous hydrological investigations due to its capacity to replicate runoff occurrences in both short-term and long-term scenarios, as well as its user-friendly interface (Halwatura and Najim, 2013). It is specifically created to mimic the precipitation-runoff

mechanisms of complex watershed systems (Fleming and Scharffenberger, 2016). The HEC-HMS model can be employed to simulate various scenarios such as single storm events lasting from hours to days, or extended periods of stream flow (daily, monthly, and seasonal) (Fleming and Doan, 2013). The setup of the HEC-HMS model comprises four key components: basin model, meteorological model, control specifications, and input data (time series, paired data, and gridded data). There are multiple techniques available within the model to simulate processes like infiltration losses, direct runoff estimation, channel routing, base flow modelling, and meteorological modelling. The selection of the appropriate model component depends on factors such as data availability, modelling objectives, and global standards. For the present study, methods such as Soil Conservation Service Curve Number (SCS-CN), Soil Conservation Service Unit Hydrograph (SCS-UH), Muskingum and Gage weights methods, were chosen to calculate runoff volume, transform excess precipitation to surface runoff, manage channel routing, and simulate the overall process, respectively.



**Figure. 12** The schematic representation and simulation flow chart of the HEC-HMS model.

### 6.3 Results and discussion

This section provides a comprehensive assessment of the hydrological response of the watershed under specific input conditions like precipitation and Lake's flow generated from the HEC-HMS model analysis. As deliberated in the section on methodologies, crucial watershed attributes such as CN, basin lag time, watershed area, basin slope, potential maximum retention ( $S$ ), and the initial abstraction from the watershed were established.

### 6.3.1 Hydrologic parameters

The spatial variation of the CN value within the study area was determined. The study area exhibited a range of CN values, with a minimum of 70 for urban areas and a maximum of 95 for water bodies. However, for rainfall-runoff simulation, each sub-basin necessitates a singular CN value. The minimum and maximum weighted curve number values were identified as 88 and 95, respectively. The CN value directly influences runoff generation, sub-basins with lower CN values result in minimal runoff and higher infiltration rates. Conversely, sub-basins with higher CN values exhibit greater runoff potential. The basin slope is flat with 3 to 4% in the study area. The basin lag time ranges between 71.3 and 237.7 min for the study area. A lower basin lag time implies quicker surface runoff reaching the outlet point.

The time series analysis of precipitation and flow can reveal critical periods during which the watershed experienced significant runoff, indicating the onset of flooding. Hydrographs, in particular, were instrumental in understanding how the watershed responds to precipitation events. The rising and recession limbs of the hydrograph give insight into the rate of flow accumulation and dissipation, helping to identify lag times and peak flow timing. These results are essential for flood management and mitigation planning, as they identify critical times when interventions may be required.

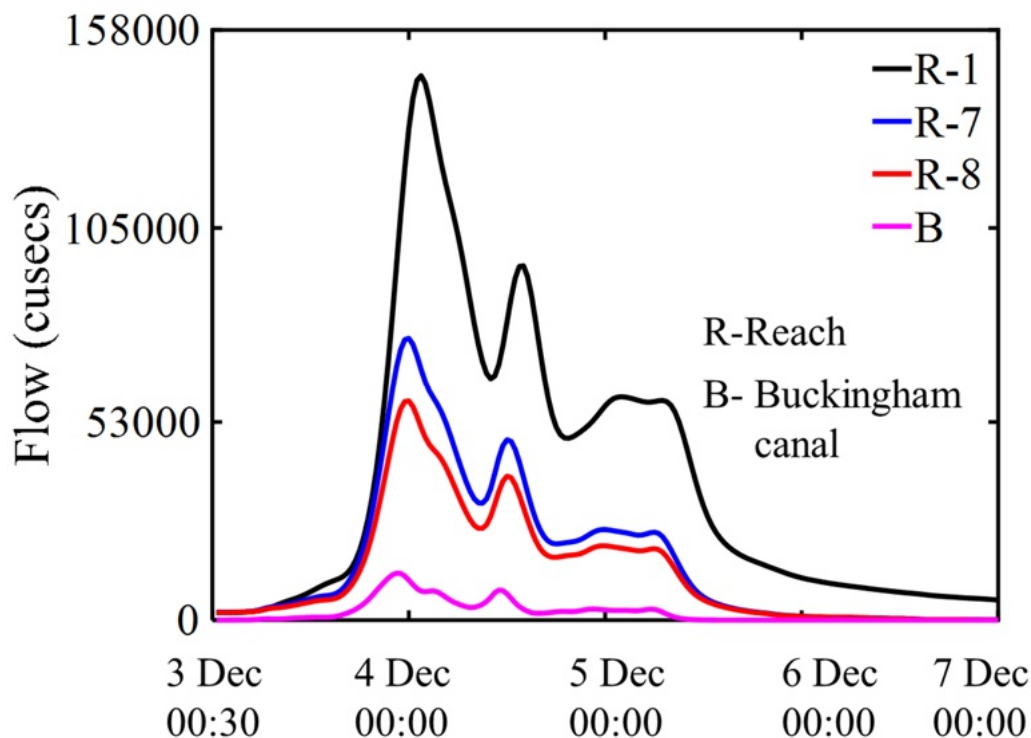
### 6.3.2 HEC-HMS model results

The primary outputs of the model include simulated hydrographs, cumulative runoff volumes, peak discharges, and rainfall-runoff relationships. Hydrographs generated at key locations, such as sub-basin outlets and river junctions, provide insights into peak discharge, time to peak, and baseflow contributions. These hydrographs play a major role in understanding the temporal dynamics of flow during the simulation period. Additionally, the cumulative runoff volumes and runoff coefficients were calculated to quantify the total water yield from the watershed and evaluated the efficiency of rainfall conversion to runoff. The simulated flow hydrographs for various reaches in the study area using the HEC- HMS model, incorporating both precipitation and Lake's release data from Poondi and Puzhal Lakes during the Michaung Cyclonic event. The hydrographs show peak flow occurring on 3 Dec (midnight), followed by a decline and subsequent fluctuations in discharge. The variations in flow across different reaches suggest the influence of precipitation patterns, basin characteristics, and channel response to stormwater runoff.

The flow decreases gradually but shows secondary peaks, suggesting intermittent heavy precipitation or delayed contributions from upstream subbasins. The varying flow patterns across different reaches and subbasins highlight the differences in watershed response due to factors such as LC, soil characteristics, drainage capacity, and the connectivity of streams. The higher peaks in some reaches or subbasins indicate regions with significant runoff accumulation, whereas lower peaks correspond to areas with reduced contributing flow. The results demonstrate the effectiveness of the HEC-HMS model in capturing the hydrological response of the watershed during extreme weather events.

The simulated flow hydrographs for various reaches in the study area using the HEC-HMS model, incorporating both precipitation and Lake's release data from Poondi and Puzhal Lakes during the Michaung Cyclonic event (Fig. 13, page no: 26). A sharp rise in flow is observed on December 3, with peak discharges exceeding 1,41,150 cusecs, indicating intense rainfall- induced runoff. This is followed by multiple secondary peaks on December 4 and 5,

likely caused by additional rainfall contributions and controlled releases from upstream Lakes. The gradual recession of flow after December 5 suggests a reduction in rainfall and a transition towards base flow conditions. This analysis is crucial for flood risk assessment and water resource management, as it provides a comprehensive understanding of how extreme weather events, combined with Lake's operations, influence river discharge patterns.



**Figure. 13** Simulated flow hydrographs for the reaches in the study area using the HEC-HMS model for the Michaung Cyclonic event with precipitation and outflow data from the Poondi and Puzhal Lakes.

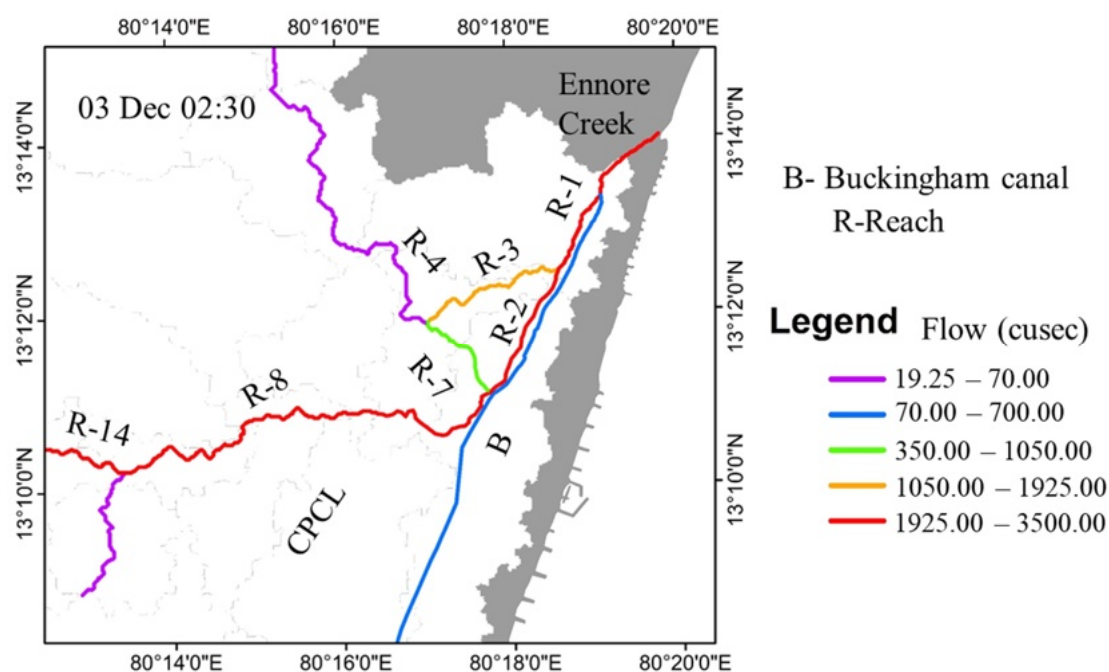
Rainfall-runoff relationships, compared with cumulative rainfall against runoff for each sub-basin, helps to highlight the spatial variations in hydrological responses across the study area. Spatial results were integrated with GIS, to visualize the runoff distribution, precipitation patterns, and sub-basin contributions. These GIS integrated maps were particularly useful for identifying areas prone to flooding or high runoff. High-resolution spatial analysis, especially when linked with LULC data, further identifies the role of urbanization, vegetation cover, and soil types in influencing hydrological behaviour. The comparative analysis, such as simulated versus observed flow data or results across different rainfall scenarios, will further validate the model's reliability and provide insights into the watershed's sensitivity to varying conditions. The analysis also includes sensitivity assessments of input parameters to identify which factors most significantly influence the results. The results were typically presented through well-organized tables, figures, and maps.

### 6.3.3 Flow in the streams/reaches

The flow in the streams or reaches represents the discharge of water through different segments of the river network and canal system of the study area. The spatial flow distribution map for various Kosasthalaiyar River reaches and the Buckingham canal in the study area, modelled using the HEC-HMS simulations (Fig. 14-16, page no: 27-28). The spatial map shows

different reaches (R-1, R-2, R-3, R-4, R-7, R-8, and R-14) with their corresponding flow magnitudes at a specific timestamp (such as before, during and after the cyclonic event). Flow values are categorized into five different classes, as indicated in the legend, and are visually represented using different colours. The Buckingham Canal, labelled as "B," is a significant hydrological feature in the study area, transporting water towards Ennore creek. The spatial distribution of flow suggests that significant water movement is occurring through the main channel and its tributaries, with peak flows potentially influenced by precipitation and upstream Lakes releases.

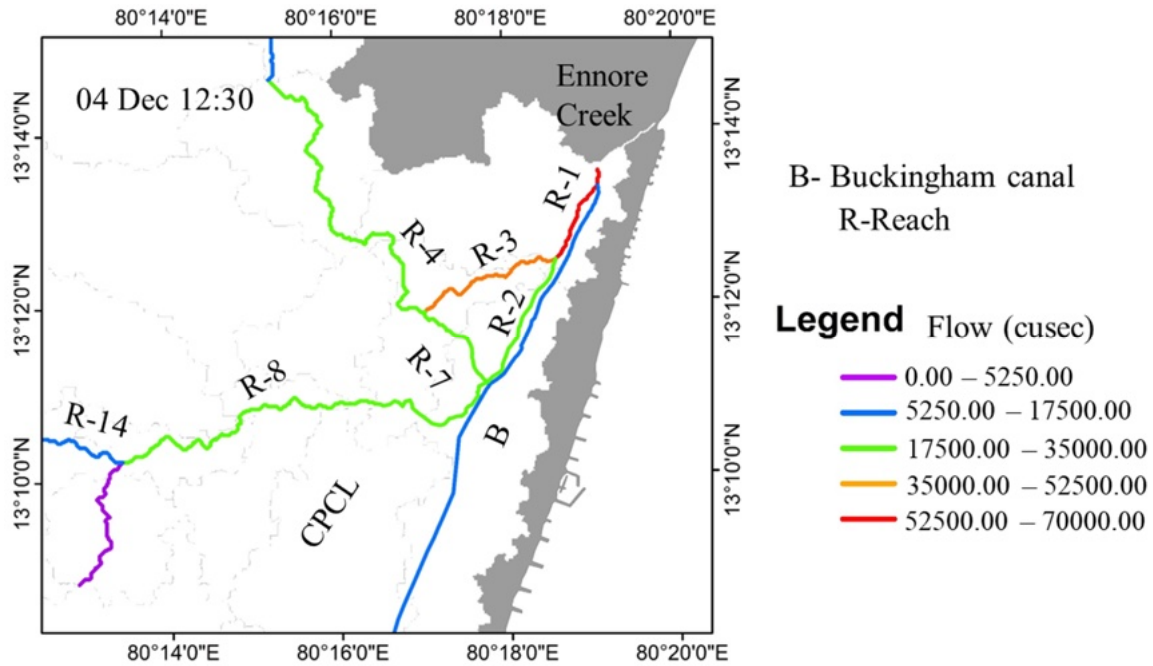
Before the cyclone the variations of flow rates in the reaches R-1, R-2, R-8 and R-14 were higher, it is because the inter connectivity between the reaches and the Puzhal Lake (Fig. 14, page no: 27). The discharge from the Puzhal was there continuously from the 1 Dec onwards. The Moderate flow was seen in reach such as R-3, while lower flow magnitudes were observed in other tributaries.



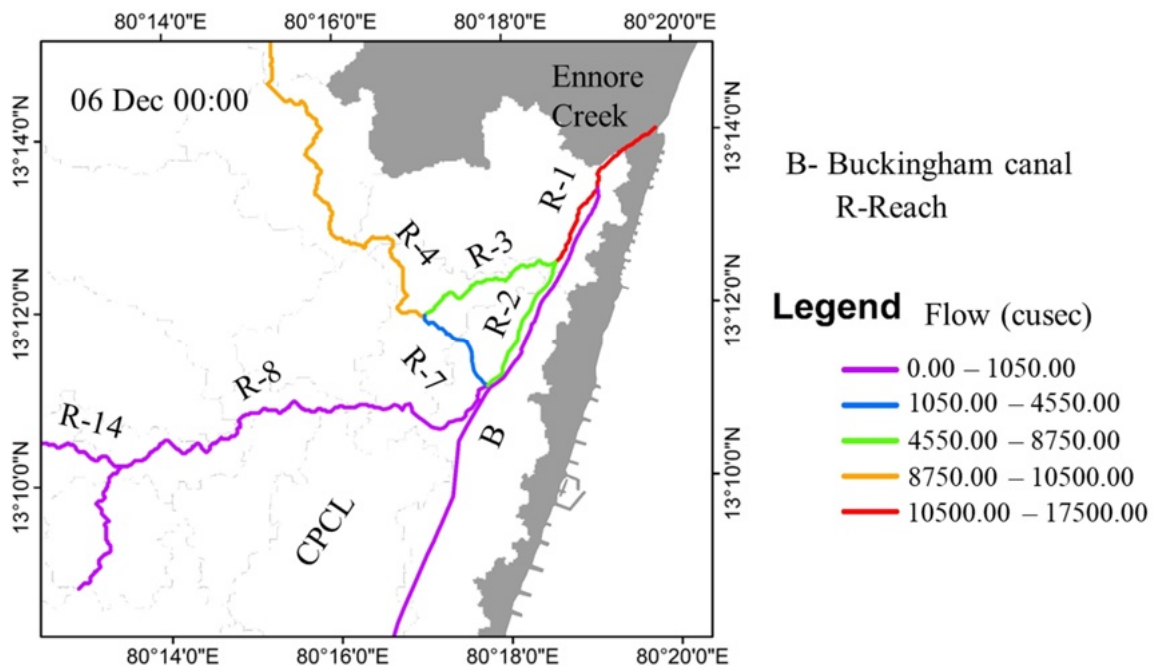
**Figure 14.** The spatial map showing the flow in the reaches before the Cyclonic event.

During the cyclone (Fig. 15, page no: 28) where high intense rainfall and the Lakes release increased the water flow rate in the reaches to 70000 cusecs in the river mouth region (R-1) and Ennore creek. The flow analysis from the HMS model revealed that the peak discharge in the Buckingham Canal and Kosasthalaiyar River was peaked around December 4, 2023 midnight. The continuous precipitation, surface runoff and flows coming from Poondi and Puzhal Lakes increased the water volume and depth in the river and canal, leading to the reversal and overflow of water from the canal to the adjoining areas (70000 cusec approx. in Kosasthalaiyar River). The other reaches also getting continuous flow from the catchment area due to rainfall and release from the Puzhal and Poondi Lakes. A similar flow pattern is observed in the Buckingham Canal due to the precipitation and the increased water flow from the Kosasthalaiyar River resulted in a reverse flow in the Canal made the flash flood in the upstream side. After the cyclone the reduction of rainfall intensity has reduced the discharge or flow in the reaches and the outflow from the Puzhal and Poondi Lakes also reduced. The changes in the flow in the reaches has shown in Fig. 16, after the cyclonic event. A similar reduction in flow is observed in the Buckingham Canal it is due to the reduction in the precipitation. These spatial flow maps of the

before, during, and after the cyclonic event provides the critical insights of the hydrodynamic response of the region, giving the flood risk assessment, water resource management, and mitigation planning of the study area.



**Figure 15.** The spatial map showing the flow in the reaches during the Cyclonic event.



**Figure 16.** The spatial map showing the flow in the reaches after the Cyclonic event.

## 6.4 Hydrologic Engineering Center - River Analysis System

Hydrologic Engineering Centre’s River Analysis System (HEC-RAS) is a hydraulic modelling software used to simulate the movement of water through natural rivers, artificial channels, floodplains, and other water systems (Fig. 17, page no: 30). It allows for both steady

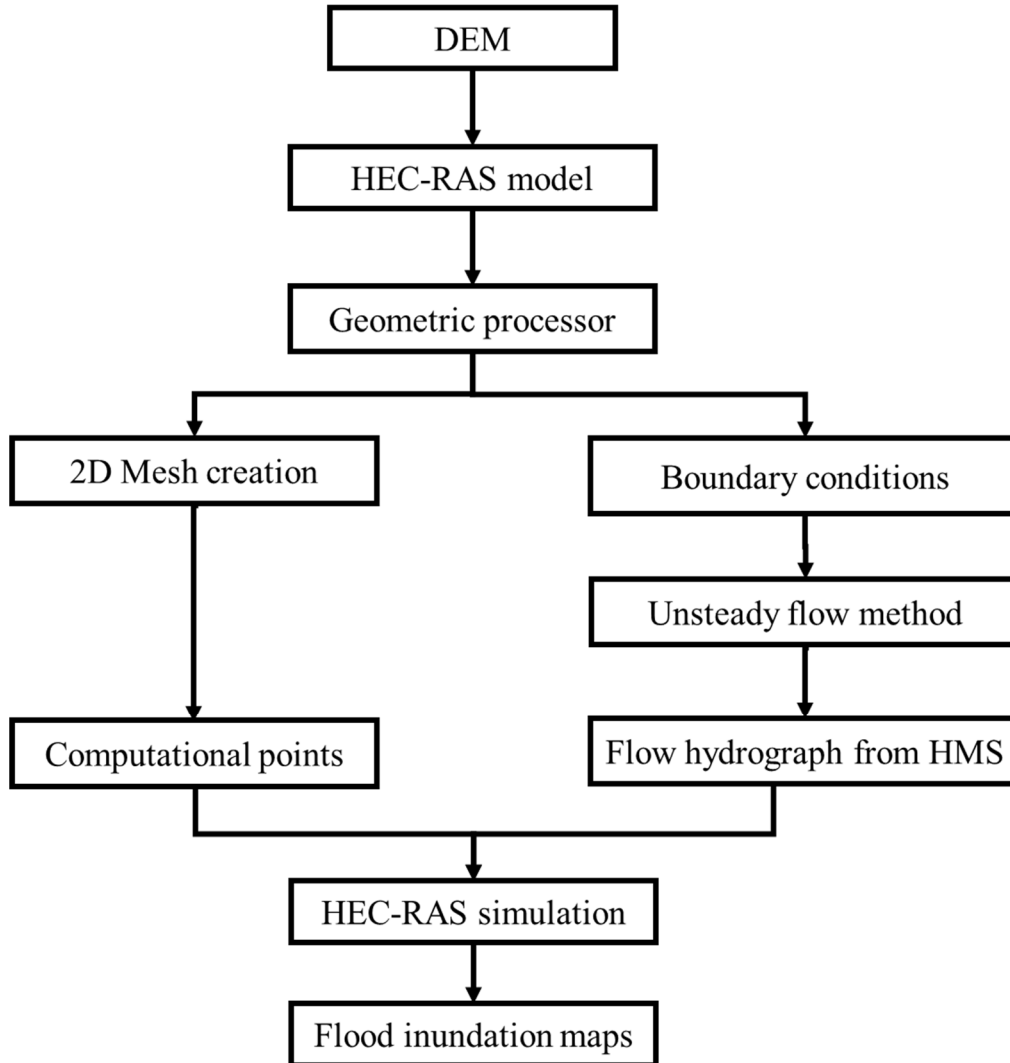
and unsteady flow analysis, making it versatile for applications such as flood mapping, dam break analysis, sediment transport, and water quality studies. The model employs the Saint-Venant equations, which are derived from the principles of continuity and momentum conservation, to simulate water surface profiles and flow dynamics. These equations enable the model to handle complex flow conditions, including subcritical, supercritical, and mixed flow regimes.

One of the key features of HEC-RAS is its ability to integrate with high-resolution terrain data, such as DEMs, to create detailed geometric representations of the river and floodplain system. The model supports the inclusion of hydraulic structures such as bridges, culverts, weirs, and levees, which are critical for understanding flow behaviour and identifying potential bottlenecks. By utilizing Manning's equation for flow resistance, HEC-RAS estimates discharge and velocity while accounting for roughness coefficients that represent varying surface conditions, such as vegetation or urbanization.

HEC-RAS can be run in both one-dimensional (1D) and two-dimensional (2D) modes, depending on the complexity of the study area and the required level of detail. The 1D approach is commonly used for long river reaches and steady-state analyses, while the 2D mode is ideal for urban flood modelling and dynamic flow conditions, where lateral flow and floodplain interactions are significant. The model allows 1D steady flow simulations, and 1D and 2D unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modelling (Brunner & CEIWR-HEC, 2021). HEC-RAS 2D employs shallow water equations to describe the motion of water in terms of depth-averaged 2D velocity and water depth. The diffusion wave approximation approach is used for computing the flow field in the 2D mesh, as it leads to shorter computation time and may reduce model instability (Brunner, 2016).

The model area is discretized into grid cells, and HEC-RAS generates a detailed hydraulic property table for each cell and cell face. The water surface profiles provided by the model using several hydraulic design features can help decision-makers to invest resources effectively to prepare for catastrophes and improve the quality of life, by analysing the extent of flooding and flood inundation zones. The 2D modelling capabilities were enhanced through the creation of computational meshes, which divide the terrain into smaller cells to capture the spatial distribution of water depths and velocities.

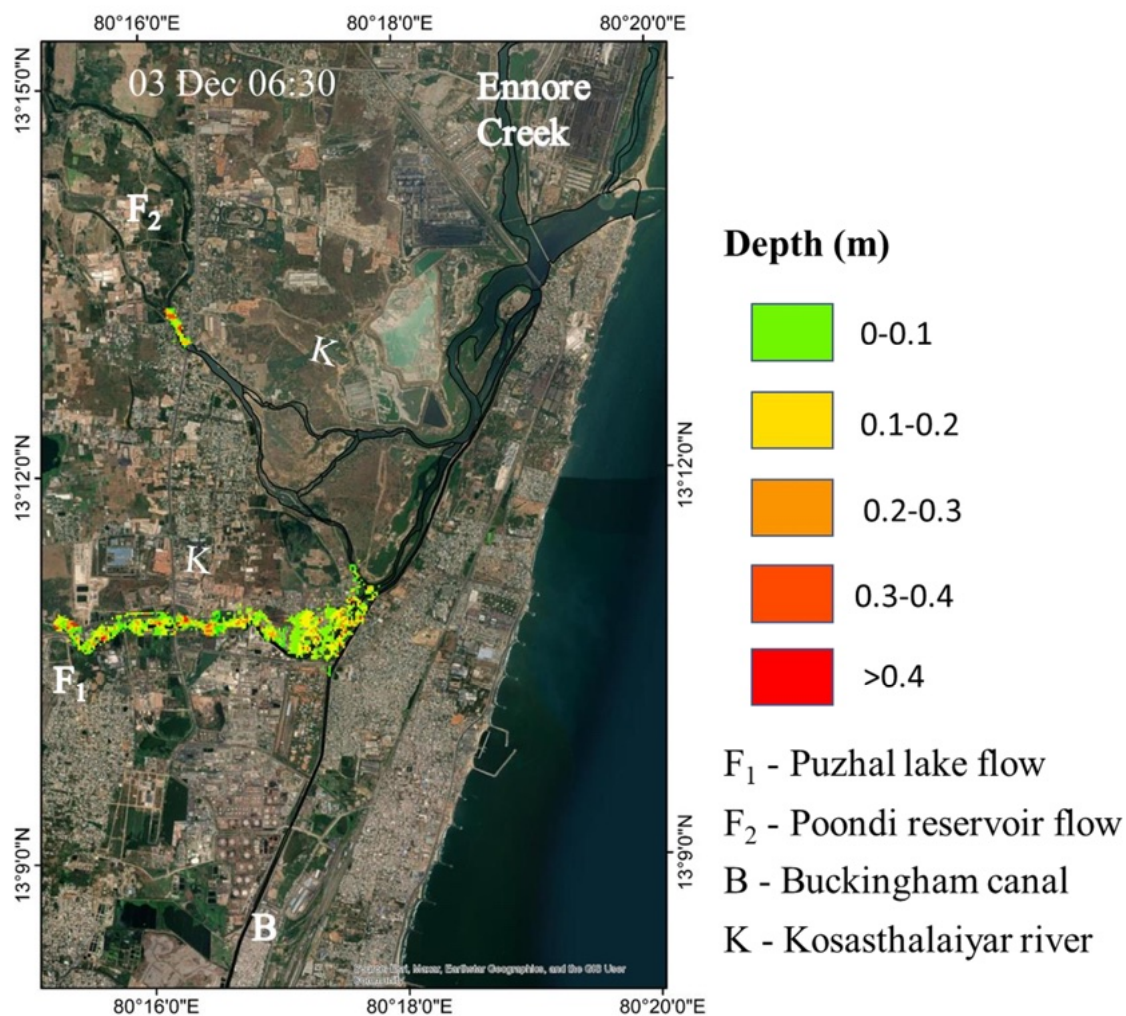
The model outputs include water surface profiles, flow velocities, flood extents, and energy gradients, which are visualized in both tabular and graphical formats. These results can be exported to GIS platforms for further spatial analysis, enabling the creation of flood inundation maps and risk assessments. The ability of HEC-RAS to incorporate real-world data, such as rainfall records, boundary conditions (BCs), and observed flows, enhances its reliability and accuracy in predicting flood scenarios. This makes it an essential tool for engineers, hydrologists, and urban planners in designing flood control measures, evaluating the impacts of infrastructure projects, and mitigating the risks associated with extreme hydrological events. Hydraulic modelling and inundation mapping were generated using RAS Mapper, a spatial data integration and mapping tool in HEC-RAS. In HEC-RAS Mapper, the development of an RAS terrain, laying out the geometric data, extracting the terrain data, and visualization of results in the form of maps and tables can be inaugurated.



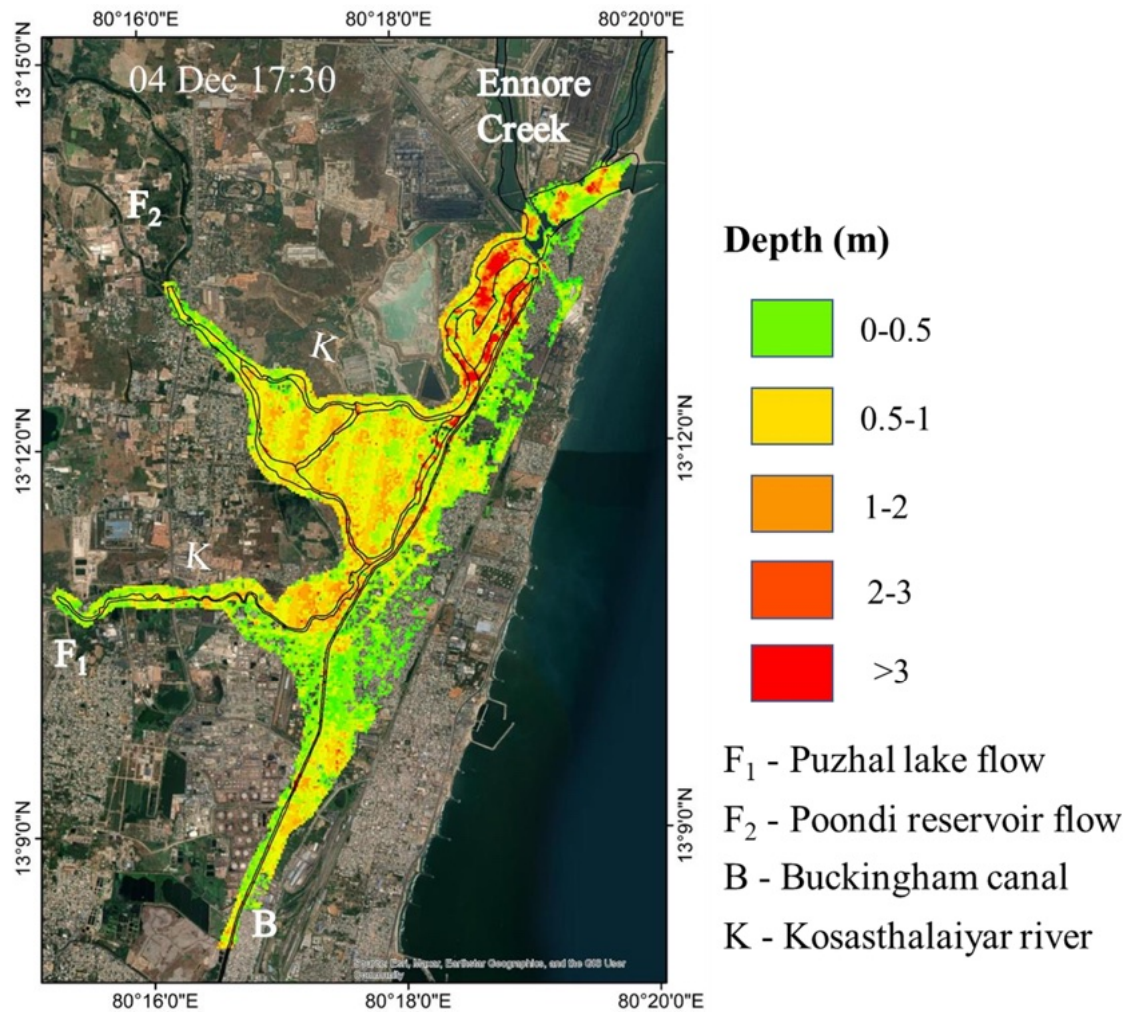
**Figure. 17** The schematic representation and simulation flow chart of the HEC-RAS model.

Depth maps were generated for the study area using HEC-RAS 2D. The inundation depths (m) were exported to Arc-GIS 10.1 and used to identify areas with low, medium, and high inundation depths, reflecting low, moderate, and high-risk, respectively. Figures 25 & 26 shows the depth maps prepared for the 30 m DEMs. The flood inundation map represents the depth of water in the Kosasthalaiyar River and Buckingham Canal before the Michaung Cyclonic event, as simulated using the HEC-RAS model (Fig. 18, page no: 31). The map uses a colour gradient to depict different depth ranges, with green (0-0.1 m) indicating shallow water levels and red (>0.4 m) representing deeper inundation areas. The flow contributions from Puzhal Lake ( $F_1$ ) and Poondi Lake ( $F_2$ ) are also marked, showing how water is distributed across the region.

Flood inundation map was generated during the Michaung Cyclonic event, with flow contributions from the Puzhal and Poondi Lakes, in addition to precipitation across the study area using the HEC-RAS model (Fig. 19, page no: 32). The entire catchment area was experienced continuous precipitation, and the flow from the Puzhal Lake ( $F_1$ ) and Poondi Lake ( $F_2$ ) resulting in significant increment in the flow depths and exceeding the capacity of the Kosasthalaiyar river and Buckingham canal. This caused overflow into the adjacent areas and leads to flood inundation, which causes the reverse flow in the canal.



**Figure 18.** Flood inundation map (depth) for the Kosasthalaiyar River and Buckingham Canal generated from the HEC-RAS model before the Michaung Cyclonic event.



**Figure 19.** Flood inundation map (depth) for the Kosasthalaiyar river and Buckingham canal generated from the RAS model during the Michaung Cyclonic event.

## 7. Soil/sediment sample analysis

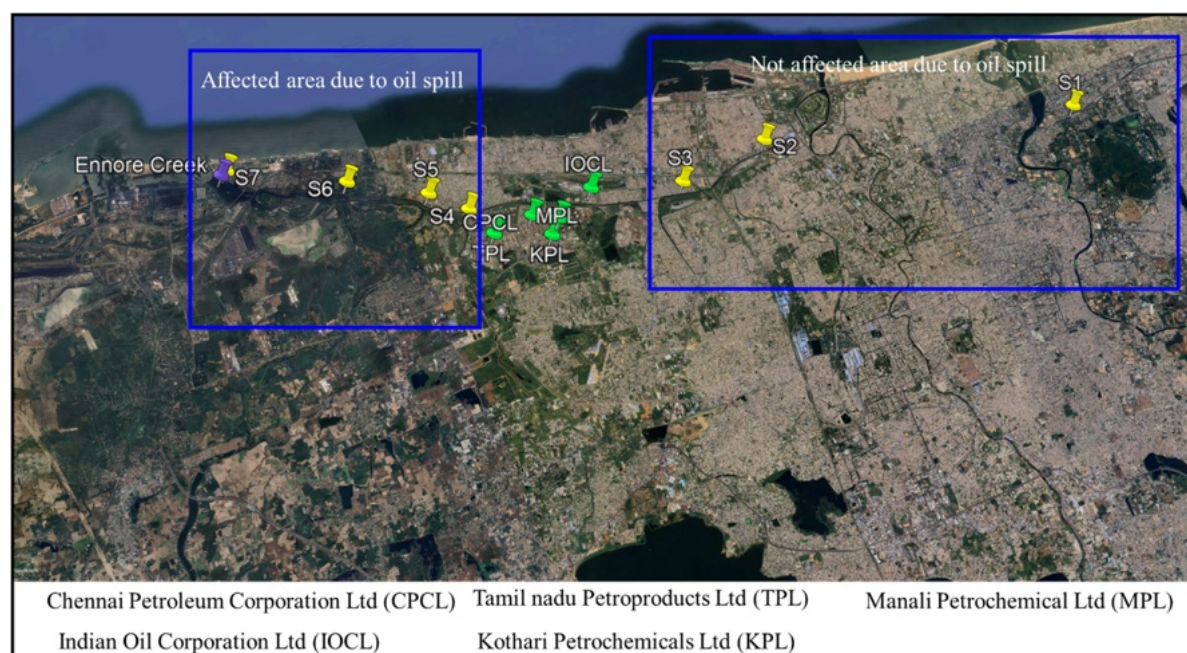
Soil/sediment samples were collected from various locations along the Buckingham Canal to analyze Total Petroleum Hydrocarbon (TPH) contamination. The sampling sites were chosen based on proximity to potential pollution sources, such as industrial discharge points, urban runoff zones, and areas influenced by tidal exchange. A core cutting sampler is a specialized tool used for collecting undisturbed sediment samples from aquatic environments such as rivers, Lakes, and canals. This method is ideal for studying sediment composition, pollution levels, and stratification over time. The core cutting sampler equipment has a cylindrical coring device made of stainless steel or polyvinyl chloride pipe along with this an extension rod was used for compacted sediment samples. The handheld global positioning system (GPS) was used to record the location of the sampling points. The gloves and sample containers were used for collecting the samples and for contamination-free handling.

The coastal environments receive a huge amount of sewage and industrial waste through rivers and estuaries specially in developing countries (Adeniji et al., 2017; Arumugam et al., 2013). Petroleum hydrocarbons often contaminate coastal environment through waste

discharge from petrochemical industries, harbour's, marine traffics and oil spillage (Das and Chandran, 2011). Petroleum hydrocarbons are complex mixtures of aliphatic and aromatic compounds and are major constituents in a variety of commercial products such as gasoline, crude oil, lubricating oils, fuel oils, mineral oils, solvents and mineral spirits. It degrades at a very slow rate and forms one of the pollutants of potential concern in the marine environment (Das and Chandran, 2011; Kostka et al., 2020).

The TPH gets released into the environment through domestic and industrial wastewaters, ship accidents, spills or leaks and other petroleum by- products get emitted from commercial or domestic uses (Mohebbi-Nozar et al., 2015; Yuan et al., 2014). The marine environment, particularly the coastal and estuarine regions are ecologically sensitive areas with diverse morphology and unique hydrodynamic conditions. The near shore areas are subjected to excessive contaminations not only by the anthropogenic inputs but also by the sea-based activities (transportation, oil exploration and production etc.). Shipping has a significant contribution of TPH by transporting these compounds in the marine environment (Massoud et al., 1996). TPH content in the sediment samples varied from 2.33 to 30.07  $\mu\text{g g}^{-1}$  (dry weight) (2.33 to 30.07 mg/Kg). The level of TPHs was highest in the sediment at Ennore creek as the location used frequently for movement of fishing boats and excessive shipping activities in Chennai harbour. Further, oil spill occurred due to the oil tanker ship accident at Ennore port (near Chennai harbour) in January 2017 which released more than 100 Tons of heavy fuel oil (Sivagami et al., 2019).

### 7.1 Location map



**Figure 20.** Field sample location map

In addition to the above, the TPH estimates from the ground based discrete sediment samples are highly biased and deviate from the satellite based spatial TPH estimates. Extrapolation of such TPH values from discrete samples would lead to erroneous results. This is because oil typically floats on water due to its lower density, and when an oil spill occurs, the oil tends to remain on the water surface rather than getting settled to the channel bed. Oil fraction found in

channel bed sediment samples could come from the settling of suspended sediment grain and bio-genic particles with the adsorbed oil compound and require longer period for settling.

## 7.2 Sample collection

- Soil samples were collected from seven locations from Buckingham Canal and Ennore Creek.
- Out of the seven samples, four were collected from the bed of Buckingham Canal, one from the land, one from the convergence of the Kosasthalaiyar River and Buckingham Canal (near Ennore railway bridge), and one near Ennore Creek.
- The samples were collected from locations affected by the oil spill (S4-S7) and from unaffected areas (S1-S3) for comparison.
- Soil samples were collected using a core cutting instrument, adhering to the IS standard procedures to maintain the consistency and texture of the samples.
- At each location, two samples were taken: one from the topsoil layer and another from the bottom layer (approximately 1 foot below the surface). Station names were labelled on each sample to prevent mixing and ensure traceability.
- A total of 500 grams of soil was collected at each location for analysis in the laboratory.
- The sampler was carefully extracted to maintain the stratification of sediment layers.
- The excess water was allowed to drain naturally.

## 7.3 Sample preparation

Before Gas Chromatography (GC) analysis, the sediment samples underwent several preparation steps to extract and purify petroleum hydrocarbons. Samples were air-dried at room temperature to remove excess moisture. Large debris and organic material were removed, and the samples were homogenized using a mortar and pestle or a mechanical grinder. A widely used technique where approximately 10–20 g of dried sediment was extracted using a mixture of *n* – hexane and dichloromethane (1:1 ratio) over 24 hours. The extract was passed through a silica gel/alumina column to separate hydrocarbons from interfering compounds (e.g., natural organic matter). The purified extract was concentrated using a rotary evaporator before gas chromatography analysis.

## 7.4 Sample analysis

The samples were analysed for TPH using Gas Chromatography (GC), and the testing method employed was TX 1005. GC is the preferred analytical technique for detecting and quantifying petroleum hydrocarbons in environmental samples. A Gas Chromatograph (GC) equipped with a Flame Ionization Detector (FID) or Mass Spectrometry (GC-MS) was used for analysis. A non-polar capillary column (e.g., 5% phenyl-methyl polysiloxane) was selected for hydrocarbon separation. Carrier gas (e.g., helium or nitrogen) was used to transport the sample through the column. A 1–2  $\mu$ L aliquot of the purified extract was injected into the GC system. The initial temperature was kept at 50°C for 2 minutes after that slowly increasing the temperature up to 300°C with 5 to 10°C interval for every minute. After reaching the temperature 300°C, the sample kept for 10 to 20 minutes for complete separation of hydrocarbons. The FID detected hydrocarbons based on ionization of organic molecules, while GC-MS provided compound identification using mass spectral data.

A series of known hydrocarbon mixtures (e.g., diesel, crude oil) were analysed to establish a calibration curve. Hydrocarbons in the sediment samples were identified by comparing their retention times to standard compounds. Summed peak areas of different hydrocarbon fractions provided the TPH concentration in mg/Kg of sediment. High TPH levels can degrade sediment quality, harm aquatic life, and disrupt microbial communities. The sediment sampling and GC-based TPH analysis provided critical insights into hydrocarbon pollution in the Buckingham Canal. These findings can inform pollution control strategies and environmental restoration efforts in the region.

**Table 4.** The TPH concentration measured by the GC for the soil/sediment samples collected in the Buckingham Canal.

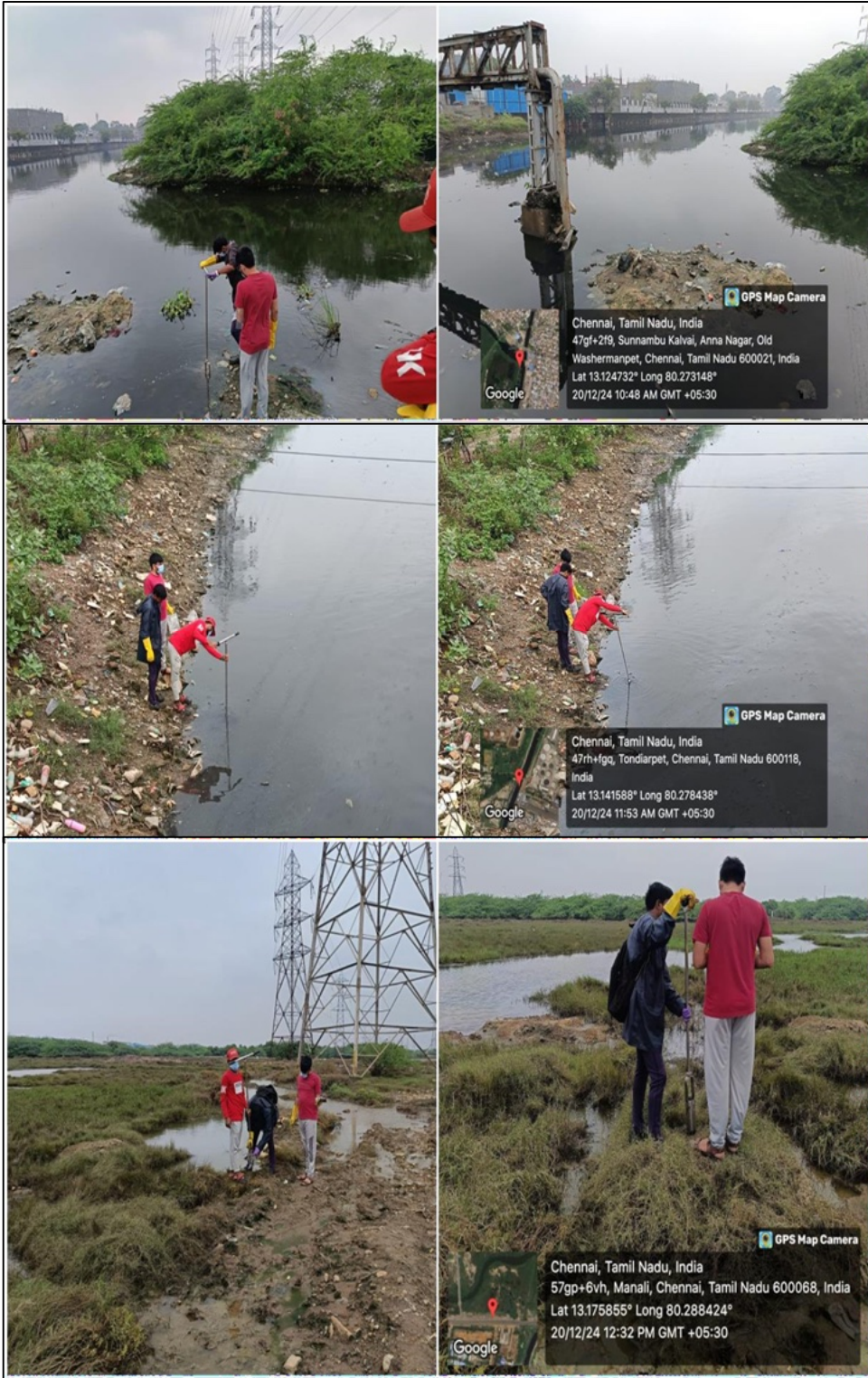
Id		Latitude	Longitude	Parameters	Testing method	Results (mg/Kg)
S1	Top	13.093467°	80.274209°	TPH	TX 1005	1.10
	Bottom					1.25
S2	Top	13.119465°	80.272164°			1.20
	Bottom					1.35
S3	Top	13.007093°	80.247955°			4.96
	Bottom					5.45
S4	Top	13.175972°	80.288402°			BDL
	Bottom					10.7
S5	Top	13.184159°	80.296933°			8.95
	Bottom					16.8
S6	Top	13.202889°	80.308780°			5.46
	Bottom					4.65
S7	Top	13.230960°	80.324630°			4.91
	Bottom					29.62

The persistent presence of TPH in the channel bed sediments is likely due to the continuous discharge of urban runoff, municipal waste, oil releases from fishing boats and commercial/industrial discharges into the Buckingham Canal and Ennore creek.

## 7.5 Results and Discussion

- The sediment samples taken from the bed and 1 foot below in the upstream not affected by oil spill and downstream areas.
- The soil samples (S1 to S3) collected from the unaffected areas i.e. upstream of Manali Industrial area due to oil spill showed the TPH concentrations ranging from 1-5 mg/Kg.
- The presence of this TPH concentration in the unaffected areas is likely due to the continuous discharge of urban runoff, municipal waste, and commercial/industrial discharges into the Buckingham Canal.
- The samples labelled S4 (land), S5, and S6 exhibited TPH concentrations, even one year after the oil spill event. The persistent presence of TPH in the soil is likely due to the continuous discharge of urban runoff, residential and industrial wastewater into Buckingham Canal.

- The bottom-layer sample from S7 showed the highest TPH concentration, likely caused by oil releases from fishing boats parked near Ennore Creek.
- Sediment soil samples collected from the bed of the Buckingham canal and land area showed the TPH values are in the range of 1-30 mg/Kg vicinity of CPCL and B-canal.
- The bed samples always have some TPH fraction its due to the accumulation of hydrocarbons in the bed fraction due to the percolation/infiltration of industrial, commercial, municipal waste disposal, and surface/urban runoff.
- The upstream samples showed that the TPH values which can be considered as pre-existing TPH content due to urban runoff, municipal waste, and commercial discharges.
- The downstream samples showed the values in the range of 4-30 mg/Kg which indicates thousand times less by the report downloaded from NGT on oil spill case. This is in line with similar study carried out by Barath kumar et al., 2023 & NCCR.
- The possibility of the TPH fraction in the bed samples between the B-canal basin areas and between the rivers (wetlands/mangrove's areas) it is due to the particle settling velocity low and residual time of water higher and it makes the adjacent areas soil saturated with water.
- To further verify the oil concentration (quantity) in the soil matrix collected the soil samples from the land area nearby the vicinity of Manali industrial area.
- The samples collected in the land surface area has low values due to the surface runoff and the 1 foot below samples showed that 5 mg/Kg.



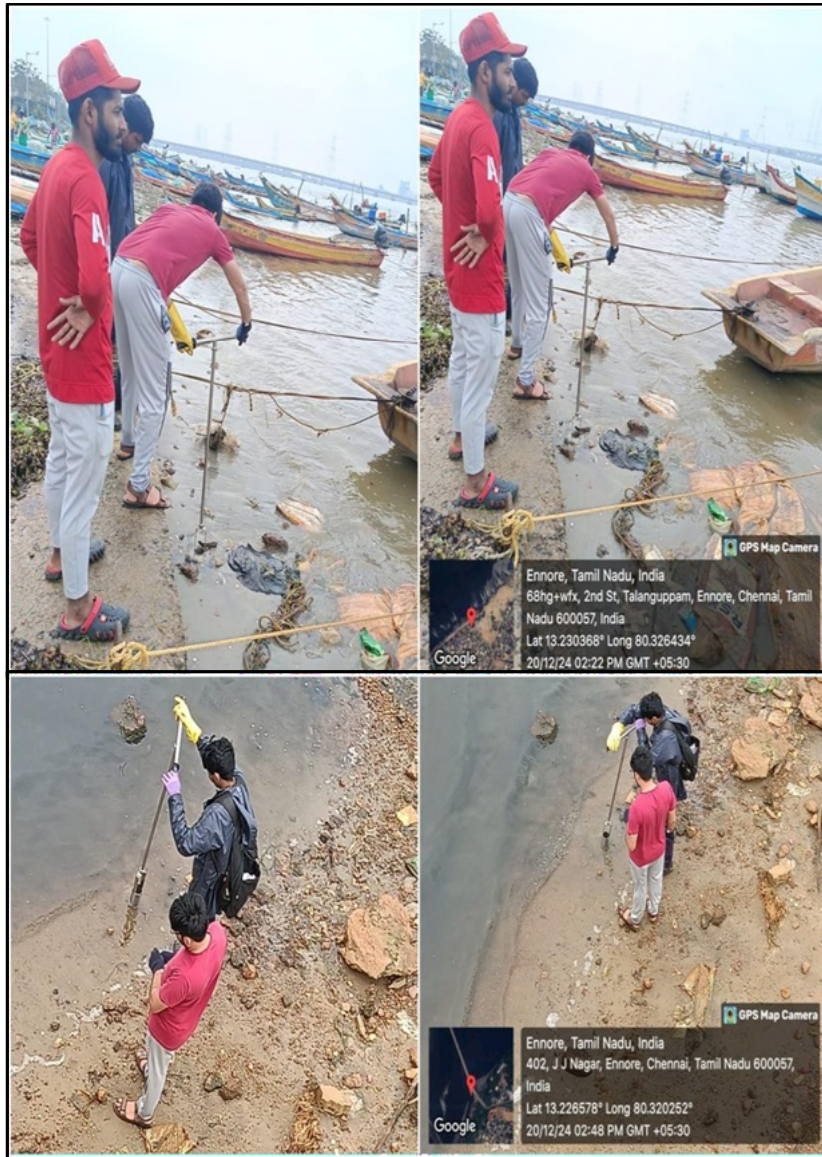



Figure 21. Field sample collection photographs.

## 8. Conclusion

1. The image acquired on 19th November 2023, prior to the oil spill, was analysed to establish baseline conditions of the study area. This pre-spill image (Refer page no: 13), showed no traces of oil contamination, with natural features such as water bodies and surrounding vegetation appearing in their typical spectral characteristics.
2. Satellite observations on 7<sup>th</sup> Dec, 2023 image revealed the oil spill quantity from Manali industrial area to Ennore creek including the residential / adjacent area is 20.53 M<sup>3</sup> (16.4 T). (Refer page no: 15). **The oil volume was calculated by multiplying the oil thickness in each pixel by the pixel's coverage area. The combination of oil fraction, thickness, and volume maps offers a comprehensive understanding of the spill's magnitude and distribution, enabling informed decision-making for mitigation and remediation efforts.**
3. The 26<sup>th</sup> Dec, 2023 post-mitigation image was examined to evaluate the effectiveness of the clean-up operations. The oil volume image (Refer page no: 16) showed no visible traces of oil, suggesting successful removal.
4. Oil typically floats on water due to its lower density, and when an oil spill occurs, the oil tends to remain on the water surface rather than settling down to the channel bed and requires longer period for settling.
5. The TPH estimates from the ground based discrete sediment samples are highly biased. Extrapolation of such TPH values from discrete samples to arrive oil quantity for the entire area would lead to erroneous results.
6. Present sediment analysis at upstream of Manali Industrial area reveals TPH concentration in the range of 1-5 mg/Kg and downstream is 1 to 30 mg/Kg (Refer page no: 35 and 36). This is in line with similar study submitted by Barath kumar et al., in Aug 2023 & NCCR (Annexure).
7. The persistent presence of TPH in the channel bed sediments is likely due to the continuous discharge of urban runoff, municipal waste, oil releases from fishing boats and commercial/industrial discharges into the Buckingham Canal and Ennore creek.
8. No visible oil traces were observed on the water surface during the field survey.
9. The flood inundation map was generated during the cyclonic rainfall event, with flow contributions from the Puzhal and Poondi Lakes, in addition to precipitation across the region.
  - The entire catchment area experienced continuous precipitation and runoff flows, resulting in flow depths significantly exceeding the capacity of the Kosasthalaiyar river.

- This caused the overflow of the water from the canal to the adjoining areas and led to the reverse flow of water in the canal segments during high tide.
- The continuous precipitation, surface runoff and flows coming from Poondi and Puzhal Lakes increased the water volume and depth in the river and canal, leading to the reversal and overflow of water from the canal to the adjoining areas (70000 cusec approx. in K-river).



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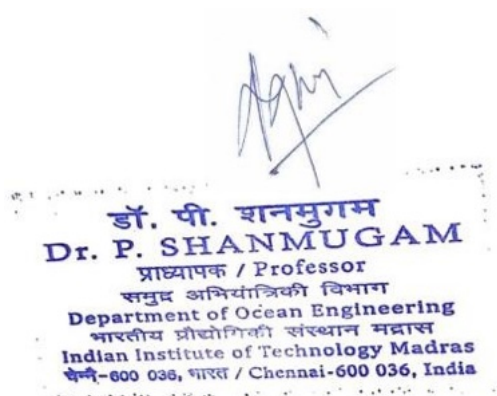
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## RESEARCH



# Spatial distribution of total petroleum hydrocarbons in the seawater and sediment of Southeast coast of India

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**Abstract** The spatial distribution of total petroleum hydrocarbons (TPH) were analysed in the seawater and sediment samples collected from 27 locations along the Southeast coast of India. A first-time assessment was carried out on the distribution of TPH in both water and sediments for the entire coastline of Tamil Nadu. The concentration of TPH in seawater showed large spatial variation ranging from below detection level (BDL) to 47.5 µg/L and 0.01 to 53.12 µg/L in the surface and bottom waters, respectively. TPH levels exceeded the regulatory limits specified by FAO, China's Marine Monitoring Standards and the European Community in the seawater samples of Thoothukudi harbour (S2 station). The results showed that seawaters of southern stations were comparatively more polluted with TPH. TPH values in sediment were between 2.33 and 30.07 µg/g, and their levels remained below the Marine Sediment Quality Standard (500 µg/g). The spatial profile of TPH in sediments were contrasting to that observed for seawater. Higher TPH values were observed in sediments of the northern region than southern. TPH contents are strongly correlated with clay ( $R^2=0.776$ ;  $P<0.001$ ) and silt ( $R^2=0.648$ ;  $P<0.001$ ); conversely, there is a significant negative

correlation between TPH and sand ( $R^2=0.753$ ;  $P<0.001$ ). ANOVA analysis demonstrated a significant difference ( $F=11.75$ ;  $p<0.01$ ) between the TPH concentrations of water and sediments. Non-metric multidimensional scaling (nMDS) was performed to determine the similarity among sampling stations that formed five clustered groups. Sediment along the southeast coast can be categorised as slightly polluted with respect to TPH as per the ATSDR standards.

**Keywords** Tamil Nadu coast · Coastal water · Total petroleum hydrocarbons · Anthropogenic

## Introduction

The coastal environments receive a huge amount of sewage and industrial waste through rivers and estuaries specially in developing countries (Adeniji et al., 2017; Muthukumar et al., 2013). Petroleum hydrocarbons often contaminate coastal environment through waste discharge from petrochemical industries, harbours, marine traffics and oil spillage (Das & Chandran, 2011). Petroleum hydrocarbons are complex mixtures of aliphatic and aromatic compounds and are major constituents in a variety of commercial products such as gasoline, crude oil, lubricating oils, fuel oils, mineral oils, solvents and mineral spirits. It degrades at a very slow rate and forms one of the pollutants of potential concern in the marine environment (Das & Chandran, 2011; Kostka et al., 2020). Total petroleum hydrocarbon

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is highly toxic with mutagenic and carcinogenic properties (de Mora et al., 2010; Hallier-Soulier et al., 1996; Masakorala et al., 2013; Nicolaus et al., 2017). Previous studies have reported that petroleum hydrocarbons can be toxic to larvae in the sea even at very low levels (0.1 ppm) (Mazhar et al., 1987; USEPA, 1986). In some cases, death and genetic mutations in marine mammals, shellfish, fish, reptiles and birds occurred due to the toxicity of petroleum hydrocarbons (Ansari et al., 2012; Kennish, 1997; Mazhar et al., 1987). Therefore, periodic assessment of TPH in the coastal water and sediment is essential to ensure the safety of the coastal ecosystem. Once petroleum hydrocarbon enters into the coastal water, they gradually settle down to the sediments by getting deposited as layer (0–20 cm) in the bottom sediment (Al-Imarah et al., 2006). The lower molecular weight fraction of petroleum hydrocarbons generally gets removed by evaporation, while the heavier components get dispersed in the water layer. Their accumulation in sediments gets subsequently transferred to biota affecting the benthic organisms, bottom feeders and pose risks to human health through trophic transfer (Chouksey et al., 2004; Hentati et al., 2013). The total petroleum hydrocarbon load to the ocean was estimated to be  $2.37 \times 10^6$  tonnes.y<sup>-1</sup> (Kennish, 1997) from different human activity-based sources such as coastal refineries, urban runoff, tanker accidents, operational discharges (oil transportation and shipping sources), air-borne fallout, natural seep and offshore production discharges (GESAMP, 1993). The National Response Centre has recorded the petroleum discharge to the marine environment to be 1.3 million tonnes/year from the identifiable sources (National Response Centre, 2003). The Bay of Bengal coast is highly vulnerable for oil pollution. The major cause being large are oil tankers that are transporting fuel mainly through the southern Bay of Bengal (Sen Gupta et al., 1993; Sharma, 2009).

In the present study, we assessed the spatial profile of TPH covering the south east coast of India (~876 km long) of the Indian Peninsula. The Environmental Information System Centre has reported that Tamil Nadu has about 12,000 industries, and out of these, 5500 industries are situated in and around the coastal areas (Ramesh et al., 2008). Coastal activities such as industrial oil discharge, oil exploration, oil refining, ports and harbour, fishing, tourism and recreational activities are responsible for the hydrocarbon pollution along this coast (Ramesh et al., 2008). Previous studies have assessed the TPH pollution in sediment and water at some selected locations

(Gurumoorthi & Venkatachalapathy, 2017; Natarajan et al., 2006; Selvaraj et al., 1999; Topgi et al., 1982; Veerasingam et al., 2010; Venkatachalapathy et al., 2010a, b). However, there is no study available yet on the distribution of TPH in both water and sediments for the entire coastline of Tamil Nadu, even though various industrial settlements like factories, oil refineries, ports and fishing harbours along the Tamil Nadu coast are increasing in number. Therefore, it becomes imperative to assess the distribution of total petroleum hydrocarbon in the Tamil Nadu Coast. The main objectives of this study were to assess the distribution of total petroleum hydrocarbon (TPH) in both seawater and sediments of the Tamil Nadu coast, as well as to determine the content of sand, silt, and clay for sediment characterization. The results of this study could serve as comprehensive baseline information on TPH pollution for planning and management to ensure the safety of the coastal ecosystem.

## Material and methods

### Study area

The Indian coast is divided into two categories, namely, coasts on the western India and coasts of the eastern India. The southern part of the eastern coast of India forms the southeast coast of India, which mostly comprises the coast of Tamil Nadu and Pondicherry states (Ingole, 2005). The Tamil Nadu coastline, situated on the southeast coast of the Indian Peninsula, is a length of 1076 km, establishing it as India's second-longest coastline. Prominent ports like Ennore, Chennai, Thoothukudi, and Nagapattinam are strategically situated along this coastal stretch. Within Tamil Nadu, there exists a substantial industrial presence around 12,000 industries. Among these, approximately 5500 industries are strategically located in and around the coastal regions. Notably, about 1500 industries are situated along the Chennai coast (Ramesh et al., 2008). The primary coastal activities contributing to marine pollution along the Tamil Nadu coast involve the release and disposal of both treated (at a rate of 1.8 million litres per day) and untreated sewage, as well as industrial waste. In addition, heated water discharge from power plants cooling systems, oil spillage, chemical spillage and activities such as oil exploration, oil refining, fishing using

mechanized vessels, painting of fishing vessels, draining of waste oil, scrapping of fishing vessels, dumping of wastes and trash fishes, dredging, dumping of ship wastes, cargo handling, recreation, and tourism activities and salt production are equally responsible for coastal pollution in Tamil Nadu (Ramesh et al., 2008). Additionally, Tamil Nadu presently accounts for 15% of India's overall marine catches. There are thirteen significant landing centres for mechanized boats distributed along the extensive 1000 km coastline, accommodating a total of 6012 vessels (Bavinck et al., 2008; Bhathal, 2005). These fishing activities might also lead to petroleum hydrocarbon pollution.

An important feature of the Tamil Nadu coast is the presence of 796 km long Buckingham Canal (part of the National Waterway 4 (NW-4), which originates in the Godavari district of Andhra Pradesh and runs parallel to the coastline up to Villupuram District of Tamil Nadu. In this segment, of the coastal region, the canal opens into the coastal waters at various locations such as Ennore Creek, Cooum river estuary (Chennai), Adyar river estuary (Chennai), Muttukadu Backwaters, Edaiyur Backwaters, Sadras Backwaters, Palar River estuary, Marakanam and Pondicherry. The canal receives untreated sewage and industrial discharge from Chennai and the nearby industrial establishments.

#### Sample collections and analysis

Surface and bottom seawater and surface sediment samples were collected from 27 ecologically distinct locations along the Tamil Nadu coast (Fig. 1). Samples were collected on-board Coastal Research Vessel Sagar Purvi equipped with all essential equipment. Pre-cleaned (using *n*-hexane) and oven-dried (50 °C) amber glass bottles were rinsed with ambient seawater before collecting the water samples. Seawater samples from the surface (<0.5 m) and bottom were collected using a Niskin's water sampler. Physicochemical parameters such as pH, temperature and dissolved oxygen (DO) were measured onboard. Suspended particulate matter (SPM) was calculated as the difference between the initial and final weight of the filter paper after drying at 105 °C overnight. One litre water sample was collected from each location and stored at 4 °C until further analysis. Total petroleum hydrocarbon content in the water was extracted in triplicates with *n*-hexane by following the standard method (IOC-UNESCO, 1984). The organic phase

containing the analytes was separated, dried with anhydrous Na<sub>2</sub>SO<sub>4</sub> and concentrated using a rotary evaporator. The extracts were analysed using a UV-fluorescence spectrometer (Hitachi, F-2700).

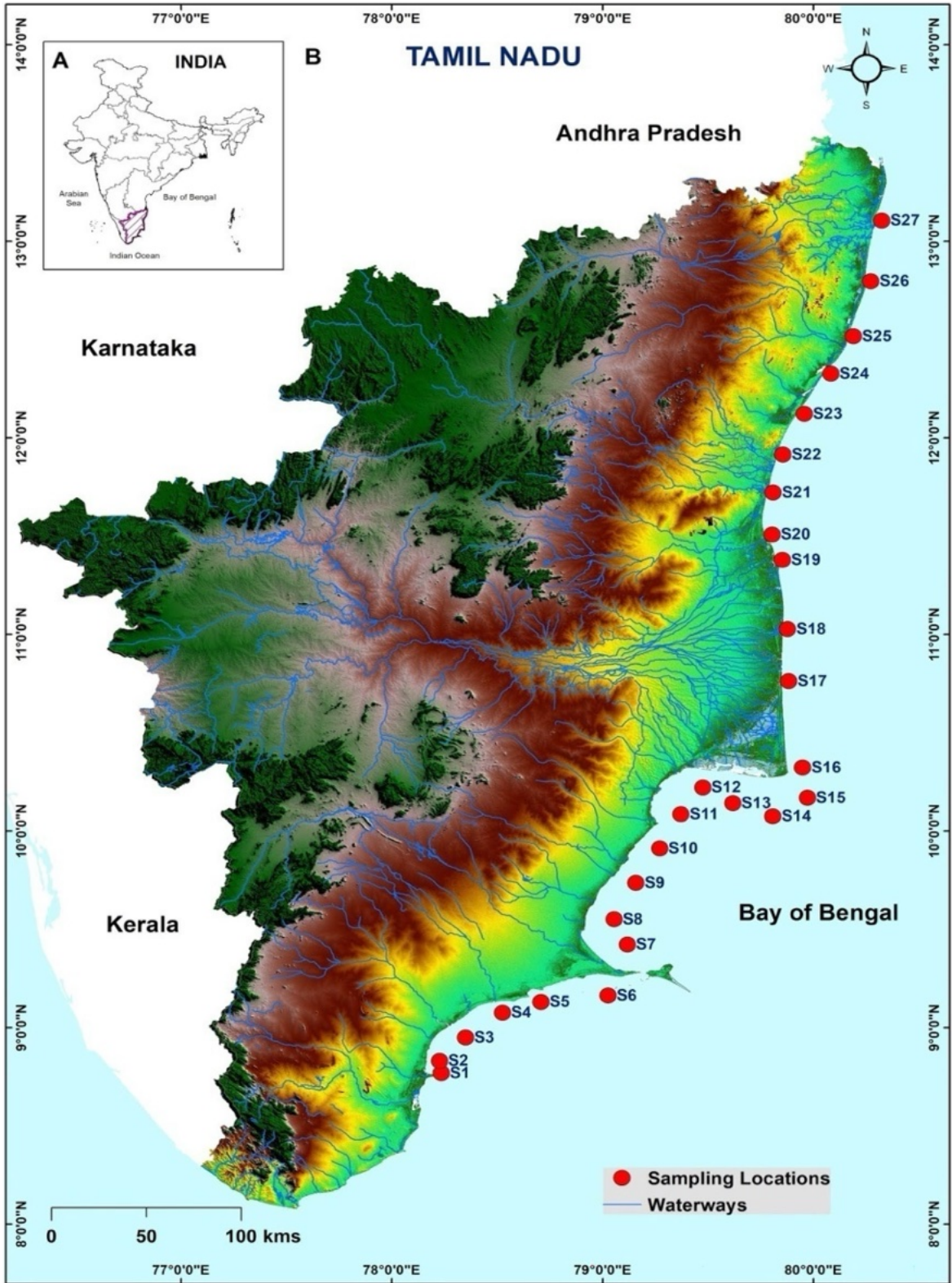
Sediment samples were collected using Van Veen Grab and stored at 4 °C until further analysis. Samples were air-dried and gently ground by mortar and pestle. Total petroleum hydrocarbon in the sediment was extracted using *n*-hexane by sonicating the mixture in an ultrasonic bath for 2 h (IOC-UNESCO, 1982; Tam et al., 2005). The supernatant hexane extract was filtered with 0.45- $\mu$ m filter paper and cleaned with anhydrous Na<sub>2</sub>SO<sub>4</sub>. Total petroleum hydrocarbon content in the concentrated extract was measured by UV fluorescence spectrometer. The total petroleum hydrocarbon contents were quantified as chrysene equivalent based on the emission at 360 nm monitored at 310 nm excitation (MOOPAM, 2005). All samples were analysed for TPH in triplicates, and average values are reported. Samples were spiked with the Chrysene standard to evaluate the percentage recovery of the analytical method. Percentage recoveries for spiked samples were 92–102%, with a precision of 95%. The method detection limit of TPH as chrysene equivalent was 0.01  $\mu$ g/L and 0.1  $\mu$ g/g for seawater and sediment, respectively.

#### Sediment characteristics

About 100 g each of sediment samples were desalinated by washing repeatedly with distilled water, treated with hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) to remove organic matter and dried at 50–60 °C. Dried sediment samples were sieved by a mechanical sieve shaker and used for sediment characterization (Buchanan, 1984; Ingram, 1970). Sediment fractions (<62  $\mu$ m) were analysed using a Malvern particle size analyser (Mastersizer—2000G) to quantify the distribution of silt and clay (Ramaswamy & Rao, 2006).

#### Statistical analysis

Statistical analysis was carried out by using SPSS 22 software. One-way ANOVA approach is chosen to gain a deeper understanding of the nuanced variations existing between two different environmental media. In the present study, one-way ANOVA has been used to analyse the TPH in water (surface and bottom) and sediment data to assess the nature of



◀**Fig. 1** Sampling stations along Tamil Nadu coast. S1, Thoothukudi harbour; S2, Thoothukudi harbour-2; S3, Vaippar river mouth; S4, Mookaiyur fishing harbour; S5, Valinokkam; S6, Mandapam; S7, Vaigai River mouth; S8, Thiruppalaikudi; S9, Thondi; S10, Kottaipattinam fishing port; S11, Kattumavadi harbour; S12, Mallipattinam; S13, Kodiyakarai-1; S14, Kodiyakarai-2; S15, Kodiyakarai-3; S16, Vedaranyam canal; S17, Nagapattinam; S18, Tharangambadi; S19, Kollidam River mouth; S20, Parangipettai; S21, Cuddalore; S22, Pondicherry; S23, Marakkanam; S24, Near Palar River Mouth; S25, Kalpakkam; S26, Muttukadu; S27, Chennai harbour

the significant differences between the two environmental media. Non-metric multidimensional scaling (nMDS) was performed using PRIMER 6.1 software to determine the similarity among stations. To understand the resemblance of spatial distribution of TPH concentrations in the studied coast, non-metric multidimensional scaling (nMDS) analysis was performed. nMDS is a rank-based indirect gradient analysis approach in which the actual distance is substituted with ranks to elucidate the spatial interrelationship among a set of data.

## Result and discussion

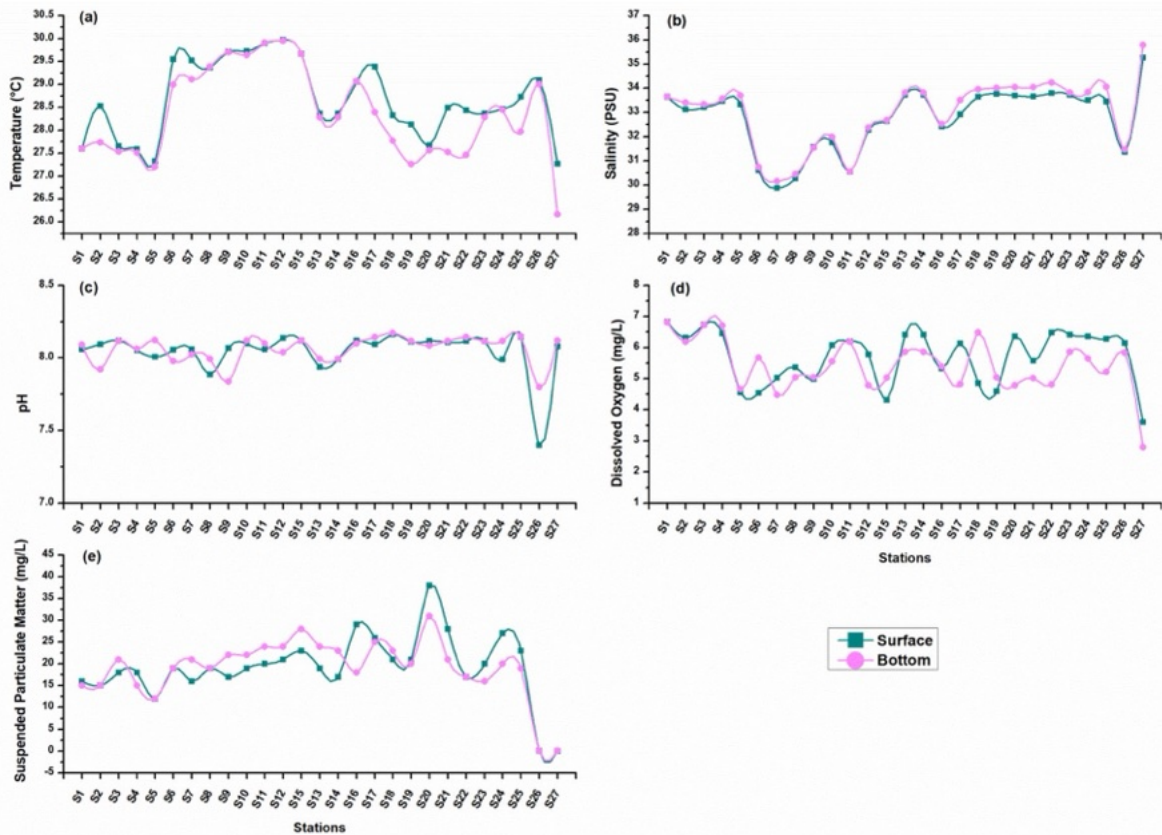
### Seawater characteristics

The observed values for physicochemical parameters were within the expected range for the seawater in the present study area (Fig. 2a–e). The highest seawater temperature was recorded at S12 (surface water) and lowest was recorded for S27 bottom waters (Fig. 2a). Salinity values (29.88 to 35.78 PSU) were always observed to be higher for surface seawater than bottom water (Fig. 2b). Due to the influence of freshwater discharge from Vaigai River at S6, S7 and S8 and from Muttukadu backwater at S26, salinity values at these stations were observed to be comparatively lower. The hydrogen ion concentration, i.e. pH values varied between 7.40 (lowest for S26) and 8.17 (S18 bottom water) (Fig. 2c). The lowest pH observed at S26 station could be due to the freshwater input from Muttukadu backwaters. The findings of the current study corroborated with previous observations in the Muttukadu coastal region, where salinity and pH values were reported to be consistent (pH 7.40; salinity 31.36 psu) due to the influence of freshwater input (Barath Kumar et al., 2018). DO values varied from 3.60 to 6.82 mg/l

in surface waters and for bottom water samples it varied from 2.80 to 6.81 mg/l (Fig. 2d). DO levels in seawater at S27 stations (2.80 mg/L at bottom and 3.60 mg/L at surface) were less than the minimum of 4 mg/L O<sub>2</sub> concentration essential for the survival of aquatic organism. According to China's Seawater Quality Standard (GB3097-1997), the DO values of seawater along the coast complied with the clean (category I) to slightly polluted (category III) category. The seawater at S27 was found to be the most deficient in DO and belonged to the medium polluted (category IV) to highly polluted (category V) category of seawater. S27 station is located close to the Adyar river estuary, which collects a large volume of untreated sewage from Chennai (Jayaprakash et al., 2012; Silambarasan et al., 2012). As a result, the breakdown of organic waste released into coastal waters at this location might have caused the depletion of DO. A previous study by Barath Kumar et al. (2018) also recorded below the minimum of 4 mg/L O<sub>2</sub> (2.80 mg/L) at Pattinapakkam which is located near the Adyar river estuary. According to a study conducted by Mishra et al. (2015), it was revealed that the mouths of the Cooum and Adyar rivers consistently showed the lowest dissolved oxygen levels (0 to 12.37 mg/l). They have recorded hypoxia (<4 mg/l) at mouth regions during low tide throughout the year. Furthermore, recent research by Begum et al. (2021) has reported even more extreme conditions, with occurrences of anoxia (complete absence of DO) near the Adyar river. It is evidence that S27 is polluted with organic waste from the Chennai megacity through the Adyar and Cooum river estuary. The resulting low DO levels pose significant threats to aquatic life, emphasizing the need for immediate environmental intervention and measures to manage sewage and organic waste disposal to restore the health of the coastal ecosystem. SPM levels exhibited significant variation along the coast, in surface water, SPM ranged from 0.014 to 38 mg/l, whereas it varied between 0.018 and 31 mg/l in the bottom water. SPM concentrations were found to be very low in the water of the northern region of coast (S26 and S27) (Fig. 2e).

### Spatial distribution of TPH in surface and bottom seawater

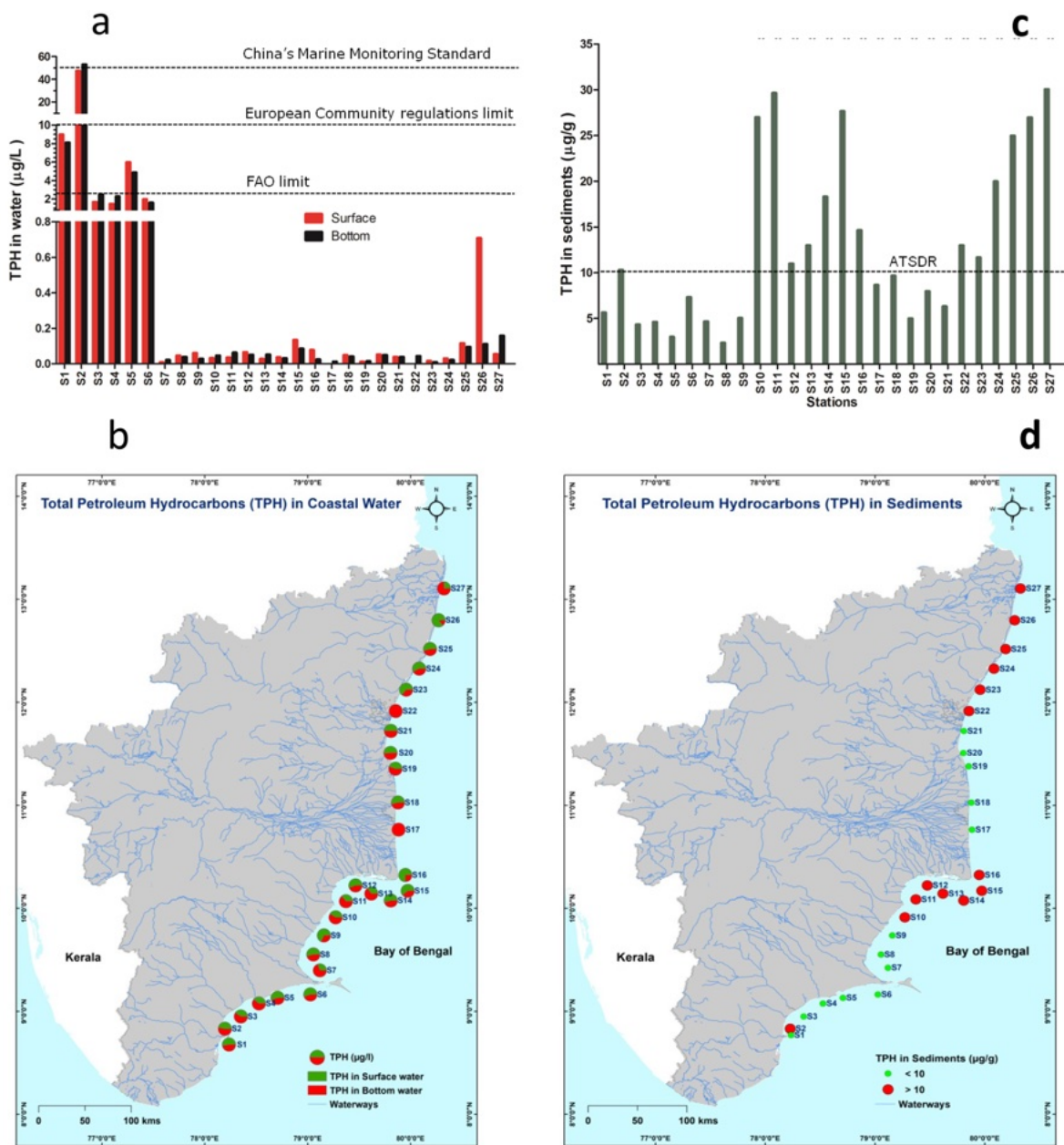
Total petroleum hydrocarbon concentration in the seawater (surface and bottom) and sediment is presented in Fig. 3a–d. The concentrations in the surface and bottom waters ranged between BDL–47.5 µg/L



**Fig. 2** a–e Physicochemical parameters of the coastal waters of Tamil Nadu, **a** temperature, **b** salinity, **c** pH, **d** dissolved oxygen (DO) and **e** suspended particulate matter (SPM)

and 0.01–53.12  $\mu\text{g/L}$ , respectively. The total petroleum hydrocarbon content was observed to be often high in the bottom water compared to the surface water. Higher concentrations of TPH were recorded for the water samples collected towards the south end (Thoothukudi) and north end (Chennai) stations, whereas the central coast seems to be unpolluted with respect to TPH (Fig. 3b). The presence of many industries, harbour and intense urban developments in the north and south coast of Tamil Nadu might be responsible for the elevated TPH in the nearby coast. Such kind of anthropogenic influence is relatively less in the central coast of Tamil Nadu. The spatial distribution patterns of TPH indicated that they are mostly from marine-based sources such as harbour activities, ship movements, oil transport, industrial effluents discharge, fishing and ferry activities since accidental oil spills or natural seepages were not reported recently in the southern region of Tamil Nadu. The

concentration of TPH observed in the seawater samples from the southern region were higher. Similar high TPH levels were observed in the sediments towards the north. The present and previous studies have shown that southern region of Tamil Nadu coast (Gulf of Mannar coast) is sandy with abundant calcareous debris (Jonathan et al., 2004; Karikalan et al., 2020; Kumar et al., 2013). The northern regions were characterised by mud with the dominance of organic matter from the river. Sandy sediments have lesser efficiency to absorb TPH from the water compared to muddy sediments because the clay, colloidal materials and organic matter in the mud are generally surface-active (Gorleku et al., 2014; Gurumoorthi & Venkatachalapathy, 2017; Massoud et al., 1996; Trapido, 1999). The waves play an important role in vertical mixing and sediment transport. The correlation of textural distribution with TPHs content in the surface sediments along the coast suggested that they



**Fig. 3** Spatial distribution of total petroleum hydrocarbons (a values and b stations) with environmental quality standards in water (FAO: Food and Agriculture Organisation permissible limit is 2.5 µg/L) and sediments (c values and d stations) along

Tamil Nadu coast showing the comparison of TPH concentration with ATSDR standards (ASTDR: Agency for Toxic Substances and Disease Registry; unpolluted if TPH is < 10 µg/g and polluted if exceeds 10 µg/g)

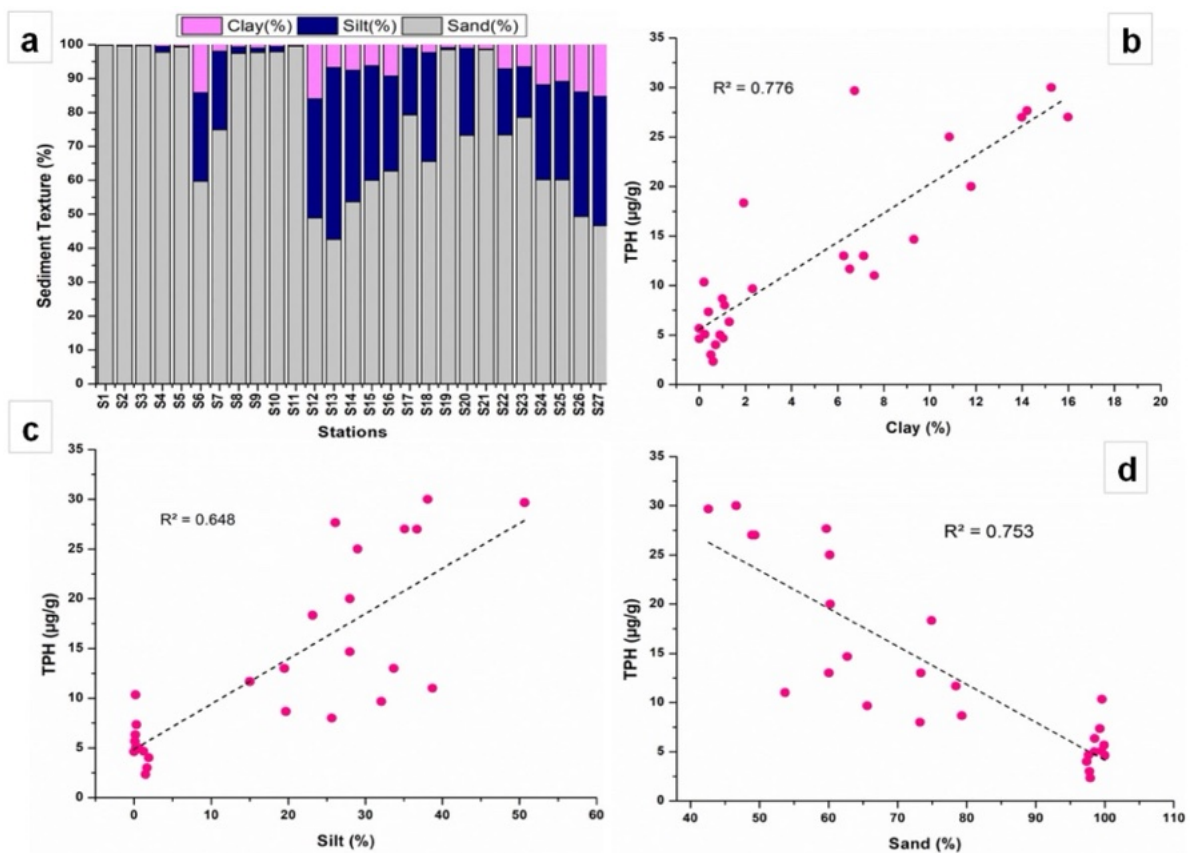
were mainly controlled by waves and longshore currents (Kaliraj et al., 2014). High TPH concentration in seawater at S1, S2 and S4 stations in the Gulf of Mannar (GoM) may be attributed to the release of

TPH from sediments to the water column by turbulence and mixing because the swells and waves are high in the GoM during the month of January to April (Gowthaman et al., 2013).

## Textural characteristics and distribution of TPH in sediment

The textural characteristics of sediment such as sand, silt and clay contents significantly influenced the distribution of TPH and control their partitioning in water and sediment (Szava-Kovats, 2008). The textural characteristics of the collected sediment samples are presented in Fig. 4a. The percentage of the sand fractions at the Tamil Nadu coast varied from 42.60 to 99.80% with a mean value of 76.84%. The highest values of sand were recorded at S1, while a lower value of sand was found at S13. The sand particles were dominant in southern regions compared to the Northern regions of the Tamil Nadu coast due to the northeast monsoon current. The dominance of sand fractions observed at stations S1–S5 located adjacent to Thoothukudi

harbour might be due to the establishment of a spit and the construction of a jetty for the port of Thoothukudi to protect the region from the action of currents. The increased sand content indicated the transport of the finer sediments by the currents from the abrasion zone once it reach the coastal zone (Jonathan et al., 2004; Szefer & Skwarzec, 1988). The percentage of silt and clay fraction was found to vary from 0.10 to 50.67% with the mean value of 18.05% (higher percentage at S13; lower at S1&S3) and 0.10 to 15.98% with the mean value of 5.11% (higher percentage at S12 and lower at S1) respectively. Both silt and clay were more dominant in the northern part of the Tamil Nadu coast due to the input of mud and organic matter from rivers such as Palar River, Cooum, Adyar river and Muttukadu backwater (Venkatachalapathy, et al., 2010a, b). Previous studies have also reported



**Fig. 4** Correlation analysis for the total petroleum hydrocarbons and components of the sediment texture along the Tamil Nadu coastal sediments. **a** Percentage distributions of clay, silt, and

sand; **b** and **c** positive correlation between clay (**b**), silt (**c**) and TPH concentration of sediments of Tamil Nadu coast. **d** Negative correlation between sand and TPH concentrations of sediments

that sediments of Chennai harbour, Cooum and Adayar contain high percentages of mud and silt (Venkatachalapathy et al., 2010a, b).

Total petroleum hydrocarbon content in the sediment samples varied from 2.33 to 30.07  $\mu\text{g/g}$  (dry weight) (Fig. 3c, d). The level of TPHs was highest in the sediment at S27 as the location used frequently for movement of fishing boats and excessive shipping activities in Chennai harbour. Discharges of petroleum refinery industries and land-based wastewater are also common in this station. Further, oil spill occurred due to the oil tanker ship accident at Ennore port (near Chennai harbour) in January 2017 which released more than 100 tonnes of heavy fuel oil (Sivagami et al., 2019). Other stations such as S10, S11 and S15 which are located near fishing harbours also showed a high level of TPH in the sediments (Fig. 3d). The high level of TPH in the fishing areas need to be assessed regularly to ensure the safety of habitat and human health risk due to the consumption of edible organism in the catchment (Li et al., 2010).

#### Statistical analysis

A strong positive correlation was found between TPH and sediment fractions such as clay ( $R^2=0.776$ ;  $P<0.001$ ) (Fig. 4b) and silt ( $R^2=0.648$ ;  $P<0.001$ ) (Fig. 4c). Sand fractions showed a strong negative correlation ( $R^2=0.753$ ;  $P<0.001$ ) (Fig. 4d). The correlation results indicated that TPH was strongly bound with muddy sediments, whereas sand particles are poor in organic content and have less potential to retain hydrocarbons (Barath Kumar et al., 2017; Gorleku et al., 2014; Trapido, 1999; Veerasingam et al., 2015).

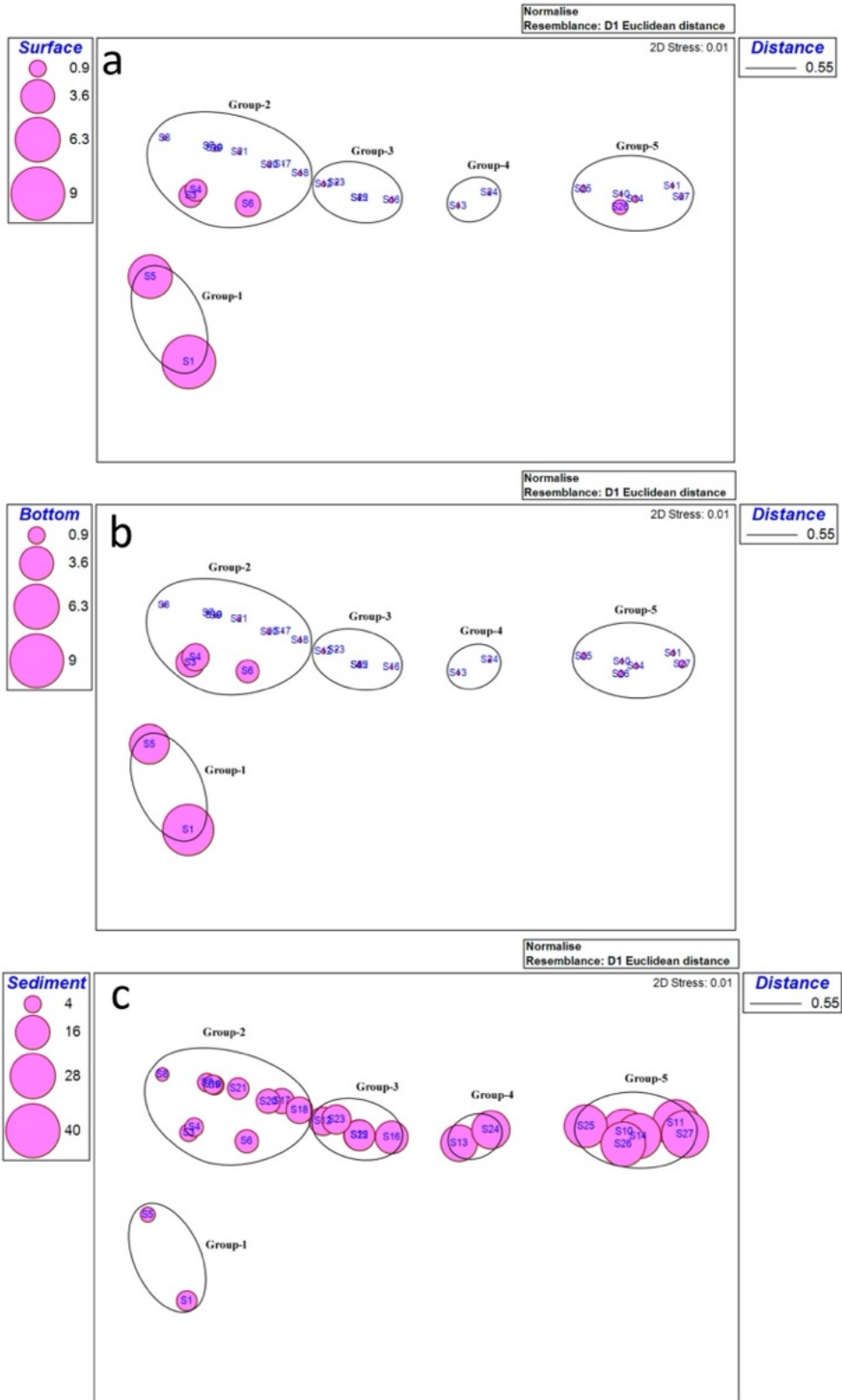
The results of the non-metric multidimensional scaling (nMDS) analysis demonstrated that the 27 studied stations clustered into five groups and lied within the Euclidean distance of 1.55 (excluding S2). Total petroleum hydrocarbon concentrations in sediment and water showed opposite trend in all five clustered groups (Fig. 5a–c). Group 1 (S1 and S5) was with high TPH levels in seawater, and group 2 to 5 were with high TPH content in the sediment. The group 5 stations were having the highest sediment TPH values ranging from 25.00 to 30.07  $\mu\text{g/g}$  which could be attributed to the fishing boat and harbour activities. One-way ANOVA indicated a significant difference ( $F=11.75$ ;  $p<0.01$ ) in TPH concentrations of water and sediments with insignificant

correlation between surface seawater,  $R^2=0.017$ , and bottom seawater,  $R^2=0.015$ . However, the chances of TPH in sediment being released again into the water column may cause secondary pollution (Zhao et al., 2015). The concentrations of TPH in surface water were strongly correlated ( $R^2=0.997$ ) with TPH concentration in the bottom water due to the mixing.

#### Compliance with guideline limits

As per environmental quality standards, TPH in water samples except at station S2 (bottom water) were below the Grade II quality standard of 50  $\mu\text{g/L}$  and can be regarded as clean water Class I (CSBTS, 1997). However, maximum TPH (S2, 53.12  $\mu\text{g/L}$ ) was five times higher than the European Community regulations limit of 10  $\mu\text{g/L}$  (San Sebastián et al., 2001). The seawater in the southern region was more polluted with TPH and might pose risk to living organisms in the seawater. Comparison of TPH ( $\mu\text{g/L}$ ) levels in the seawater of studied locations (Table 1) indicates that the observed values of TPH in this study are lower than previously reported values for the Tamil Nadu coast (Natarajan et al., 2006). Total petroleum hydrocarbon values reported in the seawater of several other coastal areas in India and other parts of the world are much higher than the values observed during this study (Table 1). Total petroleum hydrocarbon levels in the surface and bottom seawater (Fig. 3a, b) exceeded the guideline levels of 2.5  $\mu\text{g/L}$  (FAO, 1982) in coastal waters samples of S1, S2 and S5 located at the southern region of Gulf of Mannar to Thoothukudi harbour.

ATSDR (1999) specifies TPH concentration to be below 10  $\mu\text{g/g}$  for unpolluted environments and estuarine sediments. The average TPH content (13.08  $\mu\text{g/g}$ ) in the sediment assessed in the present study along the Tamil Nadu coast exceeded the level (Fig. 3c) 10  $\mu\text{g/g}$  of ATSDR (1999) indicating that these areas are slightly polluted from the major industries, harbour and petroleum-related activities along the coast. Total petroleum hydrocarbon concentration observed in the sediment was much lower than TPH in several of the other studies as compared in Table 1. Total petroleum hydrocarbon values recorded in sediments during this study were lower than that reported for west coast of India (Chouksey et al., 2004). This could be due to the heavy traffic of oil tankers along the Arabian Sea shipping route than in the Bay of Bengal (Veerasingam et al., 2010). The



◀**Fig. 5** Non-multidimensional scaling (n-MDS) bubble plot showing similarities and grouping of sampling stations surface water (a), bottom water (b) and sediments (c). The circle indicates that the division of the 5 main groups separated by similarity and bubbles indicates the relative values of TPH for each station of Tamil Nadu coast. The size of the bubbles indicates the level of TPH concentrations during the study

concentrations of TPHs recorded in Tamil Nadu coast sediments were comparable (1.88–39.76  $\mu\text{g/g}$ ) to the previously reported values in the sediments of Chennai

Coast (Venkatachalapathy et al., 2010a, b). Further, TPHs content in the sediment reported in earlier studies along Indian coast and other coastal regions were much lower than that observed in the present study. However, present TPH in sediments were much higher than recently reported levels (6.41  $\mu\text{g/g}$ ) in Tuticorin coast (Balachandar et al., 2021) (Table 1). However, in the present study, TPH concentrations in the sediment were lower than the Marine Sediment Quality Standard of first-class standard values of 500  $\mu\text{g/g}$  (CSBTS, 2002).

**Table 1** Total hydrocarbon petroleum (TPH) in water and sediments in Indian Coast and other coastal regions

Study area	Water ( $\mu\text{g/L}$ )	Sediment ( $\mu\text{g/g}$ )	Reference
<b>Water</b>			
<b>Indian Coast</b>			
Northern Indian Ocean, India	0.6–26.5		(Gupta et al., 1980)
Southern Bay of Bengal, India	34–165		(Topgi et al., 1982)
Chennai coast, India	11–139		(Selvaraj et al., 1999)
Thane Creek, Mumbai coast, India	2.9–39.2		(Chouksey et al., 2004)
Andhra Pradesh coast, India	0.81–45.72		(Natarajan et al., 2006)
Tamil Nadu coast, India	0.2–5.8		(Natarajan et al., 2006)
Uppanar to Coleroon, Tamil Nadu, India	2.28–14.02		(Veerasingam et al., 2011)
Paradip port, Odisha, India	1.01–8.50		(Panigrahy et al., 2014)
Gopalpur port, Odisha, India	0.25–0.91		(Panigrahy et al., 2014)
Haldia port, West Bengal, India	1.60–20.11		(Panigrahy et al., 2014)
Diamond Harbour, West Bengal, India	1.35–1.71		(Panigrahy et al., 2014)
<b>World coast</b>			
Northwestern Arabian Gulf	1.2–546		(El Samra et al., 1986)
Strait of Johor, in Peninsular Malaysia	25–2795		(Abdullah et al., 1996)
Coastal waters from Malaysian west coast	5–386		(Abdullah et al., 1996)
Gulf of Thailand and East Coast of Peninsular	0.05–4.13		(Wongnapapan et al., 1999)
Bohai Bay, China	24–508		(Li et al., 2010)
Romanian Black sea Sector	29–271		(Țigănuș et al., 2016)
Buffalo Estuary, South Africa	7.65–477		(Adeniji et al., 2017)
Tamil Nadu coast, India (Surface)	BDL–47.5		Present study
Tamil Nadu coast, India (Bottom)	0.10–53.12		
<b>Sediment</b>			
<b>Indian Coast</b>			
Arabian Sea along the Indian coast		0.6–5.8	(Sen Gupta et al., 1993)
Thane Creek, Mumbai coast, India		7.6–42.8	(Chouksey et al., 2004)
Bassein-Mumbai coast, India		7.0–38.2	(Chouksey et al., 2004)
Chennai Coast, India		1.88–39.76	(Venkatachalapathy et al., 2010a, b)
Pondicherry to Nagapattinam, India		1.48–4.23	(Veerasingam et al., 2010)
Southeast Coast of India		2.2–5.6	(Muthukumar et al., 2013)
Kanyakumari Coast, India		3.14–14.59	(Gurumoorthi & Venkatachalapathy, 2017)
Pulicat Lake, Southeast coast of India		0.28–6.86	(Hemalatha et al., 2020)

**Table 1** (continued)

Study area	Water ( $\mu\text{g/L}$ )	Sediment ( $\mu\text{g/g}$ )	Reference
Ennore coast, India		3.25–17.47	(Balachandar et al., 2021)
Tuticorin coast, India		2.05–10.16	(Balachandar et al., 2021)
<b>World coast</b>			
Arabian Gulf		5.4–92.0	(Al-Lihaibi & Ghazi, 1997)
Jiaozhou Bay, China		0.54–8.12	(Wang et al., 2006)
Gulf of Fos, France		7.8–180	(Mille et al., 2007)
Koh Sichang-Sriracha, Thailand		1.1–153.4	(Wattayakorn & Rungsupa, 2012)
Musa Bay, Iran		17–97	(Tehrani et al., 2013)
Coastal Area of Putatan and Papar, Sabah		0.26–4.59	(Mohd Ali et al., 2013)
Bohai Bay, China		6.3–535	(Zhou et al., 2014)
Northern Persian Gulf, Iran		BDL–1.71	(Mohebbi-Nozar et al., 2015)
Musa Bay, Iran		16.48–97.15	(Tehrani et al., 2016)
Tamil Nadu coast, India		2.33–30.07	Present study

Below detection limit (BDL)  $\leq 0.01 \mu\text{g/L}$

## Conclusions

The total petroleum hydrocarbon contamination in the seawater and sediment of ~876 km stretch of Tamil Nadu coast was assessed. The concentration of TPH was ranged from BDL to 47.5  $\mu\text{g/L}$  and 0.01 to 53.12  $\mu\text{g/L}$  in the surface and bottom seawaters, respectively, and their levels in few locations of the southern region have exceeded the international regulatory limit. In sediment, the concentrations of TPH varied from 2.33 to 30.07  $\mu\text{g/g}$  and highest levels in the sediment of Chennai harbour due to movement of fishing boats and excessive shipping activities. Concentrations in the sediment showed strong correlation with silt and clay due to their active binding surfaces. Non-metric multidimensional scaling (nMDS) analysis clustered the 27 studied stations into five groups within the Euclidean distance of 1.55. The trend of TPH content in sediment and water were contrasting with each other without any correlation. According to ATSDR, TPH concentration in the sediment of the Tamil Nadu coast can be categorised as slightly polluted. Water of the studied coastal stretch is fairly unpolluted with respect to TPH in comparison with the prescribed regulatory limit by international agencies. However, levels are expected to rise in the near future since coastal areas

of Tamil Nadu are growing faster with the addition of new harbours, petroleum refinery industries, oil exploration and other large industries. The present TPH values can serve as the baseline value, and regular monitoring of the TPH level in different components of coastal environment is suggested to ensure the ecological safety in sediment.

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**Author contribution** S. Barath Kumar: cruise sampling, collection and analysis of field samples, data analysis, interpretation and manuscript preparation. P. Raja and M. Savurirajan: participated in the cruise sampling. S.R. Marigoudar: coordination of sampling, interpretation of results and reviewing. K.V. Sharma: finalization, reviewing, and editing. M.V. Ramana Murthy: leading the project administration and funding.

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**Code availability** Not applicable.

## Declarations

**Ethics approval** This manuscript does not contain experimental studies on animals and is not covered under ethical approval.

**Consent to participate** This manuscript does not contain any studies with human participants and consent is not applicable.

**Consent for publication** This article has the consent of all the authors and has the institutional concurrence with the manuscript number NCCR/MS361.

**Conflict of interest** The authors declare no competing interests.

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**Date: 19.02.2025**

**To,**

**Member Secretary**

**Tamil Nadu Pollution Control Board,**

**No.76, Mount Salai, Guindy, Chennai - 600032.**

**Subject: Rebuttal To The Queries Raised In The Matter Of “The Assessment Of Ennore Oil Spill During Michaung Cyclone” Report Submitted By IIT Madras**

Dear Sir,

We acknowledge the concerns raised regarding the oil spill assessment conducted by IIT Madras concerning the Chennai Petroleum Corporation Limited (CPCL) oil spill incident following Cyclone Michaung. Below, we provide clarifications to the key concerns raised in the order dated 24.01.2025.

- 1. As stated in Statement 2 of the order “...A DISCREPANCY IN OIL QUANTITY ESTIMATION, QUANTITY ASSESSMENT, ETC...”**

Oil quantity estimation was conducted through the methodology outlined in our report under “Quantification of Oil in the Contaminated Areas” (refer to Page 25 of our report). This approach involved estimating oil volume across five categories:

1. **Oil present in soil**
2. **Oil pools in the islands and Buckingham Canal overflow**
3. **Oil sheen on Buckingham Canal and Kosasthalaiyar River**
4. **Oil present in residential and industrial areas**
5. **Oil stains on mangroves and riverbanks**

To estimate the volume of ‘**Oil present in soil**’, we identified 8 soil contaminated zones out of the 20 identified hotspots. We used **conservative estimates for depth of contamination as 1 foot (despite field observations ranging from 1 to 2.5 feet) and TPH concentration as 30 g/kg (despite measured values reaching 46 g/kg)**. Factoring in the area of each contaminated zone measured using Google Earth Pro, depth of soil contaminated, density of oil, and TPH concentration, we estimated approximately 487 cubic meters of trapped oil, assuming only one-third of the soil mass is affected. If the soil was fully contaminated, this would rise to 1,623 cubic meters which is a least conservative estimate.

For the other categories, we used **field-verified area measurements**, with contributions from the **coast guard, and independent surveyors** to ensure reliable assessments. Oil thickness assumptions were based on **visual observations, and they were very conservative**.

Our report explicitly states that several factors were **excluded** from the final estimate, such as **floating oily sludge removed by CPCL’s cleanup measures prior to our study (393 tonnes), TPH present in sediments and water, oil trapped in inaccessible islands, and contamination within CPCL premises. Since our assessment was conducted after cleanup activities were completed, our estimate is very conservative and likely an underestimation of the actual spill.**

Hence, we are confident that the final estimated range of 517 to 2,569 tonnes accounts for **only a fraction of the actual spill**. Our methodology reflects a transparent approach that considers both conservative and worst-case scenarios. **Any variation in estimates is due to the complexity and scale of oil dispersion in the environment.**

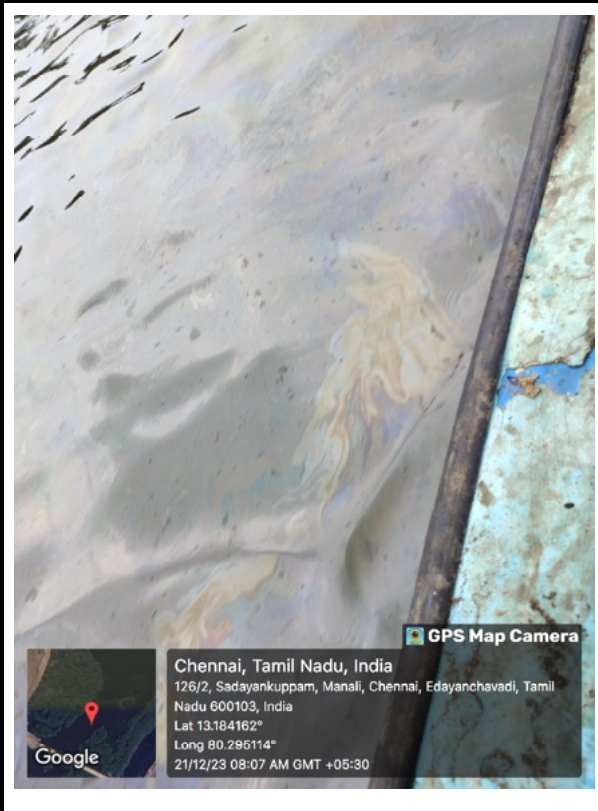
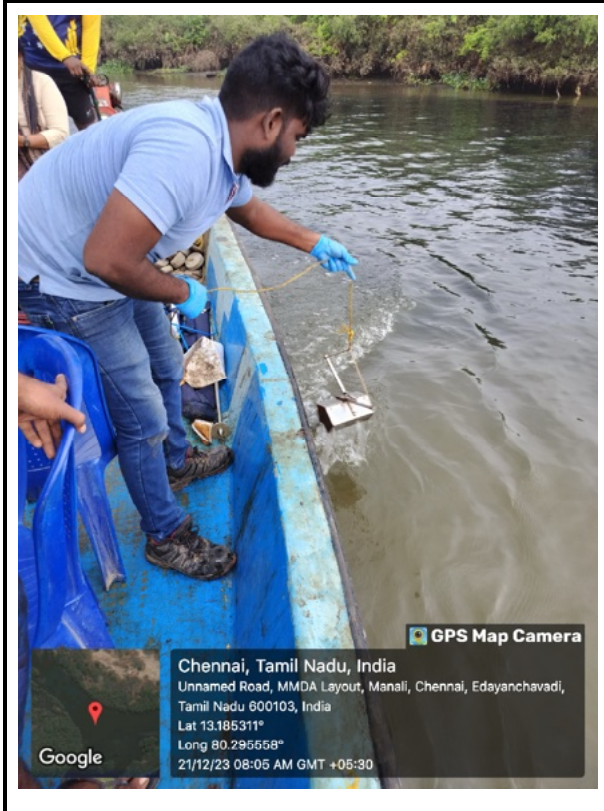
**2. As stated in statement 4 of the order “...REPORTS WERE NOT BASED ON THE ACTUAL SAMPLES TAKEN IN THE AFFECTED LOCATIONS.”**

Our field team collected soil, water, and sediment samples along the Kosasthalaiyar River and Buckingham Canal covering all impacted regions. Field assessments were conducted using boats, drones and by road. Water and sediment samples were collected at 500-meter intervals along a 12 km stretch from Indian Oil Corporation Limited (IOCL) in Tondiarpet to Ennore Creek. Sampling locations were chosen based on **visual inspections of contamination zones and hyperspectral drone surveys** with oil observed on water, sediments, soil, canal and river embankments, and mangroves (**refer from page 6-20 of our report**).

Water samples were taken from both surface and bottom layers using a bailer. Sediment samples were collected using a grab sampler from the river and the canal. Soil samples were collected using soil core sampler/slide hammer upto 4 feet depth in the contaminated zones. **TPH concentrations** ranged from 0.28 to 7.21 g/L in water, 17 to 120 g/kg in sediments and 13.6 to 46.55 g/kg which was measured using **gravimetric** method.

**Gas Chromatography-Mass Spectrometry (GC-MS) analysis** was conducted to identify the spilled oil during the floods. The field sample chromatogram was compared with those of crude oil, furnace oil, and slop oil. Upon analyzing the individual compounds in each chromatogram (across all four samples) for their m/z fragmentation pattern, it was noted that many compounds in the field sample (such as Decane, Dodecane, Tridecane, Hexadecane, Phytane, etc.) corresponded with those in **slop oil and furnace oil**. Hence, it is plausible that the oil present in the flood water is either furnace oil or slop oil.

**The images below contain GPS coordinates and sampling dates, confirming that the samples were collected from the affected locations. The dates indicate sampling occurred near the completion of cleanup activities, which, according to news reports ([oil-spill-in-ennore-brings-fishing-to-a-standstill](#)), concluded on December 20, 2023.**





**3. “As stated in statement 4 of the order...THE STUDY OF THE DEPTH OF THE OIL WAS NOT DONE, AS THEY HAD TAKEN ONLY RANDOM SAMPLES.”**

We would like to reiterate that our sampling methodology was **field validated**, ensuring that contamination depth was properly assessed. Soil samples were collected **up to 4 feet deep**, covering the hotspots where oil contamination was observed. Field observations confirmed that oil had penetrated the soil to depths ranging from **1 to 2.5 feet** in the identified contaminated zones.

To minimize over-estimation, we adopted **1 foot as the depth for calculations**, even though actual field measurements indicated deeper contamination. The **random sampling claim is inaccurate**, as our samples were collected from **identified hotspots**, ensuring that contamination was systematically assessed across multiple locations.

## OUR LATEST FINDINGS

Following the oil spill incident, we conducted site visits in **February 2024, June 2024, and October 2024**. In February we visited two contaminated locations where oil contamination was still persistent. During the **June and October visits**, we carried out extensive sampling to measure TPH concentration. In **June**, water, soil, and sediment samples were collected. Due to the **high TPH concentrations detected in sediments**, our **October sampling focused on sediment and soil** to further evaluate contamination persistence. Given that **water is a flowing matrix**, TPH measurements in water would not provide a reliable indication of long-term contamination.

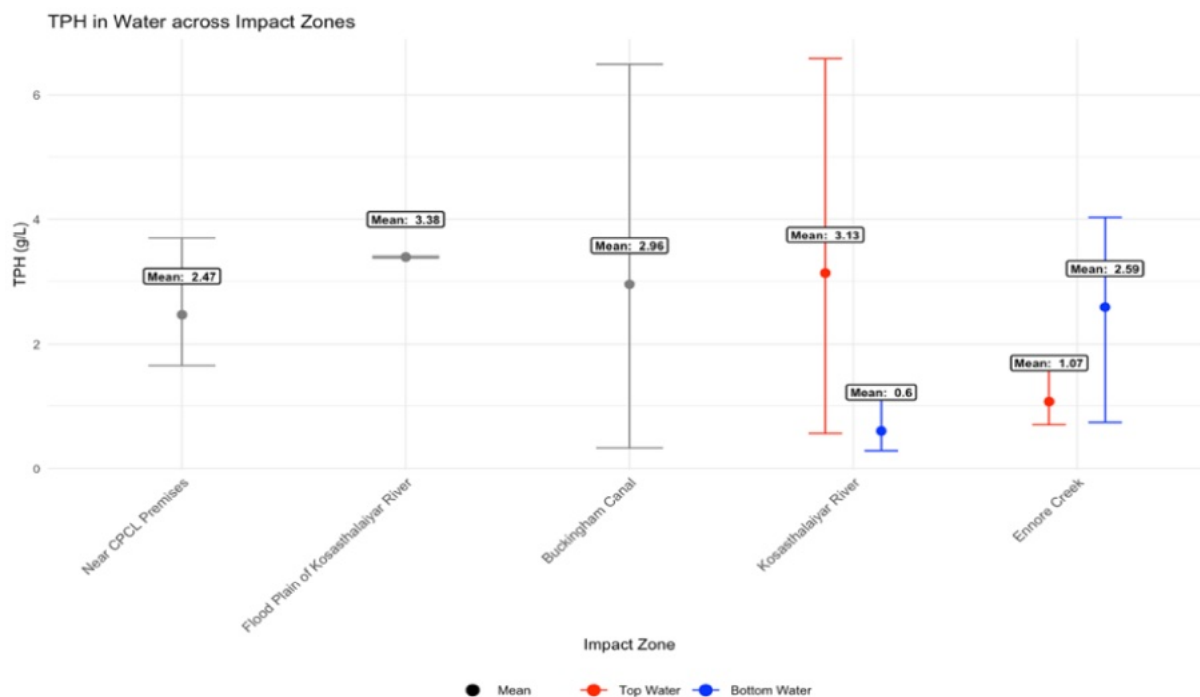


**Images taken in February 2024: The first image captures oil contamination revealed after scraping off the fresh sand on the surface, while the second image shows the layer of oil contamination just beneath the topsoil.**

**TPH CONCENTRATION IN WATER SAMPLES COLLECTED IN JUNE 2024:**

Sample ID	Latitude	Longitude	Impact Zone		TPH (g/L)
L20	13.141573	80.278587	Near CPCL Premises		1.64 ± 0.11
L21	13.154972	80.285117	Near CPCL Premises		3.69 ± 1.61
L19	13.171607	80.284298	Near CPCL Premises		2.08 ± 0.72
L17	13.176725	80.291264	Flood Plain of Kosasthalaiyar River		3.37 ± 1.41
L18	13.179911	80.293154	Flood Plain of Kosasthalaiyar River		3.40 ± 0.88
L22	13.16016	80.287679	Buckingham Canal		4.78 ± 0.23
L23	13.166064	80.289465	Buckingham Canal		2.61 ± 1.78
L24	13.175829	80.2916	Buckingham Canal		1.44 ± 0.18
L25	13.179764	80.294017	Buckingham Canal		3.05 ± 0.17
L26	13.182955	80.296054	Buckingham Canal		1.63 ± 1.21
L27	13.188529	80.301422	Buckingham Canal		0.33 ± 0.12
L29	13.192031	80.303443	Buckingham Canal		4.95 ± 1.92
L28	13.19564	80.30498333	Buckingham Canal		2.79 ± 2.77
L30	13.215732	80.316061	Buckingham Canal		6.49 ± 0.30
L15	13.219993	80.318522	Buckingham Canal		1.48 ± 0.41
L7	13.183536	80.294524	Kosasthalaiyar River	Top water	0.57 ± 0.05
				Bottom Water	0.56 ± 0.17
L6	13.19045	80.300511	Kosasthalaiyar River	Top water	0.33 ± 0.08
				Bottom Water	1.13 ± 0.64
L5	13.195179	80.303134	Kosasthalaiyar River	Top water	0.45 ± 0.09
				Bottom Water	4.08 ± 3.07
L4	13.198915	80.304542	Kosasthalaiyar River	Top water	1.32 ± 0.37
				Bottom Water	2.56 ± 3.34
L3	13.211001	80.312611	Kosasthalaiyar River	Top water	0.67 ± 0.07
				Bottom Water	6.58 ± 0.13

L2	13.214184	80.31367	Kosasthalaiyar River	Top water	0.57 ± 0.10
				Bottom Water	3.12 ± 0.72
L1	13.217909	80.314783	Kosasthalaiyar River	Top water	0.29 ± 0.09
				Bottom Water	3.90 ± 2.74
L8	13.223639	80.319028	Ennore Creek	Top water	0.74 ± 0.35
				Bottom Water	0.70 ± 0.20
L9	13.225977	80.320215	Ennore Creek	Top water	2.57 ± 0.09
				Bottom Water	1.04 ± 0.30
L10	13.227023	80.320941	Ennore Creek	Top water	2.53 ± 0.12
				Bottom Water	0.96 ± 0.03
L11	13.22921	80.324436	Ennore Creek	Top water	4.03 ± 0.39
				Bottom Water	1.56 ± 0.24
L12	13.2311	80.32602	Ennore Creek	Top water	3.09 ± 0.28
				Bottom Water	1.07 ± 0.46

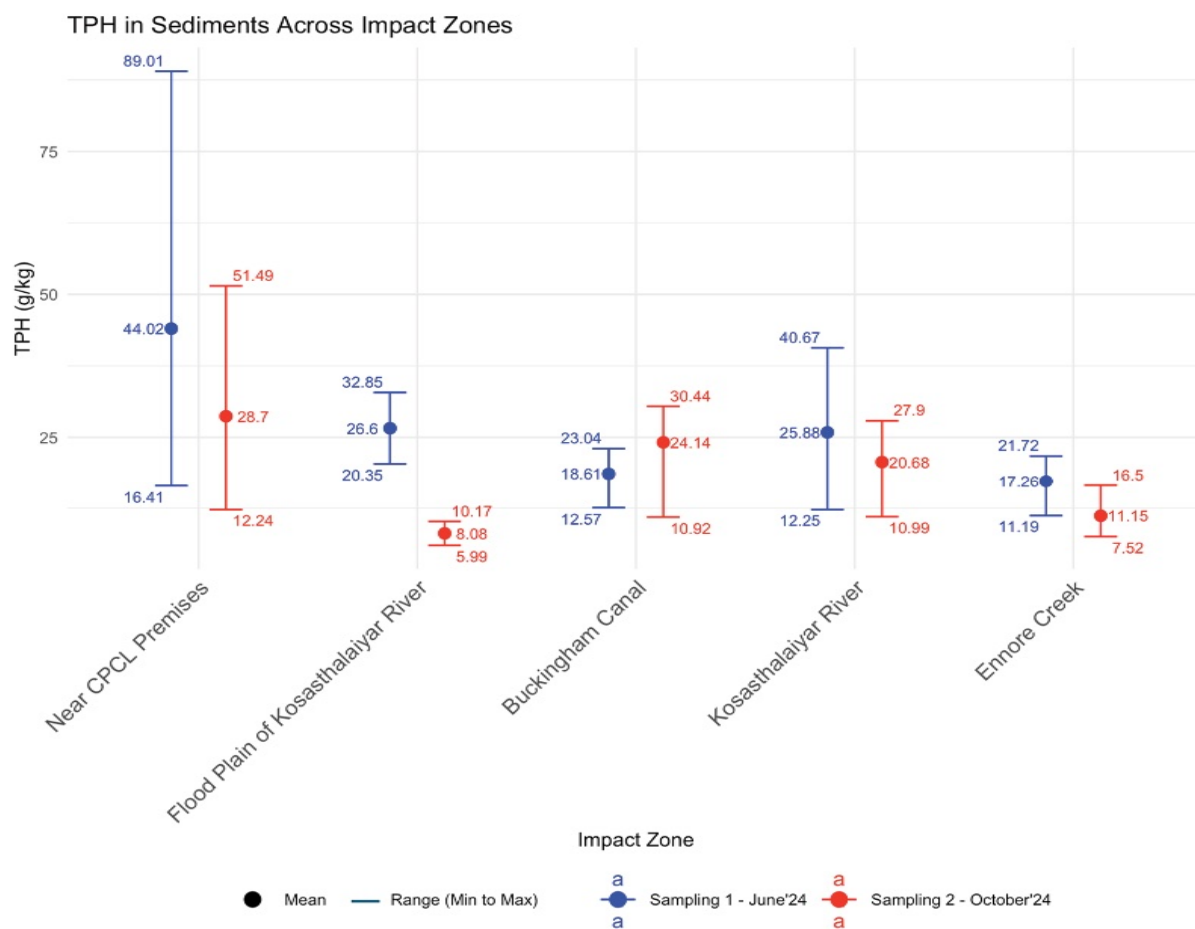


Across all five impact zones, the mean Total Petroleum Hydrocarbon (TPH) levels in the collected samples ranged from  $0.29 \pm 0.09$  g/L to  $6.58 \pm 0.13$  g/L. **Highest concentrations were found in Buckingham Canal and Kosasthalaiyar River, with peak values exceeding 6 g/L.** Given that **no specific CPCB standard exists for TPH in water**, these findings emphasize the need for continuous monitoring and pollution control measures since TPH contamination could pose long-term environmental and ecological risks, affecting water quality, sediment health, and aquatic ecosystems.

***TPH CONCENTRATION IN SEDIMENT SAMPLES IN JUNE 2024 AND OCTOBER 2024:***

Sample ID	Latitude	Longitude	Impact Zone	June 2024 TPH (g/kg)	October 2024 TPH (g/kg)
L20	13.141573	80.278587	Near CPCL Premises	$16.41 \pm 7.00$	$12.24 \pm 1.33$
L21	13.154972	80.285117	Near CPCL Premises	$26.63 \pm 2.64$	$22.37 \pm 1.02$
L19	13.171607	80.284298	Near CPCL Premises	$89.01 \pm 3.46$	$51.49 \pm 6.70$
L17	13.176725	80.291264	Flood Plain of Kosasthalaiyar River	$32.85 \pm 5.96$	$10.17 \pm 4.92$
L18	13.179911	80.293154	Flood Plain of Kosasthalaiyar River	$20.35 \pm 6.73$	$5.99 \pm 0.53$
L22	13.16016	80.287679	Buckingham Canal	$21.69 \pm 2.68$	$27.88 \pm 5.41$
L23	13.166064	80.289465	Buckingham Canal	$16.59 \pm 1.80$	$23.01 \pm 1.76$
L24	13.175829	80.2916	Buckingham Canal	$15.39 \pm 3.15$	$22.31 \pm 2.76$
L25	13.179764	80.294017	Buckingham Canal	$23.04 \pm 1.00$	$27.51 \pm 1.38$
L26	13.182955	80.296054	Buckingham Canal	$20.27 \pm 0.85$	$25.08 \pm 1.43$
L27	13.188529	80.301422	Buckingham Canal	$17.62 \pm 2.41$	$30.44 \pm 5.32$
L29	13.192031	80.303443	Buckingham Canal	$21.73 \pm 3.74$	$25.43 \pm 6.42$
L28	13.19564	80.30498333	Buckingham Canal	$12.57 \pm 5.18$	$24.66 \pm 3.01$
L30	13.215732	80.316061	Buckingham Canal	$0.34 \pm 0.04$	$27.59 \pm 3.55$
L15	13.219993	80.318522	Buckingham Canal	Sample not collected	$10.92 \pm 0.34$
L7	13.183536	80.294524	Kosasthalaiyar River	$16.37 \pm 3.08$	$20.18 \pm 7.47$

L6	13.19045	80.300511	Kosasthalaiyar River	12.25 ± 0.16	19.59 ± 8.68
L5	13.195179	80.303134	Kosasthalaiyar River	19.66 ± 14.88	16.48 ± 0.54
L4	13.198915	80.304542	Kosasthalaiyar River	38.03 ± 1.10	26.95 ± 5.26
L3	13.211001	80.312611	Kosasthalaiyar River	40.67 ± 12.51	22.35 ± 2.05
L2	13.214184	80.31367	Kosasthalaiyar River	34.26 ± 3.88	24.42 ± 4.62
L1	13.217909	80.314783	Kosasthalaiyar River	19.91 ± 6.28	19.77 ± 4.25
L8	13.223639	80.319028	Ennore Creek	16.95 ± 3.25	13.55 ± 1.21
L9	13.225977	80.320215	Ennore Creek	21.72 ± 1.73	11.45 ± 2.68
L10	13.227023	80.320941	Ennore Creek	19.07 ± 1.17	9.80 ± 0.87
L11	13.22921	80.324436	Ennore Creek	17.35 ± 2.70	8.08 ± 1.27
L12	13.2311	80.32602	Ennore Creek	11.19 ± 1.07	7.52 ± 0.81



The data reveals that TPH concentrations in sediments remain significantly high across all impacted zones, extending to the creek, indicating persistent contamination. **The highest levels were recorded at L19, near the CPCL premises, with 89.01 g/kg in June 2024 and 51.49 g/kg in October 2024.** While TPH levels have decreased in certain areas between June and October, this reduction is not consistent throughout all locations. The continued presence of TPH after several months highlights that surface-level cleanup efforts were inadequate in addressing deeper sediment contamination. Unlike water, sediments act as a repository for petroleum hydrocarbons, posing long-term ecological risks, which underscores the need for more comprehensive remediation strategies.

***TPH CONCENTRATION IN SOIL SAMPLES IN JUNE 2024 AND OCTOBER 2024:***

Sample ID	Latitude	Longitude	Impact Zone	June 2024 TPH (g/kg)	October 2024 TPH (g/kg)	Soil Depth (ft)
L16	13.175992	80.290814	Flood Plain of Kosasthalaiyar River	9.81 ± 1.83	17.11 ± 4.72	0'-0.5'
L17	13.176725	80.291264	Flood Plain of Kosasthalaiyar River	14.59 ± 2.42	31.26 ± 5.81	0'-0.5'
L18	13.179911	80.293154	Flood Plain of Kosasthalaiyar River	26.68 ± 1.82	5.99 ± 0.53	0'-0.5'
L7	13.183536	80.294524	Kosasthalaiyar River Islands	34.94 ± 14.40	12.47 ± 3.94	0'-0.5'
L6	13.19045	80.300511	Kosasthalaiyar River Islands	8.63 ± 1.50	12.05 ± 2.24	0'-0.5'
L4	13.198915	80.304542	Kosasthalaiyar River Islands	17.87 ± 1.77	21.39 ± 2.54	0'-0.5'
L2	13.215001	80.313625	Kosasthalaiyar River Islands	18.54 ± 3.33	22.04 ± 1.11	0'-0.5'
L14	13.226256	80.320836	Private Property near Ennore Road Bridge	6.73 ± 4.68	4.79 ± 0.69	0'-0.5'
L14	13.226256	80.320836	Private Property near Ennore Road Bridge	20.49 ± 11.10	18.34 ± 5.33	0.5'-1'

L14	13.226256	80.320836	Private Property near Ennore Road Bridge	9.75 ± 2.16	15.24 ± 5.13	1'-1.5'
L14	13.226256	80.320836	Private Property near Ennore Road Bridge	5.95 ± 1.04	4.90 ± 0.97	1.5'-2'

Soil samples were collected from the **Flood Plain of the Kosasthalaiyar River**, one of the primary entry points of the oil spill during our December 2023 field survey. A significant amount of oil was released onto the floodplain, eventually seeping into the river (refer to page 12 of our report). TPH levels in this zone ranged from 9.81–26.68 g/kg in June and 5.99–31.26 g/kg in October. While L18 showed a decline in TPH (from 26.68 to 5.99 g/kg), L16 and L17 exhibited an increase (L16: 9.81 to 17.11 g/kg; L17: 14.59 to 31.26 g/kg).

In **Kosasthalaiyar River Islands**, TPH levels ranged from 8.63 - 34.94 g/kg in June and 12.05 - 22.04 g/kg in October. L7 showed a significant decrease (from 34.94 to 12.47 g/kg), while L4, L6, and L2 exhibited slight increases, reinforcing the need for long-term monitoring and intervention.

A **Private Property near Ennore Road Bridge (L14)**, heavily impacted during the oil spill in December 2023 (refer to figure 12 of our report), exhibited fluctuating TPH concentrations across depths. The highest levels were found at 0.5–1 feet (20.49 g/kg in June, 18.34 g/kg in October), while deeper layers (1.5–2 feet) had lower TPH, indicating contamination is primarily concentrated in surface and near-surface layers.

**If the cleanup had been truly effective, contamination levels would have consistently declined across all monitored locations. However, the rise in TPH levels suggests incomplete remediation and raises significant concerns about its overall effectiveness.**

**The below are the geotagged images from the field sampling conducted in June 2024 and October 2024**



Black stains seen on pneumatophores in June 2024



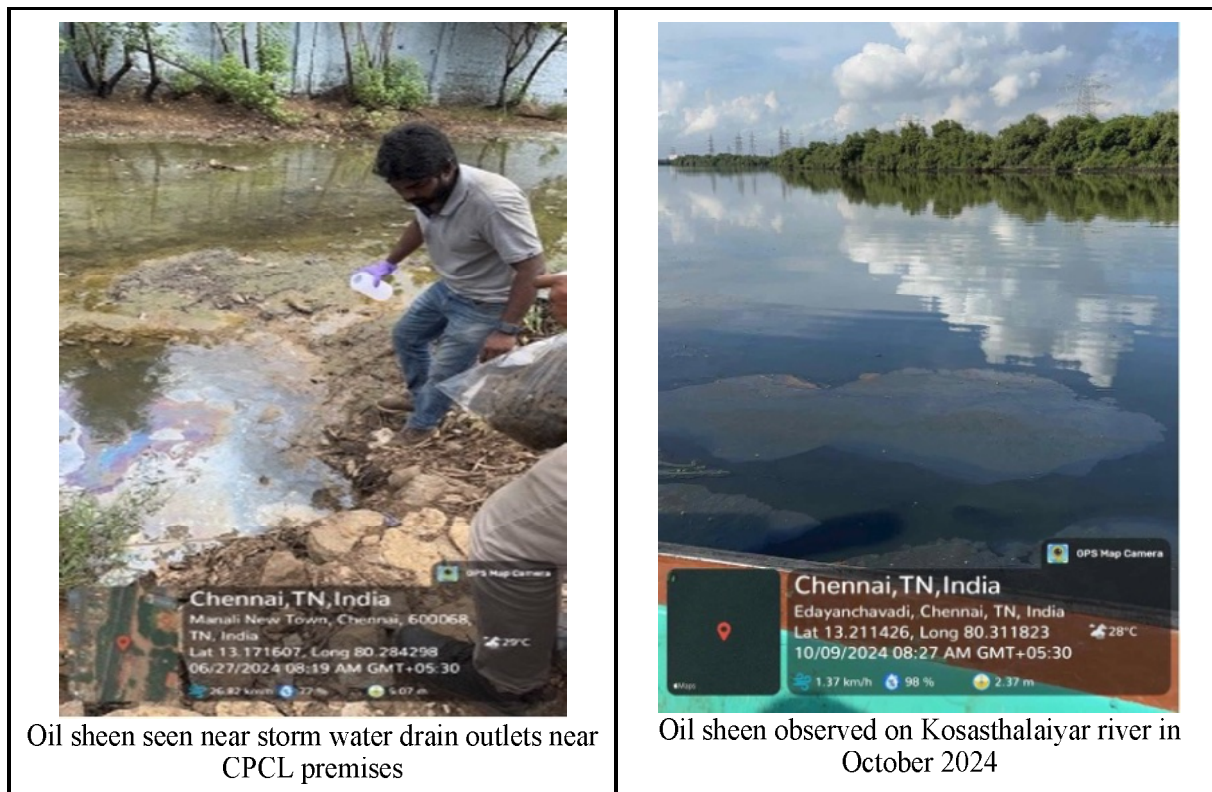
Oil sheen observed when the river sediments were disturbed



Oil stains seen on trees and walls near CPCL premises



Oil sheen observed at Entry Point 1 - Storm water canal discharge into surplus canal of Kosasthalaiyar River in June 2024



***BIODIVERSITY IMPACT ASSESSMENT BY ICFRE - INSTITUTE OF FOREST BIODIVERSITY, HYDERABAD:***

The oil spill has severely impacted biodiversity in the affected area, **staining mangroves up to 10 feet high, submerging saplings in oil slicks, and contaminating crab burrows, endangering benthic organisms.** The spill led to **widespread mortality among shrimp, crabs, fish, and birds at the time of the incident (refer to figures 14 and 15 in our report).** To assess the ecological damage, a biodiversity impact assessment was commissioned to the ICFRE - Institute of Forest Biodiversity, Hyderabad.

*The following text summarizes their findings:*

- **Elevated microbial contamination was observed in both water and sediment samples across all measured parameters (ie. TVC, TC, FC, ECLO and SFLO) in the oil spill-affected areas, with significantly higher counts of total viable bacteria and E. coli compared to the control sites.** This suggests disarray in natural filtration, sewage leakage

and organic matter as a result of the oil spill has made the conditions apt for the proliferation of microbes in this region.

- Average chlorophyll-a levels were similar between impacted ( $1.7 \text{ mg/m}^3$ ) and reference sites ( $1.9 \text{ mg/m}^3$ ), but the impacted areas showed wide variations ranging from  $0.1 \text{ mg/m}^3$  to  $4.6 \text{ mg/m}^3$ . This could be due to environmental instability in some regions, while in others, increased nutrient input from the oil spill may have boosted phytoplankton productivity. **The average phytoplankton population density was higher in the impacted region ( $1154.0 \times 10^3/\text{L}$ ) than in the reference area ( $953.0 \times 10^3/\text{L}$ ), indicating altered nutrient availability. It was also noted that the impacted regions showed a broader range of phytoplankton population density which stipulates localised blooms or extinctions.**
- **The studies conducted in zooplankton indicated notable variation in the population density of the oil spill impacted region which ranged from 250 to  $18,500 \times 10^3$  individuals per  $100\text{m}^3$ . In comparison a much more stable zooplankton density ( $250$  to  $1,250 \times 10^3$  individuals per  $100\text{m}^3$ ) was observed in the reference region, indicating a healthy population.** 75.26% of zooplankton studied in the affected regions were copepods suggesting a clear imbalance in the community with only certain species able to adapt and thrive in the region. In reference areas, rotifers were dominant accounting to 56% of total zooplankton observed. This shows a more diverse and stable community.
- **According to the studies conducted it was observed that the oil spill impacted regions that had more variability in mangrove stand densities ( $9\text{-}53$  plants/ $100 \text{ m}^2$ ) in contrast to the more stable reference regions ( $11 - 34$  plants/ $100\text{m}^2$ ).** Localised disturbances from the oil spill could have caused variability in the affected regions. The recruitment density in reference sites ( $29.04$  recruits/ $\text{m}^2$ ) were much more than that of oil spill affected areas ( $4.8$  recruits/ $\text{m}^2$ ), suggesting the poor conditions retard the establishment of new mangrove saplings in the affected areas. It was noted that the seedling to sapling ratio of the oil spill affected region was low as compared to that of reference region, which suggested that the oil spill contamination lead to limited survival and growth of seedlings.
- **Macrobenthic study in the affected region of Ennore creek varied broadly, ranging from 13 to 1,125 individuals/ $\text{m}^2$ , suggesting patchy distribution due to the**

**contamination and toxicity in the affected areas.** The reference region showed more stable densities with 25 to 5,175 individuals/m<sup>2</sup> suggesting a more healthy habitat.

- Birds were heavily coated with oil during the spill, but nine months later, no signs of oil contamination were observed. This suggests a possible recovery from short-term effects. **Regular monitoring is needed to assess any long-term impacts on bird populations.**
- **A large number of fish were found dead during the spill, and fish diversity remained low even after nine months, with only four species recorded, compared to eight finfish and two shellfish species in the reference region.** This suggests habitat degradation in the spill-affected areas, while the higher catch rates in the reference region indicate a healthier fish population.
- Toxicity tests indicated an increase in rate of mortality with increase in sample concentration and exposure time, and showed varying levels of resistance in organisms in different zones. **Slowest mortality response was seen in the mouth zone (Ennore Creek) with lower concentration of 25%, whereas quickest onset of mortality was observed in upstream locations at higher concentrations. The reference didn't show any mortality indicating contamination in experimental zones.**

*Recommendations highlighted by ICFRE - IFB, Hyderabad:*

- **Bioremediation** should be implemented to accelerate hydrocarbon degradation, along with regular water quality monitoring for pollutants and heavy metals.
- Habitat restoration efforts, including **mangrove replantation and artificial reef installations**, are essential to support ecosystem recovery.
- **Sustainable fishery management measures**, such as temporary fishing bans and livelihood support for affected communities, are advised to restore fish populations.
- Additionally, **continued monitoring of avian biodiversity** and habitat protection are crucial to assess long-term ecological impacts.

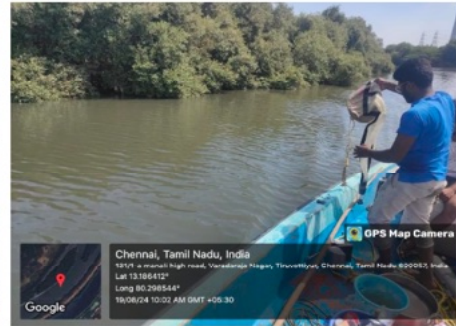
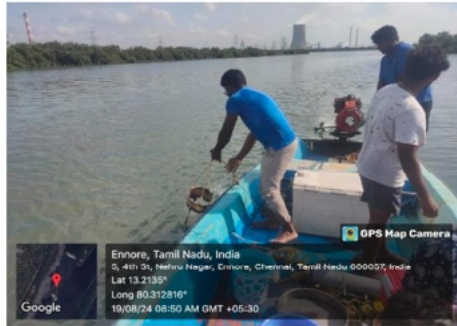
**These measures, combined with stricter pollution control policies, will help rehabilitate the affected ecosystem and ensure long-term environmental resilience.**



Sampling locations of the study region used to collect the water sediment samples for biological parameters.



Sampling locations of the study region used to collect the data on diversity of mangroves from the Ennore Creek.



Sampling by the ICFRE-IFB team

Our assessment of the Ennore oil spill was conducted using systematic methodologies, incorporating both conservative and worst-case estimates to ensure accuracy while avoiding overestimation. Extensive field surveys and laboratory analyses were carried out across all affected regions. The detection of elevated TPH levels in sediments and soil in our latest findings underscores the spill's long-term environmental impact, highlighting the need for remediation measures in the affected areas.

**The claims raised in the order challenging our findings were vague, lacking scientific basis and field assessment reports. Our field sampling was conducted at regular intervals, consistently detecting persistent oil contamination in soil and sediments, with concentrations significantly exceeding the CPCB limit of 5 g/kg.**

**We emphasize that our report explicitly excludes the certain factors from the final estimate, such as the 393 tonnes of floating oily sludge removed by CPCL before our study, as well as TPH present in sediments and water, oil trapped in inaccessible islands, and contamination within CPCL premises. Since our assessment was conducted after cleanup activities were completed, our estimate is highly conservative and likely an underestimation of the actual spill.**

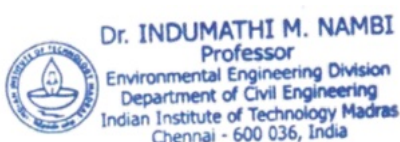
**Thus, we are confident that the final estimated spill range of 517 to 2,569 tonnes represents only a fraction of the true magnitude.** Our methodology is transparent, considering both conservative and worst-case scenarios. Our analysis remains grounded in scientific evidence, as detailed in this letter.

A comprehensive environmental report including assessments of biodiversity and socio-economic impacts is currently being prepared and will be submitted as part of Phase 2 of this project.

Yours Sincerely,



Prof. Indumathi M Nambi







**Dr. Indumathi M Nambi**

**Professor**

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**Phone: +91-44-22574289**

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**Date: 19.02.2025**

To,

**Member Secretary**

**Tamil Nadu Pollution Control Board,**

**No.76, Mount Salai, Guindy, Chennai - 600032.**

**Subject: Rebuttal To The Queries Raised In The Matter Of “The Assessment Of Ennore Oil Spill During Michaung Cyclone” Report Submitted By ITT Madras**

Dear Sir,

We acknowledge the concerns raised regarding the oil spill assessment conducted by IIT Madras concerning the Chennai Petroleum Corporation Limited (CPCL) oil spill incident following Cyclone Michaung. Below, we provide clarifications to the key concerns raised in the order dated 24.01.2025.

**1. As stated in Statement 2 of the order “...A DISCREPANCY IN OIL QUANTITY ESTIMATION, QUANTITY ASSESSMENT, ETC...”**

Oil quantity estimation was conducted through the methodology outlined in our report under “Quantification of Oil in the Contaminated Areas” (refer to Page 25 of our report). This approach involved estimating oil volume across five categories:

1. **Oil present in soil**
2. **Oil pools in the islands and Buckingham Canal overflow**
3. **Oil sheen on Buckingham Canal and Kosasthalaiyar River**
4. **Oil present in residential and industrial areas**

### 5. Oil stains on mangroves and riverbanks

To estimate the volume of 'Oil present in soil', we identified 8 soil contaminated zones out of the 20 identified hotspots. We used **conservative estimates** for **depth of contamination as 1 foot (despite field observations ranging from 1 to 2.5 feet) and TPH concentration as 30 g/kg (despite measured values reaching 46 g/kg)**. Factoring in the area of each contaminated zone measured using Google Earth Pro, depth of soil contaminated, density of oil, and TPH concentration, we estimated approximately 487 cubic meters of trapped oil, assuming only one-third of the soil mass is affected. If the soil was fully contaminated, this would rise to 1,623 cubic meters which is a least conservative estimate.

#### CPCL's Reply:

Oil being a lighter component /low density, oil tends to float over the surface of water. Settling & percolation of oil in the sediment requires longer duration. TPH value of IITM CE report in the range of 13,600 – 46,550 mg/Kg is unrealistic

When an oil spill occurs, the oil tends to remain on the water surface rather than getting settled to the channel bed. Oil fraction found in channel bed sediment samples could come from the settling of suspended sediment grain and bio-genic particles with the adsorbed oil compound and require longer period for settling.

Comparison of TPH value reported by various agencies in the same period is tabulated below:

Sl.No	Name of the Agency	Reference	As reported	Standardized to mg/kg
1	NIO	TNPCB filed in NGT on NIO report on 09.09.24	0.63– 1.83 mg/g	<b>630-1830</b>
2	NCCR	NCCR report	100 – 1000 µg/gm	<b>100-1000</b>
3	TERI	CPCL filed TERI report on 09.09.24.	5.84-47.34 mg/Kg	<b>5.84-47.34</b>

4	IITM	TNPCB filed in NGT on IIT report on 09.09.24	13.6 -46.5 g/Kg	<b>13,600-46,550</b>
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The above table clearly depicts sample analysis is completely wrong and resulted in exorbitantly higher TPH values for sediments are 46 – 136 times higher than NCCR results.

IITM report has taken these erroneous values whiles computing the oil quantity. This misleading faulty quantity should not be considered for estimation of oil quantity.

IIT has not commented on the reports of NCCR, NIO and TERI TPH values which are much lower.

For the other categories, we used **field-verified area measurements**, with contributions from the **coast guard, and independent surveyors** to ensure reliable assessments. Oil thickness assumptions were based on **visual observations, and they were very conservative.**

### **CPCL's Reply:**

The field verification data would differ from person to person and is highly subjective. Perception by different agencies / persons will vary widely. Taking thickness value based on visual inspection is unscientific and leads to error.

Moreover, mapping the drone images & with the presumed oil thickness in google map will always lead to misleading results. Hence, the statement of conservative measurement is not acceptable.

Our report explicitly states that several factors were **excluded** from the final estimate, such as **floating oily sludge removed by CPCL's cleanup measures prior to our study (393 tonnes), TPH present in sediments and water, oil trapped in inaccessible islands, and contamination within CPCL premises. Since our assessment was conducted after cleanup activities were completed, our estimate is very conservative and likely an**

**underestimation of the actual spill.**

Hence, we are confident that the final estimated range of 517 to 2,569 tonnes accounts for **only a fraction of the actual spill**. Our methodology reflects a transparent approach that considers both conservative and worst-case scenarios. **Any variation in estimates is due to the complexity and scale of oil dispersion in the environment.**

**CPCL's Reply:**

This is the disclaimer given in the 2nd IIT report which clearly indicates that the oil estimation is subjective and is based on perception.

IITM states that 393 MT of oily sludge removed by CPCL is from "The Hindu Bureau" (IITM report page No: 6) and it clearly reveals the fact that in the absence of reliable data they have taken from the News journal without verifying the veracity of the data.

In fact, the quantity of 395 MT is the oily water collected from the Ennore Creek area during the oil spill incident. The report has anonymously consider this quantity as 100% oil and used it for validating their data. During the initial period, the oily water received from the Ennore creek area was having thin layer of oil at the top whereas the drums received after 2-3 days had water only. While receiving TNPCB officials also witnessed & recorded the above. **During the oil spill incident, CPCL collected the following materials containing oil in the stretch from Ennore Creek area under the supervision of TNPCB & state authorities CPCL treated this oily water & recovered the oil amounts to 2.29 MT only.**

Hence, such a huge quantity is not reasonable.

**2. As stated in statement 4 of the order "...REPORTS WERE NOT BASED ON THE ACTUAL SAMPLES TAKEN IN THE AFFECTED LOCATIONS."**

Our field team collected soil, water, and sediment samples along the Kosasthalaiyar River and Buckingham Canal covering all impacted regions. Field assessments were conducted using

boats, drones and by road. Water and sediment samples were collected at 500-meter intervals along a 12 km stretch from Indian Oil Corporation Limited (IOCL) in Tondiarpet to Ennore Creek. Sampling locations were chosen based on **visual inspections of contamination zones and hyperspectral drone surveys** with oil observed on water, sediments, soil, canal and river embankments, and mangroves (**refer from page 6-20 of our report**).

### **CPCL's Reply:**

Even though entire Manali and Ennore industrial area were inundated IIT team has not verified the other industries. Though it is mentioned in the report that Upstream of B Canal from Manali High Road to Kodungaiyur was covered, nowhere else they furnished the analysis or the results of Kodungaiyur area.

It may be noted that in The Energy and Research Institute (TERI) study TPH content of the sediments shows 11.46 to 18.17 mg/Kg at the upstream of CPCL in Kodungaiyur area (TERI report page No:41) and this factor was not at all considered in report. TNPCB has also submitted to NGT that oil traces were observed at Upstream of CPCL (Filed in NGT on 09.12.23)

Water samples were taken from both surface and bottom layers using a bailer. Sediment samples were collected using a grab sampler from the river and the canal. Soil samples were collected using soil core sampler/slide hammer upto 4 feet depth in the contaminated zones. **TPH concentrations** ranged from 0.28 to 7.21 g/L in water, 17 to 120 g/kg in sediments and 13.6 to 46.55 g/kg which was measured using **gravimetric** method.

### **CPCL's Reply:**

It may be noted that all the agencies viz NCCR, NIO, TERI & TNPCB has followed the similar method of collecting water & sediment samples and the results of TPH concentration in water

is compared in the following table: (sediments TPH comparison already given)

Sl.No	Name of the Agency	Reference	As reported	Standardized to mg/lit
1	TNPCB	TNPCB has filed the TPH values in NGT on 27.02.24	0.217-2.458 mg/lit	<b>0.217-2.458</b>
2	NIO	TNPCB filed in NGT on NIO report on 09.09.24	0.025-2.11 mg/lit	<b>0.025-2.11</b>
3	NCCR	NCCR report	27.77 – 1008 µg/ lit	<b>0.0277-1.008</b>
4	TERI	CPCL filed TERI report on 09.09.24.	0.2-3.9 mg/lit	<b>0.2-3.9</b>
5	IITM	TNPCB filed in NGT on IIT report on 09.09.24	0.28 g/L – 7.21 g/lit	<b>280-7210</b>

The above table clearly depicts sample analysis is completely wrong and resulted in exorbitantly higher TPH values for water are 70,00 – 10,000 times higher than NCCR results.

IIT has not commented on the reports of TNPCB, NCCR, NIO and TERI TPH values which are much lower.

Hence, the results are not representing the actual scenario.

**Gas Chromatography-Mass Spectrometry (GC-MS) analysis** was conducted to identify the spilled oil during the floods. The field sample chromatogram was compared with those of crude oil, furnace oil, and slop oil. Upon analyzing the individual compounds in each chromatogram (across all four samples) for their m/z fragmentation pattern, it was noted that many compounds in the field sample (such as Decane, Dodecane, Tridecane, Hexadecane, Phytane, etc.) corresponded with those in **slop oil and furnace oil**. Hence, it is plausible that the oil present in the flood water is either furnace oil or slop oil.

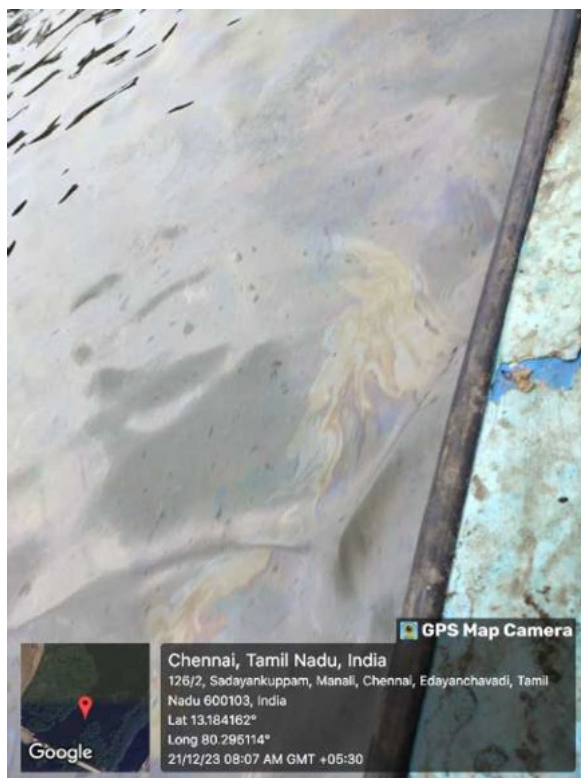
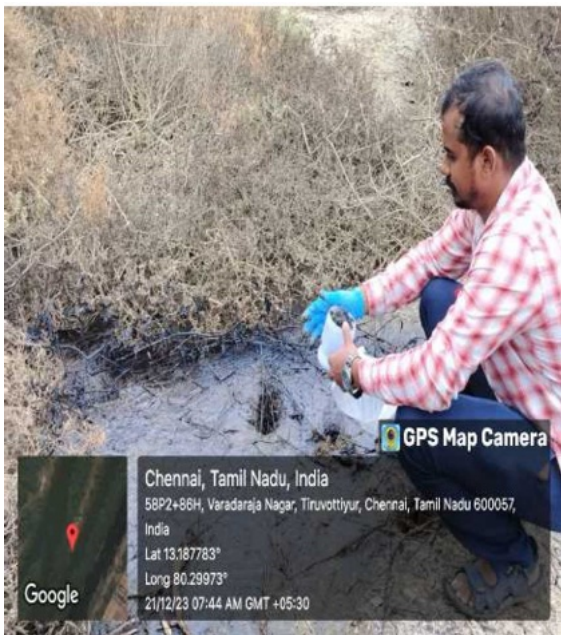
### **CPCL's Reply:**

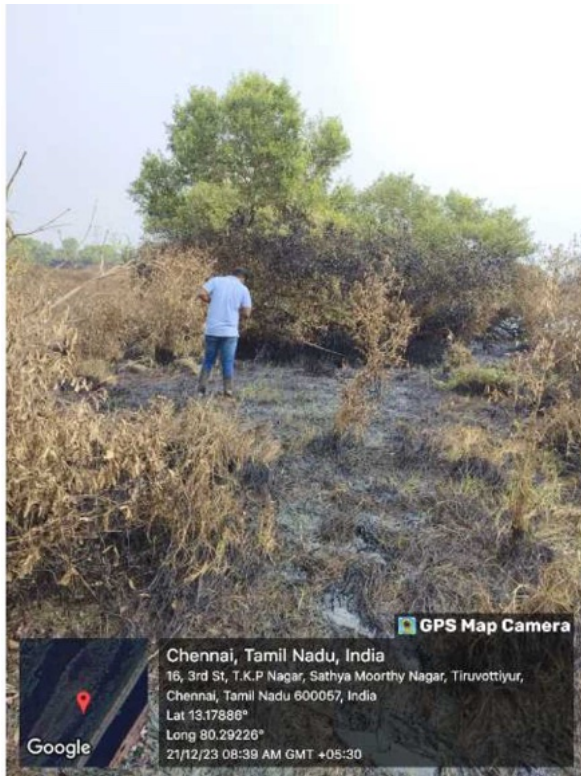
Manali & Ennore industrial area has more than 25 major petrochemical / chemical industries and lot of small industries, workshop & carriages. Also, in the Manali industrial belt, various oil marketing terminal, lube blending plants, Railway loco shed, which handle furnace oil, lube oil etc. All these industries were inundated during the flood due to Michuang cyclone and subsequent release of surplus water from nearby reservoirs, surface oil would have been washed away from any or many of these industries. The report team has not made any attempt to identify the source and miserably failed to account the other Manali Industries.

IIT report-2 submitted to Hon'ble NGT on 24.01.25 by TNPCB , discrepancies in the source identification by IIT 1<sup>st</sup> report was brought to the notice of NGT. Out of 30 Nos of open reservoirs, 13 do not belong to CPCL. Out of the 12 open reservoirs pointed out by IITM-CE report as the main source of oil spill, 2 reservoirs are outside CPCL and the balance reservoirs are also used as raw water reservoirs, storm ponds, Guard Pond, Fire water ponds for storing oil free water only.

The 2<sup>nd</sup> report submitted by IITM to TNPCB is silent on the above matter and confirms that the source identification is not correct.

**The images below contain GPS coordinates and sampling dates, confirming that the samples were collected from the affected locations. The dates indicate sampling occurred near the completion of cleanup activities, which, according to news reports ([oil-spill-in-ennore- brings-fishing-to-a-standstill](#)), concluded on December 20, 2023.**





57GR+4C2 Buckingham Canal Bridge, Manali High Rd, Tiruvottiyur, Chennai, Tamil Nadu 600068, India

Latitude

13.1757099°

Local 10:18:24 AM

GMT 04:48:24 AM

Longitude

80.29041741°

Note: Kalainagar nagar bridge Sludge 1

Altitude 2 meters

Tuesday, 19.12.2023

3. “As stated in statement 4 of the order...THE STUDY OF THE DEPTH OF THE OIL WAS NOT DONE, AS THEY HAD TAKEN ONLY RANDOM SAMPLES.”

We would like to reiterate that our sampling methodology was **field validated**, ensuring that contamination depth was properly assessed. Soil samples were collected **up to 4 feet deep**, covering the hotspots where oil contamination was observed. Field observations confirmed that oil had penetrated the soil to depths ranging from **1 to 2.5 feet** in the identified contaminated zones.

To minimize over-estimation, we adopted **1 foot as the depth for calculations**, even though actual field measurements indicated deeper contamination. The **random sampling claim is inaccurate**, as our samples were collected from **identified hotspots**, ensuring that contamination was systematically assessed across multiple locations.

**CPCL's Reply:**

It may be noted that all the agencies viz NCCR, NIO, TERI & TNPCB has followed the similar method of collecting water. Further, IITM has assumed arbitrarily contamination of 1 foot throughout the area considered without any basis which is also incorrect.

Report has taken lot of assumptions without any base in finalizing the quantity rather than facts.

**Assumption 1** : As referred above, **average TPH values** were taken irrespective the area. (IIT report page No: 26)

**Assumption 2** : **The report** has assumed a **uniform thickness of 0.1 mm for the entire residential and industrial area** which is unscientific. In the residential & industrial area. (IIT report page No: 30). **The report** has assumed a uniform thickness of 0.1 mm for the entire area which is unscientific. If the oil thickness is 0.1 mm as per **the report** as on 21.12.2023, **the normal life of people in that area would have been affected.**

**Assumption 3** : Similarly **the report** assumed **depth of oil estimation in pool 1 mm** without measuring the thickness and was applied uniformly to all the area. (IIT report page No: 28)

**Assumption 4** : **The report** arbitrarily taken **10,000 sq.m of oil pool in mangrove area** and another 10,000 sq.m of oil pool near pipelines without proper justifications. **The report** assumed a **uniform oil thickness of 1mm** all over the area. (IIT report page No: 28)

**Assumption 5** : Area calculated is based on the **oil marking height & the length of the mangrove tree area** and is unscientific as the mangroves will have branches & space between trees etc. **The report** considered the whole area like wall and arrived at the area. (IIT report page No: 32)

**Assumption 6** : **The report** has assumed **0.01 mm oil thickness in the mangrove area.** (IIT report page No: 32)

**Assumption 7** : Assumption of oil layer of **10 mm without any basis in open reservoir tanks** such as Fire water ponds, water plant regeneration water tank, building etc. is beyond imagination (IIT report page No: 36)

Estimation of oil quantity with the above assumptions in the absence of true measurements will always be misleading.

## OUR LATEST FINDINGS

Following the oil spill incident, we conducted site visits in **February 2024, June 2024, and October 2024**. In February we visited two contaminated locations where oil contamination was still persistent. During the **June and October visits**, we carried out extensive sampling to measure TPH concentration. In **June**, water, soil, and sediment samples were collected. Due to the **high TPH concentrations detected in sediments**, our **October sampling focused on sediment and soil** to further evaluate contamination persistence. Given that **water is a flowing matrix**, TPH measurements in water would not provide a reliable indication of long-term contamination.

Chennai - Ennore  
22 February 2024 at 5:44:44 PM 6,166 of 7,346



Chennai - Manali New Town  
22 February 2024 at 3:58:13 PM 6,164 of 7,346

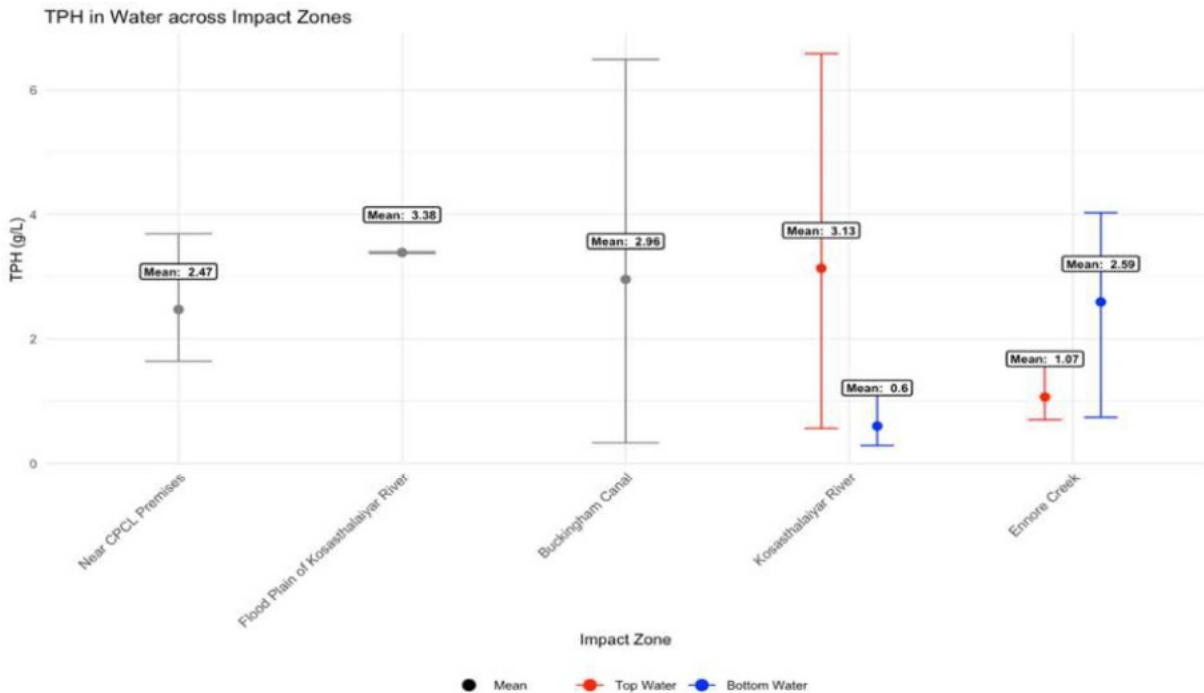


**Images taken in February 2024: The first image captures oil contamination revealed after scraping off the fresh sand on the surface, while the second image shows the layer of oil contamination just beneath the topsoil.**

**TPH CONCENTRATION IN WATER SAMPLES COLLECTED IN JUNE 2024.**

Sample ID	Latitude	Longitude	Impact Zone	TPH(g/L)	
L20	13.141573	80.27858	Near CPCL Premises	1.64±0.11	
L21	13.15497	80.28511	Near CPCL Premises	3.69± 1.61	
L19	13.17160	80.28429	Near CPCL Premises	2.08 ±0.72	
L17	13.17672	80.29126	Flood Plain of Kosasthalaiyar River	3.37 ± 1.41	
L18	13.17991	80.29315	Flood Plain of Kosasthalaiyar River	3.40 ±0.88	
L22	13.16016	80.28767	Buckingham Canal	4.78 ±0.23	
L23	13.16606	80.28946	Buckingham Canal	2.61 ± 1.78	
L24	13.17582	80.2916	Buckingham Canal	1.44 ± 0.18	
L25	13.17976	80.29401	Buckingham Canal	3.05 ±0.17	
L26	13.18295	80.29605	Buckingham Canal	1.63 ± 1.21	
L27	13.18852	80.30142	Buckingham Canal	0.33 ±0.12	
L29	13.19203	80.30344	Buckingham Canal	4.95 ± 1.92	
L28	13.19564	80.3049833	Buckingham Canal	2.79 ±2.77	
L30	13.21573	80.31606	Buckingham Canal	6.49 ±0.30	
L15	13.219993	80.31852	Buckingham Canal	1.48 ±0.41	
L7	13.18353	80.29452	Kosasthalaiyar River	Top water	0.57 ±0.05
				Bottom Water	0.56 ±0.17
L6	13.1904	80.30051	Kosasthalaiyar River	Top water	0.33 ±0.08
				Bottom Water	1.13 ±0.64
L5	13.19517	80.30313	Kosasthalaiyar River	Top water	0.45 ±0.09
				Bottom Water	4.08 ±3.07
L4	13.19891	80.30454	Kosasthalaiyar River	Top water	1.32 ±0.37
				Bottom Water	2.56 ±3.34
L3	13.21100	80.31261	Kosasthalaiyar River	Top water	0.67 ± 0.07
				Bottom Water	6.58±0.13

L2	4	13.21418	80.31367	Kosasthalaiyar River	Top water	0.57 ±0.10
					Bottom Water	3.12 ±0.72
L1	9	13.21790	80.314783	Kosasthalaiyar River	Top water	0.29 ±0.09
					Bottom Water	3.90 ±2.74
L8	9	13.22363	80.319028	Ennore Creek	Top water	0.74 ±0.35
					Bottom Water	0.70 ±0.20
L9		13.225977	80.320215	Ennore Creek	Top water	2.57 ±0.09
					Bottom Water	1.04 ±0.30
L10		13.227023	80.320941	Ennore Creek	Top water	2.53 ±0.12
					Bottom Water	0.96 ±0.03
L11		13.22921	80.324436	Ennore Creek	Top water	4.03 ±0.39
					Bottom Water	1.56 ±0.24
L12		13.2311	80.32602	Ennore Creek	Top water	3.09 ±0.28
					Bottom Water	1.07 ±0.46

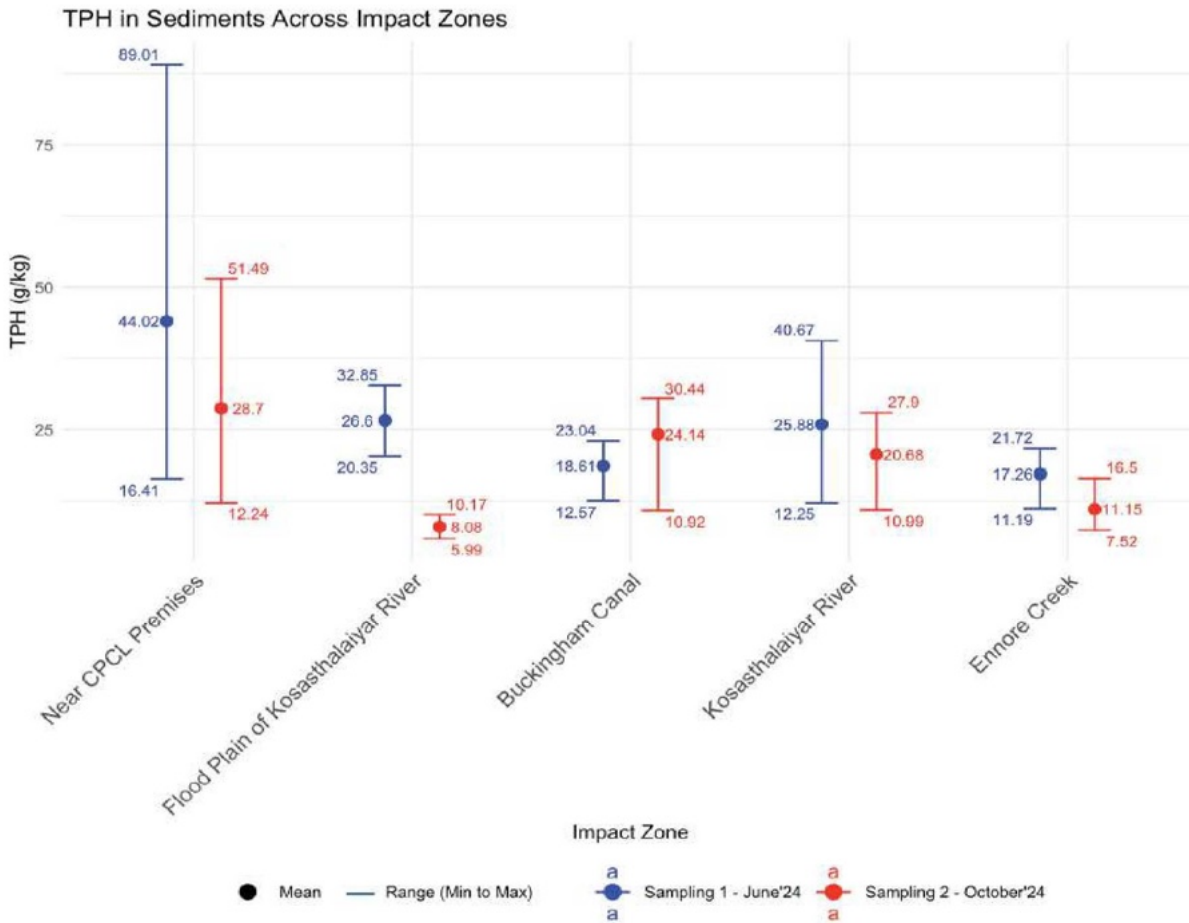


Across all five impact zones, the mean Total Petroleum Hydrocarbon (TPH) levels in the collected samples ranged from  $0.29 \pm 0.09$  g/L to  $6.58 \pm 0.13$  g/L. **Highest concentrations were** found in Buckingham Canal and Kosasthalaiyar River, with peak values exceeding **6 g/L**. Given that **no specific CPCB standard exists for TPH in water**, these findings emphasize the need for continuous monitoring and pollution control measures since TPH contamination could pose longterm environmental and ecological risks, affecting water quality, sediment health, and aquatic ecosystems.

**TPH CONCENTRATION IN SEDIMENT SAMPLES IN JUNE 2024 AND OCTOBER 2024:**

Sample ID	Latitude	Longitude	Impact Zone	June 2024 TPH (g/kg)	October 2024 TPH (g/kg)
L20	13.14157 3	80.27858 7	Near CPCL Premises	16.41 $\pm$ 7.00	12.24 $\pm$ 1.33
L21	13.15497 2	80.28511 7	Near CPCL Premises	26.63 $\pm$ 2.64	22.37 $\pm$ 1.02
L19	13.17160 7	80.28429 8	Near CPCL Premises	89.01 $\pm$ 3.46	51.49 $\pm$ 6.70
L17	13.17672 5	80.29126 4	Flood Plain of Kosasthalaiyar River	32.85 $\pm$ 5.96	10.17 $\pm$ 4.92
L18	13.17991 1	80.29315 4	Flood Plain of Kosasthalaiyar River	20.35 $\pm$ 6.73	5.99 $\pm$ 0.53
L22	13.1601 6	80.28767 9	Buckingham Canal	21.69 $\pm$ 2.68	27.88 $\pm$ 5.41
L23	13.16606 4	80.28946 5	Buckingham Canal	16.59 $\pm$ 1.80	23.01 $\pm$ 1.76
L24	13.17582 9	80.2916	Buckingham Canal	15.39 $\pm$ 3.15	22.31 $\pm$ 2.76
L25	13.17976 4	80.29401 7	Buckingham Canal	23.04 $\pm$ 1.00	27.51 $\pm$ 1.38
L26	13.18295 5	80.29605 4	Buckingham Canal	20.27 $\pm$ 0.85	25.08 $\pm$ 1.43
L27	13.18852 9	80.30142 2	Buckingham Canal	17.62 $\pm$ 2.41	30.44 $\pm$ 5.32
L29	13.19203 1	80.30344 3	Buckingham Canal	21.73 $\pm$ 3.74	25.43 $\pm$ 6.42
L28	13.1956 4	80.304983 33	Buckingham Canal	12.57 $\pm$ 5.18	24.66 $\pm$ 3.01
L30	13.21573 2	80.31606 1	Buckingham Canal	0.34 $\pm$ 0.04	27.59 $\pm$ 3.55
L15	13.21999 3	80.31852 2	Buckingham Canal	Sample not collected	10.92 $\pm$ 0.34
L7	13.18353 6	80.29452 4	Kosasthalaiyar River	16.37 $\pm$ 3.08	20.18 $\pm$ 7.47

L6	13.19045	80.300511	Kosasthalaiyar River	12.25 ±0.16	19.59 ±8.68
L5	13.19517	80.303134	Kosasthalaiyar River	19.66 ± 14.88	16.48 ±0.54
L4	13.19891	80.304542	Kosasthalaiyar River	38.03 ±1.10	26.95 ± 5.26
L3	13.21100	80.312611	Kosasthalaiyar River	40.67 ± 12.51	22.35 ±2.05
L2	13.21418	80.31367	Kosasthalaiyar River	34.26 ±3.88	24.42 ± 4.62
L1	13.21790	80.31478	Kosasthalaiyar River	19.91 ±6.28	19.77 ±4.25
L8	13.22363	80.319028	Ennore Creek	16.95 ±3.25	13.55 ± 1.21
L9	13.22597	80.32021	Ennore Creek	21.72 ± 1.73	11.45 ±2.68
L10	13.22702	80.320941	Ennore Creek	19.07 ± 1.17	9.80 ±0.87
L11	13.22921	80.324436	Ennore Creek	17.35 ±2.70	8.08 ± 1.27
L12	13.2311	80.32602	Ennore Creek	11.19 ± 1.07	7.52 ±0.81



The data reveals that TPH concentrations in sediments remain significantly high across all impacted zones, extending to the creek, indicating persistent contamination. **The highest levels were recorded at L19, near the CPCL premises, with 89.01 g/kg in June 2024 and 51.49 g/kg in October 2024.** While TPH levels have decreased in certain areas between June and October, this reduction is not consistent throughout all locations. The continued presence of TPH after several months highlights that surface-level cleanup efforts were inadequate in addressing deeper sediment contamination. Unlike water, sediments act as a repository for petroleum hydrocarbons, posing long-term ecological risks, which underscores the need for more comprehensive remediation strategies.

***TPH CONCENTRATION IN SOIL SAMPLES IN JUNE 2024 AND OCTOBER 2024:***

Sample ID	Latitude	Longitude	Impact Zone	June 2024 TPH (g/kg)	October 2024 TPH (g/kg)	Soil Depth (ft)
L16	13.17599 2	80.29081 4	Flood Plain of Kosasthalaiyar River	9.81 ± 1.83	17.11 ±4.72	0'-0.5'
L17	13.17672 5	80.29126 4	Flood Plain of Kosasthalaiyar River	14.59 ±2.42	31.26 ±5.81	0'-0.5'
L18	13.17991 1	80.29315 4	Flood Plain of Kosasthalaiyar River	26.68 ±1.82	5.99 ±0.53	0'-0.5'
L7	13.18353 6	80.29452 4	Kosasthalaiyar River Islands	34.94 ± 14.40	12.47 ±3.94	0'-0.5'
L6	13.19045 1	80.30051 1	Kosasthalaiyar River Islands	8.63 ±1.50	12.05 ±2.24	0'-0.5'
L4	13.19891 5	80.30454 2	Kosasthalaiyar River Islands	17.87 ± 1.77	21.39±2.54	0'-0.5'
L2	13.21500 1	80.31362 5	Kosasthalaiyar River Islands	18.54 ±3.33	22.04 ± 1.11	0'-0.5'
L14	13.22625 6	80.32083 6	Private Property near Ennore Road	6.73 ±4.68	4.79 ±0.69	0'-0.5'
L14	13.22625 6	80.32083 6	Private Property near Ennore Road	20.49 ± 11.10	18.34 ±5.33	0.5'-r
L14	13.226256	80.320836	Private Property near Ennore Road	9.75 ±2.16	15.24 ±5.13	r-1.5'

L14	13.226256	80.320836	Private Property near Ennore Road	5.95 ±1.04	4.90 ±0.97	1.5'-2'
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Soil samples were collected from the **Flood Plain of the Kosasthalaiyar River**, one of the primary entry points of the oil spill during our December 2023 field survey. A significant amount of oil was released onto the floodplain, eventually seeping into the river (refer to page 12 of our report). TPH levels in this zone ranged from 9.81-26.68 g/kg in June and 5.99-31.26 g/kg in October. While L18 showed a decline in TPH (from 26.68 to 5.99 g/kg), L16 and L17 exhibited an increase (L16: 9.81 to 17.11 g/kg; L17: 14.59 to 31.26 g/kg).

In **Kosasthalaiyar River Islands**, TPH levels ranged from 8.63 - 34.94 g/kg in June and 12.05 - 22.04 g/kg in October. L7 showed a significant decrease (from 34.94 to 12.47 g/kg), while L4, L6, and L2 exhibited slight increases, reinforcing the need for long-term monitoring and intervention.

### CPCL's Reply:

In the first IITM report submitted by TNPCB on 09.09.24 did not consider neither the effect of anthropogenic activities nor checked the TPH value in the upstream of CPCL. However, the IITM during their 2<sup>nd</sup> report, checked the TPH value in the upstream of CPCL and the same was submitted to this Hon'ble NGT on 28.02.25 by TNPCB.

As per the report, the TPH value of water and sediments in Buckingham canal upstream of CPCL is furnished below.

Same ID & Location	Impact Zone	Water TPH	Sediment TPH	
		g/L	g/Kg	
		June 2024	June 2024	Oct 2024
L20 13.141573 & 80.278587	Near CPCL Premises - B' canal (Upstream of CPCL)	1.64±0.11	16.41 ±7.00	12.24 ± 1.33
Other B' canal area	Down stream of CPCL	0.33 to 6.49	0.34 to 23.04	22.31 to 30.44

- a) TPH value in water & sediment at upstream of CPCL is almost 50 to 60% of TPH observed in downstream of CPCL.
- b) In some of the locations, the TPH value in water & sediment at downstream of CPCL ( L6,L7,L12,L15,L24,L28 & L30) are lesser than the TPH value upstream of CPCL and in most of the other locations, the values are almost equal.
- c) The above clearly indicates that the TPH value at Ennore creek was due to anthropogenic sources like sewage wastewater and solid waste dumps.
- d) In few locations where higher value of TPH value at the downstream of TPH may be due to deposits of anthropogenic sources over the period of time.

### 1. Higher values of TPH reported in IITM 1<sup>st</sup> and 2<sup>nd</sup> report

In the 1<sup>st</sup> report, IITM reported higher TPH value of water and sediments. CPCL already raised this issue of reporting of higher TPH value in sediments to the court on 24.01.25 comparing with NIO,NCCR & TERI reports.

In the 2<sup>nd</sup> report also IITM reported higher TPH values. CPCL has requested IIT oceanography to check the TPH value of sediments at upstream and downstream of CPCL/ Manali Industries. Comparative statement is furnished below.

Reports		Upstream of CPCL in g/Kg	Downstream of CPCL in g/Kg
IIT 2 <sup>nd</sup> report submitted by TNPCB	June 2024	16.41 ±7.00	0.34 to 23.04
	Oct 2024	12.24 ± 1.33	22.31 to 30.44
Present IIT oceanography report	Jan 2025	0.001 to 0.005	0.001-0.030

- a) It is also submitted that the sediment TPH value at upstream and downstream reported are much higher than the value of IIT oceanography report. IIT oceanography report TPH values are in consistent with other reports submitted by NIO, TERI, NCCR & TNPCB.
- b) In similar way, IIT reported higher values in their 1<sup>st</sup> report, and this resulted in higher oil quantity estimation of 517 MT of oil quantity.

From the above, there may be error in the methodology of testing carried out by IIT-M (both 1<sup>st</sup> & 2<sup>nd</sup>).

A **Private Property near Ennore Road Bridge (L14)**, heavily impacted during the oil spill in December 2023 (refer to figure 12 of our report), exhibited fluctuating TPH concentrations across depths. The highest levels were found at 0.5-1 feet (20.49 g/kg in June, 18.34 g/kg in October), while deeper layers (1.5-2 feet) had lower TPH, indicating contamination is primarily concentrated in surface and near-surface layers.

**If the cleanup had been truly effective, contamination levels would have consistently declined across all monitored locations. However, the rise in TPH levels suggests incomplete remediation and raises significant concerns about its overall effectiveness.**

#### **CPCL's Reply:**

As a responsible corporate citizen, CPCL stepped into restoration activities in consultation with state Government Authorities, Tamil Nadu Forest Department and Tamil Nadu Pollution control board (TNPCB) authorities. 128 boats and 512 manpower on daily basis were engaged for cleaning activity. Containment booms of around 1500 meters were installed at various locations in Ennore creek. Six Nos of oil skimmers were deployed for oil slick removal activities. Around 35,000 Nos of absorbent pads and 500 meters of absorbent booms were also used. The absorbent booms and pads were used to absorb the residual oil traces from the water. Shore areas were also cleaned. **The restoration activity in the Ennore creek was carried out on war footing basis and the work was completed on 20.12.24 as declared by Tamil Nadu Government.** Mangrove area was cleaned/ pruned as per the advice of Tamil Nadu Forest Department. Subsequently bioremediation of Mangrove area was carried out by using Herbal Nano bio dispersant on the advice of TNPCB thro' National Institute of Oceanography (NIO) Goa in Jan'24. This work was also completed as on 31.01.2024.

Further, CPCL is also planning to carry out the analysis of water, soil & sediments in the above coordinates through an expert agency and will submit the report shortly.

The below are the geotagged images from the field sampling conducted in June 2024 and October 2024



Black stains seen on pneumatophores in June 2024



Oil sheen observed when the river sediments were disturbed



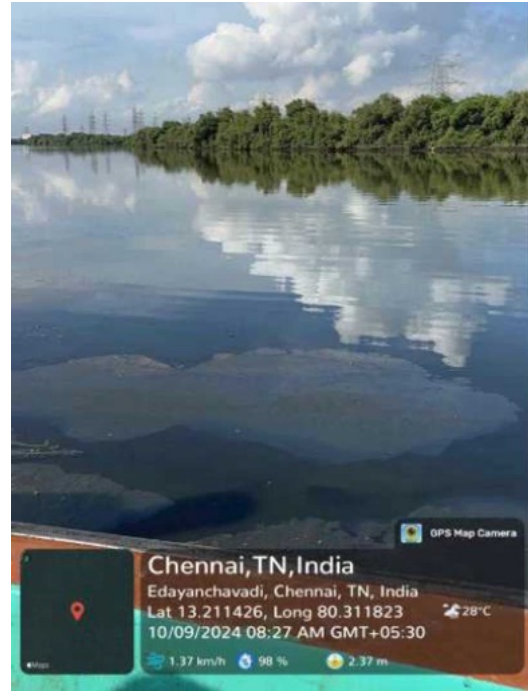
Oil stains seen on trees and walls near CPCL premises



Oil sheen observed at Entry Point 1 - Storm water canal discharge into surplus canal of Kosasthalaiyar River in June 2024



Oil sheen seen near storm water drain outlets near CPCL premises



Oil sheen observed on Kosasthalaiyar river in October 2024

### **BIODIVERSITY IMPACT ASSESSMENT BY ICFRE - INSTITUTE OF FOREST BIODIVERSITY, HYDERABAD**

The oil spill has severely impacted biodiversity in the affected area, **staining mangroves up to 10 feet high, submerging saplings in oil slicks, and contaminating crab burrows, endangering benthic organisms.** The spill led to **widespread mortality among shrimp, crabs, fish, and birds at the time of the incident (refer to figures 14 and 15 in our report).** To assess the ecological damage, a biodiversity impact assessment was commissioned to the ICFRE - Institute of Forest Biodiversity, Hyderabad.

*The following text summarizes their findings:*

- **Elevated microbial contamination was observed in both water and sediment samples across all measured parameters (ie. TVC, TC, FC, ECLO and SFLO) in the oil spill- affected areas, with significantly higher counts of total viable bacteria and E. coli compared to the control sites.** This suggests disarray in natural filtration, sewage leakage and organic matter as a result of the oil spill has made the conditions apt for the proliferation of microbes in this region.

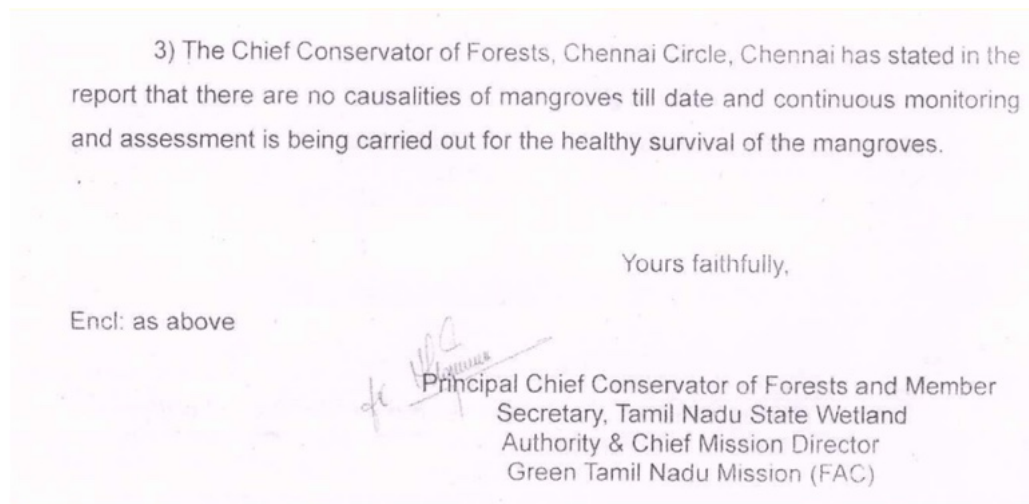
**CPCL's Reply:**

*E. coli* presence would be more due to sewage properties and the same was mentioned by ICFRE.

- Average chlorophyll-a levels were similar between impacted (1.7 mg/m<sup>3</sup>) and reference sites (1.9 mg/m<sup>3</sup>), but the impacted areas showed wide variations ranging from 0.1 mg/m<sup>3</sup> to 4.6 mg/m<sup>3</sup>. This could be due to environmental instability in some regions, while in others, increased nutrient input from the oil spill may have boosted phytoplankton productivity. **The average phytoplankton population density was higher in the impacted region (1154.0 x 10<sup>3</sup>/L) than in the reference area (953.0 x 10<sup>3</sup>/L), indicating altered nutrient availability. It was also noted that the impacted regions showed a broader range of phytoplankton population density which stipulates localised blooms or extinctions.**
- The studies conducted in zooplankton indicated notable variation in the population density of the oil spill impacted region which ranged from 250 to 18,500 x 10<sup>3</sup> individuals per 100m<sup>3</sup>. In comparison a much more stable zooplankton density (250 to 1,250 x 10<sup>3</sup> individuals per 100m<sup>3</sup>) was observed in the reference region, indicating a healthy population. 75.26% of zooplankton studied in the affected regions were copepods suggesting a clear imbalance in the community with only certain species able to adapt and thrive in the region. In reference areas, rotifers were dominant accounting to 56% of total zooplankton observed. This shows a more diverse and stable community.
- **According to the studies conducted it was observed that the oil spill impacted regions that had more variability in mangrove stand densities (9-53 plants/100 m<sup>2</sup>) in contrast to the more stable reference regions (11-34 plants/100m<sup>2</sup>).** Localised disturbances from the oil spill could have caused variability in the affected regions. The recruitment density in reference sites (29.04 recruits/m<sup>2</sup>) were much more than that of oil spill affected areas (4.8 recruits/m<sup>2</sup>), suggesting the poor conditions retard the establishment of new mangrove saplings in the affected areas. It was noted that the seedling to sapling ratio of the oil spill affected region was low as compared to that of reference region, which suggested that the oil spill contamination lead to limited survival and growth of seedlings.

**CPCL's Reply:**

This clearly indicates that the mangroves were not affected as their densities are intact. The Principle Chief Conservator of Forest in his memo filed in NGT on 25.03.2024 also confirmed that there are no causalities of Mangrove which is furnished below.



- **Macrobenthic study in the affected region of Ennore creek varied broadly, ranging from 13 to 1,125 individuals/m<sup>2</sup>, suggesting patchy distribution due to the contamination and toxicity in the affected areas.** The reference region showed more stable densities with 25 to 5,175 individuals/m<sup>2</sup> suggesting a more healthy habitat.
- Birds were heavily coated with oil during the spill, but nine months later, no signs of oil contamination were observed. This suggests a possible recovery from short-term effects. **Regular monitoring is needed to assess any long-term impacts on bird populations.**
- **A large number of fish were found dead during the spill, and fish diversity remained low even after nine months, with only four species recorded, compared to eight finfish and two shellfish species in the reference region.** This suggests habitat degradation in the spill-affected areas, while the higher catch rates in the reference region indicate a healthier fish population.
- Toxicity tests indicated an increase in rate of mortality with increase in sample concentration and exposure time, and showed varying levels of resistance in organisms in different zones. **Slowest mortality response was seen in the mouth zone (Ennore Creek) with lower concentration of 25%, whereas quickest onset of mortality was observed in upstream locations at higher**

concentrations. The reference didn't show any mortality indicating contamination in experimental zones.

*Recommendations highlighted by ICFRE - IFB, Hyderabad:*

- **Bioremediation** should be implemented to accelerate hydrocarbon degradation, along with regular water quality monitoring for pollutants and heavy metals.
- Habitat restoration efforts, including **mangrove replantation and artificial reef installations**, are essential to support ecosystem recovery.
- **Sustainable fishery management measures**, such as temporary fishing bans and livelihood support for affected communities, are advised to restore fish populations.
- Additionally, **continued monitoring of avian biodiversity** and habitat protection are crucial to assess long-term ecological impacts.

**These measures, combined with stricter pollution control policies, will help rehabilitate the affected ecosystem and ensure long-term environmental resilience.**

**CPCL's Reply:**

As per the directions given by TNPCB, CPCL has deployed NIO to carry out bio remediation of the Ennore Creek area using Herbal Nano Bio dispersant and the job was completed in Jan 2024. The Marine Eco system is completely restored and there is no impact on the Marine Eco system due to the oil spill as per the studies carried out through NIO & TERI.



Sampling locations of the study region used to collect the water sediment samples for biological parameters.



Sampling locations of the study region used to collect the data on diversity of mangroves from the Ennore Creek.



Sampling by the ICFRE-IFB team

Our assessment of the Ennore oil spill was conducted using systematic methodologies, incorporating both conservative and worst-case estimates to ensure accuracy while avoiding overestimation. Extensive field surveys and laboratory analyses were carried out across all affected regions. The detection of elevated TPH levels in sediments and soil in our latest findings underscores the spill's long-term environmental impact, highlighting the need for remediation measures in the affected areas.

**CPCL's Reply:**

The TPH estimates from the ground based discrete sediment samples are highly biased. Extrapolation of such TPH values from discrete samples to arrive oil quantity for the entire area would lead to erroneous results.

Due to the various assumptions and extrapolation of data the estimation of oil quantity is not a true representation. The restoration activity in the Ennore creek was carried out on war footing basis and the work was completed on 20.12.24 as declared by Tamil Nadu Government.

**The claims raised in the order challenging our findings were vague, lacking scientific basis and field assessment reports. Our field sampling was conducted at regular intervals, consistently detecting persistent oil contamination in soil and sediments, with concentrations significantly exceeding the CPCB limit of 5 g/kg.**

**CPCL's Reply:**

Oil typically floats on water due to its lower density, and when an oil spill occurs, the oil tends to remain on the water surface rather than getting settled to the channel bed. Oil fraction found in channel bed sediment samples could come from the settling of suspended sediment grain and bio-genic particles with the adsorbed oil compound and require longer period for settling.

The TPH estimates from the ground based discrete sediment samples are highly biased. Extrapolation of such TPH values from discrete samples to arrive oil quantity for the entire area would lead to erroneous results.

The persistent presence of TPH in the channel bed sediments is likely due to the continuous discharge of urban runoff, municipal waste, oil releases from fishing boats and

commercial/industrial discharges into the Buckingham Canal and Ennore creek.

IITM has not followed any scientific method in the estimation of oil quantity. But, mapping of oil through the satellite imaging & spatial distribution analysis will give a more accurate result and CPCL has engaged two expert agencies to carry out the above said study. The reports will be submitted shortly.

**We emphasize that our report explicitly excludes the certain factors from the final estimate, such as the 393 tonnes of floating oily sludge removed by CPCL before our study, as well as TPH present in sediments and water, oil trapped in inaccessible islands, and contamination within CPCL premises. Since our assessment was conducted after cleanup activities were completed, our estimate is highly conservative and likely an underestimation of the actual spill.**

#### **CPCL's Reply:**

IITM report miserably failed to identify the source.

IITM states that 393 MT of oily sludge removed by CPCL is from "The Hindu Bureau" and it clearly reveals the fact that in the absence of reliable data they have taken from the News journal without verifying the veracity of the data.

In fact, the quantity of 395 MT is the oily water collected from the Ennore Creek area during the oil spill incident. The report has anonymously consider this quantity as 100% oil and used it for validating their data. During the initial period, the oily water received from the Ennore creek area was having thin layer of oil at the top whereas the drums received after 2-3 days had water only. While receiving TNPCB officials also witnessed & recorded the above. During the oil spill incident, CPCL collected the following materials containing oil in the stretch from Ennore Creek area under the supervision of TNPCB & state authorities CPCL treated this oily water & recovered the oil amounts to 2.29 MT only.

The statement in the report on assessment of open tanks is reproduced below.

*"An assessment of the open tanks in M/s CPCL premises indicated that 417 tonnes of oil could have been stored before flooding which is much less than 912 tonnes of oil estimated. This mismatch suggests that the flood induced release from the open tanks may not have been the sole reason of the oil spill. Other possibilities could be breach of*

*oil from enclosed storage tanks of CPCL premises”*

The calculations made in the report are without knowing the facts and figures. While preparing the report, without knowing the actual boundary of CPCL, they browsed thro’ google map and marked the open water reservoir/ tanks of neighbouring company as CPCL tank. The details of tanks accounted from the other units & CPCL is given below:

Tank ID	Location of the tank	CPCL’s tank usage	Reference
0	CPCL	ETP I surge pond (Not in use now)	IIT Report, Page No: 35
1	TPL	<b>Not in CPCL</b>	
2	CPCL	ETP-4 API oil separator	
3	CPCL	ETP-1 – Pit (Not in use) Above ground	
4	CPCL	ETP I POND A (Storm pond storing water without any oil)	
5	CPCL	Raw water reservoir (East of DCU)	
6	CPCL	Refinery III Fire water pond (West)	
7	CPCL	Refinery III Fire water pond (East)	
8	CPCL	DM Plant effluent water storage	
9	CPCL	REF III STORM POND	
10	TPL	<b>Not in CPCL</b>	
11	TPL		
12	TPL		
13	TPL		
14	MPL-I		
15	IAL		
16	IAL		
17	IAL		
18	IAL		
19	TPL		
20	IAL		
21	IAL		
22	CPCL	Coke Pit	
23	CPCL	ETP-III Guard pond	
24	CPCL	Pond E (Storm pond storing water without any oil)	

25	CPCL	ETP II Guard Pond (Treated water storage and not oil)
26	CPCL	Pit for storing sludge East
27	CPCL	ETP I aerator (Not in use)
28	CPCL	Pit for storing sludge North
29	CPCL	Pond C (Storm pond storing water without any oil)

Figure 34 and Table 9 of the report identified 29 open tanks are inside CPCL through google earth. The report has taken open water reservoir of CPCL, & also the tanks of neighboring industries as open tanks of CPCL which itself is false.

Tank ID No.: 1,10,11,12,13,14,15,16,17,18,19,20 & 21 totaling 13 tanks are not in CPCL premises. The report stated that 12 open tanks discharged Oil (417 tons) into the Stormwater canals. IIT has taken open water reservoir of neighbouring industry & also CPCL Raw water reservoir, Fire water ponds, water plant water tank, building etc.as oily water storage tanks of CPCL which is not acceptable.

Though the report has mentioned the open tanks present in neighbouring industry but missed out to investigate the oil escape from that industry. In similar way, it would have checked the open storage tanks of all other industries before drawing the conclusion. They miserably failed to study the source identification.

Without applying basic concept, the report has also reported oil estimation from these water reservoirs as 417 Tons, the report has made a unacceptable statement of oil discharge from these tanks.

Assumption of oil layer of 10 mm is not reasonable, in water storage tanks is unimaginable.

In CPCL, no open tanks are used to store petroleum products. No industry would store petroleum products in open tanks as it is unsafe. Further, no open storage of petroleum products & Crude oil is not permitted as per Oil Industry Safety Directorate (OISD) & PESO. In addition to the above, open storage of petroleum products will lead to evaporation loss leading to VOC emissions as well and are not safe.

**Thus, we are confident that the final estimated spill range of 517 to 2,569 tonnes represents only a fraction of the true magnitude.** Our methodology is transparent, considering both conservative and worst-case scenarios. Our analysis remains grounded in scientific evidence, as detailed in this letter.

A comprehensive environmental report including assessments of biodiversity and socio-economic impacts is currently being prepared and will be submitted as part of Phase 2 of this project.

**CPCL's Reply:**

Based on the above said reasons, oil estimation carried out by IIT is wrong & not acceptable.

BEFORE THE NATIONAL GREEN TRIBUNAL (SZ), SITTING AT CHENNAI  
 (Under Section 18(1) read with S.14 & 15 of NGT Act, 2010)  
 ORIGINAL APPLICATION No. 180 OF 2023

**Annexure - R11**

BETWEEN

Suo Moto

...Applicant

-vs-

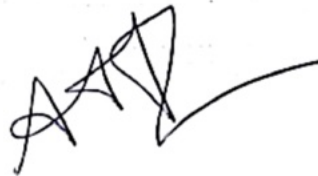
1. District Collector,  
 Chennai District, Chennai & Ors.

...Respondents

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3.	08.12.2023	Minutes Of Meeting related to suspected oil leak with Annexure	8-11

Dated at Chennai on this the 11<sup>th</sup> December, 2023.



FILED BY  
 THIRU. S. SAI SATHYA JITH  
 ADVOCATE, CHENNAI



**TAMIL NADU POLLUTION CONTROL BOARD**

From  
Dr.D.Vasudevan, M.Tech., Ph.D.,  
Joint Chief Environmental Engineer (M),  
Tamil Nadu Pollution Control Board,  
Chennai Zone,  
No.950/1, 1st Floor, Poonamallee High Road,  
Arumbakkam, Chennai – 600 106.

To  
The Member Secretary,  
TamilNadu Pollution Control Board,  
No.76, Mount Salai,  
Guindy,  
Chennai – 600 032.

**Lr. No. JCEE/TNPCB/Chennai/ New telecast /2023 dated 07.12.2023**

Sir,

Sub: TNPCB, O/o.JCEE, Chennai –Report on the suspected oil leak into Buckingham canal consequently reaching the Ennore Creek – Regarding

Ref: Telecast in Private News Channel

\*\*\*

In a private television News channel, it was telecasted about heavy traces of oil being found in the rainwater which has affected the nearby areas. A few messages about the spreading of oil in the waters of Buckingham Canal consequently reaching the Ennore Creek, which stick on the vessels/ boats used by the fishermen thereby affecting their activities, causing financial loss to the fishermen community.

Based on the above information, a team of officials of Tamil Nadu Pollution Control Board inspected the said area. The Team initially visited the Buckingham Canal stretch from Kargil Nagar bridge up to Kodungaiyur. During the inspection, the team observed traces of oil in the Buckingham Canal mainly on the banks. It was observed that the ingress of oil mainly occurred from the stormwater drain from the Manali industrial area confluence with Buckingham canal.

**Oil Traces found in Buckingham Canal**



At this juncture, the team attempted to find out the source of the oil and found that, there was some stagnant storm water along with oil, adjoining the storm outlet near South Gate of Chennai Petroleum Corporation Limited, which slowly contributed to oil traces. However, it was observed that during inspection the stormwater coming out of the Chennai Petroleum Corporation Limited premises on the southern side was not found to have oil.

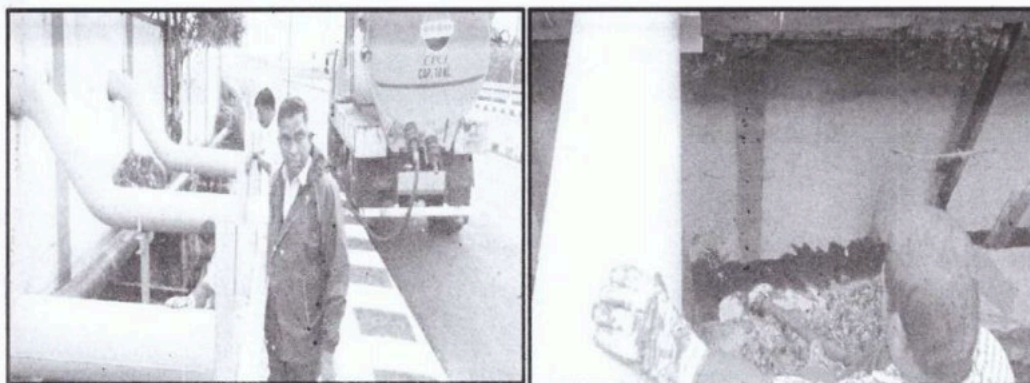
It is submitted that the unprecedented rainfall in Chennai and surrounding areas resulted in the inundation of industries in the Manali area including the Chennai Petroleum Corporation Limited. It is learnt that the premises of the Chennai Petroleum Corporation Limited is not even accessible today also due to inundation, and under such circumstance, the stagnant water has been pumped outside, in order to safeguard the Refinery during the torrential rainfall. However, even today, the stagnant water flows by gravity. Therefore, when the water was pumped, the oily matter that is found in the ground of the industry premises, get collected in the stormwater pond could have come out along with rain water.

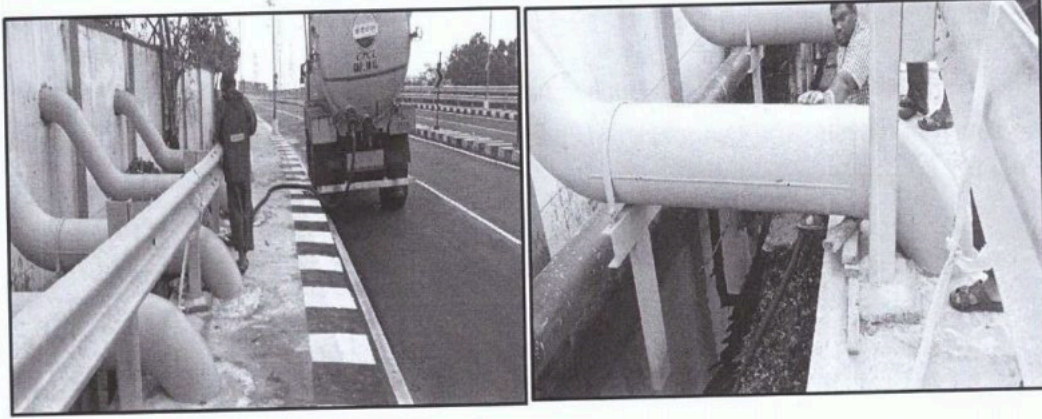
It is observed that the said stagnant oil reaches the Buckingham canal through the culvert slowly, results in oil traces in the water of Buckingham Canal. CPCL authorities are instructed to remove the said floating oil using gully sucker and they immediately carried out the same. They assured to repeat the process tomorrow morning also. The storm water containing oil is taken back for further processing along with crude oil.

Further, the CPCL authorities are also instructed to provide boomer arrangement at the location where the storm water is reaching the drain, leading to Buckingham canal. The representative of industry present assured to formulate a concrete proposal in this regard and to furnish the same for approval before execution.

It is submitted that the action of removal of stagnated storm containing oil, through Gully Sucker near the South gate, would eliminate the oil traces reaching Buckingham Canal, thereby makes the water in Buckingham canal, free of oil.

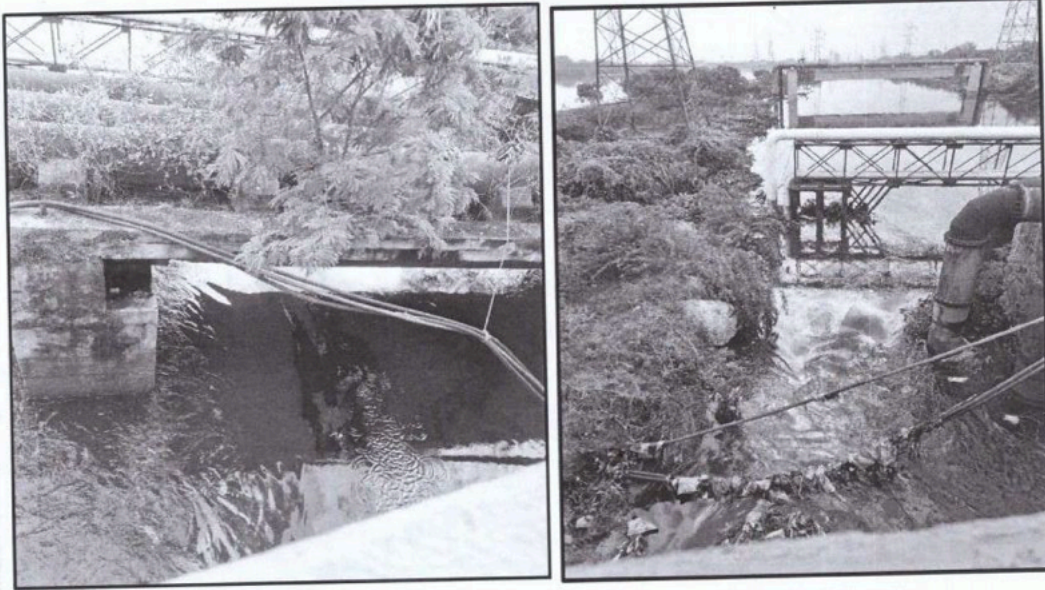
#### **Stagnated oil with storm water removal using Gully sucker**



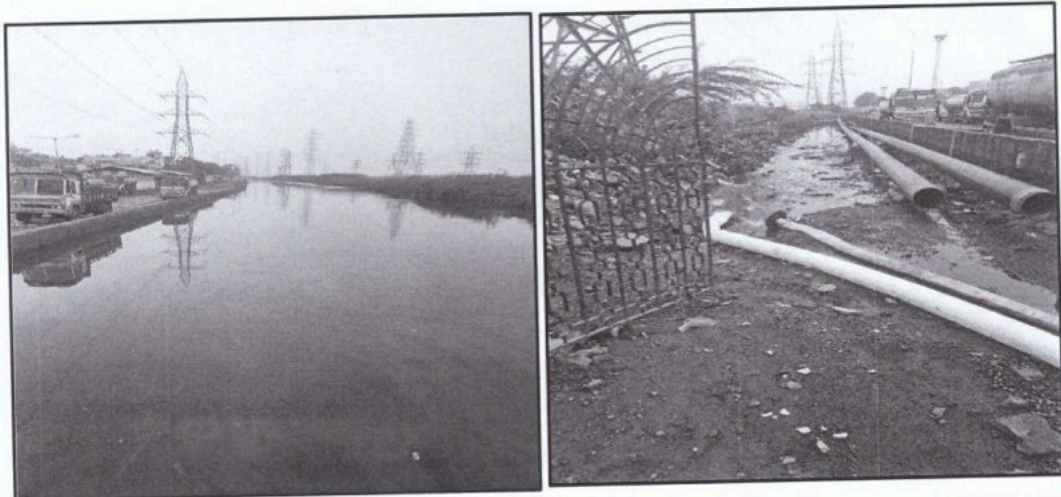


However, the inspecting team found that slight traces of oil is also found coming from the upstream of the Chennai Petroleum Corporation Limited from Kodungaiyur / Tondiarpet areas from Indian Oil Corporation Limited, Tondiarpet Terminal and container Terminal located along the Buckingham Canal at Korrukupet and Kodungaiyur areas.

**Oil traces in the upstream of Buckingham canal**



**Oil traces near Kodungaiyur IOCL, Container Terminal facility**



The team felt mild oily odour during the afternoon, when the climate was sunny, due to the volatilization of the hydrocarbon present in the oil traces. However, the same subsided in the evening.

Samples of water from the Buckingham canal and various points were collected and sent for analysis. The Team has not observed any substantial presence of oily matter in the Buckingham canal at Ennore Creek.

for study - 7/12/23  
Joint Chief Environmental Engineer (M),  
Tamil Nadu Pollution Control Board,  
Chennai Zone.



## TAMIL NADU POLLUTION CONTROL BOARD



**Proceeding No. T2/TNPCB/F- 027291/CHN/2023, dated : 08.12.2023**

**Sub:** TNPCB – Formation of Inspection Team of the Board to inspect all the Sewage Treatment Plants in major Residential Apartment complexes, Commercial establishments, IT Companies, etc., in and around Chennai, to check the position and suggest measures to restore the operations and to furnish daily report along with consolidated report on or before 15.12.2023 – Intimation – Reg.

\*\*\*\*\*

In view of the Michaung Cyclone hit in Chennai and nearby Districts of Chengalpattu, Kancheepuram and Tiruvallur, the TNPC Board decided to form eight teams with the following officials to inspect all the Sewage Treatment Plants in major Residential Apartment complexes, Commercial establishments, IT Companies, etc., in and around Chennai.

Team 1	1. Er. K. Prakash, DEE, Sriperumbudur 2. Er. S.Santhosh Kumar, AEE, O/o. DEE, Sriperumbudur
Team 2	1. Er. S.Indira Gandhi, DEE, Ambattur 2. Er. G. Manivasagam, AE, O/o. DEE, Ambattur
Team 3	1. Dr. R. Jayamurugan DEE, Chennai 2. Er. C R Sathish Kumar, AEE, O/o. DEE, Chennai
Team 4	1. Dr. Vanitha Murugaiyan, EE, Flying Squad Chennai 2. Er. Silambarasan M, AE, Flying Squad Chennai
Team 5	1. Er. P Ravichandran DEE, Thiruvallur 2. Er. Sabarinathan S, AE, O/o. DEE, Thiruvallur
Team 6	1. Er. T.Kalaiselvi, EE, O/o. JCEE(M), Chennai 2. Er. G. Kesavamorthy, AEE, O/o. AEE, Manali
Team 7	1. Er. P.S. Livingston, DEE, Gummidipoondi 2. Er. Thirumurthi Inbaraj, AE, O/o. DEE, Gummidipoondi
Team 8	1. Er. S. Senthil Kumar, AE, O/o. DEE, Maraimalai Nagar 2. Er. R. Menaga, AE, O/o. DEE, Maraimalai Nagar

All the team members are instructed to carry out the inspections during **09.12.2023 to 15.12.2023** of the all the Sewage Treatment Plants in major Residential Apartment complexes, Commercial establishments, IT Companies, etc., in and around Chennai, to check the position and suggestive measures to restore the operations

The Teams shall also inspect all the Effluent Treatment Plants in the major Industries, Common Effluent Treatment Plant, Common Bio-Medical Waste Processing facilities, Common Hazardous Waste Processing facilities. The team shall verify the status of the effluent treatment plants and give recommendations if any to improve the treatment plants to meet the standards.

The Teams are instructed to give daily report for each unit along with details in the format as attached herewith to the Board directly and also furnish their consolidated report on or before 15.12.2023 through JCEE(M), Chennai. For any further clarifications and area of inspection, it is requested to contact JCEE(M), Chennai.

**Encl:** Inspection report Format.

**To**

The above said individuals.

**Copy to**

1. P.S to Chairperson
2. P.A to Member Secretary
3. The Joint Chief Environmental Engineer (M),  
Tamil Nadu Pollution Control Board,  
Chennai
4. File

For Chairperson  
8/12/23  
8/12/23



**Tamil Nadu Pollution Control Board  
Inspection Report**

1		Name of the Inspecting Officers & Designation	1. 2.
2		Date of Inspection	
3	a	Name of the unit	
	b	Location & Address	
4		Type of the industry (Residential Apartment complexes, /Commercial establishments/ IT Companies/ Industries/ Common Effluent Treatment Plant/ Common Bio-Medical Waste Processing facilities/ Common Hazardous Waste Processing facilities)	
5	a	Name of the Occupier of the unit present during inspection.	
	b	Contact Person with phone no. / E- mail.	
6	a	Quantity of sewage/effluent in KLD:	
		i. Sewage	
		ii. Trade effluent if any	
	b	Status of sewage treatment plant(STP) / Effluent treatment plant(ETP) during inspection	Operation/not in operation.
	c	Location (Above (or) below Ground Level) & Capacity of STP/ETP	
	d	Water stagnation/ Overflow from STP/ETP/treatment facility noticed (if any)	
	e	Influence from nearby water bodies if any noticed in the STP/ETP/treatment facility	
7		Suggestions/measures to restore the operation of STP/ETP/treatment facility:	
8		Any other information if any:	
9		Recommendations:	

**Signature of the Inspecting Officers**

1.

2.



## TAMIL NADU POLLUTION CONTROL BOARD

### MINUTES OF THE MEETING RELATED TO SUSPECTED OIL LEAK INTO BUCKINGHAM CANAL ON 08.12.2023 AT 5.00 PM TO DECIDE ON THE ACTION TO BE TAKEN

#### I. TNPCB Officials

1. Dr. S. Rajan, Additional Chief Environmental Engineer - I
2. Dr.R.Rajamaickam, Additional Chief Environmental Engineer - II
3. Dr.D. Vasudevan, JCEE(M),Chennai
4. Er.S. Indiragandhi, District Environmental Engineer, Ambattur
5. Dr.R.Jayamurugan, District Environmental Engineer, Chennai
6. Er.P. S. Livingston, District Environmental Engineer, Gummidpoondi

#### II. Officials from Industries (List Enclosed)

In a private television news channel, it was telecasted about heavy traces of oil being found in the rain water which has affected the nearby areas. A few messages about the spreading of oil in the waters of Buckingham canal consequently reaching the Ennore Creek, which stick on the vessels/boats used by the fishermen thereby affecting their activities, causing financial loss to the fishermen community.

Based on the above information, on 07.12.2023, a team of officials of Tamil Nadu Pollution Control Board inspected the Buckingham canal stretch from Kargil Nagar bridge upto Kodungaiyur. During the inspection, the team observed traces of oil in the Buckingham canal mainly on the banks, and that the ingress of oil mainly occurred from the storm water drain from the Manali industrial area confluencing with Buckingham canal, and found the source of the oil traces is from the stagnant storm water near South Gate of Chennai Petroleum Corporation Limited.

Based on the inspection, CPCL was instructed to contain the Oil traces from its storm water drain. Immediately, CPCL engaged gully sucker and boomer to curtail the oil traces in storm water drain leading to the Buckingham Canal.

In continuation to the inspection, a meeting was convened on 08.12.2023 at Corporate Office with Senior Officials of TNPCB & oil industries located at Manali, Kodungaiyur, Tondiarpet areas to arrive a solution for the removal of oil traces in the canal.

The representatives of CPCL explained that due to heavy rainfall occurred on 3<sup>rd</sup> & 4<sup>th</sup> December, 2023 and release of excess water from Poondi & Puzhal reservoirs resulted heavy floods in & around Manali Industrial Area including CPCL Campus, the rain water level in the premises was about 1m which is higher than previous floods, and they pumped the stagnated water to save the installation, and in the process, the oily matter sticking on the ground could have found its way to the water body.

Further, they informed that there was no leakage from the tank farm area, process area including pipelines carrying raw material & product.

The representatives from other industrial establishments also concurred with the views expressed by the CPCL representatives.

From 07.12.2023, CPCL has started to remove the oil traces in the storm water outlet using gully sucker & boomer. They also informed that, as on 08.12.2023, they have curtailed the oil traces reaching the Buckingham Canal.

Secretary, Manali Industrial Association informed that all the industries in Manali area are not in operation till date due to water stagnation. The other oil industries located at Tondiarpet & Kodungaiyur informed that there are no leakage from the tank farm area, process area including pipelines carrying raw material & product and however there could have been traces of oil carried away with heavy storm.

The ACEE, who chaired the meeting, decided that the traces of oil found in the Buckingham Canal are to be removed.

After detailed discussion, the following decisions are arrived at:

1. Considering CPCL is the major establishment in Manali Area, it is instructed to identify the hotspots in Buckingham Canal where oily matter is stagnated and take necessary steps to remove the same using oil absorbent pads/pillows, gully



## TAMIL NADU POLLUTION CONTROL BOARD

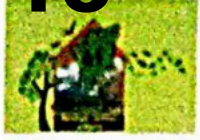
- suckers and other possible means. This exercise shall be completed before 20.12.2023.
- CPCL, other oil industries & terminals are instructed to ensure that all pipelines and tanks are intact with a view to ensure that no leakage shall occur.
- All industries were instructed to carry out pre-monsoon Leak Detection & Repair Study (LDAR) every year and furnish report to the Board.

With the above, meeting came to an end.

  
Additional Chief Environmental Engineer

To:

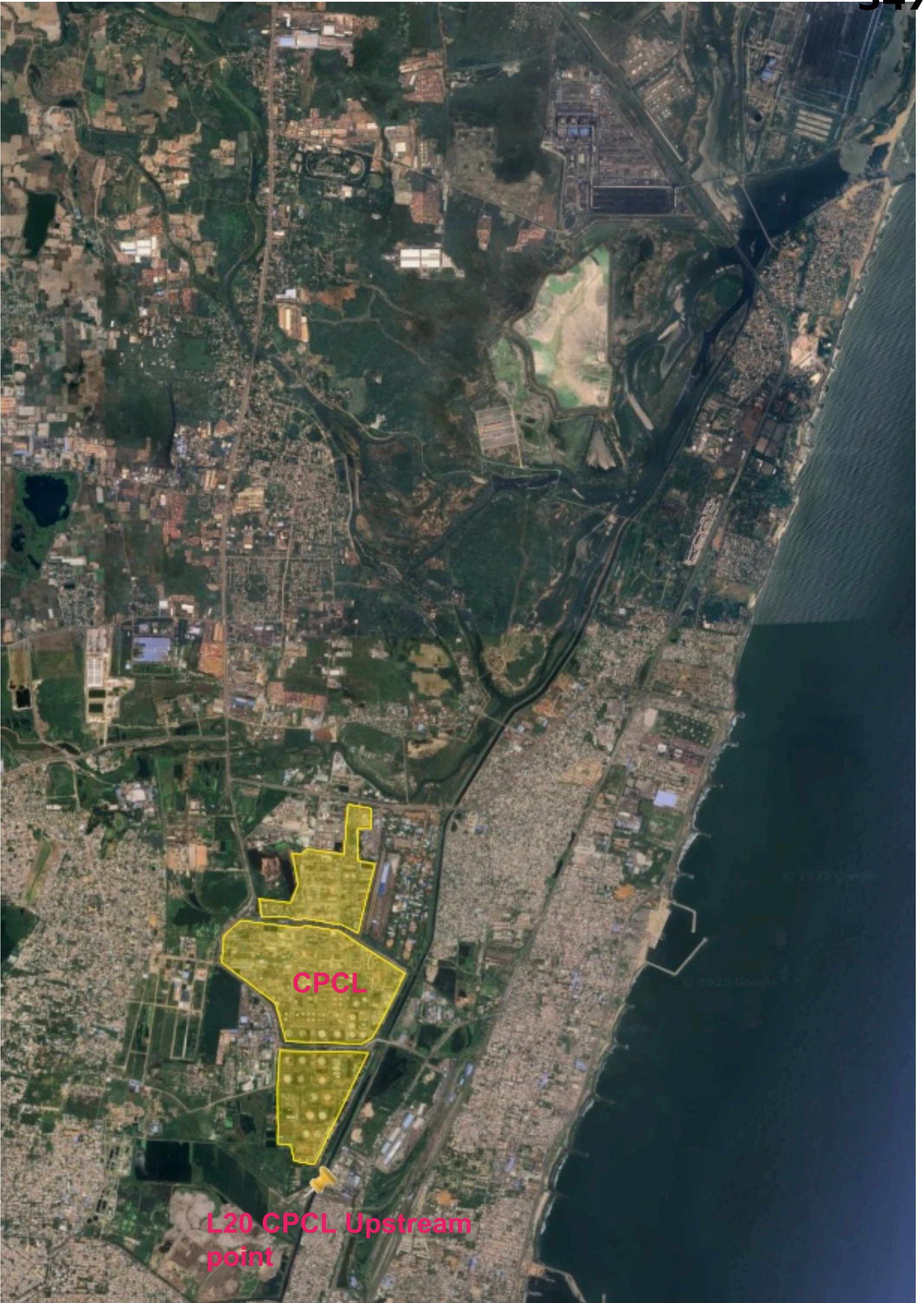
- The Joint Chief Environmental Engineer (M), Chennai – For further necessary action
- District Environmental Engineer, Ambattur – For further necessary action
- Assistant Environmental Engineer, Manali – For further necessary action
- All Participants



## TAMIL NADU POLLUTION CONTROL BOARD

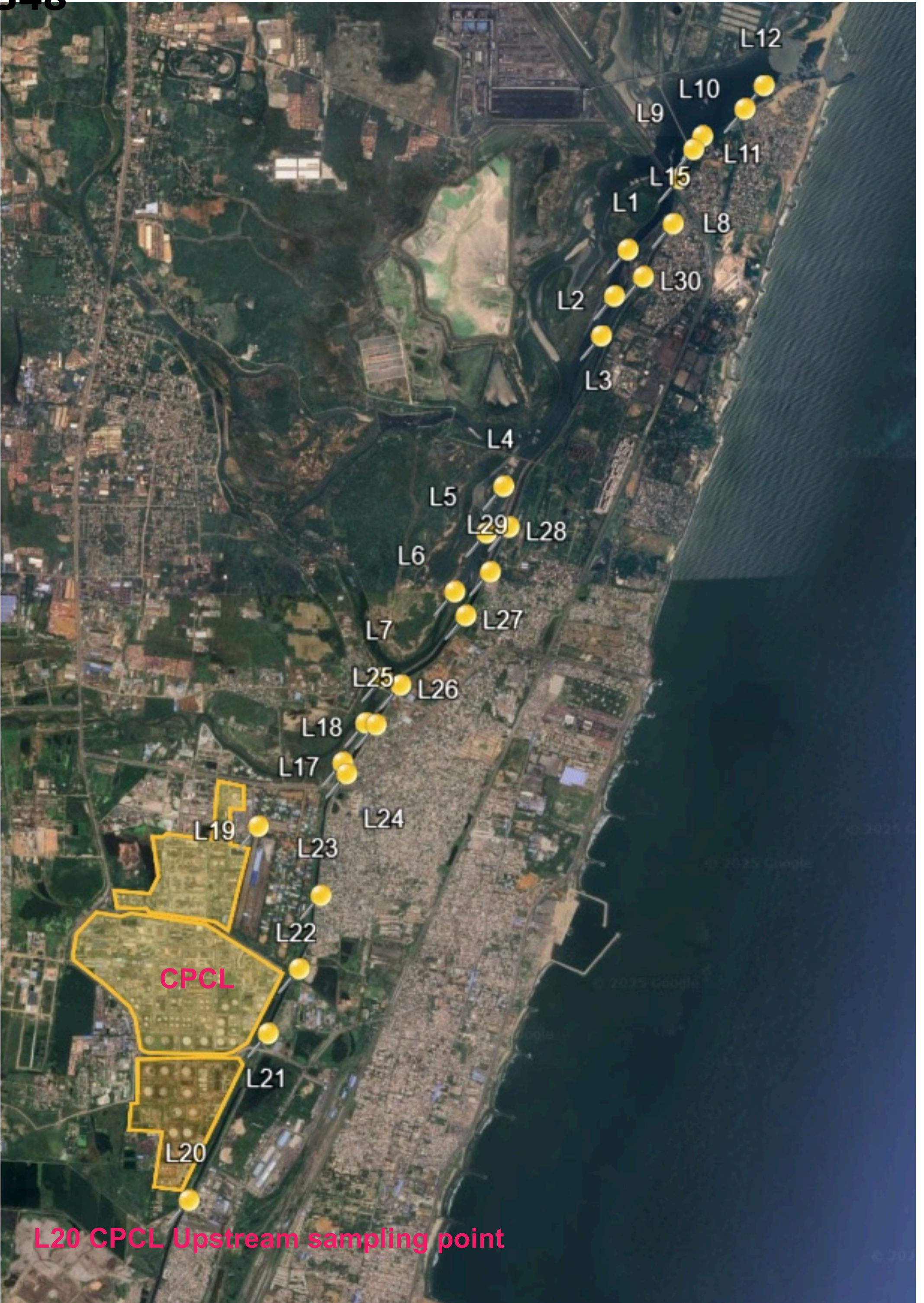
List of Industry Representatives attended the meeting on 08.12.2023

S.No	Industry Name	Name of the Official & Designation
1.	Indian Oil Corporation Limited, Lube Blending Plant	Y.D. Leela Krisha, Chief Manager Plant
2.	Manali Industrial Association	Prema Priyan, Secretary
3.	Ennore Tank Terminal Pvt Ltd	C.P.Viswamohan, Vice President
4.	Reliance Industries	T Viswanathan Terminal Manager
5.	Bharat Petroleum Corporation Limited	Aravanan R, Manager Safety
6.	Hindustan Petroleum Corporation Limited	R Mero Infento, Assistant Manager
7.	Bharat Petroleum Corporation Limited, Tondiarpet	Saurabh Gusain, Manager, Operations
8.	Chennai Petroleum Corporation Limited	K Rajasekaran, Deputy General Manager
9.	Chennai Petroleum Corporation Limited	Anil Sahni, Chief General Manager, Operations





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## IIT REPORT DISCREPANCIES

**Discrepancy # 1: Oil quantity estimation based on wrong Value of Total Petroleum Hydrocarbon (TPH)**

IIT arrived the value of 517 Tons of oil spillage based on their analysed **Total Petroleum Hydrocarbon (TPH) of water and sediments which is erroneous.**

a) **TPH values of water**

TPH content in water of IITM is very high compared to TPH analysis of different government / reputed agencies like TNPCB, National Centre for Coastal Research (NCCR), National Institute of Oceanography (NIO) and The Energy and Resources Institute (TERI).

Sl.No	Name of the Agency	Reference	As reported	Standardized to mg/lit
1	TNPCB	TNPCB has filed the TPH values in NGT on 27.02.24 (PI refer Page No: 42 -43) (Ann-1)	0.217-2.458 mg/lit	<b>0.217-2.458</b>
2	NIO	TNPCB filed in NGT on NIO report on 09.09.24 (Refer 80 <sup>th</sup> page of the NGT filed document / Refer 28 <sup>th</sup> page of the NIO report) (Ann-2)	0.025-2.11 mg/lit	<b>0.025-2.11</b>
3	NCCR	NCCR report (15 <sup>th</sup> page of the NIO report) (Ann-3)	27.77 – 1008 µg/ lit	<b>0.0277-1.008</b>
4	TERI	CPCL filed TERI report on 09.09.24. Please refer page No 9. (Ann-4)	0.2-3.9 mg/lit	<b>0.2-3.9</b>

5	IITM	TNPCB filed in NGT on IIT report on 09.09.24 (Refer 30 <sup>th</sup> page of the NGT filed document / Refer 24 <sup>th</sup> page of the IIT report) (Ann-2)	0.28 g/L – 7.21 g/lit	<b>280-7210</b>
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IIT values are more than 100 times compared to other government / reputed agencies.

b) **TPH values of sediments**

- ❖ Oil, being a lighter material than water, will float on water. Percolations down to the earth thro' water by floating oil, is not feasible and requires very longer period.
- ❖ Even though oil in the water layer is 11.54 KL (IIT report page No: 29) reporting that 487.12 KL (IIT report page No: 26) of oil in soil sediment in river is incorrect statement of IITM report. This is due improper analysis of TPH values.
- ❖ Similar to water sample, sediment TPH values of IITM is also exorbitantly higher value compared to TPH analysis of different government / reputed agencies like National Centre for Coastal Research (NCCR), National Institute of Oceanography (NIO) and The Energy and Resources Institute (TERI).

Sl.No	Name of the Agency	Reference	As reported	Standardized to mg/kg
1	NIO	TNPCB has filed the TPH values in NGT on 27.02.24 (Refer 82 <sup>th</sup> page of the NGT filed document / Refer 29 <sup>th</sup> page of the NIO report) (Ann-2)	0.63– 1.83 mg/g	<b>630-1830</b>
2	NCCR	NCCR report (Refer 16 <sup>th</sup> page of the report) (Ann-3)	100 – 1000 µg/gm	<b>100-1000</b>
3	TERI	CPCL filed TERI report on 09.09.24. Please refer page No 35. (Ann-4)	5.84-47.34 mg/Kg	<b>5.84-47.34</b>

4	IITM	TNPCB filed in NGT on IIT report on 09.09.24 (Refer 30 <sup>th</sup> page of the NGT filed document / Refer 24 <sup>th</sup> page of the IIT report) (Ann-2)	13.6 -46.5 g/Kg	<b>13,600-46,550</b>
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- ❖ The above tables clearly depict that sampling & sample analysis carried out by IITM is completely wrong and resulted in exorbitantly higher TPH values for water and sediments

- ❖ Calculation of oil spill quantity based on above erroneous TPH value has resulted in higher quantum of oil presence in the sediments.

## **Discrepancy # 2 :**

### **Quantity assessment from open tanks for 417 Tons which are not used for storage of petroleum product**

- ❖ As part of source identification, IITM reported that 30 No of open storages in CPCL.
- ❖ IITM has browsed thro' google map and marked **30 no of** the open water reservoir / tanks of CPCL & neighboring company's reservoir as CPCL tank
- ❖ Out of 30 no of open reservoirs / tanks, 13 tanks are not in belongs to CPCL.
- ❖ IITM report stated that 12 open reservoirs / tanks would have discharged oil from CPCL to the tune of 417 MT
- ❖ Out of the 12 open reservoirs / tanks, 2 tanks are not of CPCL and belong to neighboring industry. Balance 10 open reservoirs / tanks are used for storing Raw water reservoir, Fire water ponds, water plant tanks etc. Fire water is used for fighting the fire and oil cannot be stored in that. Refer photos.( Annexure-6)
- ❖ IITM report also failed to inspect the source from other industries in Manali Industrial area.



**BEFORE THE NATIONAL GREEN TRIBUNAL  
SOUTHERN ZONE, CHENNAI  
OA No. 180 of 2023 (SZ)**

**IN THE MATTER OF :**

**Tribunal on its own motion SUO MOTU**

**... Applicant**

**Vs**

**The District Collector,  
and Ors.**

**... Respondents**

**COMPILATION OF REPORTS**

**M/s. AAV PARTNERS  
S SARAVANAN  
E KARTHIKEYAN  
COUNSEL FOR 7<sup>th</sup> RESPONDENT**