BEFORE THE NATIONAL GREEN TRIBUNAL
SOUTHERN ZONE AT CHENNAI

ORIGINAL APPLICATION NO. 180 OF 2023(SZ)

Tribunal on its own motion – Suo Motu

… Applicant

Vs

District Collector and Ors.

… Respondents

TERI REPORT FILED BY 7th RESPONDENT -
CHENNAI PETROLEUM CORPORATION LIMITED

M/s. AAV PARTNERS
COUNSEL FOR 7th RESPONDENT

74-76, II Floor, Sukh Sagar, Marshall's Enclave,
Marhsall's Road, Egmore, Chennai – 600 008.

Ph – 95000 69660
Email : saleemperson@gmail.com

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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

Prepared for

Chennai Petroleum Corporation Limited (CPCL), Chennai

Prepared by

Veeranna Channashettar
Senior Fellow and Associate Director
Environmental and Industrial Biotechnology
The Energy and Resources Institute
Darbari Seth Block, India, Habitat Centre
Lodhi Road, New Delhi-110 003

TERI, Darbari Seth Block, IHC Complex, Lodhi Road,
New Delhi 110 003, India
Tel.: +91 11 2468 2100 or 2468 2111 | **F**ax: +91 11 2468 2144 or 2468 2145
Email: blal@teri.res.in | **W**eb: www.teriin.org

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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 2nd 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 28th December, 2023 to 29th 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 anthhropogenic 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 2nd December 2023 and further developed into a Cyclone on 03rd 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

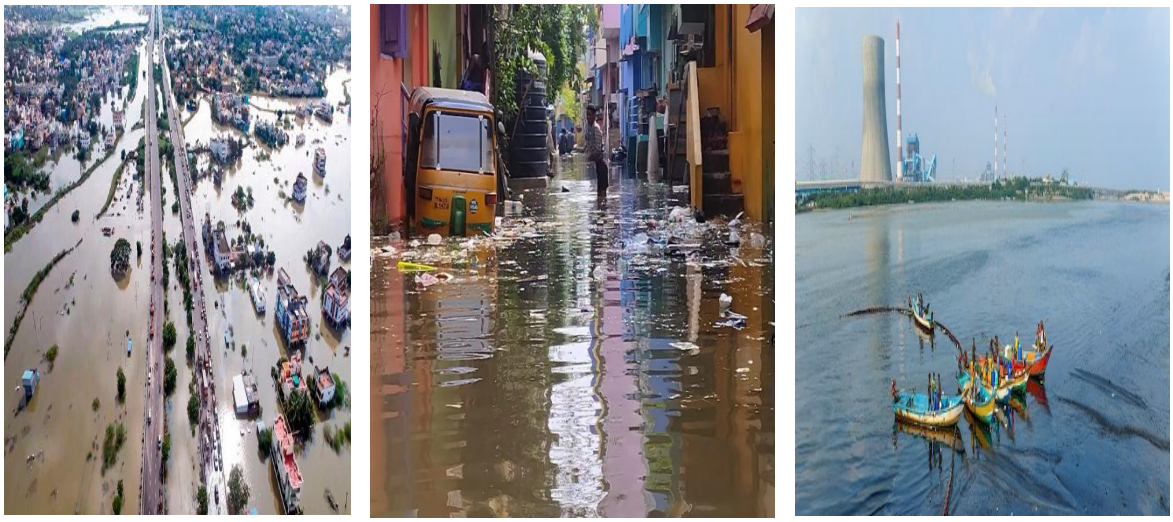

Fig.2 A drone visual shows an area that is flooded after the landfall of Cyclone Michaung, in Chennai on December. 6, 2023

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 Buckinhgam 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, Kosasthaliyar 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.

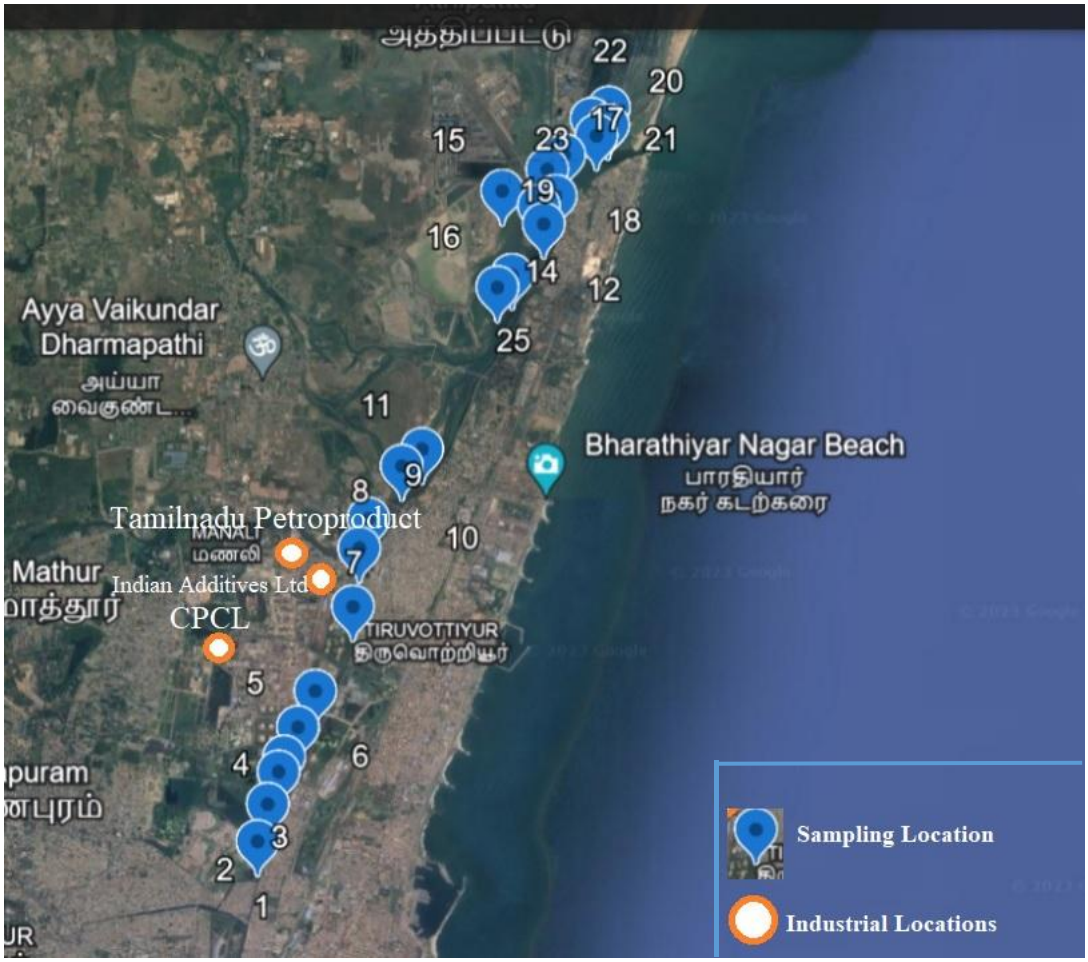

Fig. 4 Water, sediment, plant and fish sampling locations from Buckingham canal to Ennore creek

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, Dibenz[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	Sivanpadaikuppam	29-12-23	
13	CP15100635W13	Junction of Manali and Kosasthaliyar river	29-12-23	
14	CP09615714W14	Buckingam canal and Kosasthaliya river confluence	29-12-23	
15	CP29693748W15	Buckingam 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	Buckingam canal and Kosasthaliya river confluence	29-12-23	
15	CP29693748S15	Buckingam 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 Kosasthliyar 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
Plant samples				
1	CP01475004P1	Kosasthaliyar river	29-12-23	Cadmium, Lead, Mercury, Nickel, Hexavalent Chromium, Zinc, Copper.
2	CP35850279P2	Kattukuppam Bridge	29-12-23	
Fish & Prawn				
1	CP35850279F1	Under Ennore railway bridge	29-12-23	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, Dibenz[ah]Anthracene, Indeno[1,2,3-cd]Pyrene, Benzo[B]Fluoranthene.
2	CP39331517F2	Kattukuppam -Ennore Creek	29-12-23	
3	CP57554482F3	Nettukuppam -Ennore Creek	29-12-23	
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 µm mesh for zooplankton and 63 µm 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. Stackholders 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 Annexture -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 anthhropogenic activities and the flow of domestic wastewater in Buckingham canal. (table 6).

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

Sample No.	Sampling Location	pH	Oil and Grease	MBAS (Surfactants) mg/L	Phenolic compoundsmg/L	Total Organic carbon mg/L	SAR	Electrical conductivity 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	Buckingam canal and Kosasthaliya river confluence	7.04	BDL	0.6	0.044	25	13.1	4650	37	150
15	Buckingam 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	Elilnagar, 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.	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	Buckingam 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	Buckingam 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	Buckingam canal and Kosasthaliya river confluence	BLQ(LOQ:0.1)	BLQ(LOQ:0.1)
15	Buckingam 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		

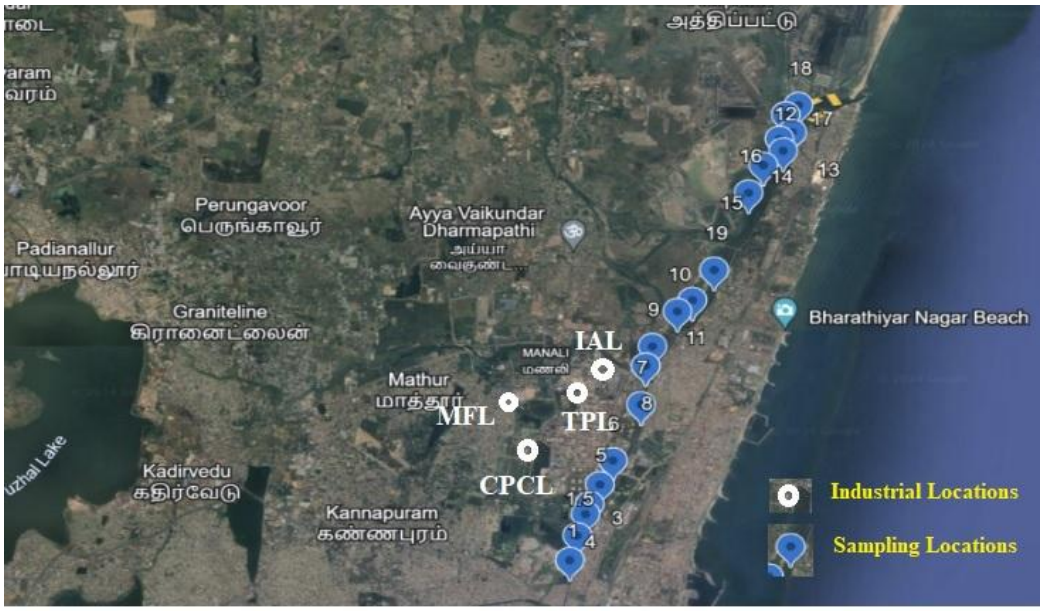

Fig. 6 Location showing on-site dissolved oxygen measured

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**
Asterionellopsis sp	0	1	4
Ceratium sp	0	1	0
Chlorella sp	400	200	100
Chaetoceros sp	0	0	6
Ditylum sp	0	6	13
Pediastrum sp	4800	4200	3400
Scenedesmus sp	60	200	130
Skeletonema sp	0	0	45
Thallasionema sp	325	120	230
Triceratium sp.	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 anthorophogenic sources contributed in qulaity 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**
Acartia sp.	0	12	53
Euterpina sp.	320	32	54
Paracalanus sp.	0	4	12
Pseudodiaptomus sp.	0	0	3
Copepod Nauplii	5600	3880	4300
Cladoceran	0	0	3
Mysis	0	0	7
Polychaete larvae	0	0	3
Pontella sp.	7	56	210
Oithona spp.	650	400	1300
Harpactoid	520	120	600
Nitokra sp.	300	600	120
Oithona brevicornis	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 anthrophogenic 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 ompounds (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 Buckingam canal and Kosasthaliya river	8.03	97	BDL(DL:5)	BDL(DL: 0.05)	BDL(DL:0.2)	3.17	1245
15	Buckingam canal and Kosasthaliya river	6.13	BDL(DL:10.0)	BDL(DL:5)	BDL(DL: 0.05)	BDL(DL:0.2)	8.68	3860
16	Kosasthaliya river - Mangroove Area	4.43	BDL(DL:10.0)	BDL(DL:5)	BDL(DL: 0.05)	BDL(DL: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:10.0)	31	0.1	BDL(DL: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[LOQ:2.0]	48.02	BDL(DL:5.0)
2	Patel Nagar, Tondiarpet	27.2	154.43	224.47	5.97	BLQ[LOQ:2.0]	42.09	BDL(DL:5.0)
3	CPCL Tondiarpet (Near Government Fertilizer Unit)	17.91	102.49	132.98	8.61	BLQ[LOQ:2.0]	23.15	BDL(DL:5.0)
4	IOCL Gate	17.14	95.92	152.91	5.93	BLQ[LOQ: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[LOQ:2.0]	16.19	BDL(DL:5.0)
6	Manali Near New Bridge	13.48	63.15	99.58	3.77	BLQ[LOQ: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[LOQ:2.0]	28.74	BDL(DL:5.0)
9	Near CMDS Steel yard, Thiruvetriyoor	16.05	114.91	327.94	10.51	BLQ[LOQ:2.0]	19.29	BDL(DL:5.0)
10	Sathyamoorti Bridge	13.15	40.72	195.43	4.88	BLQ[LOQ:2.0]	14.04	BDL(DL:5.0)
11	Sadyanguppam Bridge	24.38	185.61	180	18.58	BLQ[LOQ: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[LOQ:2.0]	11.83	BDL(DL:5.0)

13	Sivanpadai Kuppam Bridge	13.52	99.47	350	8.83	BLQ[LOQ:2.0]	16.87	BDL(DL:5.0)
14	Manali-Junction of Buckingam canal and Kosasthaliya river	17.66	49.33	772.35	4.1	BLQ[LOQ:2.0]	8.34	BDL(DL:5.0)
15	Buckingam canal and Kosasthaliya river	3.57	3.53	10.45	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BDL(DL:5.0)
16	Kosasthaliya river - Mangroove Area	4.39	BLQ[LOQ:2.0]	6.7	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BDL(DL:5.0)
17	attukuppam Railway Bridge	11..5	16	25	8.57	BLQ[LOQ:2.0]	19.77	BDL(DL:5.0)
18	Kattukuppam - After railway Bridge	7.02	8.65	63.8	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	3.8	BDL(DL:5.0)
19	Under Ennore Bridge	3.95	5.47	34.21	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BDL(DL:5.0)
20	Ennore Bridge - Near Don Bosco School	19.71	18	19.71..	9.17	BLQ[LOQ:2.0]	18.09	BDL(DL:5.0)
21	Thallakuppam Mouth of Ennore Creek	22.26	23	18..	4.88	BLQ[LOQ:2.0]	17.63	BDL(DL:5.0)
22	Nettukuppam - Mouth of Ennore Creek	3.93	BLQ[LOQ:2.0]	7.52	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BDL(DL:5.0)
23	Nettukuppam - Mouth of Ennore Creek	3.11	BLQ[LOQ:2.0]	6.8	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BLQ[LOQ:2.0]	BDL(DL:5.0)
24	NTPC Side-Ennore Creek (Opp. Nettukuppam)	11.77	16.79	99.1	BLQ[LOQ:2.0]	BLQ[LOQ: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[LOQ: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)	Chyrsene, (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)	Dibenzo(a,h)Anthracene, (mg/kg)	Benzo(g,h,i)perylene	Total PAH
1	Elilnagar, 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 CISF 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	Sadyanguppam 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 Sadyanguppam and Kattubakkam 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	Sivanpadai 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 Buckingam 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	Buckingam 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(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)
19	Under Ennore 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)	0.002	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)
20	Ennore Bridge - Near Don Bosco School	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)	0.002	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)
21	Thallakuppam Mouth of Ennore Creek	0.005	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)
22	Nettukuppam - Mouth of Ennore Creek	0.005	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)
23	Nettukuppam - Mouth of Ennore Creek	0.005	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)
24	NTPC Side-Ennore Creek (Opp. Nettukuppam)	0.005	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)
25	Between Ennore Creek and Ennore Bridge	0.005	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)

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 Buckingam canal and Kosasthaliya river	16.62	2.18
15	Buckingam 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 anthrophogenic 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. Bioaccmulation 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 fond in the study area (table 15). This similar type of bioccumulation 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 anthrophogenic 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.

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