

**BEFORE THE NATIONAL GREEN TRIBUNAL  
SOUTHERN ZONE, CHENNAI  
Original Application No. 131 of 2020 (SZ)**

**IN THE MATTER OF:**

M. Jayachandran,  
Ranipet District and Anr.

... Applicant(s)

With

The Ministry of Environment,  
Forest & Climate Change and Ors.

...Respondent(s)

RUNNING INDEX

<b>Sl.No</b>	<b>Particulars</b>	<b>Page Nos.</b>
1.	Joint Committee report on the compliance status of the 8 <sup>th</sup> Respondent Unit as on 23-9-2021	2-10
2.	Annexure -I – Photos taken during the site visit	11
3.	Annexure-II – DPR of IIT Madras	12-33



**(Dr. R. Sridhar)**  
Scientist D  
Integrated Regional Office (IRO)  
MoEFCC, Chennai

**Place: Chennai**  
**Date: 29-09-2021**

**Joint Committee report on the compliance status of the 8th  
Respondent Unit as on 23-9-2021**

**1. Background**

The Hon'ble NGT, in Original Application No. 131 of 2020 (SZ) in the matter of M. Jayachandran, Ranipet District and Anr. Vs The Ministry of Environment, Forest & Climate Change and Ors, vide its order dated 30-07-2020, had constituted a Joint Committee to inspect the unit in question (M/s Thirumalai Chemicals Ltd (TCL), SIPCOT Industrial Complex, Ranipet) and also the Puliyanaganu Eri, Palaar and Ponniyar which were polluted on account of industrial pollution and submit a factual as well as action taken report to this Tribunal.

The Joint Committee had submitted its report dated 11-02-2021 to the Hon'ble NGT. Thereafter, upon hearing of the report, the Hon'ble NGT vide its order dated 15-3-2021 directed the Joint Committee to ascertain as to whether the recommendations made by them, as regards the 8th respondent company has been complied with by them and what is the present status of compliance including the directions issued by the Tamil Nadu Pollution Control Board (TNPCB).

The Joint Committee had filed a compliance report of the recommendations by the 8<sup>th</sup> Respondent Unit in O.A. No.131 of 2020 dated 16-04-2021. Upon hearing of the compliance report, the NGT vide order dated 16-8-2021 has again directed the Joint Committee to submit the present status on upgradation of ETP, certification of its adequacy by the IIT Madras and remediation work undertaken by the 8th Respondent Unit as reads below:

*“6. It is mentioned in the conclusion portion of the report that full-fledged ZLD will be commissioned by 30th June, 2021 and once the upgraded ETP is commissioned, certification of its adequacy will be carried out by the IIT Madras by 30th June, 2021 under the supervision of Tamil Nadu Pollution Control Board. Without considering the efficacy, this Tribunal can't pass an order in respect of the same.”*

*“12 .....”As regards O.A. No.131/2020 is concerned, it is only a portion of issue that has been projected against one of the industry and certain remedial measures have been suggested by the regulators and also by the Joint Committee and it is only on the question of satisfaction of compliance of the recommendations*

*made and whether that will remedy the situation as far as 8th respondent is concerned, without going into the larger issue which has been projected in O.A. No.181/2020 and if ultimately the 8th respondent is responsible for the same, that will have to be considered in that case separately. However, even as per the compliance report, certain things will have to be done by the 8th respondent which even according to them, were planned to be completed by June 30, 2021 and that will have to be further certified by the IIT Madras regarding the adequacy of the remediation measures taken by the 8th respondent, but such reports are not now before this Tribunal.”*

*“13. So under such circumstances, we direct the Joint Committee as well as the Tamil Nadu Pollution Control Board to go into the issue on the basis of the objection filed by the 8th respondent to the Joint Committee report and the status report submitted by the Tamil Nadu Pollution Control Board and submit a further status report regarding the present status, after remediation work has been undertaken by the 8th respondent and whether that is sufficient to meet the situation as well”.*

*“14. They are directed to submit the report to this Tribunal on or before 30.09.2021 by e-filing in the form of Searchable PDF/OCR Supportable PDF and not in the form of Image PDF along with necessary hardcopies to be produced as per Rules.”*

## **2. Compliance status of the 8<sup>th</sup> Respondent Unit (i.e M/s Thirumalai Chemicals Ltd.,) as on 23-9-2021**

In order to review the compliance status of the Committee's recommendations, the Committee conducted a site visit on 23-9-2021 at 8<sup>th</sup> Respondent Unit (Photos taken during the site visit are shown in **Annexure-I**). The following committee members attended the site visit and reviewed the compliance status:

1.	Dr. R. Rajkumar Scientist 'D' CPCB, Regional Directorate, Chennai
2.	Dr. R. Sridhar Scientist 'D', Integrated Regional Office (IRO), MoEF&CC, Chennai
3.	Shri G. Ravichandran DEE, TNPCB, Vellore.
4.	Shri. Ramesh EE/WRD/Vellore Uppur Palar Basin Division, Vellore
5.	Smt. R. Poonkodi RDO, Ranipet

Based on the site inspection and information provided by the industry unit, the compliance status of the industry as on 23-9-2021 is given in the table.

<b>Sl.N</b>	<b>Recommendations of the Joint Committee pertaining to 8th Respondent Unit</b>	<b>Compliance Status (As on 23-09-2021)</b>
1	<p>As the unit was observed for non-compliance of consent order conditions, discharges noticed in violation of consent conditions, internal discharge to the environment -land, water and air resulting into acute injury or damage to the environment and injection of treated /partially treated /untreated effluents to the ground water and based on repeated violations, the unit was directed by TNPCB to restrict the production of 50 % of its consented quantity so as to achieve zero liquid discharge consistently till the commencement &amp; effective functioning of newly constructed Zero Liquid Discharge (ZLD) components.</p> <p>As the unit is in the process of establishing ZLD system and started</p>	<p>Partially Complied.</p> <p>The unit has reported that to comply the TNPCB's direction, their production has been adjusted by them such that the complex generates below 50% of the effluent by reducing the production of high effluent generation plants with the following:</p> <ol style="list-style-type: none"> <li>1. Dicarboxylic Anhydrides do not contribute to effluent generation.</li> <li>2. Dicarboxylic acids contribute to maximum effluent-reduced to less than 50% of consented quantity.</li> </ol> <p>During inspection, it was found that one of the product Dicarboxylic Anhydrides-(</p>

<b>Sl.N</b>	<b>Recommendations of the Joint Committee pertaining to 8th Respondent Unit</b>	<b>Compliance Status (As on 23-09-2021)</b>
	<p>trial runs for validation of the equipment to achieve Zero liquid discharge with respect to treating effluents, the unit shall be allowed to operate in full load only after ensuring the complete/full-fledged operation of upgraded ETP by TNPCB. The full-fledged operation of ZLD system should be commenced within four months-time by the TCL.</p>	<p>Phthalic Anhydride), the quantity was found to be exceeded the restricted quantity and other products were within 50% of its consented quantity.</p> <p>The unit has additionally installed and commissioned the modern Disc and Tube Reverse Osmosis system, conventional MEE-150KLD and Agitated Thin Film Drier (ATFD). The unit is treating the organic stream in the existing ETP and the inorganic stream is treated in the augmented Disc and Tube Reverse Osmosis system. It was also found during inspection that in the Waste Heat Evaporator (WHE) 19 Nos. of modules out of 38 and old MEE were not under operation and they are reported to be kept as standby.</p> <p>RO reject is sent to MEE followed by ATFD to recover salt. No by-pass of effluent from the treatment system noticed. During inspection the industry has recovered and stored salts within the unit premises.</p>
2	<p>After commissioning of upgraded ETP, adequacy test needs to be carried out by an independent govt academic/research institution like IIT Madras and to certify that the</p>	<p>Compliance under progress.</p> <p>Inordinate delay in doing adequacy test is observed by the Committee. As committed by the 8<sup>th</sup> Respondent Unit, the stated</p>

Sl.N	Recommendations of the Joint Committee pertaining to 8th Respondent Unit	Compliance Status (As on 23-09-2021)
	unit has achieved 100% ZLD capacity.	<p>recommendation has not yet complied with by 30<sup>th</sup> June 2021. The ZLD capacity could only be ascertained with full load adequacy test is carried out.</p> <p>However, the 8<sup>th</sup> Respondent Unit has informed the Joint Committee that the IIT Madras team had visited their premises on 23 &amp; 24 July 2021 to overview the production processes, ETP, ZLD facilities, hazardous waste disposal, etc., and carried out the audit of the treatment systems to assess the capacity for 100% ZLD. The adequacy report from the IIT Madras is not yet received.</p> <p>The 8<sup>th</sup> Respondent Unit has assured that the adequacy report of IIT Madras will be submitted before 31<sup>st</sup> October 2021.</p>
3	TCL shall, in consultation with reputed institute such as IIT, Madras, prepare a DPR within three months-time, for the remediation of the land where the untreated effluent was discharged within the industry site and execute the task of remediation of contaminated site, under the supervision of TNPCB. The entire cost for the study and remediation shall be borne by the industry as per polluter pays principle.	<p>Partially Complied.</p> <p>The DPR has been prepared by IIT Madras for remediation of the land where the untreated effluent was discharged within the industry site (<b>Annexure-II</b>).</p> <p>The 8<sup>th</sup> Respondent Unit has informed that the DPR has been submitted to TNPCB on 20-09-2021 for Board's guidance to execute the task of remediation of the site. Meanwhile, the</p>

<b>Sl.N</b>	<b>Recommendations of the Joint Committee pertaining to 8th Respondent Unit</b>	<b>Compliance Status (As on 23-09-2021)</b>
		<p>Committee found in its site visit that tree saplings are planted in the polluted site. The underneath soils are not remediated. The remedial measures are in DPR stage. The tree plantation covers up polluted soil underneath.</p> <p>Further, on perusal of the DPR, the Committee has made the following suggestions:</p> <ul style="list-style-type: none"> <li>• In the DPR, the effect on the soil quality due to the past discharge has not been studied by comparing with any reference soil from nearby /unaffected area. So, the study shall be completed by taking reference soil to know any impact in the soil quality of discharged area.</li> <li>• In the DPR, it has been recommended to develop the contaminated site as green park with trees, shrubs and grass. However, the names of the suitable local plant/species is required to be suggested to develop the contaminated site as green park.</li> <li>• As per the DPR, to remediate traces of organic present in the soil, it has been advised to inject bacteria through the boreholes. Whereas, the</li> </ul>

Sl.N	Recommendations of the Joint Committee pertaining to 8th Respondent Unit	Compliance Status (As on 23-09-2021)
		<p>details of the suitable bacteria for remediation, quantum of injection bacteria, application methodology etc. have not been suggested in the DPR.</p> <p>The above said suggestions with respect to the remediation of soil shall be included in the DPR and revised DPR shall be prepared.</p>
4	<p>2.4 Million Litres of waste water which contains RO reject water, Regeneration water from DM plant, and untreated/partially treated effluent had been stored in Raw water tanks. It was suggested by the Joint Committee that around 2.4 Million Litres of waste water that has been stored for long time in the storage tank inside the industry premises should be treated and disposed off immediately. <b>(Committee's observation during the site visit held on 12-04-2021)</b></p>	<p>Partially Complied. Compliance under progress.</p> <p>During the site visit, the Joint Committee noted that the waste water stored in the raw water tanks have been removed partly (3200 KLD) for treatment and the remaining quantity (4448 KLD) is kept untreated. Even after the elapse of 5 months from the previous committee visit, the 2.4 MLD liters of waste water is not fully treated. The Joint Committee suggested that the remaining quantity of waste water need to be disposed off within a month.</p>
5	<p>The unit shall provide garland drains around the unit premises to ensure that there is no seepage of water from outside premises into the unit and vice-Versa.</p>	<p>Complied.</p> <p>The industry has constructed the sub-surface storm water drain outside the industry premises on western side in between M/s.Tamil Nadu Chromates Chemicals Ltd dump side and M/s.Thirumalai Chemicals Ltd.</p>

Sl.N	Recommendations of the Joint Committee pertaining to 8th Respondent Unit	Compliance Status (As on 23-09-2021)
		In northern side, the industry has constructed retainer wall. The length of retainer wall is 213 meters and depth ranging from 1.5 meters to 5.0 meters. The retainer wall provided in RCC covering HDPE sheet at foundation level outside portion of the wall with earthen drain at GL so as to ensure that there is no seepage of water from outside premises into the unit and vice-versa.

**3. Objection filed by the 8<sup>th</sup> Respondent Unit to the Joint Committee report:**

The Joint Committee has gone through the counter affidavit dated 1-06-2021 of the 8<sup>th</sup> Respondent Unit which was shared to the Committee during the site visit held on 23-09-2021.

On perusal of the counter affidavit, the Joint Committee noted that the 8<sup>th</sup> Respondent Unit has not made any specific objection to implement the recommendations made by the Joint Committee. The 8<sup>th</sup> Respondent Unit is taking adequate measures to implement the Committee's recommendations as stated in the above table.

**4. Conclusion:**

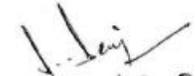
(i) The 8<sup>th</sup> Respondent Unit has assured that the adequacy report of IIT Madras will be submitted before 31<sup>st</sup> October 2021 with regard to full-fledged operation of ZLD system.

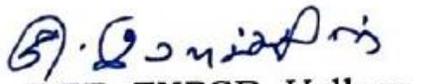
(ii) The DPR has been prepared by IIT Madras for remediation of the land where the untreated effluent was discharged within the industry site. The observations made by the Joint Committee on DPR (detailed in Para No.3 in the above Table) shall be incorporated in the DPR and accordingly revised DPR shall

be prepared within 15 days and remediation work shall be started within one month. TNPCB shall periodically monitor the remediation work.

**By considering the above facts and observation of the Joint Committee, the Hon'ble Tribunal may pass appropriate Order (s)/Direction (s) as deemed fit.**

  
29/9/2021  
RDO, Ranipet

  
(R. Ramesh)  
EE, PWD,  
Upper Palar Basin Division,  
Vellore, TN

  
DEE, TNPCB, Vellore.

  
Scientist 'D'  
CPCB), Regional Directorate,  
Chennai

  
Scientist 'D',  
Integrated Regional Office,  
MoEF&CC, Chennai

\*\*\*

**Annexure-I**

**Photos taken during the site visit of the Joint Committee held on 23-9-2021 at 8<sup>th</sup> Respondent Unit**



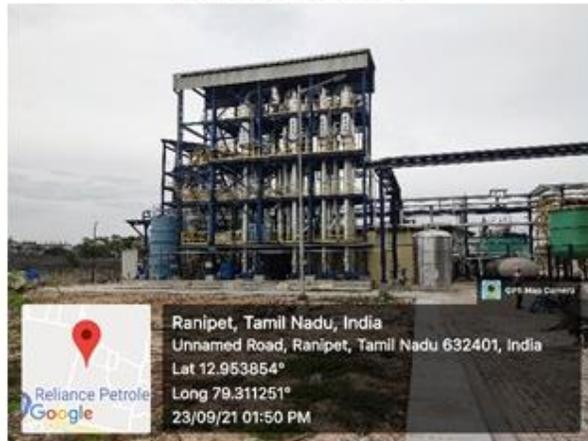
**Plantation carried out in the remediation site**



**Committee's visit to the remediation site**



**Retainer wall around the industry unit**



**New ETP with ZLD components**

**ASSESSMENT OF CONTAMINATION  
LEVEL AT THE YARD AREA OF  
THIRUMALAI CHEMICALS LIMITED,  
RANIPET**

*Prepared by*

**Dr. Ligy Philip**

**Professor**

**Department of Civil Engineering**

**Indian Institute of Technology Madras**

**Chennai-600036**



**SEPTEMBER 2021**

## **Team Members Involved**

- 1. Mr. R. Manthiram Karthik**
- 2. Mr. R. Sarath Kumar**
- 3. Mr. A. Vishnu Vardhan**
- 4. Mr. D. Kumaran**
- 5. Mr. Sumit Kumar**
- 6. Mr. Mohammed Iqbal Thayyil**
- 7. Mr. Insamam ul Huq**

# **ASSESSMENT OF CONTAMINATION LEVEL AT THE YARD AREA OF THIRUMALAI CHEMICALS LIMITED, RANIPET**

## **1. Background**

Thirumalai Chemicals Limited (TCL), Ranipet manufactures phthalic anhydride, malic acid, and fumaric acid. TCL approached IIT Madras to prepare a Project Proposal for Remediation of Contaminated site within the premises of M/S Thirumalai Chemicals Ltd (TCL), Ranipet. After a site visit and discussion with TCL officials, IIT Madras agreed to take up the work. The objective and scope of the work are defined on mutual agreement.

## **2. Objective**

Preparation of Detailed Project Report for Remediation of Contaminated **site within the premises of M/S TCL., Ranipet**

## **3. Scope**

- Identifying the concentration and the extent of pollution of Contaminated site within the premises of M/S Thirumalai Chemicals Ltd., Ranipet. Based on the discussion with the officials of TCL and the information provided regarding the raw materials and products, the signature compounds for analyses were finalized as pH, TDS, EC, chloride, sulfate, chromium, COD, Phthalic anhydride (Dicarboxylic Anhydrides), Fumaric Acid, Malic Acid, and O-xylene.
- Reporting the concentration of the pollutants
- Suggesting appropriate methodology for the remediation of the site.
- Estimating approximate time and duration of remediation activity.

## **4. Assessment of Contamination Level**

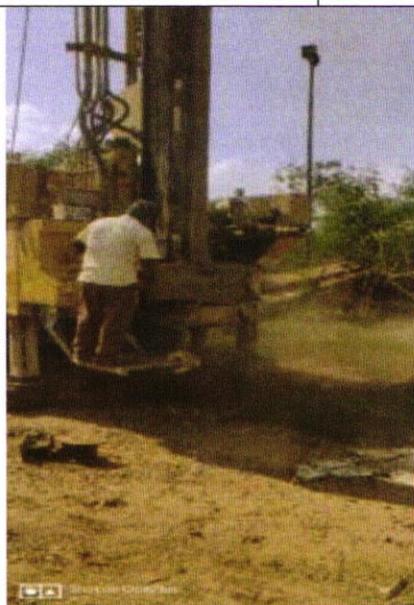
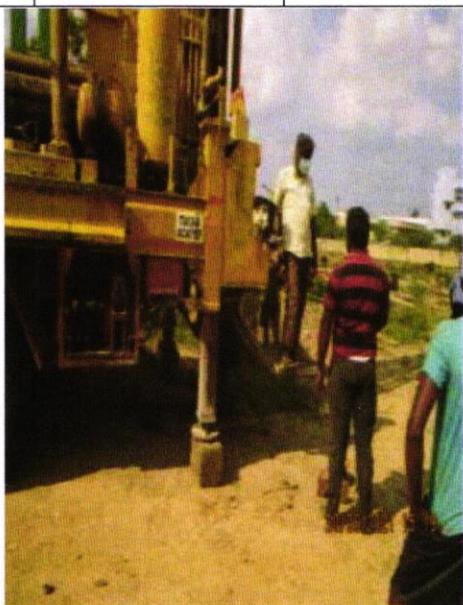
The study focussed on the assessment of contamination level at the yard area of TCL, Ranipet. IIT Madras team led by Prof. Ligy Philip visited the site on 10<sup>th</sup> April 2021 and had a detailed discussion with the officials of the industry. On 30<sup>th</sup> June 2021, the team made the second visit to the contaminated site. The entire site area (approx. area 14680 m<sup>2</sup>) was examined for the formation of grids (to collect representative samples) after fixing the boundaries (Fig 1). The contaminated site was then divided into 11 grids so that the samples collected would be representative of the entire area (Fig 2 & 3). After marking the exact sampling points, bore drilling was carried out at the mid-point of each grid up to the hard rock strata (Fig 4 & 5). The soil samples were collected at different depths. Besides, water

samples were collected from auger point 3 and point 8. The details of the sampling points are provided in **Table 1**. The nature of soil type with depth was also recorded as in Table 2.

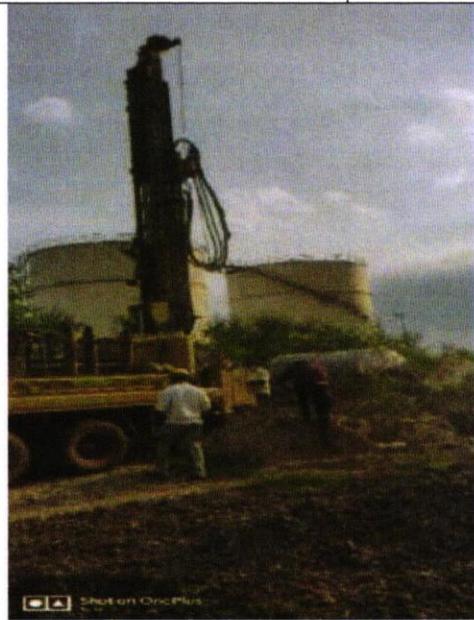
**Table 1. Details about the sampling points**

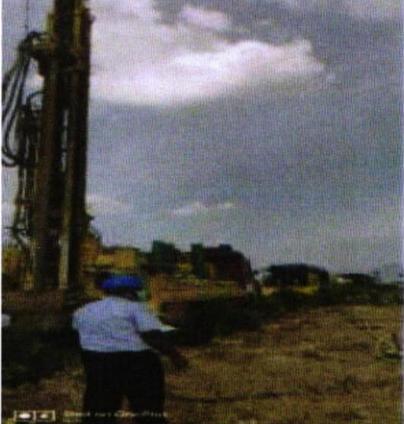
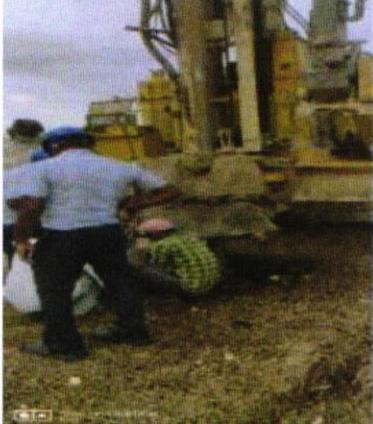
S.No.	Sampling Location details	GPS coordinates	Observed nature of the soil	Remarks
1.	<b>Location 1</b> Near Ponnai road	N12°57'19.4" E079°18'54.3"	0 cm- Muram* (top soil) 0.5 m- Quartzite* (white coloured) 1.8 m- Black coloured soil (contaminated soil) 2.1 m- Hard rock (powder)	Hard rock/Rough stone reached at 2.1 m approx.
				
2.	<b>Location 2</b> Near Security room	N12°57'19.2" E079°18'52.7"	0 cm-Muram* 0.5 m- Filled up soil/ weathered rock* 0.9 m- filled up soil 1.8 m- Black colored soil (contaminated soil) 2.7 m- Hard rock	Hard rock reached at 2.7 m approx.
				

3.	<b>Location 3</b> Near reed bed	N12 <sup>0</sup> 57'20" E79 <sup>0</sup> 18'54"	0 cm- Muram 3.9 m- Hard rock slurry (water was found)	Hard rock reached at 3.9 m approx. A water sample was also collected using a sampler after 15 mins.
----	------------------------------------	--	--	--

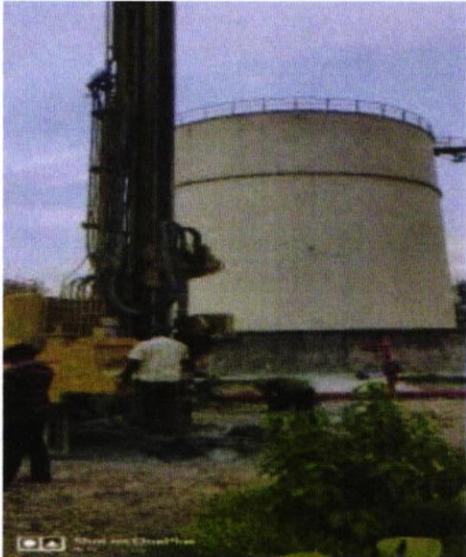


4.	<b>Location 4</b> Light tower entrance area	N12 <sup>0</sup> 57'19.8" E79 <sup>0</sup> 18'51.9"	0 cm- Muram 0.9 m- filled up soil 2.1 m- Hard rock	Hard rock reached at 2.1 m approx.
----	--	--	--	------------------------------------

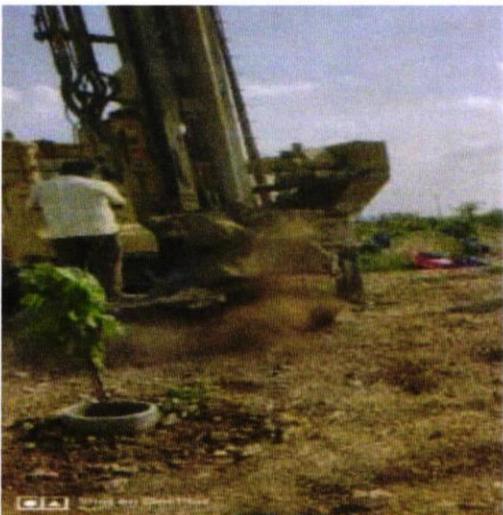


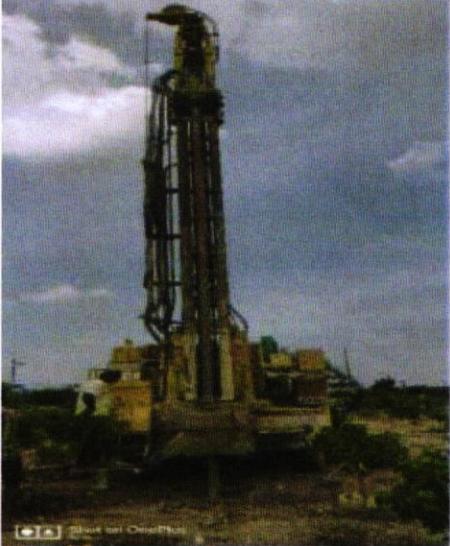
5.	<b>Location 5</b> Near reed bed	N12°57'20.8" E79°18'52.4"	0 cm-Muram 0.9 m- filled up soil 1.8 m- Black colored soil (contaminated soil) 2.7 m- Hard rock	Hard rock reached at 2.7 m approx.
				
6.	<b>Location 6</b> Front of o-xylene tanks	N12°57'19.3" E79°18'50.7"	0 cm-Muram 0.9 m- Black colored soil (contaminated soil) 1.8 m- Hard rock	Hard rock reached at 1.8 m approx.
				
7.	<b>Location 7</b>	N12°57'21.2" E79°18'51.3"	0 cm-Muram 0.9 m- Black colored soil (contaminated soil) 2.4 m- Hard rock	Hard rock reached at 2.4 m approx.
				

8.	<p><b>Location 8</b> Front of o-xylene storage Near yard shed</p>	<p>N12°57'19.5" E79°18'50"</p>	<p>0 cm- Muram soil* 0.9 m- Muram soil* 1.8 m- Black colored soil 3 m- Black colored soil (contaminated soil) 3.6 m- Hard rock slurry (water was found)</p>	<p>Hard rock reached at 3.6 m approx. A water sample was also collected using a sampler after 15 mins.</p>
----	---	------------------------------------	---	--



9.	<p><b>Location 9</b> Front of o-xylene storage Near yard shed</p>	<p>N12°57'20.3" E79°18'50.2"</p>	<p>0 cm- Muram soil 0.9 m- Muram soil 1.8 m- Black colored soil (contaminated soil) 3.6 m- Hard rock</p>	<p>Hard rock reached at 3.6 m approx.</p>
----	---	--------------------------------------	--	---



10.	<b>Location 10</b> Near TN warehouse	N12°57'21.6" E79°18'50.4"	0 cm- Muram soil 0.9 m- Black colored soil (contaminated soil) 2.1 m- Hard rock	Hard rock reached at 2.1 m approx.
				
11.	<b>Location 11</b> Near TN warehouse	N12°57'21.1" E79°18'50.4"	0 cm- Muram soil 0.9 m- Black colored soil (contaminated soil) 2.1 m- Black soil & rock powder 3.0 m- Hard rock	Hard rock reached at 3 m approx.
				

**Note:** \* denotes soil sample collected using a manual auger.



Fig 1. Grids made at the contaminated site of Thirumalai Chemicals for sample collection

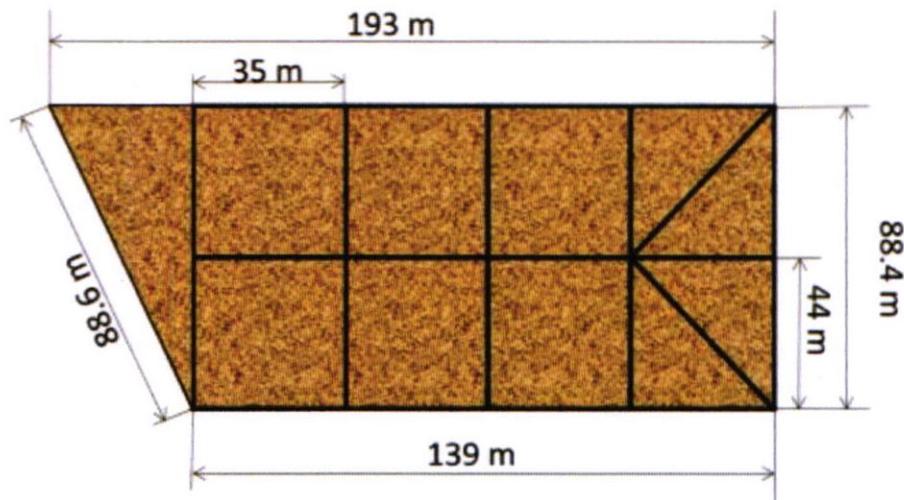


Fig 2. Schematic representation of the contaminated site with the grids made for sampling



Fig 3. Google earth image of the contaminated site with sampling points



Fig 4. Google earth image of the contaminated site with marked sampling points at each grid

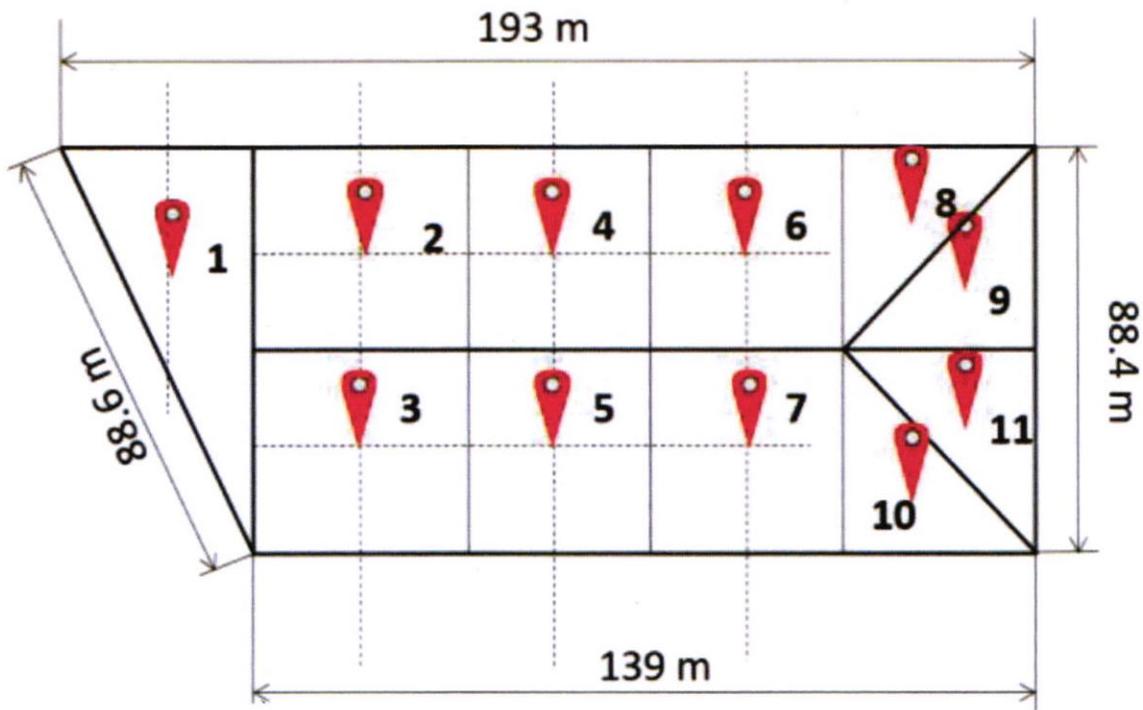


Fig 5. Schematic representation of the site with 11 sampling points marked at each grid

**Table 2. List of sampling points and their ID notions**

<b>Borehole ID</b>	<b>Sample ID</b>	<b>Depth (m)</b>	<b>Observed nature of the soil</b>
1	1.1	0	Muram
	1.2	0.5	Quartzite (white colour)
	1.3	1.8	black colored contaminated soil
	1.4	2.1	Hard rock
2	2.1	0	Muram/Filled up soil
	2.2	0.9	Weathered rock
	2.3	1.8	black colored contaminated soil
	2.4	2.7	Hard rock
3	3.1	0	Muram
	3.2	3.9	Hard rock slurry + water
4	4.1	0	Muram
	4.2	0.9	filled up soil/quartzite
	4.3	2.1	hard rock
5	5.1	0	muram
	5.2	0.9	filled up soil/quartzite
	5.3	1.8	black colored contaminated soil
	5.4	2.7	hard rock
6	6.1	0	muram
	6.2	0.9	black colored contaminated soil
	6.3	1.8	hard rock
7	7.1	0	muram
	7.2	0.9	black colored contaminated soil
	7.3	1.8	hard rock
8	8.1	0	muram
	8.2	0.9	Muram
	8.3	1.8	black colored contaminated soil
	8.4	3	black colored contaminated soil
	8.5	3.6	hard rock
9	9.1	0	muram
	9.2	0.9	muram
	9.3	1.8	black colored contaminated soil
	9.4	3.6	hard rock
10	10.1	0	muram
	10.2	0.9	black colored contaminated soil
	10.3	2.1	hard rock
11	11.1	0	muram
	11.2	0.9	black colored contaminated soil
	11.3	2.1	rock powder
	11.4	3	hard rock

## **5. Analytical methods**

### **5.1 Moisture content**

Initially, the dry crucible was weighed in a weighing balance up to four-digit accuracy. A known weight of soil sample (10 g) was added to the crucible and kept in the oven at  $105\pm 5^{\circ}\text{C}$  for 24 h. Then, the crucible was cooled to room temperature using a desiccator. The weight of the crucible with the sample was measured for the concurrent values.

### **5.2 Physicochemical parameters**

Soil samples were mixed with reagent grade water in a 1:1 ratio. The flasks were covered and continuously stirred for 5 min. The soil suspension was allowed to settle for about one h or centrifuge off the aqueous phase for the analysis (Method 9045D, US EPA). The collected supernatant was analyzed for pH, EC, anions, COD, TDS as per Standard Methods (APHA, 2012). TDS was measured by the gravimetric method after filtering the sample using a 0.45-micron nylon membrane filter.

### **5.3 Chromium**

#### **5.3.1 Total chromium**

The fresh samples (0.5 g) were extracted with 12 mL of  $\text{HNO}_3$ :  $\text{HCl}$  (3:1) using a microwave digester and diluted sufficiently with reagent grade water (Method 3052, US EPA). The diluted samples were filtered and analyzed for heavy metals using ICP-OES.

#### **5.3.2 Hexavalent chromium ( $\text{Cr}^{6+}$ )**

The fresh samples (2.5 g) were digested with 10 mL of digestion solution (2:3 ratio of  $\text{NaOH}$ :  $\text{Na}_2\text{CO}_3$ ), 0.1 g of  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ , and 1 mL of phosphate buffer using a hot plate at  $90^{\circ}\text{C}$  for one h. After digestion, the samples were allowed to cool, filtered, and diluted sufficiently with reagent grade water after adjusting pH to 7.2 to 7.5. An aliquot of a sample (0.5 mL) was mixed with 0.2 mL of diphenyl carbazide (DPC) and 0.2 mL of 5 N  $\text{H}_2\text{SO}_4$ . The concentration of  $\text{Cr}^{6+}$  was determined using UV Spectrophotometer at 540 nm.

### **5.4 Organic acids**

Into a 50-mL beaker, 10 g of fresh soil sample was weighed, then 20 mL of 1 N  $\text{H}_2\text{SO}_4$  was added. This mixture was thoroughly blended and allowed to stand for 20 min. The resulting slurry was vacuum filtered using a Buchner funnel which held a GFD filter. While the soil cake was still moist, it was washed with 15 mL of water which first was used to rinse the

extraction beaker. After a second 10-mL water wash, the combined filtrate volume was adjusted to 50 mL with water. A 3-mL aliquot of extract solution was filtered using a 5-mL syringe fitted with a membrane filter (Dietz and Singley, 1994).

Organic acids were separated by reversed-phase high-performance liquid chromatography (HPLC, Dionex, USA) using an Hypersil gold column at 30°C, using isocratic elution with 4 mM H<sub>2</sub>SO<sub>4</sub> as carrier solution at a flow rate of 0.5 mL/min. Organic acids were detected at 232 nm. Standard acids were prepared as individual stock solutions and then combined to give diluted reference standards.

### **5.5 Volatile organic compounds**

The extraction of VOCs from soil samples (10 g) was carried out with 10 mL of methanol, and the supernatant was collected in a glass vial after centrifugation at 4000 rpm for 15 min. The extraction was repeated twice with 10 mL of methanol at each step. The combined supernatant was made up to 30 mL with methanol. The sample was filtered using a 0.22-micron syringe filter and analyzed for VOCs using gas chromatography with a flame ionization detector (GC-FID, Perkin Elmer, USA).

To estimate VOCs content, 5 µl of the sample was injected into the GC-FID system. The optimum conditions: Carrier gas used was nitrogen; the initial oven temperature was 90°C (hold for 5 min) which was increased to 200°C and held for 10 min. Injection temperature was 250°C with column of 30m and 530mm diameter.

### **5.6 Quality assurance and quality control**

The physicochemical parameters were carried out independently by two candidates in duplicates, and the average values were reported. For organic acids and VOCs, a known quantity of pollutants was spiked to the soil samples and extracted per the protocol mentioned in sections 2.4 and 2.5. The recovery of pollutants was observed to be more than 80%.

## **6. Results and inferences**

The physicochemical parameters (pH, EC, moisture content, COD, TOC, TDS, chlorides, and sulfates) for all the soil samples mentioned above are given in **Table 3**. The concentration of heavy metal (total chromium and hexavalent chromium), organic acids, and VOCs of the soil samples are shown in **Table 4**. The characteristics of water samples collected from the auger holes 3 and 8 are shown in **Table 5**.

**Table 3. Physicochemical parameters of soil samples at different depths**

Sample point	Sample ID	pH in water	EC in water (µS/cm)	Moisture content (%)	TDS (µg/g)	Chlorides (µg/g)	Sulphates (µg/g)	COD (µg/g)	TOC (µg/g)
1	1.1	7.05 ± 0.02	1284.50 ± 4.24	7.16 ± 0.22	890 ± 15.6	63.54 ± 14.52	507.96 ± 30.94	146.0 ± 2.8	58.24 ± 0.74
	1.2	8.03 ± 0.02	1595.00 ± 1.41	4.77 ± 0.36	1040 ± 5.5	176.01 ± 14.5	622.53 ± 15.72	112.0 ± 28.3	38.58 ± 0.86
	1.3	7.72 ± 0.02	1106.20 ± 0.00	2.93 ± 0.90	760 ± 7.3	176.28 ± 28.81	168.73 ± 4.06	62.0 ± 28.3	27.25 ± 1.14
	1.4	7.37 ± 0.00	855.50 ± 0.00	3.11 ± 1.26	540 ± 5.5	125.76 ± 39.56	59.52 ± 21.26	40.0 ± 0.8	13.61 ± 0.99
2	2.1	6.67 ± 0.02	6998.50 ± 20.51	5.72 ± 0.22	4860 ± 25.8	2044.84 ± 92.4	521.72 ± 5.40	82.0 ± 28.3	24.58 ± 0.36
	2.2	7.55 ± 0.06	2199.00 ± 12.73	4.97 ± 0.52	1500 ± 4.7	453.85 ± 95.39	111.80 ± 26.50	32.0 ± 8.5	9.63 ± 0.52
	2.3	7.19 ± 0.01	2316.50 ± 7.07	6.71 ± 0.17	1640 ± 6.3	353.35 ± 30.46	545.04 ± 7.28	26.0 ± 19.8	7.49 ± 0.27
	2.4	7.94 ± 0.04	1487.50 ± 3.54	1.27 ± 0.64	960 ± 7.1	113.26 ± 21.89	565.99 ± 12.36	20.4 ± 2.0	6.74 ± 0.05
3	3.1	7.40 ± 0.01	3095.10 ± 23.33	9.20 ± 0.39	2050 ± 7.9	593.17 ± 44.74	650.33 ± 13.28	39.6 ± 4.8	11.54 ± 0.09
	3.2	7.79 ± 0.01	3245.00 ± 0.50	11.73 ± 0.9	2200 ± 16.0	977.76 ± 89.38	62.36 ± 10.76	58.0 ± 4.2	20.80 ± 0.02
4	4.1	7.40 ± 0.01	1314.10 ± 3.54	8.30 ± 0.94	770 ± 24.2	214.56 ± 14.66	62.28 ± 10.94	58.6 ± 7.6	17.28 ± 0.46
	4.2	7.51 ± 0.01	1345.00 ± 3.54	7.40 ± 1.21	640 ± 23.4	176.81 ± 2.63	335.03 ± 32.44	24.2 ± 5.4	7.40 ± 0.08
	4.3	7.82 ± 0.00	894.50 ± 2.12	1.24 ± 0.76	610 ± 21.2	126.56 ± 37.60	157.56 ± 17.82	40.5 ± 10.6	13.88 ± 0.45
5	5.1	7.56 ± 0.02	7895.50 ± 0.71	6.39 ± 0.39	3660 ± 27.1	1414.72 ± 56.7	948.94 ± 22.26	96.0 ± 0.5	35.70 ± 0.76
	5.2	7.64 ± 0.02	4157.10 ± 1.41	8.98 ± 1.45	2150 ± 18.7	605.93 ± 26.70	623.74 ± 13.06	88.0 ± 8.5	27.64 ± 1.15
	5.3	7.40 ± 0.01	7572.00 ± 10.9	12.39 ± 0.2	4940 ± 6.3	1401.43 ± 32.7	1093.24 ± 52.2	124.0 ± 11.3	44.52 ± 0.52
	5.4	7.86 ± 0.01	2404.00 ± 8.49	5.95 ± 0.80	1470 ± 28.3	416.63 ± 11.66	105.55 ± 27.43	102.4 ± 7.9	35.12 ± 1.10
6	6.1	7.50 ± 0.01	4315.60 ± 10.45	4.78 ± 1.12	2980 ± 2.4	618.16 ± 80.09	1142.65 ± 31.1	75.0 ± 4.2	26.70 ± 0.15
	6.2	7.34 ± 0.01	4295.10 ± 14.14	6.36 ± 0.66	3040 ± 20.4	1125.98 ± 84.6	774.90 ± 18.6	68.0 ± 11.3	22.02 ± 0.78
	6.3	7.48 ± 0.01	3356.50 ± 12.02	5.05 ± 1.04	2009 ± 12.4	593.17 ± 44.74	484.64 ± 18.75	44.6 ± 6.2	17.82 ± 0.09
7	7.1	8.13 ± 0.00	3952.00 ± 0.00	7.90 ± 1.49	2650 ± 7.9	1189.26 ± 93.4	715.76 ± 40.19	76.0 ± 0.9	26.52 ± 0.08
	7.2	7.67 ± 0.02	4423.10 ± 14.14	10.98 ± 0.7	2640 ± 5.9	643.15 ± 95.43	715.82 ± 58.06	62.4 ± 12.2	26.56 ± 0.65
	7.3	7.05 ± 0.03	4211.00 ± 14.14	5.79 ± 0.24	2160 ± 5.9	618.16 ± 80.09	1057.70 ± 22.7	56.0 ± 5.7	22.10 ± 0.24

8	8.1	6.34 ± 0.01	5095.40 ± 0.00	12.95 ± 0.9	3450 ± 11.8	996.77 ± 71.17	973.20 ± 60.5	72.0 ± 1.4	21.42 ± 0.12
	8.2	7.32 ± 0.01	4105.60 ± 14.14	6.49 ± 0.01	2800 ± 9.1	718.66 ± 82.03	722.06 ± 76.35	120.0 ± 11.3	51.32 ± 0.03
	8.3	4.27 ± 0.04	4431.40 ± 14.14	9.28 ± 0.02	2940 ± 27.3	599.68 ± 17.86	968.61 ± 39.64	34.0 ± 7.1	14.20 ± 1.40
	8.4	4.53 ± 0.02	3455.20 ± 0.00	10.57 ± 0.1	1681 ± 21.6	239.55 ± 50.	754.40 ± 21.19	62.0 ± 2.8	21.46 ± 0.17
	8.5	5.57 ± 0.00	2809.50 ± 21.21	11.90 ± 0.9	1560 ± 12.6	365.84 ± 48.13	603.90 ± 52.03	108.0 ± 7.1	39.04 ± 0.19
9	9.1	7.00 ± 0.01	9345.60 ± 21.21	7.18 ± 0.33	6380 ± 7.1	2411.49 ± 53.3	923.18 ± 49.33	80.4 ± 5.1	27.34 ± 0.42
	9.2	7.13 ± 0.02	5315.10 ± 14.14	8.21 ± 0.45	3640 ± 13.4	886.66 ± 26.66	817.29 ± 59.04	114.0 ± 7.1	40.98 ± 0.98
	9.3	7.27 ± 0.02	2167.00 ± 2.83	7.13 ± 0.48	1070 ± 5.7	365.58 ± 83.85	359.21 ± 33.26	38.8 ± 4.0	13.19 ± 0.28
	9.4	6.98 ± 0.01	1427.50 ± 0.00	4.80 ± 0.39	1000 ± 17.8	218.50 ± 20.24	472.81 ± 15.78	68.0 ± 5.7	22.55 ± 0.45
10	10.1	7.40 ± 0.02	7776.70 ± 0.00	9.99 ± 0.26	5360 ± 13.9	1856 ± 25.96	1175.48 ± 37.2	56.4 ± 2.3	17.18 ± 0.27
	10.2	6.69 ± 0.01	5349.50 ± 9.90	11.24 ± 0.3	3720 ± 23.6	1073.33 ± 1.89	1590.87 ± 53.8	48.0 ± 2.8	16.99 ± 0.28
	10.3	6.77 ± 0.01	1196.40 ± 2.12	1.88 ± 0.43	680 ± 16.5	328.10 ± 30.82	3.81 ± 0.44	14.0 ± 5.7	4.87 ± 0.40
11	11.1	6.31 ± 0.01	4854.20 ± 14.14	7.51 ± 0.74	3390 ± 3.1	921.79 ± 4.14	920.92 ± 17.02	32.0 ± 5.7	12.63 ± 0.34
	11.2	6.63 ± 0.00	2615.10 ± 0.00	5.34 ± 0.19	1620 ± 22.0	580.67 ± 27.07	471.81 ± 9.22	24.4 ± 0.8	7.58 ± 0.11
	11.3	6.87 ± 0.02	1215.80 ± 4.24	4.54 ± 0.46	710 ± 8.6	302.83 ± 31.21	191.33 ± 21.9	29.6 ± 2.3	9.49 ± 0.36
	11.4	6.93 ± 0.01	1940.50 ± 2.12	6.39 ± 0.43	1050 ± 18.1	567.91 ± 45.12	32.38 ± 2.27	12.0 ± 0.24	4.12 ± 0.29

**Table 4. Concentration of chromium, organic acids, and VOCs in soil samples at different depths**

Sample point	Sample ID	Chromium		Organic acids				Volatile organic compounds		
		Total Chromium (µg/g)	Cr <sup>6+</sup> (µg/g)	Phthalic anhydride (µg/g)	Oxalic acid (µg/g)	Malic acid (µg/g)	Fumaric acid (µg/g)	Acetonitrile (µg/g)	Isopropyl alcohol (µg/g)	o-Xylene (µg/g)
1	1.1	8.088 ± 0.058	1.881 ± 0.047	BDL	2.25 ± 0.45	BDL	BDL	BDL	BDL	BDL
	1.2	1.800 ± 0.144	0.380 ± 0.002	BDL	22.44 ± 1.32	BDL	BDL	BDL	BDL	BDL
	1.3	0.888 ± 0.091	0.280 ± 0.026	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	1.4	0.504 ± 0.041	0.260 ± 0.012	BDL	BDL	BDL	BDL	BDL	BDL	BDL
2	2.1	12.960 ± 0.206	1.172 ± 0.085	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	2.2	3.072 ± 0.269	BDL	BDL	2.96 ± 0.67	BDL	BDL	BDL	BDL	BDL
	2.3	1.512 ± 0.055	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	2.4	0.528 ± 0.038	0.220 ± 0.010	BDL	BDL	BDL	BDL	BDL	BDL	BDL
3	3.1	3.648 ± 0.187	BDL	BDL	5.61 ± 1.05	BDL	BDL	BDL	BDL	BDL
	3.2	0.840 ± 0.072	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
4	4.1	2.520 ± 0.091	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	4.2	1.272 ± 0.151	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	4.3	0.504 ± 0.062	0.340 ± 0.047	BDL	13.96 ± 2.89	BDL	BDL	BDL	BDL	BDL
5	5.1	4.944 ± 0.156	0.626 ± 0.025	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	5.2	3.792 ± 0.266	BDL	BDL	18.02 ± 2.65	BDL	BDL	BDL	BDL	BDL
	5.3	3.600 ± 0.230	BDL	BDL	11.89 ± 1.79	BDL	BDL	BDL	BDL	BDL
	5.4	0.840 ± 0.110	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
6	6.1	13.800 ± 1.138	0.598 ± 0.022	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	6.2	6.504 ± 0.278	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	6.3	0.000 ± 0.113	BDL	BDL	26.14 ± 4.28	BDL	BDL	BDL	BDL	BDL
7	7.1	1.464 ± 0.780	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

	7.2	$0.384 \pm 1.740$	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	7.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
8	8.1	$1.320 \pm 1.128$	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	8.2	BDL	BDL	BDL	$29.42 \pm 5.49$	BDL	BDL	BDL	BDL	BDL
	8.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	8.4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	8.5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
9	9.1	$12.984 \pm 0.679$	$1.32 \pm 0.046$	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	9.2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	9.3	BDL	BDL	BDL	$8.12 \pm 0.98$	BDL	BDL	BDL	BDL	BDL
	9.4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
10	10.1	$5.256 \pm 0.727$	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	10.2	BDL	BDL	BDL	$13.88 \pm 1.55$	BDL	BDL	BDL	BDL	BDL
	10.3	BDL	BDL	BDL	$2.86 \pm 0.23$	BDL	BDL	BDL	BDL	BDL
11	11.1	$7.248 \pm 0.166$	$0.422 \pm 0.033$	BDL	$7.04 \pm 1.07$	BDL	BDL	BDL	BDL	BDL
	11.2	BDL	BDL	BDL	$2.51 \pm 0.62$	BDL	BDL	BDL	BDL	BDL
	11.3	BDL	BDL	BDL	$5.08 \pm 0.95$	BDL	BDL	BDL	BDL	BDL
	11.4	BDL	BDL	BDL	$2.35 \pm 0.31$	BDL	BDL	BDL	BDL	BDL

**Table 5. Characteristics of water samples collected at auger holes - 3 and 8**

Si.No	Parameters	Auger Hole 3	Auger hole 8
1	pH	7.12 ± 0.02	7.50 ± 0.01
2	EC (µS/cm)	24319 ± 26.87	12800 ± 14.14
3	TDS (mg/L)	14810 ± 669.77	8432.5 ± 457.65
4	Chlorides (mg/L)	9396.44 ± 71.64	3731.10 ± 95.77
5	Sulphates (mg/L)	116.88 ± 5.47	485.13 ± 16.17
6	COD (mg/L)	427 ± 5.66	216 ± 7.07
7	TOC (mg/L)	111.2 ± 14.6	61.99 ± 16.48
8	Total Chromium (µg/L)	BDL	BDL
9	Cr6+ (µg/L)	BDL	BDL
10	Phthalic anhydride (µg/L)	BDL	BDL
11	Oxalic acid (µg/L)	811.90 ± 34.56	BDL
12	Maleic acid (µg/L)	BDL	BDL
13	Fumaric acid (µg/L)	BDL	BDL
14	Acetonitrile (µg/L)	BDL	BDL
15	Isopropyl alcohol (µg/L)	BDL	BDL
16	o-Xylene (µg/L)	BDL	BDL

## Summary and Recommendations:

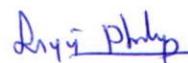
### Preamble:

Thirumalai Chemicals Ltd. (TCL) is an Organic chemical manufacturing company. Based on the information provided by the industry, they use Ortho Xylene and Maleic anhydride as raw materials and manufacture Phthalic anhydride, Malic acid, and Fumaric acid. According to the information provided by TCL, they are not using any solvents in the manufacturing process, and no other intermediates are generated during the process.

### Summary:

The analyses results showed that the organic content of the soil is not significant. Very low concentrations of oxalic acid are found in a few locations. Traces of hexavalent chromium and relatively high concentrations of total chromium (max 13.0 µg/g) are found in the topsoil. Total chromium and hexavalent chromium are primarily absent or at very low levels below the topsoil. The TDS of the two water samples is high. Some of the soil samples possess high TDS. The water samples show high COD and chlorides.

- The raw materials, by-products, and products of Thirumalai Chemicals Ltd. are organic in nature. All of them are highly biodegradable. Hence, the pollutants might have degraded due to biological activity. It is evident from the low COD values of the soil samples. The method of analysis ensures the leaching potential under normal conditions.
- Though Thirumalai Chemicals Ltd. is not using chromium in any form in their plant, the chromium found in the topsoil layer, while collecting the soil samples from the contaminated site, we observed a clear color difference between the topsoil and the soil about 1 m deep.
- Though oxalic acid, an organic substance, is neither made nor used by Thirumalai Chemicals Ltd, traces of oxalic acid was found in some soil samples and the water samples.



Dr. Ligy Philip

Professor

Environmental & Water Resources Engg.,  
Department of Civil Engineering  
Indian Institute of Technology Madras  
Chennai - 600 036, India

- It might have entered from other contaminated sites through rainwater or subsurface flow from other industries in the industrial estate that could have used oxalic acid or chromium.
- To remediate the traces of organics present in the soil, it is advised to inject bacteria through the boreholes. It will enhance the bacterial concentration and accelerate the degradation. To remediate chromium contamination, bioremediation is recommended by employing chromium-reducing bacteria and an appropriate carbon source.
- The TDS concentrations of the soil and water are very high. Natural remediation by rainwater will flush out the TDS. The groundwater contamination potential is low as the hard-rock strata exist about 3 m below the contaminated area. Since the soil depth is not high, planting trees and shrubs in the area is the best solution. Thirumalai Chemicals Ltd. has already started the work in January 2021. 502 tree saplings that were planted have grown to 5 feet plus now. It will bring the soil to its original condition in the course of time.
- The water samples collected from the site showed relatively high COD and very high TDS. COD might be coming through the irrigation water and leaching of the natural manure (chicken droppings) employed for the tree plantations. Thirumalai Chemicals Ltd. shall ensure control on the usage of the natural manure (chicken droppings) properly. Thirumalai Chemicals Ltd. shall control the amount of water used for irrigation and ensure the quality of the water used for watering the plants.
- It is recommended to develop the contaminated site as a green park with trees, shrubs, and grass. Thirumalai Chemicals Ltd. has started developing the site by turning it into a green zone in the last six months.

*Ligy Philip*

(Ligy Philip)

Dr. Ligy Philip

Professor  
Environmental & Water Resources Engg.,  
Department of Civil Engineering  
Indian Institute of Technology Madras  
Chennai - 600 036, India

### Annexure 1

Photographs were taken during the site visit, sample collection, and meeting with industry officials



