Chapter 2
RECONNAISSANCE STUDY

Preliminary informations regarding the study area were obtained by a visual reconnaissance study conducted during October -November 1993. This study was done mainly to have a thorough knowledge about the study area and also to identify potential sampling points for both air and water quality studies as well as for developing the land-use map of the area. Informations regarding the past history of the study area as well as the current data pertaining to socio-economic status, agricultural activities, etc were collected from Village Administrative Officers (VAO), Government of Pondicherry, India. Village map was simultaneously collected.

STUDIES ON THE AIR ENVIRONMENT

Monitoring of air quality of the study area was done in an extensive manner. This required a lot of methodical planning, appropriate selection of sampling sites and analytical procedures etc. The methodology that is adopted for the present study is as follows.

Selection of sampling stations

Planning a network of monitoring stations in the area required a lot of preliminary informations on:
a) qualitative and quantitative data on the local sources of air pollution.

b) topography

c) population distribution

d) land-use pattern and

e) climatology

In pursuance of the above, information on type of industries, their process flows (included raw materials used and their quantity, the main processes involved, final products and its quantity, emission etc) and stack condition were obtained from the records of Department of Science and Technology (DSTE), Government of Pondicherry, India. A visual reconnaissance study conducted during October-November 1993 formed the base. It outlined the necessity of a study in the area apart from defining to a large extent the sampling sites. The land-use map also proved to be very useful. Population distribution in the area was studied in order to identify the potential receptor sites. Climatological data was to an extent available from DSTE, major source being the Indian Meteorological Department at Pune, India, as well as Madras, India, and the French Institute, Pondicherry, India. The meteorological station at Cuddalore, Tamil Nadu, India, proved very handy in developing the pattern of wind conditions and thereby helping us to decide the priority sampling sites, lest we loose the particular conditions at that particular time of the year.

More important though not significant was information collected on the influence of extraneous sources on air quality of Pillaiyarkuppam-Kirumampakkam. Though marginal in scale it would be very apt to mention here that industrial sites located in the neighbouring town/village do contribute to pollution loads in the study area. This is based on the prevalent odour in the air and heresay.

Location of sampling sites

Principal factors which governed the location of sampling sites were the objectives, the particular method or instrument used for sampling, resources available, physical access and security against loss and tampering.

Based on the objectives, location sites were placed close to receptor sites (human settlements, agricultural fields, monocultures etc) in order to estimate the damage or effects on human health and materials. Critical areas such as hospitals, schools, prime residential areas were also covered so as to fulfil this objective. At the same time, sites upwind and downwind of sources were identified in order to assess the contribution from specific sources. Topographical and micrometeorological information were of much use in this case. Since the sources of pollution were treated as an 'area source', samplers were placed so as to cover the whole study area.

Location of the monitoring stations, were also determined by the following criteria:

a) Representativeness

A representative sampling site reflects the concentration and fluctuations of air pollutants within the area. Therefore, care was taken to place the sites away from:

i) nearby sources of air pollution like domestic chimneys and houses where wood, charcoal,
were used as fuel. Samplers were placed at least 25 meters away from such sources

ii) absorbing surfaces (foliage, walls etc)

iii) areas where considerable land-use changes were going to occur (e.g. construction, monoculture plantings etc)

iv) sampling sites also ensured representativeness of population movements.

(b) Comparability

In order to compare air quality data from different sites, the details of each location were standardized, i.e.

i) all samplers were placed at least four meters above the ground and two to three meters from vertical and horizontal surfaces.

ii) technicalities with respect to method, operation, etc were same for all samplers.

(c) Physical requirements

Monitoring sites fulfilled the following conditions:

i) it was available for the full duration of sampling.

ii) it was accessible for 24 hours.

iii) electrical power of sufficient rating was available.

iv) it was vandal-proof.

(d) Topographical and meteorological conditions

The land-use plan of the area shows the various topographical features which may affect the local meteorological conditions. No such special features (tall buildings, mountains, valley etc) exist which may bring about drastic changes in the local meteorology except for the land-sea breeze circulation which dominate and change the local wind pattern. The distance of penetration would determine the dispersion and transport of pollutants.

Sampling stations

As mentioned earlier the industries in this area are very close to potential receptor sites. Therefore it was very difficult to designate or categorize the location into industrial, residential, and sensitive areas, as promulgated by Central Pollution Control Board (CPCB). Moreover, no such core or buffer areas/zones exist in this area. Nevertheless, based on the objectives to be achieved, nature of and effects on receptors, distance between the receptors and industries, and the above mentioned facts, potential sampling stations were established (Figure 1). The stations represented.

a) Industrial location: This was at PIPDIC’s industrial estate.

b) Sensitive area: A primary school.

c) Residential area: Three locations were studied on the basis of predominant wind directions.

d) Control area: This was at Bahour (a near by village to the study area) and identical in its setting to the study area but free from the impact of industrial pollution.

Thus six sampling stations were established for extensive monitoring of the air quality of the study area.
LEGEND

- Sampling sites
  1 Resident 2
  2 Resident 1
  3 Primary School
  4 PIPDIC
  5 Resident 3

- Stack Location

Figure 1. Location of air quality monitoring stations
Period, frequency and duration of sampling

The period, frequency and duration of sampling were appropriate to the objectives of the study. Meteorological and source emission factors which influence the atmospheric concentration (Peavy et al, 1986) were taken into account. Factors primarily determining the same such as wind direction in different seasons, diurnal variation of wind speed, and other stability parameters (council of Environmental Quality, 1982) were considered. Other important determinants were such that measurable quantities of pollutants were trapped at the end of the sampling period to obtain statistically reliable averages over the duration of sampling.

Over all 5,472 hours of sampling at 8 hour continuous stretches were done covering more than 800 air quality parameter values across 12 months. Samplings were conducted during days as well as nights.

Meteorology

In an area like Pillayarkuppam-Kirumampakkam, where industries and residents are so closely placed (as shown in the land-use map) it becomes very important to study the meteorological conditions, especially with reference to receiver effects, apart from serving other important objectives. Since these areas come on the coast, where the atmosphere is turbulent, stability of the atmosphere would determine the dispersion and fate of pollutants (Battan, 1979; Byers, 1974).

In order to achieve the above, meteorological studies under parameters like temperature, relative humidity, wind speed and wind direction were carried out during the period of study. Wind roses for the study area were simultaneously generated (Figures 2-7).

Equipment

Maximum and Minimum Thermometer, Relative Humidity Meter (Hygrometer), Wind Vane, Automated Anemometer.

Method

Maximum and Minimum temperature of the ambient air were noted every day, throughout the period of study for both the study area and the control area (Bahour).

Relative humidity readings were noted every hour during day and night and the average calculated for the day for both the study area and the control area (Bahour).

Wind direction was noted every two hours during the time of sampling, using the wind vane. Predominant wind direction was then calculated, for the day.

Wind Speed was noted for every two hours during the time of sampling, using the anemometer. The readings were then averaged to give the wind speed for the day.

Selection of parameters

Process flow diagrams obtained from the companies and DSTE were scanned for possible extra emission points and stack emissions. The raw materials used and final products differ, since the area comprises companies which produce steel, chemicals, dyes, varnishes, and other user products. Since the background emissions from industries are varied, the parameters chosen for analysis for ambient air were largely dependent on the above mentioned facts. Availability of reagents, glassware
Wind speed: Km/hr

Figure 2. Wind rose March - June 48 hr av
Figure 3. Wind rose July-November, 48 hr avg.

Wind speed, Km/hr

31-46
18-31
12-18
7-12
12-18
12-18
18-31
18-31
31-46
31-46
Figure 4. Wind rose December-February 48 hr av
Figure 5. Wind rose March-June, 12 hr av
Wind speed, Km/hr

Figure 6. Wind rose July-November, 12 Hr av
Figure 7. Wind rose December-February, 12 hr av
and apparatus were other important factors. The parameters chosen were Suspended Particulate Matter (SPM), Nitrogen oxides (NOx), Sulphur dioxide (SO2), Hydrogen sulphide (H2S), Sulphuric acid (H2SO4) and Chlorine (Cl2).

**Sampling and analysis of particulates and gases**

It would be apt to mention that like in any other industrial area, apart from the industries, secondary sources such as transport, burning of domestic fuel do contribute to local pollution load (Peavy et al, 1986; Stern et al, 1973 and Institute for air pollution training, 1975). Therefore, it becomes very difficult as such to estimate pollution loads caused by industries alone. In order to minimize influence of such extraneous factors into our estimation, care was taken to keep the samplers away from such sources, as mentioned earlier.

Micrometeorological conditions vary from season to season and even day to day (Battan, 1979). Diurnal variation in the atmospheric condition due to industrial activities also takes place. Hence sampling was conducted during various seasons as well as during days and nights. This procedure was adopted under the assumption that industries do carry their full operation and production even during the night time.

For the present study extensive monitoring of air quality of the study area was done for one year. Sampling was done during February-April 1994, June and October 1994, and January 1995.

**Materials**

Materials used for various analytical purpose were as follows:

**Reagents**

Analytical grade reagents were used. Assay of most of the chemicals were above 95%. Impurities, if any, in the reagents were removed by way of interferences removal technique. Chemicals used are mentioned while explaining the various methods adopted for the estimation of different water quality parameters under study, which is given in the forthcoming paragraph under Methods.

**Plasticware and glassware**

The plasticware employed were made of high quality temperature resistant and scratch proof materials. The materials used were also odour free. Glassware used were made of alkali and temperature resistant material (Corning/Borosil make).

**Equipment**

Equipment used for the analytical work include:

(i) High volume samplers (Envirotech, APM415) with gas monitoring kits
(ii) Visible spectrophotometer (Systronics)
(iii) BOD Incubator (Gambaks-106)
(iv) High precision (0.001 gms) Anamed monopan weighing balance
(v) Whatman (FIA) glass fibre filter papers.

**Analytical methods**

Many methods exist for the sampling and analysis of ambient particulates and gases. For sampling and analysis, internationally accepted methods as documented in the treatizes of APHA (1977), were
employed. Final concentrations were compared with the standards of air quality prescribed by regulatory agencies CPCB (Central Pollution Control Board) and Ministry Of Environment (MOEn), New Delhi, India. Other important factors taken into consideration were: range, sensitivity of the method, precision, accuracy, stability, interferences, feasibility and availability of infrastructure etc as enlisted in Table 1. Thus meticulous quality control was done to ensure the authenticity of the data.

**Estimation of suspended particulates (SPM)**

Air was drawn into a covered housing and through a filter by means of high volume air sampler to an average flow rate of 1.5 m³/min. This allowed collection of suspended particles having diameter of less than 100 micron on the glass fibre filter paper. The mass concentration (µ g/Nm³) of suspended particulates in the ambient air was computed by measuring the mass of collected particulates and the volume of air sampled.

**Estimation of nitrogen oxides (NOₓ)**

Oxides of nitrogen were collected by bubbling air at the rate of 1.5 litres/min through a sodium hydroxide solution to form a stable solution of sodium nitrate. The nitrate ion produced during sampling, was determined colorimetrically by reacting the exposed absorbing reagent with hydrogen peroxide, sulphanilamide, and N(1-naphthyl) ethylenediamine dihydrochloride (NEDA). A calibration curve for the above had already been prepared.

**Estimation of sulphur dioxide (SO₂)**

Sulphur dioxide from the air stream was absorbed in a sodium tetra-chloromercurate solution to form stable dichlorosulphitomercurate. The amount of sulphur dioxide was then estimated by the colour produced when P-rosaniline hydrochloride was added to the solution. The colour was estimated by reading from a spectrophotometer for which a calibration curve had already been prepared.

**Estimation of chlorine (Clₓ)**

Sampling was performed by passing a measured volume of air through a fritted bubbler containing 35 ml of dilute methyl orange. Near a pH of 3.0, the colour of the solution ceased to vary with acidity. The dye was quantitatively bleached by free chlorine and the extent of bleaching was determined colorimetrically. A calibration curve with the blank was prepared earlier.

**Estimation of hydrogen sulphide (HₓS)**

Hydrogen sulphide in air was collected in a buffer containing 25 ml of cadmium sulphate solution at the rate of 1.5 litres per minute for 20 to 60 minutes. Hydrogen sulphide present in air produces a precipitate of cadmium sulphide at high concentrations. The gas, after acidification of the precipitate was determined iodometrically.

**Estimation of sulphuric acid mist in air (HₓSO₄)**

Sulphuric acid mist in air was absorbed in 10 to 15 ml of water in an impinger. The sulphate in the sample solution was precipitated as barium sulphate and the turbidity of the suspension was measured spectrophotometrically. A calibration curve for the above process was prepared earlier.
### Table 1. Criteria Used for the Methods Chosen

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th>Method Chosen</th>
<th>Range &amp; Sensitivity</th>
<th>Precision/Accuracy Stability</th>
<th>Interferences</th>
<th>feasibility</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Particulates</td>
<td>Gravimetric</td>
<td>1 µg/m³ to very high concentration (dependent on flow rate and average timing).</td>
<td>Repeatability 3%</td>
<td>Particulate matter that is oily, photochemical smog, wood smoke block, dense fog, high humidity, reduce air flow.</td>
<td>Feasible</td>
<td>ISI approved</td>
</tr>
<tr>
<td>2.</td>
<td>NO₂</td>
<td>Colorimetric</td>
<td>0.01-1.5 µg NO₂/ml with 59 ml of reagent and rate of 200 ml/min. for 24 hrs.</td>
<td>SO₂ interference eliminated by converting it to H₂SO₄ with H₂O₂ before analysis.</td>
<td>Feasible</td>
<td>ISI approved</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>SO₄ (Sodium Tetra chloromercurate method)</td>
<td>Colorimetric</td>
<td>Method applicable below 26 µg/m³ if absorption efficiency of particular system is known (usually 0.35%). Beer’s Law is followed through range of 0.1 to 1 OD units (i.e. 0 to 35 µg in 25 ml of final solution).</td>
<td>O₂ and NO₂ interference are removed by adding sulphuric acid. Heavy metal (especially Fe) interference is removed by adding Na salt of EDTA.</td>
<td>Feasible</td>
<td>ISI approved</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>H₂S</td>
<td>Iodometric (Titration)</td>
<td>1 ppm (or as little as 0.035 mg H₂S in 24 l of air can be determined)</td>
<td>Hydrogen selenide interference. Carbon disulphide does not.</td>
<td>Feasible</td>
<td>ISI approved</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>H₂SO₄ mist in air</td>
<td>Turbidimetric</td>
<td>lower limit is 0.1 mg/m³ (1000 µg/NM³) in 100 litre sample of air to 4 mg/m³ (4000 µg/m³) or as low as 10 µg in 10 ml absorbing solution. Values exceeding 0.4 mg in 100 ml of sampling solution may lose stability.</td>
<td>Coloured or suspended matter in large concentration will interfere. Silica in above 800 mg/l of sample solution will interfere. Organic materials, sulphate salts.</td>
<td>Feasible</td>
<td>ISI approved</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Cl₂</td>
<td>Colorimetric</td>
<td>5-1000 µg/100 ml of sampling solution (i.e. for 30 l air sample, range is 0.05 - 1 ppm) Increase of volume of air will extend range at lower end but within limits. Using Dilute sampling solution concentration of 1 µg/100 ml may be measured</td>
<td>26 chlorine concentration produced 26 times by two different methods were measured by this procedure with an average error of less than ± 5% of the amount present.</td>
<td>Free bromine, and magnesium (III, IV) in concentration of 0.1 ppm or above interfere. In solution, negative interference from SO₂ is significant, NO₂ interferes positively. Ozone may interfere positively.</td>
<td>Feasible</td>
<td>ISI approved</td>
</tr>
</tbody>
</table>
STUDIES ON THE WATER ENVIRONMENT

The basic approach to water quality characterisation studies is methodical planning and reconnaissance surveys of the area under study. The observations made during the course of these visits formed the substratum on which the entire methodology was based right from where, when, how much to sample down to how to analyse the samples.

The entire procedure of sampling site selection, sample collection, preservation and analytical techniques used for this quality characterisation studies are described below.

**Selection of sampling stations**

Sampling stations were selected depending on the following criteria:

(i) **Location**

Water resources near industries and effluent channels were taken to find out the possible contamination due to the industry. On the same time, ground water near solid waste dumps were sampled to ascertain the extent of leaching.

(ii) **Usage**

Water, which is used to a large extent, is sampled to assess its quality. Discarded wells and hand-pumps were also tested to determine the cause for the degraded water quality.

(iii) **Visual observation**

Obviously polluted, viz odoured / coloured surface water as well as ground water bodies were sampled for chemical analysis.

(iv) **Distance from the coast**

Distance from the sea was used as a reference point to assess the extent of salt water intrusion.

Based on the above criteria, thirteen representative sampling locations were selected in the study area (Figure 8). Typical of these sampling sites are shown in Plate 1. One control location was also selected. This was at Bahour (a nearby village to the study area and identical in its setting to the study area but free from the impact of industrial pollution). The land-use map also proved to be very useful for this. Samples were collected from these sites during April, May, June, October ’94 and January ’95 and analysed for the various characterisation tests. Overall some 830 analyses were performed on 60 samples.

**Selection of parameters**

Parameters to be estimated were selected depending on the use to which the water body (from where the sample had been collected) was being put to. This was done based on the guidelines laid down in IS:2296. The parameters studied include pH, Electrical conductivity, suspended solids, total suspended solids, acidity, alkalinity, hardness, chloride, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, sulphates, nitrogen, cadmium, mercury, iron, zinc and manganese.

**Sampling and preservation**

Grab samples were collected from the selected sampling stations so as to ensure representativeness of the sample in time and space, in suitable containers. Adequate care was taken for the preservation
8. Location of water quality monitoring stations: Site numbers 1 - 7 are for ground water and site numbers 8 - 13 for surface water
Plate 1. Two of the water sampling sites - results indicate that due to pollution the water is no longer as good as it looks
of the samples for those parameters which could not be analysed immediately (Table 2). This entire procedure was done in accordance with IS: 2488.

**Selection of method**

Methods were selected based on:

1. Concentration range
2. Accuracy and precision
3. Sensitivity of the method
4. Selectivity
5. Interferences
6. Time and
7. Availability of resources in the form of chemicals and glassware.

Sensitivities of the methods selected for analysis and ICP precision and bias data for the metal analysis are given in Tables 3 and 4 respectively.

**Materials**

The materials used for various analytical purpose were as follows.

**Reagents**

All reagents were analytical grade and had an assay of more than 95% unless otherwise mentioned. Deionized and doubly distilled water were used for all analytical work.

**Plasticware and glassware**

The plasticware employed were made of temperature and scratch resistant, as well as odour-free material. Alkaline and temperature-resistant Corning and Borosil glassware were used for estimation purposes.

**Equipment**

The following equipment were used for all the analytical work.

1. Anamed make - top pan electronic balance model M 7000, capacity 100 gm, sensitivity 0.001mg
2. Heating mantle - Concord Indian make with one litre capacity.
3. pH meter - systronic model 335
4. Conductivity meter - systronic model 305
5. Magnetic stirrer - Remi 2 MLH
6. Oven - Hemco Indian make with 30°C - 250°C
7. Spectrophotometer - systronic make - model No 106
8. Gambaks BOD incubator - Indian make with temperature controller 0 - 50°C ± 1°C
9. APR 3410 ICP with Minitorch
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameter</th>
<th>Recommended Sample volume</th>
<th>Type of Container</th>
<th>Preservation</th>
<th>Allowable holding periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Acidity</td>
<td>100ml</td>
<td>P,G</td>
<td>4°C Refrigeration</td>
<td>24 hrs</td>
</tr>
<tr>
<td>2.</td>
<td>Alkalinity</td>
<td>100ml</td>
<td>P,G</td>
<td>4°C Refrigeration</td>
<td>24 hrs</td>
</tr>
<tr>
<td>3.</td>
<td>BOD</td>
<td>100ml</td>
<td>P,G</td>
<td>4°C Refrigeration</td>
<td>6 hrs</td>
</tr>
<tr>
<td>4.</td>
<td>COD</td>
<td>50ml</td>
<td>P,G</td>
<td>2ml H₂SO₄ per litre</td>
<td>7 days</td>
</tr>
<tr>
<td>5.</td>
<td>Chloride</td>
<td>50ml</td>
<td>P,G</td>
<td>Not required</td>
<td>7 days</td>
</tr>
<tr>
<td>6.</td>
<td>DO: Winkler</td>
<td>300ml</td>
<td>G</td>
<td>Fix on site</td>
<td>6 hrs</td>
</tr>
<tr>
<td>7.</td>
<td>Hardness</td>
<td>100ml</td>
<td>P,G</td>
<td>4°C Refrigeration</td>
<td>7 days</td>
</tr>
<tr>
<td>8.</td>
<td>Kjeldhal Nitrogen</td>
<td>500ml</td>
<td>P,G</td>
<td>40mg HgCl₂ per litre</td>
<td>unstable</td>
</tr>
<tr>
<td>9.</td>
<td>pH</td>
<td>100ml</td>
<td>P,G</td>
<td>Determine on site</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Phosphorous</td>
<td>100ml</td>
<td>G</td>
<td>40mg HgCl₂ 1 - 4°C Refrigeration</td>
<td>7 days</td>
</tr>
<tr>
<td>11.</td>
<td>Electrical conductivity</td>
<td>100ml</td>
<td>P,G</td>
<td>4°C Refrigeration</td>
<td>24 hrs</td>
</tr>
<tr>
<td>12.</td>
<td>Solids (TS, TDS &amp; TSS)</td>
<td>100ml</td>
<td>P,G</td>
<td>4°C Refrigeration</td>
<td>24 hrs</td>
</tr>
<tr>
<td>13.</td>
<td>Sulphate</td>
<td>50ml</td>
<td>P,G</td>
<td>4°C Refrigeration</td>
<td>7 days</td>
</tr>
<tr>
<td>14.</td>
<td>Heavy Metals</td>
<td>200ml</td>
<td>P,G</td>
<td>HNO₃, 5ml litre pH = 2</td>
<td>6 months</td>
</tr>
</tbody>
</table>

Where, P = Plastic, G = Glass
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameter</th>
<th>Method Used</th>
<th>Relative Standard Deviation</th>
<th>Relative Error (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>pH</td>
<td>Electrometric</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2.</td>
<td>EC</td>
<td>Laboratory</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3.</td>
<td>Acidity</td>
<td>Titration</td>
<td>1.8 mgCaCO₃/l</td>
<td>—</td>
</tr>
<tr>
<td>4.</td>
<td>Alkalinity</td>
<td>Titration</td>
<td>1.0 mgCaCO₃/l</td>
<td>—</td>
</tr>
<tr>
<td>5.</td>
<td>Chloride</td>
<td>Argentometric</td>
<td>4.2%</td>
<td>1.7%</td>
</tr>
<tr>
<td>6.</td>
<td>Hardness</td>
<td>EDTA-Titrimetric</td>
<td>2.9%</td>
<td>0.8%</td>
</tr>
<tr>
<td>7.</td>
<td>Salinity</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>8.</td>
<td>Phosphorous</td>
<td>Stannous Chloride</td>
<td>7.6%</td>
<td>4.3%</td>
</tr>
<tr>
<td>9.</td>
<td>Nitrogen</td>
<td>Macro-Kjeldahl</td>
<td>0.04%</td>
<td>70%</td>
</tr>
<tr>
<td>10.</td>
<td>Dissolved Oxygen</td>
<td>Azide Modification</td>
<td>60 μg/l</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Iodometric</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>BOD</td>
<td>5 day test</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>12.</td>
<td>COD</td>
<td>Closed Reflux</td>
<td>±13 mg/l</td>
<td>—</td>
</tr>
<tr>
<td>13.</td>
<td>Sulphate</td>
<td>Turbimetric</td>
<td>0.13 mg/l</td>
<td>—</td>
</tr>
<tr>
<td>14.</td>
<td>Heavy Metals</td>
<td>Inductively coupled</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plasma Technique</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element</td>
<td>Concentration Range μg/l</td>
<td>Total Digestion* μg/l</td>
<td>Recoverable Digestion* μg/l</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------</td>
<td>-----------------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>69 - 1887</td>
<td>X = 1.0437 X - 12.2</td>
<td>X = 1.0175 C + 3.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S = 0.1239 X + 2.4</td>
<td>S = 0.1288 X + 6.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SR = 0.0874 X + 6.4</td>
<td>SR = 0.0643 X + 10.3</td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>17 - 47170</td>
<td>X = 0.9182 C - 2.6</td>
<td>X = 0.9658 C + 0.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S = 0.1228 X + 10.1</td>
<td>S = 0.0917 X + 6.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SR = 0.0189 X + 3.7</td>
<td>SR = 0.0327 X + 10.1</td>
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</tr>
<tr>
<td>Mercury</td>
<td>13 - 1406</td>
<td>X = 0.9544 C + 3.1</td>
<td>X = 1.0049 C - 1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S = 0.0499 X + 4.4</td>
<td>S = 0.0698 X + 2.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SR = 0.0009 X + 7.9</td>
<td>SR = 0.0571 X + 1.0</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>13 - 9359</td>
<td>X = 0.8829 C + 7.9</td>
<td>X = 0.9830 C + 5.7</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>S = 0.0683 X + 11.5</td>
<td>S = 0.1024 X + 13.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SR = -0.0046 X + 10.0</td>
<td>SR = 0.0790 X + 11.5</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>42 - 4717</td>
<td>X = 0.9699 C - 2.2</td>
<td>X = 1.0056 C + 4.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S = 0.0558 X + 7.0</td>
<td>S = 0.0799 X + 4.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SR = 0.0353 X + 3.6</td>
<td>SR = 0.0448 X + 3.5</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>17 - 47170</td>
<td>X = 0.9508 C + 0.4</td>
<td>X = 0.9869 C + 1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S = 0.0604 X + 4.4</td>
<td>S = 0.0526 X + 5.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SR = 0.0425 X + 3.6</td>
<td>SR = 0.0393 X + 2.2</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>7 - 7076</td>
<td>X = 0.9356 C - 0.30</td>
<td>X = 0.9500 C + 1.22</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>S = 0.0914 X + 3.75</td>
<td>S = 0.0597 X + 6.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SR = -0.0130 X + 10.07</td>
<td>SR = 0.0153 X + 7.78</td>
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</tr>
</tbody>
</table>

X = mean recovery, μg/l  
C = true value, μg/l  
S = multi-laboratory standard deviation, μg/l  
SR = Single analyst standard deviation, μg/l
Estimation of electrical conductivity (EC)

Conductometrically, temperature compensation was done during calibration the conductivity meter.

Estimation of electrical conductivity (EC)

Conductometry was done during calibration the pH meter in water: was measured by the pH meter. Since pH depends greatly on temperature, temperature compensation was done. The difference of the glass electrode was composed with the glass electrode and the difference.

Ph was estimated potentiometrically using a pH meter involving a glass electrode and a reference electrode.

Analytical methods

EPIC (Evolutionary Program for Instrument Control); Self

Software: PC-DOS V-3.0

Computer

IBM/PS2 Model 30

Spray chamber

Conical 45 c, all glass demountable impact sphere.

Lipase free

2-4 ml sample/min.

RF Generator

27.12 MHz, 750 Watts output

Plane Temperature

11,000 K

Case purity

99.6% Alumina Gas

Calculation accuracy

± 0.25 ppm

Precision

Relative standard deviation 2%

Sensitivity

189 ± 800 pm

Resolution

± 0.013 mm

Specifics
solids.

Care was taken to exclude large sample sizes to prevent formation of water-entrapping crust on the filter paper due to excessive residue.

**Estimation of total dissolved solids**

This too was estimated gravimetrically. A well mixed sample was filtered through a standard glass fibre filter paper and the filtrate was evaporated to dryness in a pre-weighed porcelain dish and dried to constant weight at 180°C. The increase in dish weight represented the total dissolved solids.

Care was taken to exclude large sample sizes to prevent formation of water-entrapping crust on the filter paper due to excessive residue.

**Estimation of acidity**

This was estimated by volumetric method using acid-base titration, where the sample was titrated against a strong base, generally, sodium hydroxide (NaOH). The amount of base used to raise the pH of the sample to designated levels was taken as a measure of acidity of the sample.

Indicator titrations with coloured or turbid samples was avoided. On such cases, acidity was estimated potentiometrically.

**Estimation of alkalinity**

This was estimated by volumetric method using acid-base titration, where the sample was titrated against a strong mineral acid, generally hydrochloric acid (HCl). The amount of acid used to raise the pH of the sample to designated levels, was taken as a measure of alkalinity of the sample.

Indicator titrations with coloured or turbid samples was avoided. In such cases, alkalinity was estimated potentiometrically.

**Estimation of hardness**

Hardness was estimated by complexometric titration method, where the sample was titrated against di-sodium salt of EDTA with suitable metallochromic indicators like calmagite.

Heavy metal ions which interfere during hardness estimation was inhibited using sodium sulphide (Na₂S). Organic matter interference was also removed by drying the sample and then heating in muffle furnace.

**Estimation of chloride (Cl⁻)**

Chloride was estimated through argentometric precipitation titration of neutral or slightly alkaline samples against standard silver nitrate solution. On highly coloured samples, where the endpoint could not be identified easily, aluminium hydroxide (Al(OH)₃) was added and this mixed solution was allowed to settle and then filtered. This filtrate was then used for further estimation.

**Estimation of dissolved oxygen (DO)**

DO was estimated by Winkler's iodometric method based upon redox reaction of manganese salt. It was reacted in the presence of oxygen with potassium iodide and the liberated iodine was titrated against standard sodium thio-sulphate (Na₂S₂O₃). In order to remove the effect of interfering materials, the azide modification of the Winkler's method was used.
Estimation of biochemical oxygen demand (BOD)
The 5 Day BOD test consisted of filling with sample, to overflowing, an air-tight 300 ml BOD bottle and incubating it at 25°C for 5 days. The dissolved oxygen was measured initially and also after incubation. The BOD was computed from the difference between initial and final DO.

Estimation of chemical oxygen demand (COD)
COD was estimated through dichromate closed reflux method. This was preferred over procedures using other oxidants because of superior oxidizing ability, applicability over a wide range of samples and ease of manipulation. The sample was refluxed in strong acid solution with a known excess of K₂Cr₂O₇. After digestion, the remaining unreduced K₂Cr₂O₇ was titrated with FAS to determine the amount of K₂Cr₂O₇ consumed and the COD was calculated in terms of oxygen equivalent.

Estimation of sulphates (SO₄)
Sulphate in samples was estimated by turbidimetric method, where sulphate ion was precipitated in an acetic acid medium with barium chloride (BaCl₂) to form barium sulphate (BaSO₄) crystals. The light absorbance of the (BaSO₄) suspension was measured by a spectrophotometer at 420 nm and the sulphate ion concentration was then determined by comparing the reading with a standard curve.

Estimation of nitrogen (Total Kjeldahl - N)
Organic nitrogen was estimated by macro-Kjeldahl method. Amino-nitrogen, ammonia, ammonium nitrogen of many organic materials was converted to ammonium sulphate in the presence of H₂SO₄. HgSO₄ was then digested forming a mercury ammonium complex and then decomposed by Na₂S₂O₃. After decomposition the ammonia was distilled from an alkaline medium and absorbed in indicating boric acid, from where it was determined by titration with 0.02 N H₂SO₄.

Heavy metal analysis
Samples in which heavy metals were to be analysed were first subjected to preliminary digestion, with nitric acid. The digested sample is then used for heavy metal estimation by inductively coupled plasma method.

Correlation co-efficient analysis
Multivariate linear regression between various components of ground water and surface water were done by using computer software - Lotus 1-2-3.

STUDIES ON LAND ENVIRONMENT
Studies on the land environment to assess the impact on land-use, especially agriculture as well as the impact of solid waste dumps were done as follows

The impact on land-use, especially agriculture
The impact on land-use especially on agriculture was studied by a visual survey of the agricultural fields and by interviewing a large number of farmers in Pillayarkuppam-Kirumampakkam area. The findings were compared with similar survey done in the control area (Bahour). This area is typically similar to the study area in their topography, soil type, climate and other environmental conditions but otherwise free from any industrial pollution. The following agricultural data for the
past 10 years were collected.

i) land under cultivation of food-crops and non-food crops

ii) total area under irrigated non-food crops

iii) total fallow lands

iv) land under non-agricultural use

v) land available for miscellaneous trees.

These informations were collected from the Department of Agriculture, Government of Pondicherry, India.

Impact of solid waste dumps

To assess the impact of solid wastes, samples were randomly collected from different dumping sites (Public Place) and their leachates were studied in detail. Short-term leachate (30 minutes after the waste was wetted with water) as well as long-term leachate (24 hours after wetting) were analyzed. The key indicative parameters pH, EC, hardness, alkalinity and toxic metals were estimated. These parameters were analyzed following the latest standard methods (APHA, 1992), described in this chapter under water environment.