3.1 Collection and storage of samples:

Water samples collected in this work were of integrated type. Several samples were collected by grab method in and around the sampling point and then mixed together. Samples were collected mainly from tube wells, ring wells, supply waters and river. In each set, samples were collected from the same location of the site as far as possible.

Water samples were collected in pre-cleaned plastic containers for various physico-chemical analysis. The containers were first cleaned with detergent then with chromic acid solution, rinsed with distilled water several times and dried thoroughly. For bacteriological analysis, water samples were collected in pre-sterilised glass bottles of 300ml capacity. The containers in all cases were filled as much as possible and tightly stoppered to avoid contact with air, or to prevent agitation during transport.

Storage and preservation of samples were done following standard procedure (APHA, 1995). Parameters like pH, conductivity and turbidity were measured immediately after collection. DO and temperature were determined at the time of collection itself. Other parameters were determined as quickly as possible. For estimating metals, samples after collection, were acidified with nitric acid to pH 2.0 and then kept at ~ 4°C in a refrigerator. The analysis was carried out within three months. The microbiological analysis of the water samples were carried out immediately after sample collection to prevent death of micro-organisms.
3.2 Sampling sources:

After a careful study of the topography and other aspects of the Lakhimpur district, water samples were collected from forty sampling stations distributed over twenty locations in the Lakhimpur district (Map: 5).

![Map- 5: Locations of sampling sites](image)

Out of these forty samples, twenty samples are taken from tube wells, fifteen samples from ring wells and four samples from public water supply point and one sample from river in each season. All the tube wells are shallow in depth (6m-10m) as the water level is very high in the whole district. Of these forty sampling stations, twenty nine sampling stations were from North Lakhimpur sub-division and eleven from Dhakuakhana sub-division. The names of these forty sampling stations are given in Table 3.1.
Table 3.1: Location of sampling stations

<table>
<thead>
<tr>
<th>Location number</th>
<th>Name of location</th>
<th>Sampling point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. (a)</td>
<td>North Lakhimpur (TW)</td>
<td>1</td>
</tr>
<tr>
<td>(b)</td>
<td>North Lakhimpur (RW)</td>
<td>2</td>
</tr>
<tr>
<td>(c)</td>
<td>North Lakhimpur (PWS)</td>
<td>3</td>
</tr>
<tr>
<td>2. (a)</td>
<td>Panigaon (TW)</td>
<td>4</td>
</tr>
<tr>
<td>(b)</td>
<td>Panigaon (RW)</td>
<td>5</td>
</tr>
<tr>
<td>(c)</td>
<td>Panigaon (PWS)</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Khabalu (TW)</td>
<td>7</td>
</tr>
<tr>
<td>4. (a)</td>
<td>Dhalpur (TW)</td>
<td>8</td>
</tr>
<tr>
<td>(b)</td>
<td>Dhalpur (RW)</td>
<td>9</td>
</tr>
<tr>
<td>(c)</td>
<td>Dhalpur (PWS)</td>
<td>10</td>
</tr>
<tr>
<td>5. (a)</td>
<td>Banderdewa (TW)</td>
<td>11</td>
</tr>
<tr>
<td>(b)</td>
<td>Banderdewa (RW)</td>
<td>12</td>
</tr>
<tr>
<td>6. (a)</td>
<td>Bihpuria (TW)</td>
<td>13</td>
</tr>
<tr>
<td>(b)</td>
<td>Bihpuria (RW)</td>
<td>14</td>
</tr>
<tr>
<td>7. (a)</td>
<td>Badati (TW)</td>
<td>15</td>
</tr>
<tr>
<td>(b)</td>
<td>Badati (RW)</td>
<td>16</td>
</tr>
<tr>
<td>(c)</td>
<td>Badati (PWS)</td>
<td>17</td>
</tr>
<tr>
<td>8. (a)</td>
<td>Islampur (TW)</td>
<td>18</td>
</tr>
<tr>
<td>(b)</td>
<td>Islampur (RW)</td>
<td>19</td>
</tr>
<tr>
<td>9. (a)</td>
<td>Dejoo (TW)</td>
<td>20</td>
</tr>
<tr>
<td>(b)</td>
<td>Dejoo (RW)</td>
<td>21</td>
</tr>
<tr>
<td>10. (a)</td>
<td>Kadam (TW)</td>
<td>22</td>
</tr>
<tr>
<td>(b)</td>
<td>Kadam (RW)</td>
<td>23</td>
</tr>
<tr>
<td>11. (a)</td>
<td>Chauldhuwa (TW)</td>
<td>24</td>
</tr>
<tr>
<td>(b)</td>
<td>Chauldhuwa (RW)</td>
<td>25</td>
</tr>
<tr>
<td>(c)</td>
<td>Chauldhuwa (River Subansiri)</td>
<td>26</td>
</tr>
<tr>
<td>12. (a)</td>
<td>Pathalipam (TW)</td>
<td>27</td>
</tr>
<tr>
<td>(b)</td>
<td>Pathalipam (RW)</td>
<td>28</td>
</tr>
<tr>
<td>13.</td>
<td>Dulungmukh (TW)</td>
<td>29</td>
</tr>
<tr>
<td>14. (a)</td>
<td>Dhakuakhana (TW)</td>
<td>30</td>
</tr>
<tr>
<td>(b)</td>
<td>Dhakuakhana (RW)</td>
<td>31</td>
</tr>
<tr>
<td>15. (a)</td>
<td>Bebejia (TW)</td>
<td>32</td>
</tr>
</tbody>
</table>
The approximate locations of these sampling sources are shown in Map- 5.

A brief description of these sampling points is given below.

(a) North Lakhimpur:

It is the Headquarter of the Lakhimpur district. The main road communication of northern Assam NH-52 passes through the town. According to 2001 census report, the total population of the town was 54,285. The town covers a total area of 13.74 sqkm. The people of this area use tube wells, ring wells and public water supply facility as the source of drinking water. Therefore samples were collected from tube well at K.B.Road, ring well at town Bantow and public water supply point at Chapari gaon.

(b) Panigaon:

Panigaon is a densely populated village about 11 km south of North Lakhimpur town. The Kamalabari Road leading to Majuli island passes through it. Tube well, ring well and public water supply facilities are the common source of drinking water in this area. So water samples were collected from a public ring well near Panigaon Namghar, tube well inside the Panigaon hospital campus and public water supply point at Panigaon charali.
(c). Khabalu:

Khabalu is situated on the bank of river Luit. It is a big village inhabited by ST (P) community. The village is about 22 km south of North Lakhimpur town in the Kamalabari road. The people of this village use tube well as the source of drinking water. Therefore samples were collected from tube well only.

(d). Dhalpur:

Dhalpur is a densely populated area, 60 km west of North Lakhimpur town and on the side of NH-52. It is only 4 km east of Sonitpur district border. The people of this area use tube well, ring well and public water supply facilities as the source of drinking water. Therefore water samples were collected from a highway “Dhaba” tube well, ring well near Dhalpur bazar and public water supply facilities near the Dhalpur thana.

(e). Banderdewa:

It is gateway of Itanagar, the capital town of Arunachal Pradesh. It is situated 34 km west of North Lakhimpur town in NH–52. It is surrounded by river Dikrong on one side and the other side by foothills of Arunachal Pradesh. A large number of commercial establishments are seen in this area. People of this area use water for drinking from ring well and tube well. So water samples were collected from ring well near Shivmandir and from tube well of a hotel.

(f). Bihpuria:

Bihpuria is a town situated 38 km west of North Lakhimpur town. The population of Bihpuria town is 10,868 as per 2001 census having a total area of 5.36sq.km.
Commonly used sources of drinking water in this area are ring well and tube well. Water samples were collected from the tube well of “Amrit Hotel” situated at the center of Bihpuria town and the ring well at Lohit Dikrong Higher Secondary School which is used by the school student.

(g). Badati:

It is situated 8 km south of Bihpuria town on the bank of river Dikrong and Luit. Water samples were collected from a public ring well, tube well at Badati Jamuguri village and a Public water supply facility near Badati Tinali.

(h). Islampur:

It is 4 km west of Laluk on Laluk Bihpuria road. The people of this area are largely from religious minority community. Water samples were collected from the tube well (Tara pump) which is used by many families of the locality and from a private ring well.

(i). Dejoo:

It is 18 km away from North Lakhimpur town at Pahumara Kimin road. It is nearer to Dejoo tea estate. A sizeable number of inhabitants of this area are ex-tea garden labourers of Dejoo tea estate. Drinking water samples were collected from tube well used by school students of Dejoo L.P. school and ring well of a small tea stall near Dejoo bazar.

(j). Kadam:

It is 9 km east of North Lakhimpur town and situated near NH-52. One ST (P) village was selected for collection of drinking water samples. The samples were collected from both tube well and ring well. The ring well is used by many families of the village and the tube well was selected from a private house.
(k). Chauldhuwa:

It is situated on the western side of river Subansiri and 32 km east of North Lakhimpur town. There are few roadside Dhabas in the area and river water is mostly used in the Dhabas for drinking and other purposes. So, drinking water samples were collected from river Subansiri. Also, samples from ring well inside Chauldhuwa hospital campus and tube well in the village were collected.

(l). Pathalipam:

Pathalipam is 25 km east of North Lakhimpur town on NH~52 near Ananda tea estate. The area is inhabited by various communities including tea garden labourers. Water samples were collected from a ring well provided by tea garden for use of labourers and tube well near Pathalipam Post Office.

(m). Dulungmukh:

It is a remote area on the bank of river Subansiri near foothills of Arunachal Pradesh. People of Dulungmukh use tube well and Subansiri river water as the source of drinking water. Since river water of Subansiri was collected from Chauldhuwa, only tube well water was collected from Dulungmukh.

(n). Dhakuakhana:

It is the sub-divisional headquarter and 80 km south-east of North Lakhimpur town. Dhakuakhana is a densely populated area and it was notified as a town by the Govt. of Assam on 4th December 2003. It has a total area of 13.78 square km. with a population of 11,209. Drinking water samples were collected from tube well of Baligaon and ring well of Kachugaon.
(o). Bebejia:

It is situated 12 km west of Dhakuakhana. The famous Basudev Satra is situated near Bebejia. Samples were collected from both tube well and ring well.

(p). Ghilamara:

It is 20 km north of Dhakuakhana. Drinking water samples were collected from tube well of Ghilamara hospital campus and ring well at Raidongia.

(q). Matmora:

It is 8 km east of Dhakuakhana on the bank of river Brahmaputra. The village is inhabited by ST (P) community. Most of the people of this area use tube well as the source of drinking water so samples were collected from tube well only.

(r). Kekuri:

It is situated 20 km south west of Dhakuakhana. People of this area mainly use tube well as their source of drinking water, hence samples were collected from tube well.

(s). Bilmukh:

It is situated 32 km north west of Dhakuakhana. Bilmukh has a bird observatory center in its large wetland. Commonly used source of drinking water in this area is tube well. Samples were collected from the tube well of Ujani Subansiri Miri High school.

(t). Gobinpur:

Gobinpur is situated 8 km north east of Dhakukhana. Water samples were collected from tube well of Harhi Junior College and ring well of Gobinpur village.

Following plates (plate 1 to plate 40) show the different sampling points from which water samples were collected during the work.
Plate 1: Tube well at North Lakhimpur
Plate 2: Ring well at North Lakhimpur
Plate 3: PWS at North Lakhimpur
Plate 4: Tube well at Panigaon
Plate 5: Ring well at Panigaon
Plate 6: PWS at Panigaon
Plate 7: Tube well at Khabalu
Plate 8: Tube well at Dhalpur
Plate 17: PWS at Badati
Plate 18: Tube well at Islampur
Plate 19: Ring well at Islampur
Plate 20: Tube well at Dejoo
Plate 21: Ring well at Dejoo
Plate 22: Tube well at Kadam
Plate 23: Ring well at Kadam
Plate 24: Tube well at Chaulduwa
Plate 25: Ring well at Chauldhuwa
Plate 26: River Subansiri at Chauldhuwa
Plate 27: Tube well at Pathalipam
Plate 28: Ring well at Pathalipam
Plate 29: Tube well at Dulungmukh
Plate 30: Tube well at Dhakuakhana
Plate 31: Ring well at Dhakuakhana
Plate 32: Tube well at Bebejia
Plate 33: Ring well at Bebejia
Plate 34: Tube well at Ghilamara
Plate 35: Ring well at Ghilamara
Plate 36: Tube well at Matmora
Plate 37: Tube well at Kekuri
Plate 38: Tube well at Bilmukh
Plate 39: Tube well at Gobinpur
Plate 40: Ring well at Gobinpur
3.3 Selection of sampling seasons:

After a careful study of the topography and other climatic factors for the district four sampling seasons in a year were selected for this work. These are

(I) Pre-monsoon (March to May)

(II) Monsoon (June to August)

(III) Post-monsoon (September to November)

(IV) Winter (December to February)

Water samples were collected one each in each season over a period of two years (June, 2005 to May, 2007). In this study eight seasons were covered as shown below:

A June 2005 -- August 2005
B September 2005 -- November 2005
C December 2005 -- February 2006
D March 2006 -- May 2006
A1 June 2006 -- August 2006
B1 September 2006 -- November 2006
C1 December 2006 -- February 2007
D1 March 2007 -- May 2007

3.4 Selection of parameters:

The present investigation is largely confined in monitoring water quality parameters. Although the numbers of such parameters can be very large and new parameters have found entry into the standard methodology in recent times, considering various factors such as availability of experimental facilities, the following parameters were selected for monitoring in this work.
(a) Aesthetic quality:

1. Temperature
2. Odour
3. Colour
4. Turbidity
5. Dissolved Oxygen (DO)
6. Total Hardness
7. Total Solid (TS)
8. Total Suspended Solid (TSS)
9. Total Dissolved Solid (TDS)
10. Conductance
11. pH
12. Chloride(Cl−)
13. Sulphate(SO₄²⁻)
14. Sodium(Na)
15. Potassium(K)
16. Calcium(Ca)
17. Magnesium(Mg)
18. Iron(Fe)
19. Copper(Cu)
20. Zinc(Zn)

(b) Inorganic constituents of significance to health:

1. Fluoride(F⁻)
2. Nitrate(NO₃⁻)
3. Lead (Pb)

5. Arsenic (As)

(c) Organic constituents: Biochemical Oxygen Demand (BOD)

(d) Microbiological quality:

Most Probable Number (MPN) of total coliform Organisms

3.5 The parameters and the methodology for their determination:

Water quality parameters and calibration of equipment were done carefully using standard methods (APHA, 1995). Possible contamination from containers, beakers, flasks etc. was avoided by taking adequate precautions. If several methods are available for a single parameter, the method chosen depended on the existing laboratory facilities, the ease of operation and also minimum interference by other parameters. In all cases, analytical grade reagents were used and all solutions were made in double distilled water. Stock standard solutions of metal were prepared by dissolving ultra pure metal / compound (99.99% pure) and borosil glass wares were used throughout this work.

Environmental significance of the parameters along with specific methodology followed for each parameter is given below.

3.5.1 Temperature:

Temperature influences physical, chemical and microbiological qualities of water. A rise in temperature of the water leads to the speeding up of the chemical reactions in water, reduces the solubility of gases and amplifies the taste and odour. Water in the temperature range of 7° C to 11° C has a pleasant taste and is refreshing. Temperature affects the coagulation properties of suspended impurities and therefore influences colour and turbidity of water (Camp T.R., 1963).
Disinfection of water is largely dependent on temperature and bacterial survival is very much influenced by it. It has been shown that both total and faecal coliform bacteria die more rapidly in the environment with increasing temperature. Temperature variation may be one of the factors responsible for seasonal variation of coliform organisms in water bodies.

The temperature of water body is usually lower than the surrounding air. There is a gradual decrease in the water temperature with the increase in depth. The temperature of a water body varies with climate, season and time of the day. If the temperature is above normal, the equilibrium between dissolved oxygen and atmospheric oxygen is effected and the dissolved oxygen content is reduced leading to total oxygen depletion and consequently to obnoxious septic condition. Increased temperature accelerates the biodegradation of organic material both in the overlying water and in bottom deposits, thus increasing demands on the dissolved oxygen resources of a given system.

Temperature is also very important in the determination of various other parameters such as pH, conductivity, saturation level of gases and various forms of alkalinity etc.

Temperature measurement of water was done immediately at the time of sample collection with a mercury thermometer.

3.5.2 Odour:

Water in its pure form does not have any odour. Odour in water can be due to natural or man-made causes. Natural causes may include the presence of decaying plants, algae and other organisms in the water body. Decomposition of organic matter liberates gases like ammonia, methane and hydrogen sulphide. These gases impart odour to water.
In addition, other organic and inorganic compounds give odour to water. These compounds may originate from municipal or industrial wastes or both. Some of the compounds include phenols, sulphides, halogens and metals such as copper and iron. Odour is undesirable in drinking water and in water used for food and pharmaceutical industries.

Sand and clay, when present in finely divided state produce a faint earthy taste and odour in water. Improper bituminous lining on water pipes gives a tarry odour to water passing through it. Excessive addition of bleaching powder and similar chemicals for disinfection gives an odour to water. In presence of dissolved organics, chlorination may result in formation of chlorophenols giving their distinctive odour.

In the present work, only a qualitative estimation of odour is attempted.

3.5.3 Colour:

Colour in natural waters occur due to the presence of humic acids, fulvic acids, metallic ions such as iron and manganese, suspended matter, phytoplankton and highly coloured industrial effluent etc. Ground water sometimes develops a reddish colour due to oxidation of Fe II to Fe III when iron precipitates out as the insoluble hydroxide which remains in suspension giving a reddish colour.

In most cases, colour is harmless to health but it interferes with the aesthetic qualities of water. Highly coloured, polluted water has an objectionable taste due to humic substances, originating from decay and aqueous extraction of vegetation into surface water.

Colour is an important factor in determining the suitability of water for purposes such as drinking, domestic and industrial use. In case of tube wells and ring wells due to rusting of the iron pipes and rods, a pale brown colour develops. True colour is the
colour by dissolved substances such as salts and colloidal particles like fine clay. Usually colour is determined without removing the suspended solids. This colour is called apparent colour. Almost all industrial effluents have colour and are also turbid. They impart colour to the receiving waters. The important industrial effluents which impart colour to water bodies are from the textile, leather, food, pulp and paper industries. The majority of these colours are synthetic and some of them are even harmful.

In the present work colour was observed visually.

3.5.4 Turbidity:

Turbidity is an expression of the optical property that causes light to scatter. It is the result of suspended particles in water. These particles can be in the form of clay, silt, organic matter, plankton and other micro-organisms. Under natural conditions, rivers, streams and lakes may be turbid during monsoons. This is due to the increased surface runoff which carries the topsoil from the catchment area to the water body. Ground water is less turbid than surface water because water gets filtered through layers of sand and soil. The land use pattern in the catchment area affects turbidity. Activities like washing and wading of cattle in shallow areas of water bodies can also cause turbidity. Turbidity can also be due to effluent discharge. Turbid water interferes with recreational use and aesthetic enjoyment of water. Turbid water can be dangerous for swimming. Turbidity interferes with light penetration, which in turn, reduces photosynthetic activity of plants, inhibits vision of aquatic animals etc. The degree of turbidity of a water course may be used as a measure of the intensity of pollution. EPA drinking water standards specify a maximum turbidity value of 1 N.T.U.

Turbidity values were measured immediately after sample collection with a turbidimeter (Elico, CL-52D). The instrument works on the basis of light scattering by
turbidity causing substances. The values were expressed in NTU (Nephelometric Turbidity Unit) after being calibrated with respect to a set of formazine suspensions of known turbidity.

3.5.5 Conductance:

Conductance itself is not a pollution indicator, but it reflects the degree of mineralization of water. Freshly prepared distilled water has a conductivity value of $0.5 \mu \text{Scm}^{-1}$ to $2.0 \mu \text{Scm}^{-1}$ which changes to $2 \mu \text{Scm}^{-1}$ to $4 \mu \text{Scm}^{-1}$ on standing due to absorption of atmosphere $\text{CO}_2$. Drinking water has conductivity in the range of 1500 $\mu \text{S/cm}$. Surface waters have less conductance than ground waters.

As most of the salts in the water are present in the ionic forms, capable of conducting current, therefore, conductivity is a good and rapid measure of the total dissolved solids. Total dissolved solid can be obtained roughly by multiplying the conductivity with a factor of 0.55 to 0.90 (APHA, 1985). Conductivity varies with temperature. Generally conductivity is reported at $25^0 \text{C}$.

Conductivity was measured using a digital conductivity meter (Elico, CM-180) which was calibrated before each measurement with 0.01 N KCl solution (conductivity 1287 $\mu \text{Scm}^{-1}$ at 298 K).

3.5.6 $p^H$:

$p^H$ is a measure of hydrogen ion activity, $(p^H = - \log_\text{a} \text{H}^+, \text{aH}^+ \text{ being the activity of hydrogen ions})$. It is used to express the intensity of acidic or alkaline condition of a solution.

The $p^H$ is an important water quality parameter measuring the acid-base equilibrium of dissolved components. The $p^H$ of natural water is controlled by the carbon
dioxide – bicarbonate – carbonate equilibrium system. Natural waters usually have $p^H$ between 6.5 to 8.5. $p^H$ of water gets drastically changed with time due to the exposure to air, biological activity and temperature changes (Trivedy & Goel). Significant changes in $p^H$ occur due to disposal of industrial wastes, acid mine drainage etc. Domestic sewage is generally alkaline while industrial wastes may be acidic or alkaline. Mine waters are usually acidic, with a $p^H$ that is less than 3 and when released untreated into water bodies, can decrease the $p^H$ of these water bodies drastically. Low $p^H$ causes corrosion of plant equipment and piping in the distribution system and increases the metal contamination of drinking water introducing metal ions such as copper, lead, zinc and cadmium. An increase in $p^H$ may increase the formation of trihalomethane during disinfection of water with chlorine (Payed and Tawabinni, 1991).

$p^H$ of water samples was determined immediately after the collection. The measurements were carried out using a digital $p^H$ meter (Elico, LI-127). Standard buffer solutions were used to calibrate the instrument at the time of measurement for every set of samples.

3.5.7 Total Hardness (TH):

Hardness is the property of water which prevents lather formation with soap and produces scale in hot water system. It is caused by polyvalent metallic ions particularly that of calcium and magnesium along with some contributions of other metals such as iron, manganese, barium and strontium, if present in appreciable amounts. Hardness is called temporary if it is caused by bicarbonate and carbonate salts of the cations. It can be removed simply by boiling the water. Permanent hardness is caused mainly by sulphates and chlorides of the metals. It can not be removed by simple boiling. In general practice, hardness is measured as the concentration of only calcium and magnesium ions.
(mg/L as CaCO₃) because these are far higher in concentration as compared to other cations (Sunil Kumar *et al.*, 1998). The principal sources of these two cations, calcium and magnesium, are sedimentary rocks, seepage, and runoff from soils. Ground water is harder than surface water because of higher solubilizing potential of ground water over surface water towards soils or rocks containing minerals calcite, dolomite and gypsum. Industrial sources of hardness are chemical and mining industries, building industries, pulp and paper production, sugar mills, petroleum refining, tanning, ceramics etc. Hard water is not suitable for bathing, washing and laundering. Hardness prevents the corrosion in the pipes by forming a thin layer of scale, and reduces the entry of heavy metal from the pipes to the water. The degree of hardness of drinking water has been classified in terms of its equivalent CaCO₃ concentration in the following way (APHA, 1995)

1. Soft : 0 – 60 mg/L
2. Moderately hard : 60 – 120 mg/L
3. Hard : 120 – 180 mg/L
4. Very hard : >180 mg/L

Magnesium hardness, when associated with sulphate ion particularly, imposes a laxative effect on unaccustomed persons (Abbasi, 1998). Hardness of 150-300 ppm and above may cause kidney problems (Jain, 1998). There is a strong statistical evidence of a correlation between increased hardness of drinking water up to about 175 mg/L and reduce incidence of some forms of heart disease (Tebbutt, 1998). According to WHO, the maximum permissible value of hardness for drinking water is 500 mg/L. The changes in hardness of consuming water may cause some physiological effects in man. A person who travels from soft water regions to hard water regions and vice-versa may feel minor physiological disturbances of the digestive system. These disturbances are due to change
in osmotic pressure at the intestinal blood and body fluids, of course the digestive disturbances are usually overcome after a short period of adjustment to the new water (Camp, 1963).

The total hardness of the water samples were determined by EDTA titrimetric method using Eriochrome Black T as an indicator. The expression for hardness is,

\[
\text{Total Hardness (as mg/L, CaCO}_3\text{) = } \frac{\text{ml of EDTA used x 1000}}{\text{ml of sample}}
\]

3.5.8 Total Solids (TS):

Total solids include both the dissolved and suspended solids. Silt, sand, clay and phytoplankton are all suspended solids. Dissolved solids include calcium ions, bicarbonates, chlorides, nitrates, phosphate, ferrous ions, sulphates, potassium, magnesium and other ions.

High concentrations of total solids increase water turbidity. This in turn decreases the light penetration and thus affects photosynthesis. Total solids absorb sunlight in greater proportions and thus increasing the temperature of water. They can enrich the nutrient status of water resulting in eutrophication (Sunil Kumar et al, 1998). Sometimes harmful, hazardous and lethal heavy metals are also found in the form of total solids which may be toxic to aquatic organisms.

Drinking water containing a high concentration of total solids can cause laxative effects in humans. Total solids in irrigation waters can induce the formation of saline and alkaline wastelands. On evaporation, the salts are left behind on the soil surface in the form of a thin crust or a fine powder.

Total solid was determined as the residue left after evaporation of the unfiltered sample. 50 ml of the unfiltered sample was taken in a pre-weighted borosil beaker and
evaporated carefully to dryness in a water bath. The residue and the beaker are kept in an oven at 103°C-105°C till a constant weight was obtained. TS is given by

$$TS (mg/L) = \frac{(W_2 - W_1) \times 1000}{V}$$

Where,

- $W_2$ = Final weight of the beaker and residue in gm
- $W_1$ = Initial weight of the beaker in gm
- $V$ = Volume of sample in ml

3.5.9 Total Dissolved Solid (TDS):

TDS consists of inorganic salts, some amounts of organic matters and dissolved materials. The principal inorganic anions dissolved in water, particularly in groundwater, are carbonates, chlorides, sulphates and nitrates and the cationic constituents of TDS are sodium, potassium, calcium and magnesium ions. The TDS may affect water quality adversely in various ways. Generally excessive dissolved solids may induce an unfavourable physiological reaction in the transient consumer and impart unpalatable mineral tastes to water. Further high TDS indicates that the water is highly mineralized which is, in turn, unsuitable, apart from potability, for many industrial applications. Excessive TDS destroys aquatic plants, thus adversely affecting fish and other aquatic life. Water with TDS content above 500 mg/L is not recommended for irrigation (Dierberg, 1991).

TDS was determined as the residue left after evaporation of a measured volume of the filtered sample. 50 ml of the filtered sample was evaporated to dryness in a pre-weighted borosil beaker in a water bath. The residue and the beaker were further dried in an oven at 103°C-105°C till a constant weight was obtained. The TDS is given by
TDS (mg/L) = \frac{(W_2 - W_1) \times 1000}{V}

Where, 
\( W_2 = \) Final weight of the beaker in gm
\( W_1 = \) Initial weight of the beaker in gm
\( V = \) Volume of the sample taken in ml

3.5.10 Total Suspended Solid (TSS):

The TSS is made up of particulate matter, both organic and inorganic. TSS constitutes particles of different sizes ranging from coarse to fine colloidal particles and impart turbidity of water. TSS shelters micro-organisms, reduces swimming efficiency of fishes and other aquatic life resulting in less growth and exposes aquatic life to micro-organisms (Gower, 1980). Large part of the TSS settles to the bed and in the process, damages invertebrate population, blocks spawning beds of fishes and reduces DO content. The inorganic and biological (Plankton) particulate matter affects light penetration into water, thereby resulting in a decline of primary production which cuts down food for fish (Joseph et al, 1984). If water with excessive TSS is used for irrigation, it leads to crust formation on top soil preventing water and air penetration (Joy et al, 1990).

TSS content of water samples was obtained by subtracting TDS from TS.

\[ TSS = TS - TDS \]

3.5.11 Dissolved Oxygen (DO):

Oxygen is essential to most forms of aquatic life. Dissolved oxygen (DO) in water affects the oxidation-reduction state of many other chemical compounds such as
nitrate and ammonia, sulphate- and sulphite, and ferrous and ferric ions. It is therefore, useful in self-purification.

The oxygen content of natural water varies with temperature, salinity, turbulence, the photosynthetic activity of algae and higher plants and the atmospheric pressure. Variations in the amount of DO can occur over a day. DO levels rise because of photosynthesis during the morning hours. Late in the afternoon, DO levels are the highest. As the Sun sets, photosynthesis stops. Plant and animal continue to consume oxygen through respiration. Also oxygen is used for the decomposition of organic matter in water. This reduces the DO level.

The main factor for depletion of DO in unpolluted waters is the build up of organic wastes of dead plants and animals. External sources of organic waste are sewage and industrial effluents and run-offs from agriculture fields and urban settlements. A rapid increase in algae such as during eutrophic conditions, can lead to depletion of DO. Most of the aquatic life can not survive if the DO content goes down below 5mg/L. DO also regulates the interactions between water and sediment and controls the leaching of metal ions from the soil. Excessive DO, on the other hand, makes the water corrosive.

DO was measured by Winkler's or iodometric method such that DO was allowed to react with iodide to form I$_2$ which was then titrated with standard sodium thiosulphate solution (0.025 N) adding Mn (II) salts in strongly alkaline medium. Interferences due to oxidizing agents such as NO$_2^-$ and SO$_3^{2-}$ were eliminated by addition of NaN$_3$ to alkaline iodide solution. The DO content is given by

$$\text{DO (mg/L)} = \frac{(\text{ml} \times N) \text{ of sodium thiosulphate} \times 8 \times 1000}{V_2 \times \left[ \frac{(V_1 - V)}{V_1} \right]}$$

Where,
$V_1 =$ Volume of sample bottle  
$V_2 =$ Volume of contents titrated  
$V =$ Volume of MnSO$_4$ and KI added

3.5.12 Biochemical Oxygen Demand (BOD):

BOD is a direct measure of the biodegradable part of the organic matter present in water. This usually consists of starch, fat, protein, alcohol, fatty acid, aldehyde and ester all of which are used as food by aquatic microorganisms. These organics enter water bodies through domestic or industrial waste water discharges or occur through microbial decomposition of plant and animal tissues.

BOD of water samples are measured by 5 days BOD test. For this 300 ml of water samples were taken in a BOD bottle and incubated it at 20°C for 5 days in a BOD incubator. The value is represented as BOD$_{20}$. DO is measured both before and after incubation. The pH of the water sample is also maintained at around 7.2 by means of a phosphate buffer. Calculations are expressed as

$$\text{BOD (mg/L)} = \frac{\text{DO}_f - \text{DO}_i}{P}$$

Where DO$_f$ and DO$_i$ are the final dissolved oxygen value and initial dissolved oxygen value respectively and P is the decimal volumetric fraction of dilution. An ALMICRO BOD incubator was used for incubation.

3.5.13 Chloride:

Chloride is a common constituent of all types of water. In natural freshwaters, however, its concentration remains quite low. Chloride in drinking water is relatively
harmless, if present in amounts below 250 mg/L. Chloride at higher concentration can damage metallic pipes and structures and hampers agricultural crops (Sunil Kumar et al, 1998).

Natural sources of chlorides in waters are the dissolution of salt deposits such as magnesium chloride, potassium chloride, sodium chloride and weathering of sedimentary rocks. Chlorides get added to water due to discharge of effluents from chemical industries, sewage discharges, irrigation drainage, contamination from refuge dump leaches, sea water intrusion in costal areas etc. Chloride content was determined by argentometric method. In this method, when a water sample is titrated against standard silver nitrate solution using potassium chromate as an indicator, chloride ions are quantitatively precipitated first as AgCl. After elimination of all chloride ions, silver chromate gets precipitated giving a permanent reddish tinge appearance, which indicates the end point.

Thiosulphate, cyanide, sulphite and sulphide are likely to interfere with this method. These can be eliminated by oxidation with a 30% hydrogen peroxide solution before titration with Ag NO₃. The chloride content is calculated as-

\[
\text{Chloride (mg/L)} = \frac{(A - B) \times N \times 35450}{\text{ml of sample}}
\]

Where,

A = Volume of Ag NO₃ in ml, required to titrate the sample
B = Volume of Ag NO₃ in ml, required to titrate the same volume of blank (distilled water)
N = Normality of Ag NO₃ solution
3.5.14 Nitrate:

Biochemical activities of micro-organism on nitrogenous matter in soil have been one of the primary sources of high nitrate in ground water. Apart from nitrate, nitrogen is applied in ammonium (NH$_4^+$) and (NH$_2$) forms, which generates nitrate in soil system through mineralization, which is fairly rapid in tropical and subtropical soils. Due to its high solubility in water and low retention by soil particles nitrate is prone to leaching to the sub soil layers and ultimately to the groundwater, if not taken up by plants or denitrified to N$_2$O and N$_2$. The leaching of nitrate to the groundwater can be enhanced by shallow groundwater table, excessive applications of nitrogenous fertilizers in the agricultural field, manures and irrigation and abundant rainfall. Although commercial fertilizer is suspected for major source of nitrate in groundwater, researchers have also identified natural organic nitrogen, livestock, septic-tanks and atmospheric inputs (oxides of nitrogen formed in atmosphere) as the contributing factors for enhancing concentration of nitrates in groundwater (Hill, 1982). In and around areas of high urbanization, municipal and industrial wastes may contribute high level of nitrate to the ground water. Oxides of nitrogen formed in atmosphere may also convert to nitrate in rainwater and some of it may find its way into groundwater.

A nitrate level of above 10 mg/L is known to cause “Methaemoglobinemia” (blue baby syndrome) in infants. Nitrate can be readily converted to nitrites inside the body and the nitrites can give rise to the carcinogenic nitrosamines (WHO, 1978; Nawlakhe et al, 1995). In excessive amounts it poses a health risk. Higher concentration of nitrates in water enhances the growth of algae and other aquatic plants leading to eutrophic condition.

Nitrate – nitrogen in water was determined using UV spectrophotometric technique (Elico, SL - 159) by measuring the absorbance of the phenol di-sulphonic acid
nitrate complex at 410 nm. At first, water samples were filtered and then 50 ml was evaporated until it became completely dry. The residue was dissolved in phenol disulphonic acid. The content was diluted to 50 ml and liquor ammonia was added to develop a yellow colour. The nitrate content was read directly by operating the instrument in photometry mode calibrating against a blank and a standard potassium nitrate solution.

3.5.15 Fluoride:

The presence of fluoride in ground water is attributed to the geological deposits, geochemistry of location and the application of fertilizers like rock phosphate or fluorapatite. Fluoride ions are likely to be leached out gradually, particularly on alkaline soils and move along the water front. Water with high fluoride content may cause serious health hazards including dental and skeletal fluorosis along with secondary neurological complications (Susheela, A.K., 1993). But fluoride is also considered to be beneficial for human health if taken in controlled quantity (1.0 – 1.5 mg/L) preventing dental carries. Fluoride content in the water samples were determined using SPADNS method. Fluoride reacts with the coloured complex of zirconyl acid and SPADNS [Sodium-2(para-sulphopherylaze) 1, 8 dihydroxy -3, 6 naphthalene disulphonate] to form colourless [ZrF₆]²⁻ and releases the dye. Fluoride can be estimated on the basis of this reaction by colorimetric measurement of the dye. Before employing the SPADNS method fluorides were separated from the water samples distilling them in presence of concentrated H₂SO₄ and soft glass beads to obtain fluorosilicic acid. The absorbance measurements were carried out at 570 nm using UV spectrophotometer (Elico, SL-159) and fluoride concentrations were read directly operating the instrument in photometry mode calibrating against a blank and a standard sodium fluoride solution.
3.5.16 Metals:

Metals constitute a very important group of parameters in monitoring water quality. Metals enter into the water bodies through dissolution of soil from various geological strata and discharges of domestic, industrial and agricultural wastewaters. Although it is well known that metals such as Cr, Co, Cu, Fe, Mn and Zn among others are essential for biological systems including humans, others such as As, Cd, Pb, Hg do not possess any beneficial biological effect and are toxic at certain levels. However all trace metals including micronutrient elements can exert toxic effect at high concentration. Heavy metals are harmful and insidious pollutants because of their non-biodegradable nature and their potential to cause adverse effects in human beings beyond certain level of exposure and absorption. Heavy metals can cause biochemical effects such as inhibition of enzymes, genetic damage and hypertension. Some of the heavy metals like Zn, Cr, Cd and Pb are carcinogenic (Luckey, T.D. and Venugopal, 1977). The metals studied in this investigation are Na, K, Ca, Mg, Fe, Cu, Zn, Ni, Pb and As.

(a) Sodium:

Sodium is a naturally occurring element in groundwater. Its concentration in natural fresh waters is generally lower than the calcium and magnesium. In natural waters, the major source of sodium is weathering of various rocks. Industrial and domestic wastes may also contribute sodium to ground water. According to National Academy of Sciences (1977), the higher concentration of sodium can be related to cardiovascular diseases and in women toxemia associated with pregnancy. Na is linked with high blood pressure particularly in the susceptible people. Intake of 100 mg/L of Na is known to raise blood pressure in children (Calabrese and Tuthill, 1977). High
concentration of sodium may adversely affect soil structure and permeability resulting in alkaline soils and becomes toxic to plants.

(b) Potassium:

Like sodium, potassium is also a naturally occurring element. It has similar chemistry like sodium and remains mostly in solution without undergoing any precipitation. The major source of potassium in natural freshwaters is weathering of the rocks but the quantities increase in the polluted waters due to disposal of wastewaters. It is an essential nutrient element for the plant growth. Potassium is not very much significant from the health point of view, but large quantities may be laxative. Ingestion of excessive amounts (> 2000 mg/L) may prove detrimental to the human nervous and digestive system which is a rare occurrence in potable water.

The metals sodium and potassium were determined with a flame photometer (Elico, CL - 22D), using standard calibration procedure.

(c) Calcium:

Calcium is one of the most abundant substances of the natural waters. Being present in high quantities in the rocks, it is leached from there to contaminate the water. Disposal of sewage and industrial wastes are also important sources of calcium. Calcium in an aquatic environment is an important macronutrient. It is also needed in large quantities by molluscs and vertebrates. Being an important contributor to hardness in water, it reduces the utility of water for various domestic and industrial uses.
Calcium has no hazardous effects on human health. Calcium concentrations up to 1800 mg/L have been found not to impair any physiological reaction in Man (Trivedy & Goel, 1986).

Calcium was determined by the EDTA titrimetric method. EDTA (Ethylene Diamine Tetra Acetic Acid) forms a complex with both Ca and Mg, but if the pH is sufficiently high (12 to 13), Mg is precipitated as the hydroxide and Ca – EDTA complex gives a colour change with a suitable indicator when the complex formation is complete. The indicator used was Murexide (Ammonium purpurate) which gives a colour change from pink to purple at the end point. The Ca – content was calculated as

\[
Ca (\text{mg/L}) = \frac{X \times 400.8}{\text{ml of sample}}
\]

Where, \( X \) is the volume (ml) of EDTA required to titrate the sample.

(d) Magnesium:

Like calcium, magnesium is also found in all natural waters with calcium, but its concentration remains generally lower than the calcium. The principal sources in the natural waters are various kinds of rocks. Sewage and industrial wastes are also important contributors to magnesium. It is a necessary constituent of chlorophyll. Its high content reduces the utility of water for domestic use. A concentration above 500 mg/L imparts an unpleasant taste and renders the water unfit for drinking purposes.

Magnesium is supposed to be nontoxic at low concentrations. However at higher levels magnesium salts have a laxative effect. Magnesium content of >125 mg/L can produce some cathartic and diuretic effects (Trivedy, 1990).

Magnesium was determined as given below:
Calcium and magnesium form a complex of wine red colour with Eriochrome black T at pH 10. The EDTA has got a stronger affinity for Ca\textsuperscript{2+} and Mg\textsuperscript{2+}, the former complex is broken down and a new complex of blue colour is formed. The value of Mg\textsuperscript{2+} is obtained by subtracting the value of calcium from the total of Ca\textsuperscript{2+} and Mg\textsuperscript{2+}

Magnesium was estimated as

\[
Mg \text{ (mg/L)} = \frac{(y - x) \times 400.8}{\text{ml of sample} \times 1.645}
\]

where,

\[y = \text{EDTA used in hardness determination}\]
\[x = \text{EDTA used in calcium determination for the same volume of sample.}\]

(e) Iron:

The main sources of iron in ground water are rocks, clay, soils, natural organometallic or humic compounds etc. In addition to the natural sources of iron, corrosion of pipes, pumps etc. can also increase its concentration in distribution system. The higher concentration of iron in water is not suitable for food processing, dyeing, bleaching and many other activities. Iron at 1.0 mg/L can cause the bitter astringent taste to water. A problem that frequently results from iron in water is iron bacteria. These nonpathogenic (not health threatening) bacteria occur in soil, shallow aquifers and some surface waters. The bacteria feed on iron in water. These bacteria form red–brown (iron) slime in toilet tanks and can clog water system. Iron is vital to life as an integral part of haemoglobin and oxygen transport system. But excessive accumulation of iron may be toxic to cells as it catalyses the production of hydroxyl radical. Iron intake in large amounts through drinking water and other sources is known to lead constipation and other problems (Heuber, 1991). Iron in higher concentration may also cause vomiting. At
exceedingly high concentrations, iron has been reported to be toxic to livestock and to interfere with the metabolism of phosphorous (NAS, 1974).

For determination of iron, all the iron is converted into ferrous state by boiling with hydrochloric acid and hydroxylamine. The reduced iron chelates with 1, 10 phenanthroline at pH 3.2 to 3.3 to form a complex of orange red colour. The intensity of this colour is proportional to the concentration of iron and is determined colorimetrically using a UV - visible spectrophotometer (Elico, SL - 159). Iron concentration was read directly by operating the instrument at 510 nm in photometry mode calibrating against a blank and a standard iron solution.

(f) Lead:

Lead is one of the natural constituents of earth's crust. In natural waters lead is generally present in very low concentrations. Atmospheric fallout is the most important source of lead in the fresh water (Gupta et al, 2005). Its concentration in water increases due to the discharge of industrial waste waters, such as from printing, dyeing and oil refineries etc. In drinking water lead occurs primarily from corrosion of lead pipes and solders, specially in areas of soft water.

Unlike many other trace metals, there is no demonstrated biological need for lead. Lead is classified as a carcinogen and toxic to most living organisms at higher concentration (Somasundaram et al, 2006). Lead poisoning has been recognized as an occupational illness for centuries, and it is linked with both severe and subtle health damages (Cohen, 1973; Goyer, 1990). Toxicological effects of Pb on human include inhibition of haemoglobin formation (anaemia), sterility, hypertension, learning disabilities, abortion, kidney damage and mental retardation (Amdur et al, 1991). The groups most sensitive to exposure of lead are children, infants, unborn foetus and
pregnant woman. Children have a greater ability to absorb ingested lead and also have a higher susceptibility to the metal because of their fast grow rate (Sarma B. K., 2005).

(g) Copper:

Copper occurs in the earth in free native state and in the form of its ores depending upon the geographical location and proximity of industry. The municipal waste and sewage, corrosion of Cu containing pipelines or fittings are the principal anthropogenic source of Cu in the surface water. Copper in water is exceedingly toxic to aquatic biota and toxicity varies with the species of plants or animals. The toxicity also depends on factors such as pH, hardness, presence of other toxicants and the species of the copper present in the water. Copper in excess of 1.0 mg/L may impart some taste of water (Train, 1979).

Cu is recognised as a harmless and essential metal for humans; the adult daily requirement is about 2.0 mg (De A.K, 2000). But exposure to excessive amount of Cu for a long time may lead to liver damage. Excessive dose of Cu may also lead to mucosal irritation, widespread capillary damage, renal damage and depression.

(h) Zinc:

Zinc is present in high concentrations in the wastes from pharmaceuticals, galvanizing paint, pigments, several insecticides, cosmetics etc. and their discharge increases its concentration in appreciable amounts in the waters. Zinc imparts undesirable, bitter astringent taste to water at levels above 5.0 mg/L (WHO, 1984). Water containing zinc at concentrations in excess of 5.0 mg/L may appear opalescent and develop a greasy film on boiling.
Zinc is an essential element and is necessary for the effective functioning of various enzyme systems, deficiency of which leads to growth retardation, immaturity and anaemia. At very high concentrations zinc may cause some toxic effects. Symptoms of zinc toxicity in humans include vomiting, dehydration, electrolyte imbalance, abdominal pain, nausea, lethargies, dizziness and lack of muscular co-ordination.

(i) Nickel:

Nickel enters ground waters and surface water sources by dissolution from rocks and soils, from biological recycling, from atmospheric fallout and specially from industrial wastes. Trace amounts of nickel is regarded as essential for human, plant and animal nutrition with a maximum limit of 0.1 mg/L in drinking water. Dermatitis was recognized to be the most common symptom of industrial exposure to nickel, although high occupational exposures have been associated with renal problems and lung cancer (Horvath, 1976; Falk, 1974). Epidemiological studies conducted on refinery workers indicated that nickel compounds induce nasal, laryngeal and lung cancer (Pedersen, 1978; Lessard, 1978). Women are more sensitive to nickel than men by a factor of ten.

(j) Arsenic:

Arsenic is a metalloid that is distributed ubiquitously in the Earth’s curst. It exists in nature in four valency states: -3, 0, +3 and +5. Trivalent arsenic As (III), and pentavalent arsenic As(v) are the most common states in natural matrices. Arsenic in the environment derives from natural processes such as volcanic activity, weathering and biological reactions, and human activities (mining and use of arsenic compounds in industrial applications and agriculture). The mobility of arsenic depends on physico-
chemical conditions such as redox potential, pH, and biological activity in the system. In oxygenated condition, As (v) is the dominant species as \( \text{H}_3\text{AsO}_4 \), \( \text{H}_2\text{AsO}_4^- \), \( \text{HAsO}_4^{2-} \) and \( \text{AsO}_4^{3-} \), with \( \text{H}_2\text{AsO}_4^- \) stable at pH ranging from 2 to 6.9. \( \text{H}_3\text{AsO}_4^0 \) and \( \text{AsO}_4^{3-} \) are stable under very acidic and alkaline conditions, respectively. It has been demonstrated that reduced arsenic species derive from the reduction of As (v) to As (III), and this process leads to the mobilization of arsenic in water (Ahmed et al, 2004). Therefore, high-redox and near neutral pH conditions should be maintained to minimize the solubility and mobility of arsenic (Mok WM and Wai C.M., 1994). Arsenic has been an essential element in human life since the first isolation by Albertus Magnus in 1250 A.D. It has been used in medicine, agriculture, livestock feed, electronics, industry and metallurgy. The toxicology of arsenic is a complex phenomenon as arsenic is considered to be an essential element. The toxicities of various arsenic compounds to man and animals have been studied by various workers (USEPA, 1971). Toxicity of arsenic is significantly dependent on species and oxidation state. Some studies demonstrated that its toxicity decreases in the order, arsine>arsenoxides>Organic As III > AsV>arsonium compound>As (Mandal et al, 2002). Soluble inorganic arsenicals are more toxic than organic arsenicals, and trivalent arsenic is more toxic than pentavalent arsenic (Mandal et al, 2002).

All the metals, except Na, K, Ca, Mg and Fe, were determined by Atomic Absorption Spectrophotometry (AAS) technique with the help of an instrument AAS - VARIAN Spectra, AA 220. For digestion and pre-concentration of the water samples, standard methods (APHA, 1995) were followed. The details technical parameters used for measuring the heavy metals (Cu, Pb, Ni and As) are given in Table 3.2
Table 3.2: AAS parameter for the analysis of different heavy metals

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Metal</th>
<th>Wave length (HCL) in nm</th>
<th>Flame composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAS - VARIAN</td>
<td>Arsenic</td>
<td>193.7</td>
<td>HG - ASS.</td>
</tr>
<tr>
<td>Spectra AA 220</td>
<td>Copper</td>
<td>324.8</td>
<td>Air - C₂H₂ AAS.</td>
</tr>
<tr>
<td></td>
<td>Lead</td>
<td>217.0</td>
<td>Air - C₂H₂ AAS.</td>
</tr>
<tr>
<td></td>
<td>Nickel</td>
<td>232.0</td>
<td>Air - C₂H₂ AAS.</td>
</tr>
<tr>
<td></td>
<td>Zinc</td>
<td>213.0</td>
<td>Air - C₂H₂ AAS.</td>
</tr>
</tbody>
</table>

3.5.17 Microbiological examination:

Water can be perfectly clean in appearance, free from odour and taste, and yet contain micro-organisms. The natural microbial communities of freshwater are largely responsible for the self purification processes by biodegrading organic matter (Sunil Kumar et al, 1998). Freshwater contains micro-organisms such as bacteria, fungi, viruses, protozoa and algae. Some bacteria are harmful and called pathogenic bacteria, while some others are harmless and are known as non-pathogenic bacteria (Sarma B.K., 2005). Pathogenic bacteria present in water are responsible for causing diseases like cholera, typhoid and dysentery etc. Domestic sewage released into water bodies adds a large number of bacterial species which arise from the human intestine. Human faeces can contain a variety of intestinal pathogens which cause diseases ranging from mild gastroenteritis to the serious and possibly fatal dysentery, cholera and typhoid.

It is, however very difficult to isolate pathogenic bacteria in the laboratory. Since isolation of pathogenic bacteria is time consuming as well as difficult, simple tests are performed to determine the possible presence of intestinal organisms, which are known
as coliform group of bacteria, some of which may also be non-pathogenic. The presence of intestinal bacteria also indicates the presence of pathogenic bacteria. Coliforms are good indicators of pollution. Hence, the presence of pathogenic bacteria can be detected by testing for the coliform group of bacteria. This group contains all rod shaped bacteria, which are aerobic and facultatively anaerobic, nonspore forming and gram negative. This coliform group includes Escherichia coli (E. coli), which is the most common intestinal inhabitant. It is widely used as a water quality indicator to find out the presence of human faecal matter and other pathogens possibly associated with it.

Application of poorly treated sewage to land can lead to contamination of surface and ground waters. Water supplies in urban areas get contaminated through breakage of pipes in places where sewer and water pipes are laid together. Groundwater pollution is caused by the percolation of water from sanitary land fill areas, leachates from septic tanks, damaged sewer lines, run off from livestock feed lots etc.

WHO has recommended a guideline value of 0 and 10 per 100 ml respectively for faecal coliform and total coliform organisms in unpiped supply waters. Microbiological examination for total coliforms was carried out by the multiple-tube fermentation procedure and the results have been presented as a Most Probable Number (MPN) index. The method is based on the ability of the coliform organisms to ferment lactose producing an aldehyde complex and carbon dioxide gas. Water samples, immediately after collection were distributed for multiple tube fermentation according to the following dilutions:

(a) 5 tubes of 10 ml double strength medium (Lactose broth) + 10 ml of water sample.

(b) 5 tubes of 10 ml single strength medium + 1 ml of water sample.

(c) 5 tubes of 10 ml single strength medium + 0.1 ml of water sample.
Fermentation was allowed to take place in a SICO incubator at 35 ± 0.5°C. The tubes were shaken gently after 24 ± 2 hours and examined for gas formation. If there was no gas, the tubes were re-incubated and re-examined at the end of 48 ± 3 hours. Formation or absence of gas was recorded as a positive or negative presumptive test and the MPN indices were obtained following standard procedure (ICMR, 1963).

The presence of E coli was tested by the indole formation test and was confirmed by differential test.

For indole test subcultures are made from the test tubes showing acid and gas into peptone water by means of a transferring loop in presence of spirit lamp to test tubes containing 2 ml peptone water and 1 long Durham's tube (previously sterilized) and incubated at 44°C at serological water bath for 48 hours.

Those yielding gas are showing indole positive and are regarded as containing Escherichia coli.

3.6 Health hazard survey:

A two year survey on health status of the people in the Lakhimpur district was carried out from June 2005 to May 2007 for 20 different locations which are given in Table 3.1 and approximate locations of sample collection sites are shown in Map-5.

The survey is non-experimental and descriptive research method.

The researcher visited every location as mentioned in Table 3.1 and observed the water environment used by the people for drinking purposes. Since populations in every location are quite large, the researcher directly inter-acted only a small proportion of the population. A randomize representative sample size of 300 was done by personally contacting the respondents.
The data collected were related to two years. After completing the collection process, the data were processed, classified and tabulated for analysis. To arrive at conclusions regarding health aspect of the people in the district, questionnaires (Annexure 1 and 2) were designed very carefully relating to health hazards generally occur from water environment and these were asked to the respondents. The filled up questions were collected and then grouped for interpretation.

3.7 Summary:

This chapter briefly describes the experimental strategy and methodology. The chapter starts with a discussion of the samples for analysis and their storage. The location of sampling points and sampling seasons are also briefly discussed. In the last part of the chapter, water quality parameters selected in this study have been described underlying their importance in pollution studies. The methods adopted to monitor the parameters have been simultaneously discussed along with a public health hazard survey.