Chapter 2

Methodology, Simulation and Prediction

2.1 Methodology

As a pre requisite the problems of the station were identified and cause-effect relationship was established to reach to the solution. Manipulative experiments were particularly useful in demonstrating cause and effect of chemical contamination (Stark et al., 2003a; Thompson et al., 2007). In this regard following basic steps were selected to define methodology;

- Identification of sources of the problem
- Selection of the parameter to evaluate and quantify the pollution indicators
- Designing of the sample points and cycle of collection
- Establishment of Environmental Laboratory at Maitri
- Selection of standard methods and procedure for analysis
- Application of the tertiary treatment at Maitri station
- Laboratory-scale experiment opting tertiary treatment
- Prediction of wastewater impact by mathematical modelling software
- Designing of ancillary treatment units for "Maitri"
- Suggestions for advance treatment units

2.2 Approach to Identify Problems

Being cold climatic conditions at Maitri in Antarctica, biological wastewater treatment
system (Rotating Biological Contactor) has to be assessed frequently for its efficacy while it operates for long, so that effective decision can be taken if improvisation is required. At Maitri station the drinking water source is Priyadarshini Lake (Zub Ozero) which remains in melted form only for around two months and rest of the year it freezes. However, below three meters of ice water remains unfreezed at lower layer so it caters the water requirement of the station throughout the year. It is also interconnected with glacial lakes and intermixing of gray water through chain contamination has to be considered. In this regard water quality of lakes is required to be assessed.

2.3 Assessment of Water Abundance at Priyadarshini Lake

Priyadarshini Lake covers an area of 0.29 Km$^2$ and forms the major source of water supply to the Maitri station (Ingole and Parulekar, 1990). The lake is situated about 150 m away from the Indian permanent research station “Maitri” towards north. The volume of the water fluctuates between 1.7 m$^3$/day, in winter and 5.7 m$^3$/day, in summer. The consumption of water at Maitri is relatively more in austral summer compared to the rest of the year. The number of consumers is more during summer as total strength reaches to around 65-75 in a day (Tiwari and Nayak, 2007). It is during the austral summer that most of the scientific activities are carried out.

2.3.1 Area Measurement

Ingole and Parulekar (1990) estimated the area of the Priyadarshini Lake as 0.297 km$^2$. In January 2000 Global Positioning System (GPS) of make Corvallis Microtechnology Inc. version 2.4 was used as a mapping tool without differential correction (MC-GPS, 1996) to mark the boundary of the lake. The accuracy of this instrument was quoted 10-30 meters. In the last week of January when the ambient temperature was around -4 to -2 °C and there was no inflow of water, instrument (GPS) was calibrated with necessary inputs and it was set to record the position of the point for every five second. Holding the GPS handheld positions of the points were recorded moving on foot close to edge of the water around the lake keeping the instrument vertically above the water except few points where easy approach was not possible. After getting all the coordinates it was converted into graphical data and with the application of GPS and SURFER total area
was computed.

### 2.3.2 Depth Measurement and Volume of Lake

Before feeding of glacial melt water the depth of water at various places were recorded using the marked string with around 2 kg weights which was attached at bottom to keep the string vertically over the point. Using the inflatable boat and GPS wherever depth was measured, coordinates were recorded above those points at 55 locations within the lake. Care was taken to lower the string gradually into water so as to avoid penetration into algal mats which was present at the bottom of the lake. As soon as the string was slack the depth was recorded. Maximum depth recorded was 7.2 m at middle of the lake.

### 2.3.3 Additional Feed Water Measurement

The volume of water of Priyadarshini lake never remains the same because of the Schirmacher glacier which is around 1200 m away from the lake and melts when ambient temperature reach as to +1 to +5 °C for couple of days. This melted water joins glacial lakes formed adjacent to glacier and from these lakes ultimately it joins Priyadarshini Lake. After reaching certain level, the water outflows from Priyadarshini Lake into adjacent lake. To measure the inflow into the lake two iron rods at the bank of the lake were fixed at two feet distance. A cotton string was tightened in between the iron rods and leveled with the help of spirit level, keeping in view that it just touches to the water surface level when there was no inflow into the lake when the ambient temperature recorded was -2 °C. After a few days when temperature starts raising the glacier starts melting and the melt water starts feeding into Priyadarshini Lake through connecting glacial lake, daily at the evening increment in height of water level of the lake water was measured over the string using a scale.

From 2\textsuperscript{nd} January to 29\textsuperscript{th} January 2000 (Figure 2.1) the water level recorded continuously showed an increase in water level till 21\textsuperscript{st} January, there after that it slightly increased till 27\textsuperscript{th} January and remained constant for 3 days. It was noted that the excess water started diverting to a connecting lake situated downward side of the Priyadarshini Lake and after three days temperature went down and glacier melting
stopped which barrier feeding of water into the lake. Maximum air temperature recorded on 9th and 20th January, was +4.4 °C. This lake has also got an outlet through which access water passes to a channel and ultimately joins other lake at lower level, this happens when water level raises close to 23 cm.

Figure - 2.1: Daily water increment in Priyadarshini Lake

2.4 Waste Generation

2.4.1 Sources of Gray Water in Maitri

The Indian research station Maitri is situated at higher elevation (117 m above msl) in comparison to the Priyadarshini Lake (113 m above msl), which is drinking water source for Maitri (Ghosh and Ramteke, 1997; Tiwari et al., 2006). This is the only source of drinking water which can cater the water requirement throughout the year, even in the winter condition. This water is used at various utilities of station i.e. boilers, drinking purpose, bathroom, washbasin, sink, kitchen, laboratory etc. which ultimately generates gray water. There is no black water generated as wet toilets are not in use at Maitri.

2.4.2 Liquid Waste Disposal and it's Consequences

Liquid waste obtained from bathroom, laundry room, washbasin, urinal and kitchen is sent into two different Rotating Biological contactors (RBC), made in UK by Klargest
Company, popularly known in Maitri as Klargeste (Kee, 2004). These two RBC's are kept separately outside Maitri in a closed wooden chamber. Effluent obtained from these RBC's is discharged into a collection pond, dug adjacent to these chambers. Effluent disposal pipes are enclosed with heat tracing element to avoid freezing during subzero temperature. The fate of liquid discharge is summarized below;

- Treated waste from the pond is disposed and discharged on open land around 320 m away from the pond. Further down to discharge point, lakes are situated and they get inter-connected during summer once the glacier melted water feed these glacial lakes, they overflow and join each other. There is a probability of contamination of Priyadarshini Lake through this chain.

- Priyadarshini Lake is situated 150 m away in front of wastewater collection pond at lower level. During summer period when frozen effluent melts it seeps from pond and joins Priyadarshini Lake.

- Therefore, final discharge point of the effluent is not fulfilling the criterion of the environmental protocol

### 2.4.3 Solid Waste Contamination in Lake

During summer period around 60-70 persons stay at Maitri and in the adjoining summer huts (Figure 2.2) which are built in front of the Maitri, and during winter round 25 people live in Maitri station. Solid waste mainly generates from the kitchen waste which is semi solid food waste and organic in character. Other sources include packing material in the form of wood, cartoons tetra packs etc. Fuel operated incinerator based toilet modules are used to burn excreta, which are used during summer camps and placed around 150m away in northern side of the station and few are placed at western side of the main building. Incineration process emits particulate matters and gases. Sometimes it is noticed that excreta is not burnt properly and during ash collection and disposal it creates threat to mix (suspended particles) with lake water due to high wind. Similarly, packing material not kept in closed area, are threats to disperse around Maitri in a large area as well as submerging into surrounding lake water (Ghosh et al., 1997).
2.5 Establishment of Environmental Laboratory at Maitri

It is felt necessary to establish an environmental laboratory at Maitri with the capacity to analyze physico-chemical parameters of water and wastewater sample. To set-up an environmental laboratory a suitable place was needed, where permanent equipments could be installed to carry out continuous environmental monitoring and its analysis to take effective decision and for waste management in and around the Maitri. For this purpose the old Green House room was selected at Maitri. Before placing the instruments the infrastructure assessment was carried out and provided with water arrangements, electricity connections, proper ventilation, heating of the lab etc. Various new chemicals, glassware’s and plastic wares were placed which were required to carryout the in-situ physico-chemicals, demand analysis and nutrient analysis of water and wastewater. Laboratory was strengthen to analyze i.e. pH, temperature, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, chlorides, sulfate, ammonia, nitrate, phosphate, conductivity, turbidity and chlorides, according to Standard Methods of Water and Waste Water Analysis (APHA, 1995). Following instruments are calibrated and placed in proper working condition (Figure 2.3):

- Distilled Water Unit: Quartz make with capacity 3 litre/hr, electrically operated.
\[\text{Soxlet Extraction Mantle with Digestion Unit: Six mantel type (100 °C).}\]

\[\text{B.O.D. Incubator: Digitally controlled, with temperature range 5°C to 60°C and accuracy + 0.5°C.}\]

\[\text{Hot air Oven: Range 5°C to 450°C, digitally Controlled.}\]

\[\text{Muffle furnace: Digitally Controlled, maximum temperature 1150°C.}\]

\[\text{Magnetic Stirrer with Hot Plate: 2 litre capacity with energy regulator.}\]

\[\text{Turbidity Meter: Range 0 to 100 NTU with 0.1 NTU resolutions and with tungsten lamp.}\]

\[\text{Conductivity Meter: Digital display with automatic temperature compensation.}\]

\[\text{pH Meter: Range 0 to 14, digital display with automatic temperature compensation.}\]

\[\text{Digital Spectrophotometer: Range 340 – 960 nm, with resolution 1 nm.}\]

\[\text{Analytical Balance: Sartorius make maximum capacity 200 grams, 4 digits auto calibrate with 1 mg accuracy.}\]

\[\text{Heating Mantle: Maximum surface temperature of 450° C, controlled by a built - in energy regulator.}\]

**Figure - 2.3: Environmental Laboratory at Maitri**
2.6 Sample collection Locations

2.6.1 Water Sample

Around the station several glacial and fresh water lakes exists (Figure 2.4). The main lake used for the potable water is in front of the station which is feed by interconnected glacial lakes. In this lake 10 locations were selected for water sampling, taking into account its importance i.e., feeding inlet, outlets of lake, center point, seepage point through wastewater system nearness to summer huts and toilets. Samples were collected in the year 2000 and 2004. In January 2004 out of 10 stations only seven locations could be sampled due to high wind logistics support sailing inside the lake could not be materialized. Few locations in the glacial lakes were also selected which exists near to the station.

**Figure - 2. 4 : Maitri Station, Priyadarshini Lake and Summer Camp**

Four Glacial Lakes and two Control Lakes (1 and 2 km away from Priyadarshini Lake) were selected for assessing the water quality and comparison purpose. Ten sampling locations denoted as W1 to W10 were selected from different locations within the
Priyadarshini Lake for a proper assessment of its water quality. Six locations denoted as GL1a, GL1b, GL2, GL3, GL4a and GL4b were identified in the four glacial lakes located on the western side of the station. Three additional locations denoted as CL1a, CL1b and CL2 included two freshwater lakes and are referred as Control Lakes (Figure 2.5). These samples from Control Lakes were used to obtain the background concentrations since the lakes were situated some distance away from the Maitri station and assumed to be not affected by the prevailing activities.

Figure - 2.5: Schematic diagram of Maitri Station and Sampling Location

2.6.2 Wastewater Sample Points at RBC

RBC's installed at Maitri are made of Glass fiber Reinforced Polyester (GRP) which is extremely robust and easy for transport and install. The RBC units are located in separate rooms that are not exposed to sunlight to prevent the growth of algae, which could intervene with microbial attachment (Ayoub and Saikaly, 2004) and at times overburden the discs with extra mass. B1 RBC treat waste obtained from kitchen and B3
RBC treat the waste obtained from bathroom, washbasins, laundry and urinal.

Treatment systems are installed and operate to filter and convert organic matter into stabilized unharmed material and gases. For the present study all the places where waste generates and further process takes place, efforts are made to collect the samples i.e. inlet points, primary and secondary settling tank and biozone. However few locations were also identified to collect samples i.e. collection pond, final discharge point and from connecting lakes to Priyadarshini.

2.7 Water Balance at Maitri

Efficacy of wastewater depends upon the designed load and surrounding environmental conditions of wastewater that feed into the system. To assess the actual average quantity of wastewater generated and fed into RBC's, water balance of station is developed through water intake assessment and its distribution, losses and conversion into wastewater. Water is supplied to Maitri through a submersible pump from Priyadarshini Lake which is collected in two tanks of 5 m³ volume, inside the station. In the month of January 2000 and 2003, on a particular day when the strength in the station was noticed maximum, 24 hourly assessments of wastewater generation and measurement was carried out to derive water balance (Tiwari and Kulkarni, 2005).

Water was collected in a main tank where from it is distributed into kitchen, boiler, bathroom, and washbasin and summer huts. Daily total water consumption was measured through the changes in water level of main tank, before and after pumping. Boiler was used at Maitri to circulate heated water through radiators, in each room. An expansion tank was placed to make up evaporated water, lost during circulation through boiler. Water loss was measured through change in the water level in 24 hours. However, variation in water demand is noticed during winter and summer months.

The inlet quantity of wastewater to B1 was measured from inside kitchen through a closet which joins to kitchen RBC. Water was collected in bucket before releasing into RBC and volume was measured every hour. At the outlet of RBC 220 litres capacity barrels were kept to collect the treated wastewater before releasing into pond.
Wastewater generated at laundry was assessed through daily consumption of water that was required by the washing machines based on number of persons using it.

Inlet measurement of B3 RBC which mainly receives waste water from laundry, urinal, washbasin and bathroom is assessed through back calculation because all the pipe line were concealed and no suitable place was found to measure the flow. Effluent quantity flow was measured by collecting effluent in 220 litre barrel for 24 hours. At summer huts water was collected in a tank where from it is distributed to other places like tea room (Annapurna hut), and bathrooms. The level of water on filling and after consumption was measured to calculate water consumption in summer huts.

2.8 Sample collection and Preservation

Samples (water and wastewater) were collected in the month of January-February, 2000, 2001 and 2004. Pre acid washed Nalgene; High Density Poly Ethylene (HDPE) bottles were used for water and wastewater sample collection. The bottles were soaked with 10% HCL for 24 hours and then thoroughly cleaned and rinsed with distilled water. All the borosilicate glass bottles and polyethylene container were rinsed with chromic acid solution followed with tap and distilled water and then inverted them to dry. Trace metal analysis container were rinsed with 20% HNO₃ followed by distilled water. The above procedure was followed at Maitri as well as for RBC model analysis.

In the years 1994 and 1995 samples were collected from the influent and effluent of both B1 and B3 RBC. These four sets of sample were considered as reference analysis to pursue further study. During the study period in the year 2000, composite samples were collected from influent as well as effluent of B1 and B3 RBC. Samples were also analysed for tertiary treatment. For this effluents collected after alum dose and further passing through activated carbon were analysed. Eight sets of samples were collected and analysed for performance study. In the year 2004 six sets of samples were collected and analysed from influent, effluent and bio-disk chambers of B1 and B3 RBC. Additional set of sample were collected from the wastewater collection pond in the year 2004.
Water sampling in lakes was carried out with the help of Niskin water sampler from different depths. Each sample was collected in one litre bottle for nutrient, oil and grease, physico-chemical parameters and half litre bottles were used for sample collection for trace metal analysis. A part of water, from collected sample was used to analyze the essential parameters in Environmental laboratory at Maitri. Utmost care was taken to bring the samples collected from the Lakes to laboratory within an hour to measure the essential parameters. Ambient temperature during sample collection varied from -5 °C to +3 °C and water temperature from -2 °C to +1 °C.

An inflatable boat was used to collect the samples from middle of the Priyadarshini Lake. In each of the heavy metal bottles one ml of HNO₃ was added to acidify the sample. Oil and Grease and nutrient samples were preserved with H₂SO₄ by mixing one ml of acid and making pH to 2. All the samples were preserved in near temperature range of +4 °C, for further analysis at the laboratory in Maitri and in India.

2.9 Performance Evaluation and Tertiary Treatment at Maitri in Lab Scale

Wastewater treatment system should 'work at design load and give desired effluent quality. To evaluate the performance of RBC’s 24 hourly composite samples were collected at various points, during summer period in the year 2000, and 2003. Composite samples were collected from inlets, primary settling chamber, biozone and secondary settling chambers of both the RBC’s. Sample was also collected from effluent collection pond. Having assessed the performance of RBC which gave its running efficiency at 25-60%, it was decided to seek the option to understand the effect of tertiary treatment at laboratory-scale/bench-scale (Banerjee, 1997a; Laopaiboon et al., 2002) at environmental laboratory of Maitri.

An attempt was made at the laboratory to observe the effect of tertiary treatment on the effluents of RBC. In this regard the effluent was primarily treated through the optimum dose of alum (Malhotra and Lee, 1964) which is widely used as a coagulant (Chu, 1999) and then treated through granular activated carbon. The influent waste from both the RBC’s and effluent after optimum dosing of alum and effluent from the activated carbon
column was further analyzed for physico chemical parameters viz. pH, turbidity, total suspended solids (TSS), total dissolved solids (TDS), conductivity, total alkalinity, chlorides, sulfate, temperature, COD, BOD, ammonia, total phosphates, oil and grease, hydrocarbons, nitrogen nitrite, nitrogen nitrate, phenol and heavy metals viz. nickel, cadmium, chromium (Ayub et al., 2003), copper, lead, iron, manganese, zinc, cobalt.

2.9.1 Tuning of RBC

While through performance evaluation it was assessed that the RBC’s are not working at designed efficacy, both the systems were tuned for its disc rotational speed (RPM) and biozone temperature to develop the bacterial growth properly and DO transfer and then its performance evaluation was done again collecting the sample and analyzing at environmental laboratory at Maitri.

2.10 Transportation of Samples

All the samples were kept in plastic crate and transported from Maitri to Ship by helicopter and kept in +4 °C containers in the ship and after reaching Cape Town it was transported by flight keeping in icebox with dry ice to maintain the temperature and brought to the laboratory at NCAOR for further analysis.

2.11 Lab Scale Modelling

At Polar environmental Laboratory of NCAOR two RBC’s simulating to the RBC’s of Maitri were designed keeping the physical aspect ratio 1: 200. The resident time of waste was kept similar to RBC at Maitri, rest of the parameters were designed according to dimensional analysis of RBC at Maitri and working model of RBC. These model were kept running for about four months and during this period various experiments were conducted at ambient temperature 25-30 °C taking into consideration that RBC at Maitri will perform in the same temperature. The performance evaluation is carried out on the working model i.e.

- Considering both the RBC running separately with independent waste load
- Kitchen RBC (B1) effluent diverted into influent of laundry, urinal RBC (B3)
Tertiary treatment implying alum dose and activated carbon treatment

This laboratory-scale model may be particularly useful in predicting the organic loading rate. Such information is very useful in the scale-up process of constructing a treatment plant, as a pilot plant of intermediate size (Palma et al., 2003).

2.11.1 Collection and Analysis of Wastewater Samples from RBC Model

Composite samples were collected at influent, effluent and biozone and were analyzed for physico chemical parameters viz. suspended solids (SS), volatile suspended solids (VSS), volatile dissolved solids (VDS), pH, conductivity, turbidity, total suspended solids (TDS), dissolved solids, BOD, COD, nitrate, ammonia, phosphate, sodium, potassium, calcium and trace metals (chromium, manganese, cobalt, nickel, copper, zinc, cadmium, lead and iron), using, Inductively Coupled Plasma Mass Spectrophotometer (IC-PMS) of Thermo make.

All analytical procedures were performed according to Standard Methods (APHA, 2000). Chemical oxygen demand (COD) was measured by the closed reflux method using Hach DRB 200 COD reactor; biochemical oxygen demand (BOD5) was measured by the 5-d BOD test using Orion 810™ and Thermo electron DO meter; temperature was measured through Cole Parmer thermo couple digital thermometer; sodium, potassium and calcium were measured through Elico CL 361 make flame photometer; nitrate, ammonia and phosphate were measured by colorimetric method using Thermo Genesys 20 spectrometer; conductivity, pH, and TDS were measured through Oakton pH/Con 510 Series make bench top meter; total suspended solids (TSS), dissolved solids, volatile dissolved and suspended solids were measured by the gravimetric method and for filtration a PALL make filtration unit and Nalgene filter paper 0.45 um were used. For all the analysis purpose in India Millipore type II water from Elix 3 was used and chemical balance Sartorius CP 224 S was used for general weighing purpose. Trace metal analysis, was carried out after filtering the sample through 0.45 um membrane filter on Thermo make ICP-MS.
2.12 Analysis of Samples in Laboratory

Basic parameters of water and wastewater i.e. pH, temperature, conductivity, turbidity, DO, BOD, COD, alkalinity acidity, TDS, ammonia, nitrite and nitrate were analysed in Environmental laboratory at Maitri. The preserved samples were sealed properly and brought to India for further analysis in the laboratory. Samples were filtered before analysis with 0.45 µm Whatman filter papers. All the samples were analyzed using standard methods of water and waste water analysis (APHA, 2000) for, total hardness, calcium hardness, sulfate, sodium, potassium, oil and grease, hydrocarbons, phenol and heavy metals (nickel, cadmium, chromium, copper, lead, iron, manganese, zinc, and cobalt). The samples were analyzed through following the standard method of water and wastewater analysis as follows.

Turbidity by Nephelometric method, acidity by titrametric method, alkalinity by titrimetric method, hardness by EDTA titrametric method, conductivity by conductivity meter, solids by gravimetric and oven dried method, sulfate by turbiditric method, temperature by mercury filled certified Celsius thermometer and thermocouple, metals by atomic absorption spectrometry, chlorides by argentometric method, fluoride by SPADNS method, pH by electrometric method, nitrogen (ammonia, nitrate and nitrite) by colorimetric method, phosphorus by colorimetric method, BOD by 5 day BOD test, COD by closed reflux colorimetric and open reflux titrimetric (at Maitri) method, oil and grease by partition gravimetric method.

2.12.1.1 Turbidity

Turbidity of the sample was measured by digital turbidity meter with range of 1000 NTU and 0.1 NTU resolution. Stock hydrazine sulfate and hexamethylenetetramine solution was prepared to make standard turbidity suspension and instrument was calibrated using different dilution solution from the standard solution.

2.12.1.2 Oil and Grease

To assess the concentration of oil and grease, Trichlorotrifluoroethane-soluble floatable oil and grease method is used. For the extraction, dry filter (1 µm Pall) was used. After 30
minutes settling time, soluble floatable oil and grease were estimated for the samples.

2.12.1.3 Total Dissolved and Volatile Solids

Total solids were estimated evaporating the known volume of sample at 105°C, in silica glass. The initial and final weight difference of known volume of sample produced the total solids. For total suspended solids a known volume of the sample was filtered through the glass fiber filter paper which was dried at 105°C. The weight difference of initial and final reading corresponding to known volume of sample which passes through the filter paper (1 μm Pall) gave the amount of total suspended solids. The filtrate was evaporated to dryness in a weighted dish at 180°C, thus increase in weight of the dish represents the total dissolved solids. A sample volume 100 ml was filtered in all solid determination using Nalgene filtration unit and PALL filtration pump. The residue of the total solids, suspended solids and dissolved solids was ignited at 550°C in muffle furnace and weight loss of the known weight and volume of the sample represented fixed total volatile, suspended volatile solids and dissolved volatile solids respectively.

2.12.1.4 Dissolved Oxygen (DO)

At Maitri DO was measured through Winkler method. Sample collected from the source, was soon put into 300 ml BOD bottle. DO was fixed with reagents at the site and then precipitated sample was titrated in the laboratory with standard sodium thiosulphate solution (0.025 N) putting starch as indicator. While experimented on RBC model, DO was measured through Thermo Orion 810+, DO meter which was calibrated against zero and saturated DO.

2.12.1.5 Biochemical Oxygen Demand (BOD)

At Maitri BOD was estimated by measurement of initial and final DO of the sample by Winkler method which was kept for 5 days in BOD incubator at 20°C. Dilution of water samples were prepared depending on the need and strength of sample. The lake water samples were kept for test with 25% dilution water without addition of seed. Initial and final DO of diluted water samples was measured after 5 days of incubation and average BOD estimated based on these two measurements. The waste water samples were
diluted to, 0.5%, 1%, 3% and 5%, with dilution water, according to the expected strength of wastewater sample, and kept for incubation for 5 days and initial and final DO measurement of sample as well as dilution water used, in preparation of sample were recorded. Accordingly using formulae BOD was estimated.

2.12.1.6 Chemical Oxygen Demand (COD)

The COD analysis is carried out at Maitri by open reflux method. Samples digested in 500 ml flask using 0.25 N potassium dichromate and sulfuric acid was then titrated with 0.1 ferrous ammonium sulfate solution. The samples of model experiment were analyzed by closed reflux colorimetric method using Hack DRB 200 COD reactor and setting Thermo Genesis 20 spectrometer at 600 nm. The value of COD is then estimated through calibration curve of COD prepared with standard solutions. The samples were diluted to measure the strength in line with calibration curve.

2.12.1.7 Ammonia

Ammonia was estimated by colorimetric method (Ramteke and Moghe, 1988). The pH of the filtered sample (0.45 um) is maintained by adding ZnSO_4, then mixing with Rochelle salt solution, and nessler reagent then absorbance was measured at 410 nm. Calibration curve was drawn through standard ammonium solution.

2.12.1.8 Nitrate

Nitrate in the samples (filtered through 0.45 um membrane filter) were measured through phenol disulfonic acid (PDA) method (Ramteke and Moghe, 1988). Evaporated sample to dryness by water bath was mixed with phenol disulfonic acid reagent and then NaOH was added. Color developed solution was then put for absorbance in the spectrometer at 410 nm. Calibration curve was developed using standard nitrate solution.

2.12.1.9 Total Phosphate

To determine the total phosphate, colorimetric method was used, adding phenolphthalein indicator and sulfuric acid solution and then color was developed.
through adding hydroxide after boiling the sample for 90 minutes. Further, mixing the reagents, absorbance was measured in spectrometer at 690 nm. Calibration curve was prepared by phosphate standard solution and its absorbance.

2.12.1.10  Acidity

In the water sample acidity was measured by titration using standard sodium hydroxide 0.02 N solution and phenolphthalein and methyl orange indicator.

2.12.1.11  Alkalinity

Alkalinity in the water sample was determined by volumetric analysis using Standard sulfuric acid 0.02 N as titrate and phenolphthalein and methyl orange indicator.

2.12.1.12  Hardness

Total hardness in water sample was determined by mixing sample with buffer solution followed by Erichrome black T and titration with standard EDTA. Further calcium hardness was measured by titrating sample with EDTA after adding NaOH and murexide indicator. Magnesium hardness was obtained by deducting calcium hardness from total hardness.

2.12.1.13  Chloride

Chloride in the water samples was estimated by titrating it with standard silver nitrate solution 0.0141 N. Silver nitrate was also standardize against NaCl solution.

2.12.1.14  Sulfate

In the water sample sulfate was measured by colorimetric method. Samples were mixed with conditioning reagent and BaCl₂ and the absorbance was measured at 420 nm. Standard calibration curve was drawn using standard sulfate solution.

2.12.1.15  Trace Metal Analysis

Trace metal analysis of water as well as wastewater sample was determined using GBC –
2.13 Alternative Selection for Waste Disposal

The present method of disposal of treated wastewater at Maitri is being followed as to discharge treated effluent on open ground around 320 m away from the collection pond, which seeps further and join the glacial lake and joins another lake as these lakes are interconnected and ultimately joins the Priyadarshini lake. This leads to threat of chain contamination of the lakes. An alternate solution suggested is the treated wastewater may be further treated with tertiary treatment units and thereafter Reverse Osmosis (RO) can be implemented to further filter the impurities and trace metals. The effluent from RO can be either evaporated or sprinkled over the open land.

2.14 Application of WASP7

The Water Quality Analysis Simulation Program (WASP7), an enhancement of the original WASP (Di Toro et al., 1983; Connolly and Winfield, 1984; Ambrose, 1988) is proposed. This model helps users to interpret and predict water quality responses to natural phenomena and manmade pollution for various pollution management decisions. WASP is a dynamic compartment-modelling program for aquatic systems, including both the water column and the underlying benthos. WASP allows the user to investigate 1, 2, and 3 dimensional systems, and a variety of pollutant types. The time varying processes of advection, dispersion, point and diffuse mass loading and boundary exchange are represented in the model. WASP also can be linked with hydrodynamic and sediment transport models that can provide flows, depths velocities, temperature, salinity and sediment fluxes. This water quality prediction model was employed to assess the effect of wastewater seepage from the collection pond to Priyadarshini Lake in terms of pollution and eutrofication.