Chapter 5

Design and Application of Advance Treatment Process

5.1 Plant Design in Antarctica: Factual Conditions

5.1.1 Extreme Conditions

As mentioned earlier, climatic conditions in Antarctica are severe with annual temperature range from -40°C to +5°C and with wind gusts of up to 200 km/h (Heaton and Paterson, 2003) especially at bases situated away from coastal area. Inland, temperatures are much lower. At the Amundsen-Scott South Pole station, one of only two permanently occupied inland bases, temperatures range from -83°C to -14°C, with a mean of -5°C, while the wind blows constantly, with an average speed of 20 km/h (Flynn et al., 1994). At Maitri station, temperature vary from -35°C to +7°C. Blizzards are not infrequent and can develop very quickly; snowfalls, but drifts of windblown snow accumulate around prominent objects such as buildings. Freezing of pipes connecting plant components is a serious problem (Lori et al., 1992). It also means that treated effluent discharge is usually best done intermittently so as to minimize the chance of outfall pipes freezing up. This in turn implies that plants need to include a buffer tank in which treated effluent can be stored until the next discharge (Connor, 2008).

5.1.2 Load Fluctuation

Plants must also be able to handle widely varying hydraulic and BOD loads, since number of people wintering at research stations is a small fraction of those present during the peak summer resupply period. Most people present on the bases have similar work schedules, so diurnal load fluctuations are pronounced and have to be allowed. Another aspect is that numbers on stations tend to alter stepwise, for example when the resupply vessel arrives. This means that plants need to be adjusted rapidly to the load
changes. This problem is most acute at seasonally occupied stations.

### 5.1.3 Modular Design

The climate, together with the prolonged period of darkness during winter and the fact that stations maintain only a skeleton staff during the winter months, means that there exists a total of perhaps eight weeks in summer when conditions are good for outdoor construction work (Heaton and Paterson, 2003). Much of this time will be needed for transport of plant components to the selected site, installation, and connection of pipes and utilities. Modular, prefabricated plants that can be easily disassembled for shipping and readily reassembled on site are therefore virtually a necessity. Such plants can also be commissioned and modified prior to shipping, alleviating demands on the limited staff available on-site at research stations. For convenience of transport and handling, and to protect plant components during the rough weather characteristics of the southern ocean, most countries are opting to build their plants inside the containers.

The Scott base plant fits inside two ISO-20 shipping containers (New Zealand, 2002), while, the Neumayer and Jubany plants were built into containers 2.0 m long, 1.8 m wide and 1.8 m high, made of stainless steel to minimize problems with corrosion (Ahammer et al., 2000). Compactness is necessary if plants are to fit into containers. It also has other advantages, reducing the plant's footprint and its visual impact (Heaton and Paterson, 2003) as well as minimising heating costs. Rate of microbial waste decomposition processes are temperature dependent and till date plants have all been designed to run at 12°C (New Zealand, 2002) or above.

Plants need also to have low energy consumption. Energy is expensive in Antarctica, being derived from hydrocarbon fuels shipped in at high cost and stored in heated storage tanks. Aside from saving money, installing a low power demand plant means a reduced output of emissions from the base's power station (Connor, 2008).

### 5.2 Problem of Wastewater Discharge at Maitri Station

Waste water was always a matter of concern in Antarctica in terms of its proper treatment and discharge. The Maitri station is situated in the lower elevation than the surrounding glacier and ice sheet. According to the Madrid Protocol the treated effluent can be discharged either by making hole in the ice pit or into the sea. On the contrary
both the option are impractical to opt for final effluent discharge.

5.2.1 At India Bay

Maitri is situated in a valley area surrounded by the glacier at south side, ice bound hillocks at rest of the sides. It is around 80 km from the ice shelf and open sea boundary. It generates around 875 m$^3$ of wastewater each year. Assuming 20% of wastewater loss through evaporation due to less humid and high wind prevailing in the region, transporting the effluent (around 700-800 m$^3$) to the coast is possible by loading effluent in as many as 40-50 heated tanks of 20 kl capacity. But at one time only 10 piston bully can be operated, so five round from Maitri to sea coast is not a solution in that particular environment. The present effluent discharge, may be violating the Madrid Protocol obligations.

5.2.2 Ice Pit

Ice pit is available around one to two km away from waste generation source at higher level. Laying trace heated pipe for one to two km and attaching pump to lift the liquid at desired elevation will require installation of additional generator sets, which will consume more fuel and emit the foul gases and particulate matters thus pollute the environment.

5.3 Option for Final Discharge of Wastewater

5.3.1 Improving the Effluent Quality and Discharge on Land

A practical solution for wastewater management system considering the conditions of location of Maitri station, environment and Madrid protocol is to redesign the treatment system with ancillary units, tertiary treatment units and fine quality discharge at land concept. Such a design will minimise, reuse and recycle waste generated by its activities as far as practicable and will ensure that waste is disposed of with minimal environmental impacts. This design shall include alternative technologies, materials and disposal options, and identify areas to ensure meeting Madrid Protocol.

5.4 Ancillary Unit Design Requirement for RBC's

Disposal of Antarctic wastes has both, environmental and financial costs. By minimizing the strength of waste produced these costs can be reduced. Reduction of constituents which affect the biological and tertiary treatment system needs to be added before and
after the RBCs for production of potable water quality effluent. Following units are required to be designed and added:

- Equalization Tank
- Oil and Grease Trap
- Sludge Dewatering
- Tertiary Treatment Unit
- Reverse Osmosis
- UV Disinfection

5.4.1 Equalization Tank

Flow equalization is the damping of flow rate variation so that a constant or nearly constant flow rate can be achieved. The benefits from application of flow equalization are; (a) biological treatment is enhanced, because shock loadings are eliminated or minimized as inhibiting substances can be diluted and pH can be stabilized. (b) the effluent quality and thickening performance of secondary sedimentation tanks following biological treatment is improved through constant solid loading. (c) effluent-filtration surface area is reduced. Flow equalization not only improves the performance of treatment system but is also an attractive option for upgrading the performance of overloaded treatment plants.

5.4.1.1 Mass curve for B1 RBC

The cumulative mass flow drawn for 24 hours while the occupancy of the station was highest, against the time, shows that total volume of equalization tank required is 120 litres. Considering additional volume for contingency and sludge requirement a tank of 200 litres is proposed for B1 RBC (Figure 5.1).
5.4.1.2 Mass Curve for B3 RBC

Hourly mass curve drawn for 24 hours for B3 RBC shows that there is a requirement of a tank holding total volume of equalization tank of around 460 litres. It is proposed to have 600 litres (Figure 5.2), keeping additional storage for contingency and sludge.
5.4.2 Fats, Oil and Grease Trap

Fats and oil are the major components of food stuff. The term grease is commonly used for fats, oils, waxes and other related constituents found in wastewater. Fats and oils are compounds of alcohol or glycerol with fatty acids. The glycerides of fatty acids that are liquid at ordinary temperature are called oils, and those that are solids are called fats. Fats and oils are contributed to domestic wastewater through butter, margarine, meats, seeds, nuts, certain fruits and vegetables. Fats are among the more stable organic compounds and are not easily decomposed by bacteria. It is necessary to remove oil and grease before they enter biological wastewater unit.

Normally oil and grease trap are designed on the basis of detention time and surface area:

Detention time: 3-30 minutes may be selected

\[
\text{Surface Area} \ can\ be\ calculated\ with\ formulae\ as:\ \frac{(6.22\ \times\ 10^{-3}\ \times\ Q)}{V_r}
\]

Wherein

\( Q \) is Rate of flow in \( m^3/\text{day} \), and

\( V_r \) = Minimum rising velocity of the oily material to be removed in m/minute (0.25 m/minute in most cases)

**Volume of Tank**

\[
V = Q \times t
\]

Wherein,

\( V \) = Volume of tank (m\(^3\))

\( Q \) = Flow (m\(^3\))/minute
t = detention time (minutes)

For B1 RBC (flow 700 litres/ day)

\[
V = \frac{0.7 \times 30}{24 \times 60}
\]

\[= 14.6 \text{ litres} \sim 15 \text{ litres}
\]

For B3 RBC (flow 1950 litres/ day)

\[
V = \frac{1.95 \times 30}{24 \times 60}
\]

\[= 40.6 \text{ litres} \sim 41 \text{ litres}
\]

**Surface area of the tank**

Assuming 250 m$^2$ for flow of 1 m$^3$/s (rather using equation mentioned earlier)

For B1 RBC

Surface Area (A) \[= 172 \text{ cm}^2 \sim 200 \text{ cm}^2 \]

\[= 10 \times 20 \text{ cm} (a \times b)
\]

For B3 RBC

Surface Area (A) \[= 485 \text{ cm}^2 \sim 500 \text{ cm}^2 \]

\[= 20 \times 25 \text{ cm} (a \times b)
\]

**Depth of tank**

For B1 RBC
Depth (D) = \( \frac{V}{A} = 75 \text{ cm} \) and 15 cm free board \( \sim 90 \text{ cm (c)} \)

For B3 RBC

Depth (D) = \( \frac{V}{A} = 82 \text{ cm} \) \( \sim 85 \) and 15 cm free board = 100 cm (c)

Figure 5.3 is showing the elevations of oil and grease trap.

**Figure - 5.3 : Elevations of Oil and Grease Trap**

5.4.3 Sludge Dewatering

Sludge is produced in the RBC's primary and secondary settling tank. Additional sludge will also be produced from the equalization tank, oil and grease trap, chemical coagulation and reverse osmosis process. Sludge dewatering is a physical unit operation used to reduce the moisture content of sludge. There are various methods available for sludge dewatering which have their own advantages and disadvantages of energy, quality, water requirement, skilled operator, noise, maintenance, automation., area requirement, and site protocol and they are classified as:

- Vacuum Filter
- Solid bowl centrifuge
- Imperforate basket centrifuge
- Belt filter press
Considering designed sludge volume of 800 litres and cleaning in 180 days, total sludge production from B1 RBC would be 1600 litres in a year, whereas B3 RBC will produce 1530 litres in 90 days cleaning period which equals to 6120 litres in a year. Another volume of centrate which is expected to be produced from RO, may be around 40% of total waste water (900 m$^3$) is around 360 m$^3$. So, total centrate/sludge production would be around 368 m$^3$. Monitoring various environmental conditions following sludge dewatering system has to be adopted.

5.4.3.1 Imperforate Basket centrifuge

The tubular and chamber bowl designs are used wherever the dirt content of the liquid is low, so that the stoppages for cleaning are infrequent. If the solid content of the suspension is higher which is true at Maitri as using RO produces higher solid content, then the imperforate basket centrifuge (Figure 5.4) has to be used to separate the solids, and produce a reasonably clean liquid. This consists of a simple drum-shaped basket or bowl, usually rotating around a vertical axis. The solids accumulate in the basket and are compressed by a centrifugal force, but they are not dewatered. When the rotation of the bowl is stopped, the residual liquid will drain out including some from the interstices of the solid, and the layer of solids can be removed manually, by scraping or shoveling, or by lifting out a lining bag. Unloading can be achieved semi-automatically, without stopping the machine, first by use of a skimmer pipe to remove the residual liquid, and then by lowering a knife blade into the solid and cutting it out of the bowl. As the solids have not been dewatered at all, they may be fluid enough to flow out through the same skimmer pipe. Based on the total volume of sludge per day required to be dewatered it can be designed commercially.
5.4.4 Tertiary Treatment Unit

5.4.4.1 Coagulation by Alum Dosing

It is possible by chemical precipitation to obtain a clear effluent, substantially free from matter in suspension, or in colloidal state. There are various chemicals available for chemical precipitation i.e Alum-$\text{Al}_2(\text{SO}_4)_3 \cdot 18 \text{H}_2\text{O}$, Ferric Chloride-$\text{FeCl}_3$, Ferric sulfate-$\text{Fe}_2(\text{SO}_4)_3 \cdot 3\text{H}_2\text{O}$, Ferrous Sulfate-$\text{FeSO}_4 \cdot 7 \text{H}_2\text{O}$, Lime-$\text{Ca(OH)}_2$. Laboratory experiment have been conducted adopting Aluminum Potassium Sulfate-$\text{AlK(SO}_4)_2 \cdot 18\text{H}_2\text{O}$ to observe the effect of alum in reducing the BOD, COD and suspended and dissolved particles. For any given wastewater the optimal treatment strategy should be determined by jar testing (USEPA, 2000). Jar test conducted for lab scale experiment and at Maitri, concluded use of 80 mg/l of alum for kitchen waste effluent and 40 mg/l of alum for bathroom/laundry RBC. Chemical precipitation is normally carried out through a chemical feed system, most often a automated system. An automatic feed system may consist of storage tanks, metering pumps, overflow containment basins, mixers, and aging tanks, injections quills, shot feeders, piping, fittings and valves (Figure 5.5). Chemical precipitation unit is required to be installed before the effluent enters to activated carbon unit and RO.
B1 RBC which has effluent flow of 29.2 litres/hr will require around 28 grams of alum dose to be mixed in a litre of water maintaining discharge in 24 hours, to mix with the effluent. B3 RBC will require 78 gms of alum dose in a day to mix in two litre of water, maintaining discharge and mixing with effluent in a day.

### 5.4.4.2 Activated Carbon Treatment

Carbon adsorption is primarily used for removal of refractory organic compounds, as well as residual amounts of inorganic compounds such as nitrogen, sulfides and heavy metals (Metcalf and Eddy, 1995). Under the normal conditions, after treatment with carbon, the effluent BOD ranges from 2 to 7 mg/l and effluent COD ranges from 10 to 20 mg/l. Generally fixed bed column is used for contacting wastewater with Granular Activated Carbon (GAC). The sizing of carbon contactor is based on four factors: contact time, hydraulic loading rate, carbon depth and number of contactors. Rapid Small Scale Column Test (RSSCT) is useful to predict the performance of pilot scale or full scale carbon column. For the single column design as in the case of Maitri, breakthrough curve is useful to arrive at the bed life. In the field, the breakthrough adsorption capacity \((x/m)_b\) of a GAC in a full scale column is some percentage of the theoretical adsorption capacity found from the isotherm. The time to breakthrough can be calculated using following relationship:

\[
t_b = \frac{(x/m)_b m_{GAC}}{Q (C_0 - C_b/2)}
\]
\[(x/m)_b = X_b/M_c\]

Wherein

\[(x/m)_b\] = field breakthrough adsorption capacity (g/g)

\[X_b\] = mass of organic material adsorbed in the GAC column at breakthrough, g

\[M_c\] = mass of the carbon in the column, g

\[m_{GAC}\] = mass of the carbon in column, g

\[Q\] = flowrate m³/day

\[C_o\] = influent organic concentration, g/m³

\[C_b\] = breakthrough organic concentration, g/m³

\[t_b\] = time to breakthrough, day

The theoretical adsorption capacity of the carbon for a particular contaminant can be determined by developing its adsorption isotherm. The adsorption characteristics of activated carbon used in wastewater treatment can be described by Freundlich isotherm (Metcalf and Eddy, 2009). The amount of material adsorbed is determined as a function of the concentration at constant temperature and the resulting function is called as adsorption isotherm.

\[\frac{x}{m} = K_f C_e^{1/n}\]

Wherein,

\[x/m\] = mass of adsorbate adsorbed per unit mass of adsorbent, mg adsorbate/g activated carbon
\[ K_f = \text{Freundlich capacity factor (mg absorbate/g activated carbon)} \]
\[ (L \text{ water/mg adsorbate})^{1/n} \]
\[ C_e = \text{equilibrium concentrate of adsorbate in solution after adsorption, mg/l} \]
\[ 1/n = \text{Freundlich intensity parameter} \]

In the laboratory experiment the mass of adsorbent, m is 700 gms which is kept constant throughout the experiment. Table 5.1 shows the adsorbent and adsorbate value.

**Table - 5. 1 : Adsorbent and Adsorbate Value (for COD)**

<table>
<thead>
<tr>
<th>C0 (mg/l)</th>
<th>Ce (mg/l)</th>
<th>Co-Ce (mg/l)</th>
<th>x/m (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>112.0</td>
<td>68.2</td>
<td>43.8</td>
<td>1.9</td>
</tr>
<tr>
<td>115.7</td>
<td>1.6</td>
<td>114.1</td>
<td>5.1</td>
</tr>
<tr>
<td>139.5</td>
<td>9.5</td>
<td>130.0</td>
<td>5.8</td>
</tr>
<tr>
<td>70.7</td>
<td>29.5</td>
<td>41.3</td>
<td>1.8</td>
</tr>
<tr>
<td>108.2</td>
<td>2.0</td>
<td>106.2</td>
<td>4.7</td>
</tr>
<tr>
<td>293.2</td>
<td>218.1</td>
<td>75.1</td>
<td>3.3</td>
</tr>
<tr>
<td>439.5</td>
<td>72.0</td>
<td>367.5</td>
<td>16.3</td>
</tr>
<tr>
<td>376.5</td>
<td>362.5</td>
<td>14.0</td>
<td>0.6</td>
</tr>
<tr>
<td>279.5</td>
<td>217.0</td>
<td>62.5</td>
<td>2.8</td>
</tr>
<tr>
<td>102.0</td>
<td>100.7</td>
<td>1.3</td>
<td>0.1</td>
</tr>
<tr>
<td>149.5</td>
<td>90.7</td>
<td>58.8</td>
<td>2.6</td>
</tr>
<tr>
<td>92.0</td>
<td>63.2</td>
<td>28.8</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Using above equation and the table, parameters adsorption isotherm is plotted in log-log graph and shown below in the Figure 5.6.
From the figure it is estimated that line intercepts (c) at x/m value 0.048, value of Ce is 1, and $K_C$ is 1.106, whereas slope ($1/n$) is 0.455.

### 5.4.5 Operational Performance of GAC Contactor (Laboratory Experiment)

**A. Empty Bed Contact Time (EBCT)**

\[
\text{EBCT} = \frac{V_b}{Q} = \frac{A_b D}{v_f A_b} = \frac{D}{v_f}
\]

Wherein,

- $\text{EBCT} =$ empty bed contact time, h
- $V_b =$ volume of GAC in contactor, m$^3$
- $Q =$ volumetric flow rate, m$^3$/h
- $A_b =$ cross sectional area of GAC filter bed m$^3$
- $D =$ length of GAC in contactor, m
- $v_f =$ linear approach velocity, m/h
In the experiment $Q = (25 + 6) = 31$ litre, Density of GAC = 240.1 g/l and diameter of column 0.15 m

Here $A = A_b$

$$V_f = \frac{Q}{A} = \frac{31 \times 4}{1000 \times 24 \times 3.14 \times 0.15 \times 0.15}$$

$$EBCT = \frac{0.15}{0.073} = 2.05 \text{ h}$$

**B. CARBON USAGE RATE (CUR) IN G GAC/LITRE**

$$B = \frac{m_{GAC}}{Q_t} = \frac{C_o - C_e}{q_e} = \frac{C_o - C_e}{K_f C_o^{1/m}}$$

$$= \frac{43.8}{1.106 (112)} = 4.63$$

**C. MASS OF CARBON REQUIRED FOR GIVE EBCT**

$$= EBCT \times Q \times \rho_{GAC}$$

$\rho_{GAC} =$ activated carbon density

(Weight of carbon used in column-700 g, diameter of column, 0.15 m and height, 0.165 m)

$$= \frac{700 \times 4}{(3.14 \times 0.15 \times 0.15 \times 0.165 \times 1000)} = 240.1 \text{ g/l}$$
= 2.05 x (31/24) x 240.1

= 635.7 g (actual used 700 g)

D. VOLUME OF WATER TREATED FOR GIVEN EBCT AND MASS OF GAC

= mass of GAC for given EBCT / GAC usage rate

= 700/4.63

= 151.1 litre

E. BED LIFE OF GAC USED IN EXPERIMENT

= Volume of water treated for EBCT / Q

= 151.1 / 31

= 4.87 ~ 5 day

Bed life of the activate carbon considering laboratory experiments is shown in Table 5.2.

<table>
<thead>
<tr>
<th>CO (mg/l)</th>
<th>Ce (mg/l)</th>
<th>CO-Ce (mg/l)</th>
<th>Bed Life (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>112.0</td>
<td>68.2</td>
<td>43.8</td>
<td>4.4</td>
</tr>
<tr>
<td>115.7</td>
<td>1.6</td>
<td>114.1</td>
<td>1.7</td>
</tr>
<tr>
<td>139.5</td>
<td>9.5</td>
<td>130.0</td>
<td>1.6</td>
</tr>
<tr>
<td>70.7</td>
<td>29.5</td>
<td>41.3</td>
<td>3.8</td>
</tr>
<tr>
<td>108.2</td>
<td>2.0</td>
<td>106.2</td>
<td>1.8</td>
</tr>
<tr>
<td>293.2</td>
<td>218.1</td>
<td>75.1</td>
<td>4.0</td>
</tr>
<tr>
<td>439.5</td>
<td>72.0</td>
<td>367.5</td>
<td>1.0</td>
</tr>
<tr>
<td>376.5</td>
<td>362.5</td>
<td>14.0</td>
<td>24.1</td>
</tr>
<tr>
<td>279.5</td>
<td>217.0</td>
<td>62.5</td>
<td>4.7</td>
</tr>
<tr>
<td>149.5</td>
<td>90.7</td>
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<td>3.8</td>
</tr>
<tr>
<td>92.0</td>
<td>63.2</td>
<td>28.8</td>
<td>6.2</td>
</tr>
</tbody>
</table>
5.4.6 Design of Field scale GAC Column

For the designing of the filed scale Granular Activated Carbon Column (GAC), already designed parameters available are tabulated for the comparison and calculation purpose in the Table 5.3.

Table - 5.3 : Lab Scale column (LSC) and Full Scale Column (FSC)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>LSC</th>
<th>FSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Diameter</td>
<td>mm</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Carbon Density</td>
<td>g/l</td>
<td>240</td>
<td>450</td>
</tr>
<tr>
<td>EBCT</td>
<td>h (hour)</td>
<td>2.05</td>
<td>-</td>
</tr>
<tr>
<td>Loading Rate (vf)</td>
<td>m/h</td>
<td>0.073</td>
<td>-</td>
</tr>
<tr>
<td>Flow Rate</td>
<td>litre/day</td>
<td>31</td>
<td>5000</td>
</tr>
<tr>
<td>Column Diameter</td>
<td>mm</td>
<td>150</td>
<td>-</td>
</tr>
<tr>
<td>Column Length</td>
<td>mm</td>
<td>165</td>
<td>-</td>
</tr>
<tr>
<td>Weight of GAC</td>
<td>gram</td>
<td>700</td>
<td>-</td>
</tr>
</tbody>
</table>

A. EBCT FOR FSC

Assuming the time of operation of the field column as 100 days which has to treat total flow of 5000 litre per day.

\[ Q_{FC} = 5000 \text{ litre/day}, t_{FC} = 100 \text{ d} \] (FC – Full scale and LC – Lab Scale)

So the Volume of water that will pass through the column

\[ V_{FC} = Q_{FC} \times t_{FC} \]

\[ = 5000 \times 100 \]

\[ = 500 \text{ m}^3 \]

\[ EBCT = \frac{EBCT_{LC} \times t_{FC}}{t_{LC}} \]

\[ = \frac{(100/4.4) \times 2.05}{t_{LC}} \]

\[ = 46.5 \text{ h} = 1.9 \text{ day} \]
B. LENGTH OF THE COLUMN

\[ L_{FC} = \frac{Q_{LC} \times EBCT_{FC}}{A_{FC}} \]

(Assuming diameter of column = 0.8 m, \( A_{FC} = (\pi/4) \times 0.8^2 = 0.5 \ m^2 \))

\[ = 5 \times 1.93/0.5 \]

\[ = 19.3 \ m \]

C. MASS OF ABSORBENT REQUIRED FOR FSC

\[ M_{FC} = \frac{Q_{LC} \times EBCT_{FC} \times d_{FC}^2 \times \rho_{FC}}{d_{SC}^2} \]

\[ = (5 \times 2.05 \times 0.8^2 \times 240)/(0.15^2 \times 24) \]

\[ = 2915 \ kg \]

Comments: total length of 0.8 m diameter column is 19.3 m which has to fill with total 2915 kg of GAC. But considering 1.5 m length each column of 0.8 m diameter total 24 columns has to be opted to accommodate activated carbon of density 240 kg/m³.

5.4.7 Membrane Filtration

The wastewater reclamation and reuse involves membrane filtration (Madaeni, 1999, Rosenberger et al., 2006) based advance treatment (Ramirez et al., 2003). This treatment produces high quality effluent with very low conductivity without any microbiological problems. Membrane process includes microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO), dialysis and electrolysis (ED). The requirement at Maitri based on the influent characteristics and desired high quality effluent it would be desired to include microfiltration followed by nanofiltration or reverse osmosis process which will treat the effluent from secondary treatment unit. Microfiltration has typical operating range of 0.08-2.0 μm, nanofiltration is of 0.001-0.01 μm and reverse osmosis of 0.0001-0.001 μm. RO process is suitable to remove very small molecules, color, hardness, sulfates, nitrates, sodium and other ions (Metcalf and Eddy, 2009). Decentralized treatment of domestic wastewater offers the possibility of water and nutrient reuse (Ellen et al., 2005). Recently, the introduction of Ultra Low Pressure Reverse Osmosis (ULPRO) membrane has widened the horizon of RO in
purification of surface water as well as desalination of brackish water (Ozaki and Li, 2002). Study shows that ULPRO with multi-layer thin film, composites of aromatic polyamide which has high rejection of organic compounds under very low pressure. Table 5.4 shows the typical performance of membrane filtration unit.

**Table - 5. 4 : Typical Performance of MF used as Pretreatment for RO**

<table>
<thead>
<tr>
<th>Constituents</th>
<th>MF influent (mg/l)</th>
<th>MF effluent (mg/l)</th>
<th>Average reduction (%)</th>
<th>Reduction reported in literature (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC</td>
<td>10-31</td>
<td>9-16</td>
<td>57</td>
<td>45-65</td>
</tr>
<tr>
<td>BOD</td>
<td>11-32</td>
<td>&lt;2-9.9</td>
<td>86</td>
<td>75-90</td>
</tr>
<tr>
<td>COD</td>
<td>24-150</td>
<td>16-53</td>
<td>76</td>
<td>70-85</td>
</tr>
<tr>
<td>TSS</td>
<td>8-46</td>
<td>&lt;0.5</td>
<td>97</td>
<td>95-98</td>
</tr>
<tr>
<td>TDS</td>
<td>498-622</td>
<td>498-622</td>
<td>0</td>
<td>0-2</td>
</tr>
<tr>
<td>NH₃-N</td>
<td>21-42</td>
<td>20-35</td>
<td>7</td>
<td>5-15</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>&lt;1-5</td>
<td>&lt;1-5</td>
<td>0</td>
<td>0-2</td>
</tr>
<tr>
<td>PO₄</td>
<td>6-8</td>
<td>6-8</td>
<td>0</td>
<td>0-2</td>
</tr>
<tr>
<td>SO₄</td>
<td>90-120</td>
<td>90-120</td>
<td>0</td>
<td>0-1</td>
</tr>
<tr>
<td>Cl</td>
<td>93-115</td>
<td>93-115</td>
<td>0</td>
<td>0-1</td>
</tr>
</tbody>
</table>

(Whitley and Burchett, 1999)

Nanofiltration also known as “loose” RO, can reject particles as small as 0.001 μm. Both inorganic and organic constituents, bacteria and viruses are removed and disinfection requirement is minimized. In wastewater treatment RO is used for the removal of dissolved constituents from wastewater remaining after advance treatment like microfiltration. Table 5.5 shows the typical performance of RO system.
Table - 5.5: Typical Performance of RO used

<table>
<thead>
<tr>
<th>Constituents</th>
<th>RO Influent (mg/l)</th>
<th>RO effluent (mg/l)</th>
<th>Average reduction (%)</th>
<th>Reduction reported in literature (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC</td>
<td>9-16</td>
<td>&lt;0.5</td>
<td>&gt;94</td>
<td>85-95</td>
</tr>
<tr>
<td>BOD</td>
<td>&lt;2-9.9</td>
<td>&lt;2</td>
<td>&gt;40</td>
<td>30-60</td>
</tr>
<tr>
<td>COD</td>
<td>16-53</td>
<td>&lt;2</td>
<td>&gt;91</td>
<td>85-95</td>
</tr>
<tr>
<td>TSS</td>
<td>&lt;0.5</td>
<td>~ 0</td>
<td>&gt;99</td>
<td>95-100</td>
</tr>
<tr>
<td>TDS</td>
<td>498-622</td>
<td>9-19</td>
<td>0</td>
<td>90-98</td>
</tr>
<tr>
<td>NH3-N</td>
<td>20-35</td>
<td>1-3</td>
<td>96</td>
<td>90-98</td>
</tr>
<tr>
<td>NO3-N</td>
<td>&lt;1-5</td>
<td>0.08-3.2</td>
<td>96</td>
<td>65-85</td>
</tr>
<tr>
<td>PO4</td>
<td>6-8</td>
<td>0.1-1</td>
<td>~99</td>
<td>95-99</td>
</tr>
<tr>
<td>SO4</td>
<td>90-120</td>
<td>&lt;0.5-0.7</td>
<td>99</td>
<td>95-99</td>
</tr>
<tr>
<td>Cl</td>
<td>93-115</td>
<td>0.9-0.5</td>
<td>99</td>
<td>90-98</td>
</tr>
<tr>
<td>Turbidity</td>
<td>0.03-0.08 NTU</td>
<td>0.03 NTU</td>
<td>97</td>
<td>40-80</td>
</tr>
</tbody>
</table>

(Whitley and Burchett, 1999)

5.4.8 UV Disinfection

The germicidal properties of radiation emitted from Ultraviolet (UV) light sources as a wastewater disinfectant has evolved during 1990. With proper dosage UV radiation has proved to be an effective bactericide and virucide for wastewater, while not contributing to the formation of toxic byproducts (Metcalf and Eddy, 2009). System can be adopted as open channel or closed channel disinfection. The effectiveness of the UV disinfection process depends on the characteristics of the microorganism. An UV disinfection system can be installed at Maitri station to avoid any bacterial contamination through discharge of treated wastewater.

5.5 Outcome

Wastewater treatment and management in Antarctica is on one side requirement of Madrid Protocol and on other side need of the hour. Final wastewater effluent discharge after maceration/biological treatment especially for the stations situated inland needs different approach. The stations, situated near the coastal areas have the option to treat
the waste to an optimum stringent standard and discharge into sea. However, the energy consumption and cost involved affect the policy and environmental concern. At Maitri station after conducting experiment and taking into consideration various aspects, it is found necessary to design the ancillary units such as; equalization tank, oil and grease trap, sludge dewatering unit, tertiary treatment unit of activated carbon. The final effluent after passing through the activated carbon further needs to be polished using Reverse Osmosis and disinfected with UV disinfection unit. An attempt has been made in the present study to design equalization tanks, oil and grease trap and tertiary treatment unit for Maitri station. Considering the lab scale experiments it can be concluded that present RBC system at Maitri can be upgraded with installation of these units to get fine quality effluent water.