Wastewater Fate at Maitri in Antarctica

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At 'Maitri' drinking water source is Priyadarshini Lake which is situated at 200 m away from the station. Water consumption leads to wastewater generation and to treat the waste water two rotating biological contactors (RBC), B1 and B3 of different capacity were installed. The maximum treatment capacity of B3 RBC is 5 kl/d and B1:RBC is having capacity of 1 kl/d. At the sampling point temperature, pH was measured and within 15 min of sampling it was brought to the laboratory at Maitri to analyse basic parameters, ie, BOD, COD, conductivity, TSS, Cl, NH_3-N, DO, total alkalinity and turbidity. The treatment efficacy of B1:RBC was observed only 66.7% in terms of BOD and 68.9% of COD. But, due to lower pH, the ammonia nitrogen of effluent was less than the influent because the ammonia producing bacteria were not working effectively at lower pH. Tertiary treatment at lab scale of B1 RBC shows that BOD and COD are further removed by 40.3% and 21.9%, respectively. The treatment efficacy of B3:RBC was observed only 29.8% in terms of BOD and 41.4% of COD. The BOD and COD were further removed by 22.2% and 30%, respectively in tertiary treatment of B3 RBC at lab scale experiment. The tertiary treatment was found to be very effective even when the treatment system was not tuned fully, however, if tuned and tertiary treatment system was applied further the efficacy improvisation would have been expected upto 95%-98%.

Keywords: Rotating biological contactor; Efficacy; Tertiary treatment; Biochemical oxygen demand; Chemical oxygen demand

INTRODUCTION

Antarctica is known for superlatives, windiest, coldest and driest continent on earth, India has set its second permanent station in Antarctica on the Dronning Maud land of Schirmacher Oasis[1], as designated in 'Maitri' at 70°45"57" S and 11°44"09" E. To carryout various scientific activities around 55 persons during the summer and around 25 persons during the winter, one can stay at Maitri station. Drinking water is sourced from Priyadarshini Lake, which is situated at 200 m away from the station. Water consumption leads to wastewater generation. To treat the waste water in two different places rotating biological contactors (RBC) are installed[2]. The major objective of an RBC is the removal of soluble organic matter by conversion into insoluble microbial cells, which can be removed by sedimentation, thereby providing an effluent of high quality. The maximum capacity[3] of B3:RBC is 5 kl/d and B1:RBC is 1 kl/d. These systems were installed during the IX-Indian Antarctic Scientific Expedition (IASE) in the year 1989-90. During the summer period, the lowest temperature recorded around –15° C and maximum +4°C during the winter lowest temperature as recorded around –38° C. The treatment systems were installed in enclosed room outside of Maitri, which is in operation throughout the year irrespective of seasonal variation became of summer and winter. The performance of RBC was evaluated in terms of biochemical oxygen demand (BOD), chemical oxygen demand (COD) and ammonical nitrogen (NH_3-N).

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Water Consumption

Water collected from the lake is used by the resident of Maitri as well as the summer camp members. Water is collected in the tanks at Maitri from where it is discharged to summer camp tank for further use by resident of summer camp, however during winter period; water is consumed only by winter members because no one stays at summer camp. Summer camps utilize the water from the month of January to March (Figure1). Water flow was measured from the flow meter installed at submersible pump of the pumping house. The flow was also verified from two marked storage tanks of size 1mX1mX3m based on the initial and final volume difference at particular time of the day after and before pumping the water into the storage tank. Maximum water supply in a month is recorded as 164.5 m^3 in the month of January and minimum 50.4 m^3 in the month of April.

Wastewater Source

Wastewater generated from the kitchen by dishwashing, washbasins, washing of food grains, which is organic in nature and contains oil and grease too. All the waste generated inside the kitchen is carried through the combination of insulated iron and thick plastic pipe to B1:RBC. Another type of waste is generated from bathroom,

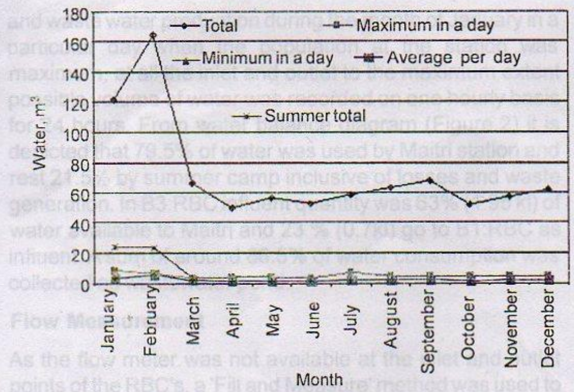

Figure 1 Monthly water supply pattern

washbasin and laundry which is alkaline in nature and carried to B3:RBC through combination of copper, iron and thick insulated plastic pipe.

MATERIAL AND METHODS

Rotating Biological Contactor (RBC)

Design Features

Klargester bio discs are manufactured in glass fibre reinforced polyester (GRP). These RBC are light in weight, easy to transport and easy to install. GRP is extremely robust, but susceptible to damage by sharp objects and from point loads. The RBC consists of banks of polypropylene media attached to a central shaft and is supported by two bearings, which are mounted on the rear bearing support bracket and the drive platform steelwork. The main operational features of the rotor unit are outlined below.

The RBC is divided into three stages by means of a fixed baffle attached to the biozone and rotating baffles fixed to the shaft. The media is splited into stages designed to promote effective and efficient growth of bio-culture to effect treatment.

The RBC is rotated slowly through a reduction gearbox and peripheral drive gear and is arranged so that a proportion of its surface area is submerged in the effluent at any one time. As the RBC rotates, the surface of the media is subjected alternately to sewage and air, encouraging an aerobic, biologically active film of micro-organisms (biomass) to become established on each side of the media sheets. This biologically active film grows in size, is self regulating and oxidizes the pollutants in the sewage. The micro organisms use the untreated waste as a substrate (food) and as they do so, multiply in number, maintaining a specific biomass thickness to ensure optimum process efficiency. Material from the first stages of the RBC falls into the primary settlement tank (PST) through the pipe in the biozone casing, whereas material from the remaining stages of RBC is kept in suspension and carried forward into the final settlement tank (FST).

In order to ensure a balanced and constant flow a stable environment, dosing buckets fitted to the first stage of the RBC shaft lift and transfer the partially clarified liquor to the final stages of RBC at a constant rate, irrespective of changes to incoming flow rates and water level.

The final settlement tank (FST) comprises the secondary settlement or final zone, which is situated under the drive motor. It is formed by a full depth GRP baffle across the width of the unit and it is in this final zone that any biological culture, which falls from the later stages of RBC, is allowed to settle out. The treated effluent enters this zone from the biozone. By utilising the procedure, sludge storage volume of B1:RBC was kept as 300 l and desludging period was 180 days, where as for B3:RBC sludge storage volume was kept as 1530 l and desludging period was 91 days. Design features of B1:RBC and B3:RBC'c are enumerated in Table1.

Operation

Generally, 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[4] and at sometime overburden the discs with extra mass. The B1:RBC was designed for maximum hydraulic load for 1.2 m^3/day and BOD load as 0.36 kg/day whereas B3:RBC was designed to take maximum hydraulic load as 5.0 m^3/day and BOD load as 1.5 kg/day. The equipment was designed to achieve an effluent discharge standard of not more than 20 mg/l of BOD and 30 mg/l suspended solids and 20 ml/l of ammonia nitrogen assuming that ambient temperature within the plant is 5° C. The RBC comprises main components, namely, primary settling zone, biozone and secondary settling zone. The direction of disc rotation was selected to be opposite to the direction of wastewater flow in order to reduce on short circuiting. The ambient temperature under which sample collection and analysis performed ranged between –12° C to +3° C.

Water Balance at Maitri

In order to find out the water consumption, distribution loss

Table 1 Design features of B1 and B3 RBC

Design features	Description	
	B1:RBC	B3:RBC
Design load, l/day	1200	5000
Number of disc	56	100
Surface area of disk, m^2	56.0	200.0
Thickness of disk, mm	4.0	4.0
Dia/dimention of disk, mm	500x500	1000x1000
Dia of shaft, mm	100	150
Rotational speed, RPM	5	5
Spacing of disk, mm	15	15
Disk submergence, %	45%	45%
Power requirement	50 W	150 W

and waste water production during the month of January in a particular day when the population at the station was maximum, at all the inlet and outlet to the maximum extent possible volume of water was recorded on one hourly basis for 24 hours. From water balance diagram (Figure 2) it is depicted that 79.5% of water was used by Maitri station and rest 21.5% by summer camp inclusive of losses and waste generation. In B3:RBC influent quantity was 63% (1.95 kl) of water available to Maitri and 23 % (0.7kl) go to B1:RBC as influent. A sum of around 86.5% of water consumption was collected as wastewater pond.

Flow Measurement

As the flow meter was not available at the inlet and outlet points of the RBC's, a 'Fill and Measure' method was used to assess the volume at inlet as well as outlet points. Volume was measured at every hour for 24 h and then cumulative volume was calculated to produce a mass curve. Mass curve was developed to design the storage and feeding tanks for B1:RBC and B3:RBC to help in arresting the shock load, which would improve the efficacy of treatment system. Storage tank capacity for B1:RBC calculated around 90 l where as for B3:RBC it is 460 l.

Sample Collection and Preservation

The wastewater produced from various sources was directly fed in to RBC through two separate pipes. Wastewater generated from kitchen was directly fed through single pipe to B1:RBC, where as wastewater generated from washbasin, bathroom, laundry and urinals were collected in separate small pipes which ultimatly joins the single pipe before feeding to B3:RBC. Composite samples (24 h) were collected before the inlets to RBC, from appropriate places at various course of time, and from outlets of RBCs, as well as from tap water which were stored in high density polypropylene bottles. At the sampling point temperature pH was measured and within 15 min of sampling it was brought to the laboratory at Maitri station and analysed for basic parameters, *ie*, BOD, COD, conductivity, TSS, Cl, NH_3-N, DO, total alkalinity and turbidity. Rest sample

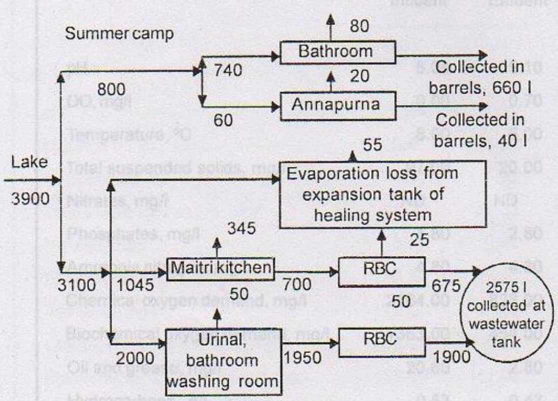

Figure 2 Water balance at Maitri station

collected was preserved with HNO_3 for trace metals and H_2SO_4 for organic, oil and grease, sealed properly and brought to India for further analysis in the laboratory. Samples were prepared by filtering with 0.45 μm Whatman filter papers. All analyses were performed according to standard methods for analysis of water and wastewater[5]. Samples for trace metal analysis were preserved and analyzed by GBC, atomic spectrophotometer in the laboratory.

Tertiary Treatment Experiment

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 alum dose by flocculation and the obtained supernatant liquid was passed through the vertical column of 90 mm dia with 165 mm height consisting of activated charcoal (2-5 mm dia and 600-1000 m^2/g sp. surface area) of total weight of 700 g. Influent before introduction of alum and effluent through activated carbon treatment was analyzed for temperature, pH BOD, COD, conductivity and DO at Maitri laboratory and later trace metals at the Institute's laboratory. One gram of alum was mixed well in distilled water and 10,20,40,80 and 150 ml of aqueous solution was mixed and flocculated well in a liter of series of waste obtained from inlet of B1:RBC and B3:RBC. An optimum dose of alum solution which gave the maximum settlement of suspended particles was selected to pass through the activated carbon column. For this purpose, alum dose of 80mg/l was selected for B1:RBC influent and 40 mg/l for B1:RBC influent. 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

RESULTS AND DISCUSSIONS

Kitchen RBC (B1)

The wastewater treatment system is RBC which was installed at Maitri in the year 1999. These RBC' are designed and manufactured by Klargester Company, UK. Since the beginning, wastewater produced at Maitri is segregated and being treated in different RBCs. Kitchen waste contains high organic matter, which generates from washing of food grains, dishes condense milk, vegetable oil and others sources. The strength of the waste changes day to day, pertaining to the food habits during various occasions. Hydraulic loading on B1:RBC was noticed maximum during the summer which is 0.08 l/m^2 d. Three samples collected were on various course of time such as business-as-usual, normal day and the day when strength was high, and different varieties of food served. The average water consumption as shown in water balance diagram depicted 1.045 kl, out of which, wastewater converted, reaches to the kitchen RBC (B1) was approximately 0.7 kl per day during the summer period when the strength is more, however during the winter period it reduces. Three samples were collected and analyzed in different course of time, where first sample was collected in the first weak of January running as-usual-scenario. It shows that waste is of acidic nature and septic which of high strength of BOD and COD. The treatment efficacy was observed only 66.7% of BOD and 68.9% of COD. But due to lower pH the ammonia nitrogen of effluent is less than the influent because the ammonia producing bacteria were not working effectively at lower pH. Nitrification was probably hampered due to low alkalinity in the wastewater[6]. Oil and grease which were also mixing in the influent making the film over the liquid and thus disrupting the oxygen transfer at sediments tank. However, in the biological chamber due to continuous movement of the disc it was emulsifying. Microbe growth was observed on the disc of gray color which is clear indication of the overloading on the treatment system. The biomass development in aerobic unit did not always cover the entire disk surface[7]. Mostly suspended BOD and COD were removed in the sediment tanks and biological chamber reduces the BOD and COD load contributing due to dissolved matter. The trace heavy metals were removed very effectively as the copper, iron and zinc which are essential growth elements for bacteria were consumed by the bacteria but the temperature was as low as 8°C to 6°C which was not optimal temperature for microbes to work effectively for denitrification[8] as compare to 12°C to 20°C. It was also noticed that the rpm of biodisc is 1.2, during the treatment process. Realizing lower temperature in the biozone, the temperature inside biodisc increased to 22° C and after few days the composite samples were collected and analyzed. Increase in temperature could only improve the ammonia nitrogen content in the effluent which shows the nitrogen decaying bacteria started growing and assimilating the organic content but still the efficiency for BOD removal was 48.3% and for COD it was around 24.7%. The third samples were taken on the day when the strength was high at the station. The temperature was maintained at biodisc as 20° C to 22° C. It was observed that ammonia nitrogen in the effluent is further improved and the nitrate concentration is also recorded. This is the indicator that the treatment efficiency was improved and the BOD removal efficiency observed as 45.8% and COD as 49.2% even though when the load was more (Table 2). This RBC was designed as maximum BOD of 300 mg/l in the influent with the maximum flow of 1.32 m^3/day. The overloading was also observed and quite evident from the grey color of the microbes as developed on the biodisc. This high BOD and COD were adding to the effluent from the secondary settling tank where from the sludge was not removed properly and the anaerobic condition generated and producing gases which kept suspended the sludge and finally to the effluent which ultimately added upto more BOD and COD value in the effluent. Oil and grease and hydrocarbon are also responsible to hamper the treatment efficiency of the system. Among the trace metals in the third sample, copper, manganese, zinc concentration found lower in the effluent except the iron content and the possible reason might be the introduction of inorganic iron from the iron pipe which is little old.

Tertiary Treatment B1:RBC

Four liters of treated effluent collected from B1 RBC to study the tertiary treatment and effect of series treatment. To assess the optimum dose of alum for maximum settlement of particles present in the wastewater, four jar of one litre capacity filled with treated wastewater and different dose of alum mixed in water and stirred for 5 min. The jar selected for further treatment, which shows the maximum settlement of coagulated particles. Supernatant liquid holding the volume of 900 ml passed through the column filled with activated carbon, with a constant rate of flow 50 ml/min.

Table 2 Physico-chemical characteristics of wastewater of B1 (Kitchen)

Parameters	Sample 1		Tertiary treatment (effluent)		Sample 2		Sample 3	
	Influent	Effluent	Alum	Activated carbon	Influent	Effluent	Influent	Effluent
pH	5.08	5.10	5.0	7.5	4.99	4.54	5.9	6.5
DO, mg/l	0.00	0.70	-	-	0.53	1.00	0.6	1.5
Temperature, °C	8.00	6.00	11.0	11.0	22.00	21.00	20.0	19.0
Total suspended solids, mg/l	97.00	20.00	13	8.0	-	-	-	-
Nitrates, mg/l	ND	ND	ND	ND	-	-	-	-
Phosphates, mg/l	1.80	2.80	1.2	0.3	-	-	-	-
Ammonia nitrogen, mg/l	4.80	4.30	3.8	3.7	2.85	3.54	4.7	71.5
Chemical oxygen demand, mg/l	2664.00	828.00	576.0	450.0	728.00	548.00	2387.0	1212.0
Biochemical oxygen demand, mg/l	1363.00	454.00	414.0	247.0	620.00	320.00	600.0	325.0
Oil and grease, mg/l	20.60	2.80	ND	ND	-	-	-	-
Hydrocarbons, g/l	0.53	0.47	ND	ND	-	-	-	-

The analysis results (Table 2) shows that even at low temperature and when the treated system was not functioning to desired level of treatment, suspended solids were reduced by 35%. BOD and COD removal was obtained as 8.8% and 30.4%, respectively. Among the trace metals, manganese iron and zinc were further reduced. The supernatant liquid after alum dosing was passed through the column of activated carbon, which increased the pH of liquid to 7.5 reduced the suspended solids by 38.5%. BOD and COD were further removed by 40.3% and 21.9%. Oil, grease and hydrocarbons were completely removed and the trace metal were also completely removed except iron.

Urinal Laundry Bathroom RBC (B3)

Another RBC (B3) was also installed in the year 1999 at Maitri which is designed and manufactured by Klargester Company, UK. In this RBC, waste was discharged through a common connecting pipe from bathroom, urinal and laundry. Hydraulic loading on the RBC was maximum during the summer is 0.102 l/m^2 d . Three samples were collected on various occasion such as business-as-usual, normal day and the day when strength was maximum inside the Maitri station as well as in summer huts. The average water consumption as shown in water balance diagram depicted as 2.0 kl and wastewater produce and reaches to RBC (B3) is approximately 1.95 kl per day during the summer period when the strength was more. Three samples were collected and analyzed in different course of time in conjunction with the samples collected of kitchen RBC. First sample was collected in the first weak of January running as-usual-scenario. It shows that waste pH is normal in nature, DO content is very less (Table 3) which was of moderate strength of BOD and COD. The treatment efficacy was observed only 29.8% of BOD and 41.4% of COD. But due to lower temperature inside the biozone the ammonia nitrogen of effluent was less than the influent because the ammonia producing bacteria were not working effectively at lower temperature. Oil and grease which were also mixing in the influent from the washing of hands muddled with grease and oil and sometimes small containers of the boiler room, consisting oil and grease makes the film over the liquid and thus disrupting the oxygen transfer at sediments tank. However, in the biological chamber due to continuous movement of the disc, it was emulsifying. Saline layer of microbe growth was observed very less on the disc. The trace heavy metals were removed from the biozone as the copper, iron and zinc which are essential growth elements for bacteria were consumed by the bacteria, but the temperature is low as 8° C to 6° C, which is not optimal temperature to work microbes effectively as compared to 12° C to 20° C. RPM of the biodisc recorded was low as 1.4. The optimum temperature was not maintained in the biodisc so it was raised to 21° C and after few days the composite samples were collected and analyzed. Increase in temperature could only improve the ammonia nitrogen content in the effluent which shows the nitrogen decaying bacteria started growing and assimilating the organic content but still the efficiency for BOD removal was 16.7% and for COD it was 25.7%. The third samples were taken on the day when the strength was high at the station. The temperature was maintain at biodisc to 19° C to 21° C, and it was observed that ammonia nitrogen in the effluent is further improved and so the nitrate concentration was also recorded. This is the indicator that the treatment efficiency was improved and the BOD removal efficiency observed as 31.5% and COD as 44%. This RBC was designed of maximum BOD of 300 mg/l in the influent with the maximum flow of 5.0 m^3/day. BOD load is less than the design load and the pH of the effluent were recorded of reasonable quality. Laundry effluent which consist nitrogen and

Table 3 Physico-chemical characteristics of wastewater of B3 (urinal, bathroom and laundry)

Parameters	Sample 1		Tertiary treatment (effluent)		Sample 2		Sample 3	
	Influent	Effluent	Alum	Activated carbon	Influent	Effluent	Influent	Effluent
pH	7.20	6.90	7.00	7.80	6.98	7.28	5.2	7.2
DO, mg/l	0.40	4.30	-	-	0.54	4.60	0.3	3.8
Temperature, °C	8.00	6.00	11.00	11.00	21.00	21.00	19.0	19.5
Total suspended solids, mg/l	41.00	26.00	78.00	48.00	-	-	-	-
Nitrates, mg/l	3.18	2.45	0.44	0.14	-	-	-	-
Phosphates, mg/l	0.30	1.50	1.60	1.80	-	-	-	-
Ammonia, mg/l	122.50	47.50	42.00	22.00	9.80	21.80	71.0	165.0
Chemical oxygen demand, mg/l	522.00	306.00	180.00	126.00	280.00	208.00	400.0	224.0
Biochemical oxygen demand, mg/l	158.00	114.00	54.00	42.00	120.00	100.00	108.0	74.0
Oil and grease, mg/l	5.80	4.20	ND	ND	-	-	-	-
Hydrocarbons, g/l	0.35	0.27	ND	ND	-	-	-	-

phosphorus required for bacteria cell reproduction but the carbon, calcium, magnesium and other trace elements are not in the effluent to generate the bio cells. This resulting into undeveloped biodisc and thus the treatment efficiency was low. Oil, grease and hydrocarbon were also responsible to hamper the treatment efficiency of the system. Among the trace metals in the third sample copper, manganese, zinc concentration were found lower in effluent except the iron content (Table 3).

Tertiary Treatment B3:RBC

The first sample obtained from both the RBC were used for laboratory study of the tertiary treatment. Four liters of treated effluent collected from B1 RBC to study the tertiary treatment and effect of series treatment. To assess the optimum dose of alum for maximum settlement of particles present in the wastewater, four jar of one litre capacity filled with treated wastewater and different dose of alum mixed in water and stirred for 5 min. The jar selected for further treatment, which shown maximum settlement of coagulated particles. Supernatant liquid holding the volume of 900 ml passed through the column filled with activated carbon, with a constant rate of flow 50 ml/min. The optimum alum dose influent was selected and the analysis results (Table 3) shows that pH of the effluent was further improved to 7.0. Suspended solids were increased due to flocculation process of colloidal particles which kept them in suspension. Nitrates and ammonia were reduced and BOD and COD were reduced by 52.6% and 41.2%, respectively. Oil, grease and heavy metals were removed. Among the trace metals, manganese and zinc were removed and iron was reduced. The supernatant liquid after alum dosing was passed through the column of activated carbon, which increased the pH of liquid to 7.8 reduced the suspended solids by 38.5%. BOD and COD were further removed by 22.2% and 30%. Oil, grease and hydrocarbons were completely removed trace metal are also completely removed except the iron.

CONCLUSION

The BOD load from kitchen waste was very high, which contains high organic matters. Both the RBC's were designed to accept the BOD load of 300 mg/l, to work at optimum temperature of 12° C to 20° C designed rpm of RBC's were 5 where as during operation it was noticed around 1 rpm to 2 rpm. The lower rpm of RBC transfers less oxygen to the bacteria and diffuses less oxygen to the liquid inside the biozone. The RBC's were designed to bear the shock loading but operating in low temperature, fluctuation in the flow, affect the treatment process because ammonia removal rate significantly decrease by sudden cooling. Waste obtained from the different sources are being treated in two different RBC's this resulting in availing more food and trace elements in B1:RBC, which are essential in cell growth to bacteria and found deficiency in B3:RBC. As the maximum flow of B3:RBC was 5 m^3/day whereas average waste flow of Maitri was around, 3.1 m^3/day. This indicates that entire waste load could be treated into single RBC (B3). This would not only neutralize the pH of waste but also provide essential growth elements to bacterial cell.

Bioaugmentation of nitrifying bacteria for short solids retention time nitrification is an attractive alternative for wastewater treatment plants in cold climate and mixing of centrate from kitchen RBC, which could be used as a source for bioaugmentation of B3:RBC. Improvements in the treatment efficacy could also be achieved if the RBC system can be step feed as compared to single feed mode.

Oil and grease trap should be fixed before the waste enters into RBC which would help in faster cell development rather than becoming toxic to bacteria. An equalization tank of around 460 l for B3:RBC and around 120 l for B1:RBC would be equally useful with alum dosing to regulate flow variation as well as settlement of suspended solids of kitchen waste thus reducing overall BOD load. Temperature of the biozone should also be maintained to around 20o C for proper cell growth of the bacteria.

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