International Journal of Geology, Earth and Environmental Sciences ISSN: 2277-2081 (Online)
An Online International Journal Available at http://www.cibtech.org/jgee.htm
2012 Vol. 2 (2) May-August, pp.300-310/Choudhary and Ojha.
Research Article

PROCESS AND FUNCTION OF ADVANCE WASTE WATER TREATMENT TECHNOLOGY FOR TEXTILE BASED EFFLUENT

Anil Choudhary[1] and *Deepak Ojha[2]
[1 2]Department of Zoology, Jai Narain Vyas University, Jodhpur-342010 (Rajasthan)
**Author for Correspondence*

ABSTRACT

A systematic process of Primary, Secondary, Tertiary and Advance (Reverse Osmosis) treatment for textile based industrial effluent gave very good results. In primary treatment using Screening Chamber I, II, III**,** Sedimentation with Combined Silt and Oil Trapping Tank, Collection Tank (with Airation), Dosing of Chemicals (lime 10%, Ferrous 5%, and Polyelectrolyte 0.1%), Flash Mixture, Primary Flocculator, Lamella Tube Settler/ Primary Clariflocculator, pH control Tank gave better result in 30 minute retention time and In Secondary treatment Conventional plug flow process with Fine Bubble diffused Aeration removed 50 % of the BOD in first one hour. 25% BOD removed in the next two hr. and the remaining 25 % in the last three hours, Total 6 to 8 hr detention period of Aeration gave very good Result. Height of aeration tank should not more than 3.5 to 4.0 meters. In tertiary treatment process a series of Dual Media Filter (DMF) and Activated Charcoal Filter (ACF), Ion exchange Resign (mix bed of Cation-Anion Resign) removes colour and more than50 micron Suspended solids. BEG Filter than Cartige Filter pass only less than 5 micron particles than it enter into RO membranes. Reverse Osmosis is an advance process to remove dissolve solids and other impurities of water with low cost. Total cost of ETP to RO is 80 lakh for 240 KLD and operation and maintenance cost is 30-35 Rs. per KLD with RO reject management and sludge disposal.

Key Words: *Treatment, Diffused Aeration, Dissolve solids, Reverse osmosis*

INTRODUCTION

A systematic process and function of Primary, Secondary, Tertiary and Advance (Reverse Osmosis) treatment technology of effluent can solve the industrial pollution problems. Physical, chemical and biological methods are used to remove contaminants from waste-water. In order to achieve different levels of contaminant removal, individual waste-water treatment procedures are combined into a variety of systems, classified as primary, secondary, and tertiary waste-water treatment. More rigorous treatment of waste-water includes the removal of specific contaminants as well as the removal and control of nutrient . This paper describes the mixture of conventional and advanced technologies in current use and explains how they are applied for the effective treatment of industrial waste-water. It thus entails environmental and health hazards and, consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of waste-water management is the protection of the environment in a manner commensurate with public health and socio-economic concerns.

MATERIALS AND METHODS

Primary and secondary waste water treatment technology studied in Pali, Jodhpur CETPs. The Design, process, and functions drawback noted of that plants and Advance waste water treatment technology studied at Gogad Fabrics Pvt.ltd. with technical Support of Paradise Environmental Services, Surat. Some technique Studied from Thermex Pvt. ltd, Pune. Study material Adapted from Liu and Lipták, Wastewater Treatment and Metcalf and Eddy, Inc., Wastewater Engineering, 3rd edition.

RESULTS

A systematic and deep study of Pali CETPs was done and also studied the new technology adopted by Gogad Fabrics Pvt. Ltd. Pali (Rajasthan).

We found that Screening chambers were not cleaned from time to time in CETPs so Suspended Solids increased in the influent. Floc in primary Equalization Tank also noted. After Dosing of Chemicals we observed Bulking of Sludge in primary Clariflocculator. It was due to high effluent flow rate, flagellate protozoa's and low pH below 9.0. In Aeration tank oldest technology complete contact mix adopted which require more electricity and more detention time for BOD removal. Level of DO in depth of aeration tank very low and anaerobic condition observed. Return sludge not agitated and MLSS not maintain between 2500-2800 mg/lit. Oil and grease at final treated also observed that means Tilted Plate separator for oil and grease removing not working properly. Treated effluents Color and TDS not remove by this technology, which adopted by CETPs of Pali, so it seems always like untreated effluent.

RESULTS AND DISCUSSION

Process of Primary, Secondary, Tertiary and Advance (Reverse Osmosis) treatment for textile based industrial effluent gave very good results. In primary treatment using Screening Chamber I, II, III**,** Sedimentation with Combined Silt and Oil Trapping Tank, Collection Tank (with Aeration), Dosing of Chemicals (lime 10%, Ferrous 5%, and Polyelectrolyte 0.1%), Flash Mixture, Primary Flocculator, Lamella Tube Settler/ Primary Clariflocculator, pH control Tank gave better result in 30 minute retention time and In Secondary treatment Conventional plug flow process with Fine Bubble diffused Aeration removed 50 % of the BOD in first one hour. 25% BOD removed in the next two hr. and the remaining 25 % in the last three hours, Total 6 to 8 hr detention period of Aeration gave very good Result. Height of aeration tank should not more than 3.5 to 4.0 meters. In tertiary treatment process a series of Dual Media Filter (DMF) and Activated Charcoal Filter (ACF), Ion exchange Resign (mix bed of Cation-Anion Resign) removes colour and more than50 micron Suspended solids. BEG Filter than Cartige Filter pass only less than 5 micron particles than, it enter into RO membranes. Reverse Osmosis is an advance process to remove dissolve solids and other impurities of water with low cost. Total cost of ETP to RO is 80 lakh for 240 KLD and operation and maintenance cost is 30-35 Rs. per KLD with RO reject management and sludge disposal.

Table 1: Result of Primary, Secondary, Tertiary and RO Treatment for Textile industrial effluent

Inlet Effluent Parameters	After Primary Treatment	After Secondary Treatment	After Tertiary Treatment	After RO Treatment
pH-8.5-9.0	8.0-9.0	7.5-8.5	8.0-9.0	6.5-7.5
TSS-500-1500mg/lit	250-750mg/lit *(50%) Decrease*	200-600mg/lit *(20%) Decrease*	80-240mg/lit *(60%) Decrease*	8-24mg/lit *(90%) Decrease*
COD-1500-3000mg/lit	600-1200mg/lit *(60%) Decrease*	300-600mg/lit *(50%) Decrease*	150-300mg/lit *(50%) Decrease*	12-30 mg/lit *(90%) Decrease*
BOD-200-400mg/lit	50-100mg/lit *(25%) Decrease*	20-40mg/lit *(60%) Decrease*	6-34mg/lit *(15%) Decrease*	Nil

DISCUSSION

Primary Treatment:

1. Screening Chamber I,II, III
2. Sedimentation with Combined Silt and Oil Trapping Tank
3. Collection Tank (with Airation)
4. Dosing of Chemical Tank
5. Flash Mixture
6. Primary Flocculator
7. Lamella Tube Settler/ Primary Clariflocculator
8. pH control Tank

1. Screening Chamber I, II, III:

At the Inlet point of all CETPs Three stage **screening chamber** will be Require. This chamber removes large size floatable and Suspended Solids Such as Polythene, cloth, wooden Parts, and other garbage.

Sedimentation (Primary Grit Chamber): It is the simplest and most popular Method to Removes Total suspended Solids from waste water with gravitational settling. This process is used for the removal of grit, particulate matter in the primary settling basin, biological flocs in the activated sludge settling basin, and chemical flow when the chemical coagulation process is used. Sedimentation takes place in a settling tank, also referred to as a clarifier. Primary Treatment basically depends on Sedimentation of suspended solids that was also reported by Morrill (1932).

- **2. Use of Combined Silt and Oil Trapping Tank:**

Oil in textile based effluent causing treatment problems such as bulking of sludge, Death of aerobic bacteria, formation of flocs. It is also reported at CETPs of Pali. This unit is also called Mud –Sludge and Suspended Solid Removing and Holding Tank. Upstream to Downstream effluent flow of this tank settles the Maximum Silt and Suspended Solids. With this tank an extra attachment is *Oil and Grease Trapping Machine* can also be operated. It removes floating oil and Grease from incoming effluent.

Oil and Grease Trapping Machine:

It is called Oil Skimmer, which removes Oil and Grease from waste water. Aerobic Bacteria in aeration Tank mostly affect by Oil, so it is very important to remove that. Settled sludge, Heavy Metals also rise up by the contact of this oil that was describe by Liu *et.al.*,(1999) and also reported by Metcalf *et.al.,(*1991).

2. **Primary Collection Tank (with Aeration):**

After Maximum sludge settled in above tank effluent enters into this Tank. Diffused Aeration gave Better Result in Treatment and Maintain aerobic condition by return aerobic sludge of Airation Tank. A new approach finds out that "Anaerobic condition in Primary Treatment cause Problems related to making of Flocs". Proper Airation in this tank causes reduction of H_2S, CH_4 Gases which interrupt the process of treatment.

3. Dosing of Chemicals:

Chemical coagulation of raw waste-water before sedimentation promotes the flocculation of finely divided solids into more readily settleable flocs, thereby enhancing the efficiency of suspended solid, BOD_{3_5} day and phosphorus, Heavy Metal removal as compared to plain sedimentation without coagulation also reported by Amirtharajah, (1991).The degree of clarification obtained depends on the quantity of chemicals used and the care with which the process is controlled.

By the Jar test for the proper Dosing of Chemicals Lime 10% to 15% solution, Ferric sulphate 5% solution, and Polyelectrolyte 0. 1% solution gave very good result. Being a good oxidizing agent, the iron salts can remove hydrogen sulphide, hydrogen sulphate and its corresponding Odour from waste water that was also reported by Birdie *et.al.,(*1994).

pH between 10.0 to11.0 after lime-ferrous dosing makes large size maximum flocks, which settle d own fastly by polyelectrolyte dosing. We observed that when pH below 10.0, quantity of flocks decreased and sludge did not settle properly. The removal of Colour from Red-Black or Dark green into Yellow or Light Green by proper dosing of chemicals in Primary Treatment and Chemical Oxygen Demand are **60%** decrease, Total Suspended Solids **50%** decrease, Hardness **20%** decrease but Total Dissolve Solids **32%** increase due to addition of Lime solution in primary treatment.

4. Flash Mixture:

Suspended solids removal with the above chemicals added and completely dispersed throughout the effluent by rapid mixing for 20-30 seconds in a basin with a turbine mixer is called Flash Mixture. Coagulated particles are brought together via flocculation by mechanically inducing velocity gradients within the liquid.

Sedimentation after Chemical Dosing:-

After chemical dosing in Primary Treatment plant detention period of both tanks (Clariflocculator/ Lamella Tube Settler) should be 30 minute Maximum and Sufficient that was also reported by Birdie *et.al.,(*1994).

6. Clariflocculator: "Removing *of suspended solids with gravitational Force".*

After proper mixing of dosing chemicals in flash Mixture effluents enter into Primary Flocculator. Maximum amount of sludge making in the form of "Heavy flocks" settle down in this tank. It is Primary Settling Tank I.

pH of Primary Clariflocculator tank should be maintained between 10.0 to 11.0.

Below this pH settled sludge rise up.

7. Lamella Tube Settler: It is advance Primary Clariflocculator. It is Primary settling Tank which is in Lamella Shape. Where effluent flow downstream to upstream then by the gravitational force in this tank both large and small size Suspended Particles Settle down Fastly by these tube deck designs in vertical "v" shape. Maximum sludge settles down in these settling Tanks that was also reported by Morrill (1932).

pH control Tank: Primary Treated Effluents pH should be maintain 8.0 to 9.0 by Con.HCL. This HCL also reduce colour of effluent. High pH is harmful for aerobic bacteria of Aeration Tank.

Secondary Treatment:

Aeration: Aeration is stomach of Effluent Treatment Plant. It digests all type of Organic matter, H_2S and CO_2. Highly agitate and aerated Suspended Solid called Activated Sludge. Activated Sludge is group of Several Aerobic Bacteria which removes Organic Matter and Heavy Metals of effluent. **Conventional plug flow** process with diffused Aeration gave better result (95 %) in less time. Size of diffuser pores should be 0.3mm. The capacity of aeration tank is usually kept 18.5 m^3/ kg of BOD load. The quantity of air 0.6 cu.m per 1000 lit of water. Inlet effluents BOD in Aeration Tank should be less than 140 – 180 mg/ lit. Diffused Aeration Tank with retention period 6 to 8 hr. gave very good result. In this aeration tank it has been noted that 50 % of the BOD is removed in first one hour. 25 % BOD removed in the next two hr. and the remaining 25 % in the last three hours in the 6 to 8 hr. detention period of tank that was also reported by Birdie *et.al., (*1994). Therefore it has been observed that longer detention period increase the cost of aeration units and operational cost too high, whereas the efficiency is not so high. If Sludge Volume of Aeration Tank less than 250- 300 ml/lit or MLSS less than 2500-2800 mg/lit then Activated Sludge collected into other tank and highly aerated and agitate these sludge (Highly Aerobic Bacteria) return into Aeration Tank to remove more BOD and COD of effluent. Aeration tanks colour changed into Pink or Dark reddish/Brown that indicate sufficient aerobic bacterial Growth.

Useful Bacteria in Aeration Tank: - Some useful bacterial mixture in aeration tank playing very important role. These are Acetobacter *Spp.,* Alcaligenes *Spp.,* Azotobacter *Spp.,* Flavobacterium *Spp., Pseudomonas Spp. Zoglea spp.*

Secondary Tube deck Settler: - It's also called Secondary Lamella Tank. After Aeration Effluent enter into ***Secondary Tube deck Settler***. The flow of effluent in all Tanks should be downstream to Upstream which remove more suspended solids with gravitational force. Sludge of First Tank of this unit which is

Activated sludge and separate by tube deck designer tank and collected into another tank and highly agited or aerated then return into aeration tank. These tube deck designs in vertical "v" shape and proper dosing of chemicals mostly Hydrogen Peroxide (H_2O_2) with Sodium Hypo Chloride (NaOCl), ozonation (O_3+ H_2O_2) remove Colour, Suspended Solids, COD (25% reduce), Aerobic and Anaerobic Bacteria of effluents. Detention time of this tank 20 to 30 minute sufficient that was also reported by Birdie *et.al.,(*1994).

Advantage of Chlorination and Ozonation:

- Chlorine and Ozone has very high Oxidation potential 1.36 and 2.07 respectively.
- It completely oxidizes the ammonia and other impurities of water.
- It can oxidize sulphydryl (–SH groups) which found in water.
- The colors of water remove which is due to organic matter.
- In the chemical reaction "nascent oxygen" liberated from the hypochlorous acid and oxidizes harmful bacterial cell and destroying them.
- It completely destroys all the disease bacteria and direct combinate with Protoplasm.
- It removes taste and odour from water.
- It prevents growth of weeds in water.
- Very small detention time require for removing of colour and bacteria of water.

Tertiary Treatment:

Tertiary treatment removes significant amounts of nitrogen, phosphorus, heavy metals, biodegradable organics, and large amount of colour of water.

Filtration and Activated carbon used in this process.

Dual Media Filter (DMF):

It is a rapid Sand Filter placed within closed Mile steel Rubber lining, watertight cylinder. The filter media consist of coarse sand layers of effective size varying from 0.35 mm to 0.55 mm. The finer variety should be near top and coarser variety near the bottom. Only 60% volume of Tank fills by sand. The water passes through the sand bed under a pressure greater than atmospheric from upstream to downstream in filter process. Color, TSS, Salt and organic material removed in it.

1. Activated Carbon Filter (ACF):

Design and process of Activated carbon filter is same to Dual Media Filter only add Activated carbon on upper layer of fine filtering sand. Activated carbon is the most widely used for the removal of taste, odour, colour, TSS, iron, manganese, excessive chlorine, H_2S, CO_2 and Phenol of water with their excellent properties to attracting of impurities. The commercial activated carbon available in 90% purities and their density about145 kg/m^2.

The manufacture of the activated carbon is done by heating or charring of the wood, Coconut cover, or Saw dust other similar carbon containing substances at about 500 c to 800 c in a closed vessel. Activated Carbon found granular or powdered form with highly porous and has got number of carbon atoms with free valence both of which give it the high absorptive. Activated Carbon removes more than 50 micron particles from water. After more color removing carbon can be regenerate by steam treatment to again increase the efficiency of Carbon.

Advance Treatment: Total Dissolve Solids, Hardness, Color and Total Suspended Solids more removes by this Advance Treatment Process. TDS of effluent is only removed in this process. In the advance treatment process we study about **Reverse Osmosis (R.O.)** Technique**.**

There are effective five stage of R.O. Process for water filtration.

1. **Dual media filter (DMF)**
2. **Activated carbon filter (ACF)**
3. **Organic Scavenger filter/Ion exchange Resign**
4. **Bag and Cartige filter**
5. **R.O. Membrane**

1. Dual media filter (DMF):-
Design and process of this DMF is same to Tertiary treatment.
2. Activated carbon filter (ACF):-
Design and process of this DMF is same to Tertiary treatment.
3. Organic Scavenger filter/Ion exchange Resign:-
In this filter mostly Cation and Anaion Resin used as a mixed bed. Negative and Positive charged ion of water adsorbed by this resin and decreased alkalinity and Hardness of water. These resins also regenerate by NaOH, HCl. Cation resin charged by NaOH and adsorb CO^{-}_{3}, HCO^{-}_{3}, Cl^{-}, I^{-}, Br^{-}, and SO^{-}_{4}**.** Anaion resin charged by HCl and adsorbs Na^{+}, Mg^{+}, and Ca^{+}.
4. Bag and Cartige filter:-
Maximum large size particles removes in above process, only less than 50 micron particles enter in these filters. Bag and Cartige filter removing the Suspended Solids of Water. They have high dirt holding capacity.
Table 2: Description of Bag filter and Cartige Filter

Bag Filter	Cartige Filter
Removes 50 to 25 micron particles	Removes 25 to 5 micron particles
High dirt Holding Capacity	Very high dirt Holding Capacity
Low cost	High cost
Reuse by washing HCl or Shop is Easy	Reuse by washing HCl or Shop is very Difficult
Maximum pressure capacity 1.5 kg/cm^2	Maximum pressure capacity 1.5 kg/cm^2
1.0 kg/cm^2 pressure maintain during running process	1.0 kg/cm^2 pressure maintain during running process

Only less than 5 micron particles enter into RO membrane.
Reverse Osmosis (R.O.):
Reverse Osmosis is an advance process to ***remove dissolve solids*** and other impurities of water with low cost reported by Pittner,(1993)There are two type of membrane, first is Domestic and second is Industrial use. Domestic Membrane is electric charged and removed maximum amount of organic and inorganic compounds of water. Industrial Membrane is not electric charged because very large amount of organic matter found in industrial waste water that causing chocking of membrane and increasing the porosity of membrane.
Process and design of RO membrane:
- Spiral-wound, Tubular sheet, Plate and frame, Fiber, Ceramic type membrane using in water treatment. Mostly high efficiency and low cost Spiral –wound Membrane using in industrial waste water treatment. Mostly 8"Diametre and 40" length (1 meter) using which treat 1000 lit/hr. Effluent enters into the membrane with the series of filtration by Raw Water pump to DMF, ACF, Organic scavenger, Bag filter, Cartige filter. We are trying to control the TSS not exceed 5 micron than it allow into Membrane. If particles size increase then load on membrane also increased. Treated effluent enters into membrane after Cartige Filter(less than 5 micron particles) with the High Pressure Pump. After 5 minute of effluent passing through Membrane, It is causing cleaning of Membrane. Then controlling the Reject valve and maintain pressure of Low pressure switch (between 0.5- 1.0 kg/cm^2) and High Pressure switch (not exceed 15 kg/cm^2). If High Pressure pumps Pressure is less than 0.0 kg/cm2 or more than 15 kg/cm2, both low and high Pressure pump switch automatically off and controls the damage of Bag filter, Cartige filter and Membrane. Before controlling the reject valve effluent only passing and cleaning of membrane, not treated and it come out by reject pipe. When reject valve control (closed) then effluent enter into membrane by filtering process with back pressure. Maximum TSS and Salt remove in membrane and treated effluent come out through Permit line with less than 0.001 micron also reported by Wagner (2001). Less amount of reject water (High TDS effluent) also come out. After treatment reject valve should be open slowly and maintain pressure between 0.5 kg/cm^2 to 15 kg/cm^2. Alternative cleaning of membrane 10 to 15 minute should be done by only RO water with using HCl or NaOH.

A. Before Reject Valve Control
B. During Reject Valve Control
C. After Reject Valve Control

Chemical reactions:-

$CaCo_3 + 2\ HCl \rightarrow CaCl_2 + CO_2 + H_2O$
$NaOH + CaCO_3 \rightarrow Na_2CO_3 + Ca(OH)_2$
$NaOH + SiO_2 \rightarrow Na_2SiO_3 + H_2O$

RO Reject Management:

- Reject from RO membrane is a very difficult problem but it can be used in washing of machinery, cleaning of road.
- RO reject collected into large size (low depth) pond and using solar evaporator to evaporate this collected water.

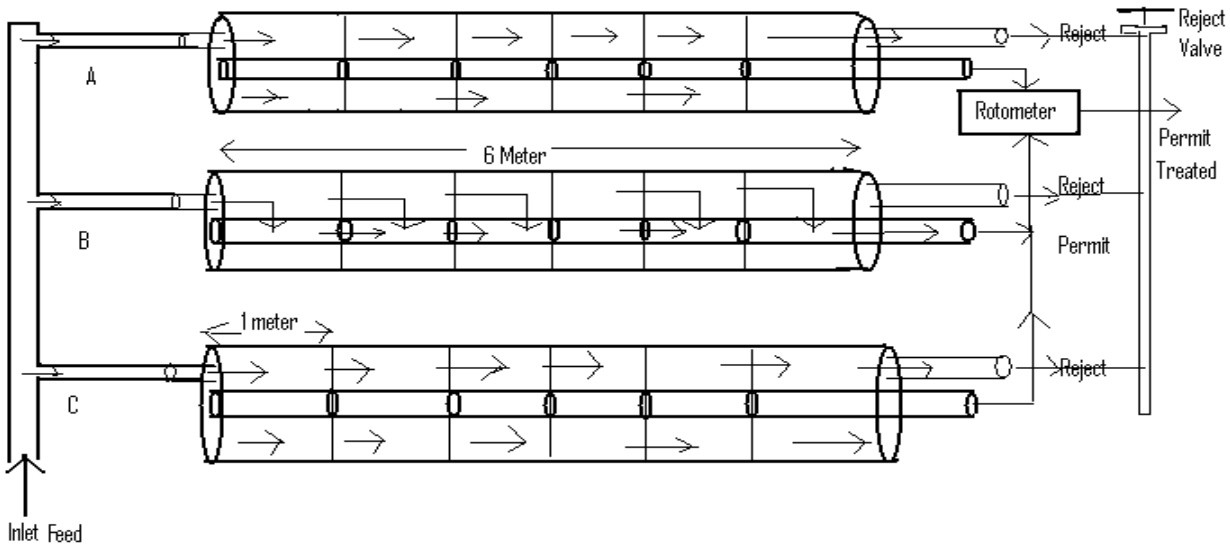


Figure 1: Process and Function of RO Membrane

Sludge Drying Bed:

- All sludge collected into sludge drying bed. Polyelectrolyte in sludge cause compact formation of sludge and controlling the leaching of Heavy metal and other toxic matter into ground water.

Table 3: Plantation near sludge drying bed or sludge storage area:

Name of Plants	Function
Brassica Juncea	Remove Cr and other heavy metal
Sun Flower	Remove all type of Heavy metals
Sebertia acumineta	Remove Ni
Bulrush (scirpus spp.)	Remove Cl^-, Br^-, SO_4^-
Maiden Cane	Remove Cl^-, Br^-, SO_4^-
Cattails (Typha spp.)	Remove Cl, Br^-, SO_4^-

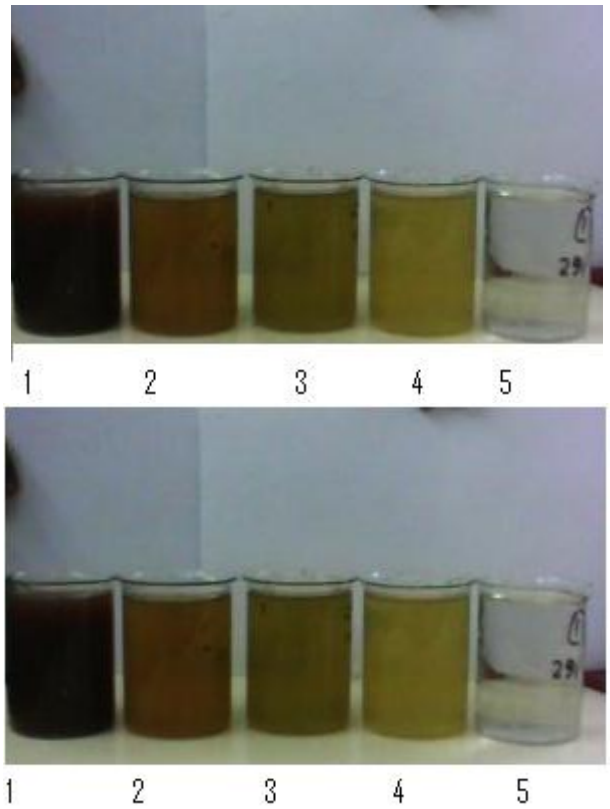


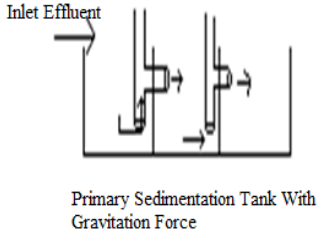
Figure 2: Inlet and Outlet textile based industrial effluent after Primary, Secondary, Tertiary and RO treatment

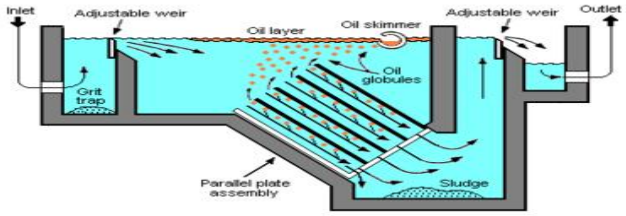
1. *Inlet of Effluent Treatment Plant*
2. *Primary Treated waste Water*
3. *Secondary Treated Waste Water*
4. *Tertiary Treated Waste Water*
5. *RO Treated Waste Water*

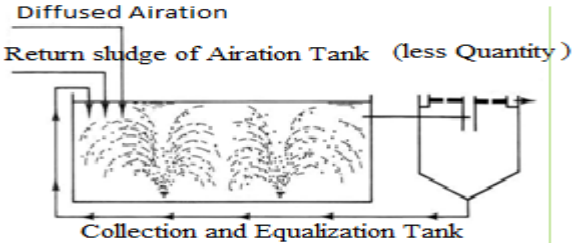
Cost of Treatment:

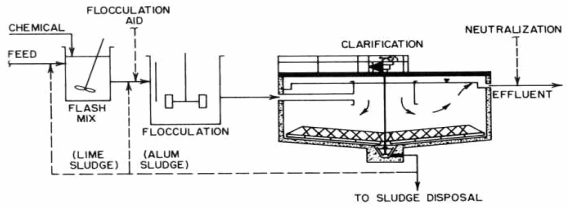
- Initial cost of ETP to RO is 80 lakhs for 240 KLD.
- Operation and maintenance cost is 30-35 Rs. per KLD.

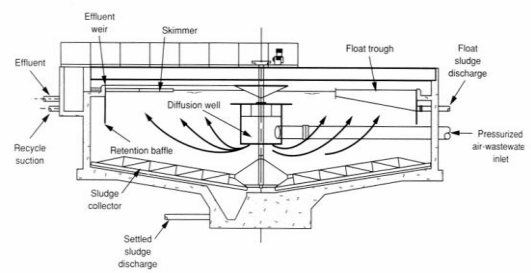
Primary and Secondary Treatment Plant:

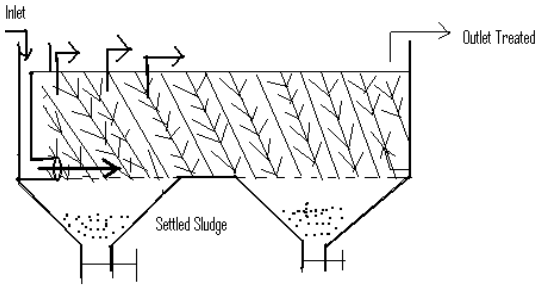




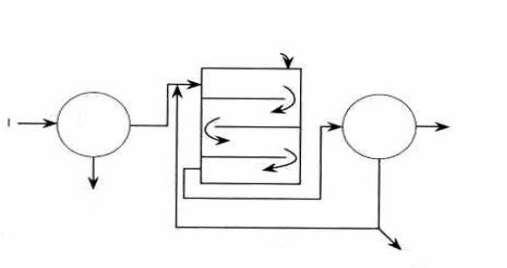


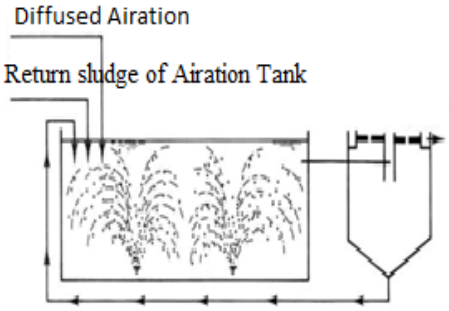


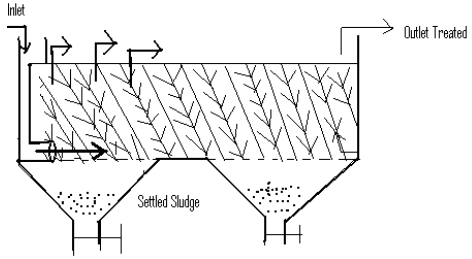




Clariflocculator with Flash Mixture **Clariflocculator** **Primary Lamella Tube deck Settler**





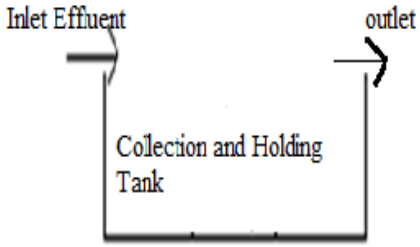


(A) (B) (C)

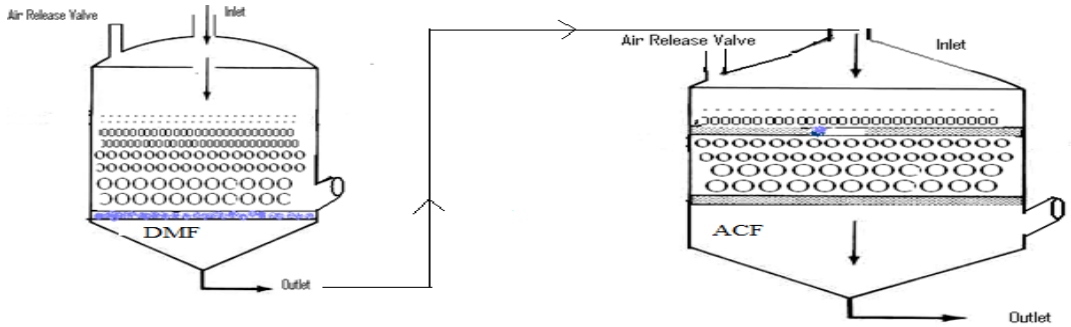
Conventional plug flow with Fine Bubble diffused Aeration (A), Return sludge Aeration Tank (B), Secondary Lamella Tube deck Settler(C)

(*Source*: Adapted from Liu and Lipták, *Wastewater Treatment and* Metcalf and Eddy, Inc., *Wastewater Engineering*, 3rd edition)

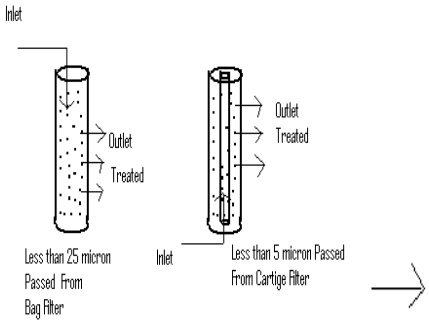
Tertiary and RO Plant:



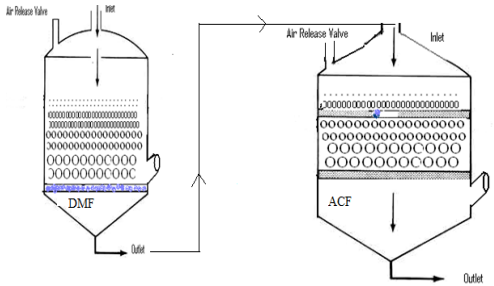
Collection and Holding Tank



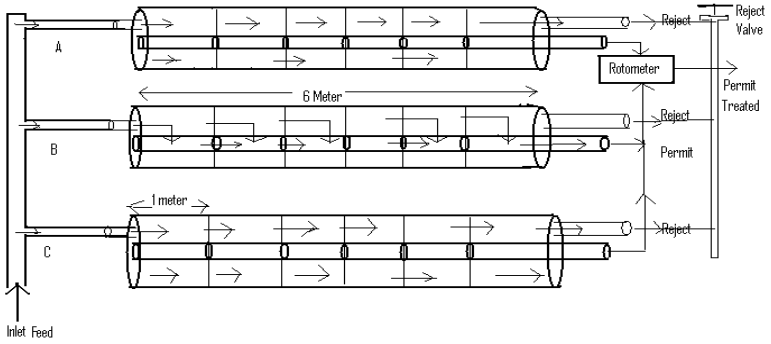
Dual Media Filter and Activated Charcoal Filter/Resin Filter



Beg Filter and Cartige Filter



Dual Media Filter and Activated Charcoal Filter



RO Membrane

***(Source*: Adapted from Liu and Lipták, *Wastewater Treatment.* Metcalf and Eddy, Inc., *Wastewater Engineering*, 3rd edition)**

REFERENCES

American Water Works Association (1999). *Water Quality and Treatment*, 5th edition (American Water Works Association, Denver, CO.)

Amirtharajah A, MC Clark, and RR Trussell (1991). *Mixing in Coagulation and Flocculation* (American Water Works Association Research Foundation, Denver, CO.)

Arceivala SJ (1998). *Wastewater Treatment for Pollution Control*, 2nd edition (Tata McGraw-Hill Publishing Company Limited, New Delhi, India).

Birdie GS, and JS Birdie (1994). Handbook of Water Supply and Sanitary Engineering, 4th edition, *Dhanpat Rai and Sons*, Delhi.

Camp TR (1946). Sedimentation and the Design of Setting Tanks. *Transactions ASCE* 111.

Dick RI and KW Young (1972). Analysis of Thickening Performance of Final Settling Tanks. *Proceedings of the 27th Industrial Waste Conference, Purdue University, Engineering Extension Series* 141, Purdue, IN.

Egan-Benck K, G McCarty and W Winkler (1993). Choosing Diffusers. *Water Environment and Technology* **5**(2) 54–59.

Fitch EB (1956). Effect of Flow Path Effect on Sedimentation. *Sewage and Industrial Wastes* **28**(1) 1.

Harrison Roy M (1983). Handbook of Pollution: Causes, Effects and Control, II Series, no. 44. *The Royal Society of Chemistry, Burlington House*, London.

Liu DHF and BG Lipták (1999). *Wastewater Treatment*. Boca Raton, Florida: Lewis,

McCarthy J (1982). Technology Assessment of Fine Bubble Aerators. U.S. Environmental Protection **Agency (EPA)**. Wastewater Research Division. Municipal Environmental Research Laboratory. Cincinnati, Ohio.

Metcalf and Eddy Inc. (2003). *Wastewater Engineering: Treatment and Reuse*, fourth edition. New York: McGraw-Hill.

Metcalf and Eddy Inc. (1991). *Wastewater Engineering: Treatment Disposal and Reuse*, third edition. New York: McGraw-Hill.

Morrill AB (1932). Sedimentation Basin Research and Design. *Journal American Water Works Association* **24** 1442.

Pittner GA (1993). The Economics of Desalination Processes". Chapter 3 in *Reverse Osmosis: Membrane Technology, Water Chemistry, and Industrial Applications*. New York: Van Nostrand Reinhold.

Qasim S (1999). Wastewater Treatment Plants, Planning, Design, and Operation,2d ed.,Technomic Publishing Co., Lancaster, PA.

Sharma P.D. (2003). Handbook of Ecology and Environment, 7th edition (Rastogi Publications, Meerut, India).

U. S. EPA (1989). *Design Manual: Fine Pore Aeration Systems.* EPA Center for Environmental Research Information. Cincinnati, Ohio. EPA/625/1-89/023.

U.S. EPA (1985). *Summary Report: Fine Pore (Fine Bubble) Aeration Systems*. EPA Water Engineering Research Laboratory. Cincinnati, Ohio. EPA/625/8-85/010.

U.S. EPA (1995). *Technological Assessment o f F i n e B u b b l e A e r a t o r s* .EPA-600/2-82-003.

U.S. EPA (1999). Wastewater technology fact sheet fine bubble aeration, EPA 832-F-99-065.

Wagner J (2001). *Membrane filtration handbook: Practical tips and hints*. Osmonics, Inc.

Water Environment Federation and American Society of Civil Engineers (1992). *Design of Municipal Wastewater Treatment Plants, Volume (1)*. WEF Manual of Practice No. 8 and ASCE Manual and Report on Engineering Practice No. 76. Vermont: Book Press Inc.