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Recycling of Woven Fabric Dyeing Wastewater Practiced in Perundurai Common Effluent Treatment Plant

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Abstract

Textile dyeing industries in Erode and Tirupur district of Tamilnadu (India) discharge effluents ranging between 100 and 200m³/t of production. Dyeing is performed by Jigger or advanced Soft Flow reactor process. Coloring of hosiery fabric takes place in the presence of high concentration of sodium sulphate or sodium chloride (30 – 75 kg/m³) in dye solutions. Wash water and dye bath waste water are the process effluents of dyeing industry which are collected separately and follow the advanced treatment for maximum recycling of recovered waters.

Wash water is treated using a sequence of physicochemical and biological unit process, the waste water is passed into ultrafiltration (UF), two stages reverse osmosis (RO) membrane system where the permeate is reused for processes. The rejects about 10 – 12 % of the inlet volume is subject to reverse osmosis for sent to evaporators. Dye bath water after treating, the permeate is used in process for dye bath preparation and the reject of about 20 – 25% is sent to multi effect evaporator / solar evaporation pond (SEP). The final rejects from reverse osmosis system is directed to multi effect evaporator system where condensed waters are recovered. The removal of Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Chloride are in the range of 82 – 97%, 90 – 97% and 78 – 97% respectively. This study was carrier out Common Effluent Treatment Plant (CETP), Perundurai, SIPCOT, Erode district.

Keywords: Textile effluent, Recycling wastewater, Reverse osmosis, PH, COD

1. Introduction

The second basic needs of man ‘cloth’ are supplied by processing of natural and man-made fibres in the textile industries. Increasing population and modernized civilization trend gave rise to booming of textile sectors in India. An estimate shows that textiles account for 14% of India’s industrial production and around 27% of its export earnings.

India is the second largest export of cotton yarn. There are about 10,000 garment manufacturers and 2200 bleaching and dyeing industries in India. Majority are concentrated at Erode and Tirupur district of Tamil Nadu, Surat in Gujarat and Ludiyana in Punjab. Erode and Tirupur district atlest having 50% of dyeing and bleaching industries where in 30% industries are attached to CETP. Dyeing is a combined process of bleaching and coloring, which generates voluminous quantities of wastewaters and in turn causes environmental degradation. These effluents consist of high TDS, chloride, sulphate, hardness and carcinogenic dye ingredients (1).

2. Overview of Common Effluent Treatment Plant (CETP, SIPCOT - Perundurai)

Textile is a major source of income and of great importance for India's economy. At the same time textile processing has major environmental impact. A large proportion of the environmental issues are related to the use and discharge of water. Textile manufacturing is among the major industrial water users. To produce one kg of textile fabrication about 200 liters of water is used.

A lot of chemicals are added to the process for cleaning and dyeing purposes. Obviously the wastewater effluent from this unit contains considerable amounts of hazardous pollutants, and where heavy metals are very common. In India most of the effluent from the textile industry is discharged untreated into rivers. Today 70% of available water in India is polluted and two thirds of illness in India is related to water-borne diseases.

Water treatment is a very important step to change these conditions and to achieve a sustainable situation. India's government has an awareness of this and limits for water effluent quality exist. Unfortunately, this regulation is not closely supervised and a lot of places do not follow the regulation. In newly developed industrial areas advanced wastewater treatment is used for textile effluent, as the one such place is SIPCOT in Perundurai (2).

2.1 SIPCOT

The government is promoting industrial growth in backward and hitherto underdeveloped areas that have potential to grow. SIPCOT is an organization arranging this in the state of Tamil Nadu. Companies, willing to start up industries 'in that area, lease the land for 99 years and are guaranteed good infrastructure, electricity, sewage and water supply 24 hours a day.

2.1.1 SIPCOT Perundurai

SIPCOT Perundurai was started in the year 2000 and it is divided into two parts, the east and the west part, totally 1240 ha. SIPCOT only leases 732 ha of the total area and today 288 ha of the area is licensed. Currently 210 industries are located in the area within the fields of chemicals, textiles industries, food manufacturing, tanning and engineering products. SIPCOT has a common sewage plant, where black water from all industries is treated. The water comes by gravity in stone-laid drainage pipes and is then taken care of by oxidization ponds.

SIPCOT Perundurai industrial plan is an area designed for 54 different units within textile processing. The processes run at the textile industries are dyeing, bleaching and yarning. The industries in SIPCOT are mainly working with cotton. The cotton contributes with much organic matter in the water effluent. Each of the industries has two different pipe systems for wastewater. One system is taking care of the water from the first washing after dying, called the dye bath effluent. This water has always very high TDS, over 2100 mg/l and is therefore not measured. The other system is far the remaining effluents from acid wash, water washing, soap washing and softening water are called wash water. The industries have a sensor that measures the TDS value from the wash water, ensuring that it does not exceed 2100 mg/l. If the value is higher a valve will close and direct the water back to the receiving tank to dilute with the other wash water. The textile has two different effluent wastewater streams. The dye bath has a high TDS, above 2100 mg/I, and the wash water has a lower TDS, below 2100 mg/l. Each industry will also measure the flow in both effluent pipes. All effluent from the industries is sent to Perundurai Common Effluent Treatment Plant, PCETP.

2.1.2 Perundurai Common Effluent Treatment Plant

Each industry bears the responsibility for dealing with the effluent water from their processing. Therefore the 14 textile units together formed PCETP. Each of the units has different shares in the treatment plant and consequently they are allowed different maximum flows that they can discharge to the treatment plant. The treatment plant only handles industrial effluent from those 14 textile industries. PCETP can operate 3600 m^3/d wash water and 450 m^3/d dye bath.

2.1.2.1 Dye bath treatment plant

The dye bath treatment uses an evaporator for cleaning the water. Before the evaporator the water is pre-treated in the form of sedimentation and fine screening. The evaporation unit is a high technology system that vaporizes the water in five different evaporation tanks, three falling and two forced circulation (vacuum) tanks. They reduce the power input by using two heat exchangers and by doing so recover heat from the outgoing water to the incoming water. The outcomes from the evaporation tanks are two different waters, distilled water that goes back to the industries and the second water that goes to solar dryer ponds. The water in the solar dryer ponds evaporates to the atmosphere in 10 days. The rest consists to 95% of sodium chloride (Na CI). The salt is collected from the bottom of the ponds and stored in sacks under roof. They produce 3.6 tons of salt every day and the space for storage is limited so this soon becomes a big and critical issue. Purify the salt where it can be reused in the textile industries.

2.1.2.2 Wash water treatment plant

The wash water treatment plant was opened in July 2002 which reduces COD and BOD by 40-60%. They regularly measure pH, TSS, BOD, COD and TDS. The plant has no seasonal variation as the textile industry produces the same quantity the throughout the year. However, the hourly inflow varies widely in both quality and quantity. The receiving tank and the bar screens are designed for the peak flow, but the units down stream. If the equalization tank are designed for an average flow and an average quality. The energy consumption is approximately 0.9 kWh/m^3 water treated and the cost is Rs.12-20 m^3 treated water.

2.1.2.2.1 Flowchart for PCETP

The flowchart for Wash water treatment plant in PCETP is shown in the Figure 1. A number is connected to every unit. The bar screen (1) is where the wastewater first passes through and is situated in the influent of the receiving sump (2). It is used to take care of rags and large objects in the wastewater, so that these objects do not destroy the forthcoming units, for example pumps. PCETP has two screens that are located inside the receiving sump. The shapes are rectangular, size 1.5 x 2.5 m^2. The clear openings (spaces between bars) of the first screen are 10-15 mm and clear openings of the second screen are 20 mm. The screen is hand-cleaned once in a day and this is sufficient because the character of the water is good.

The purpose of the receiving sump is to attain the same flow into the treatment plant. The diameter of the receiving sump is 8.0 meters and it has a depth of 2.3 meters. The flow into the treatment plant is about 132-150 m^3/h and TDS is less then 2100 mg/l. In general, TDS is around 1800 mg/l, pH is about 8-9 and the retention time in the tank is approximately 45 minutes.

Afterwards the water is pumped to the equalization tank (3). The water is spread over three floating aerators, which distribute the water on to the surface of the equalization tank. The water is mixed with air so that an anaerobic process does not occur and settling of suspended solids is avoided. The equalization tank is there to equalize the temperature, quality and flow rate of the water. In other words, minimizing the fluctuation in those parameters for the downstream units. The equalization tank in PCETP has a diameter of 32 meters and a depth of 4 meters. The retention time in the tank is about 24 hours with a low of 150 m^3/h.

The water is then again pumped to the flash mixing tank (4). The first goal for the mixing tank is to raise the wastewater pH to form metal hydroxide particles, by .the addition of lime. The next step is to add iron sulphate and polyelectrolyte into the wastewater. Iron sulphate destabilizes the colloids so they are able to floccculate. The polyelectrolyte attaches to the metal solid particles and small metal hydroxide particles become entangled in the polyelectrolyte. This increases the particle size, which promotes settling. The mixing tank has a volume of 1.5 x 1.5 x 1.8 m^3 and the mixer is mechanical. In PCETP they add lime to raise the pH to II. Water samples are collected about every two hours from the equalization tank so the dose of the chemicals can be regulated to the quality of the water. On average, the chemicals added in I liter wash water are 80-90 ml Lime, Ca(OH) 5% and 20 ml iron sulphate, FeS04 5%. The water retention time in the flash mixing tank is about two minutes.

After that the water goes into the clariflocculator (5), where the particles coagulate and sink to the bottom as sludge. The deposited sludge is scratched off from the bottom of the tank and pumped into the sludge sump. The cleaner water reaches the top; it flows out through the outfall, which extends all around the settling tank. The outlet water from the clariflocculator goes to the clarified effluent sump (6). The sump is used to provide a constant flow into the next unit, the Auto Valveless Gravity Filter (AVGF) (7). The clarified effluent sump in PCETP has a retention time of 30 minutes. The dimension of the tank is 10.0 x 6.0 x 2.5 m^3. The water is pumped by means of the Autovalves gravity tilter feed pump is to the Automatic Valves Gravity Filter (AVGF). The purpose of the filtering is to remove suspended solids, which did not settle in the sedimentation basin. The reason the particles do not settle could be that they are too small and do not have sufficient time to settle. The particles instead follow the water out. The wastewater passes through the filter bed composed of granular material. The removed particles are accumulated in the voids in the sand therefore the head increases. When the pressure gets too high, automatic backwashing starts to remove the suspended solids. In PCETP, the sand filter is used because it is effective and made of cheap material. They have three different sand stones of a different density to increase the flow. The coarse material is on the bottom and the fine material on the top. The driving force in the sand filter is the capillary drainage system in the bottom. The flow in the filters is 7 m^3/h. This gives a retention time of approximately 10 minutes. The filter is backwashed for about 15 minutes with a flow of 50 m^3/h, in general twice a day. The backwash water from the sand filter goes back to the receiving sump.

After the AVGF, HCI is added and mixed into the water with a static mixer (8) to reduce the pH to 7.5 - 7.8. A static mixer is placed on the pipe to the stability tank and is designed with baffles. This mixes the water hydraulically with HCI. The water then goes to the stabilization sump (9), where the pH in the water stabilizes, resulting in fixed pH at 7.5 - 7.8 before the water goes to the carbon filter.

The water is pumped into an Automatic Carbon Filter (ACF) (10). The most effective method to take away unwanted materials such as odour, heavy metals organic and inorganic pollutants is to use an ACF. Activated carbon can be prepared from anything consisting of carbon, for example hardwood or nut shell. The materials are heated to 200-1OOO°C without oxygen and are activated by reheating to a high temperature whilst providing steam. This will give a fine capillary structure with a surface area of 1000-2000m²/g. The carbon will adsorb the pollution and in that way remove the substance. PCETP has two granular carbon filters, one in each system. The volume of the tanks is 10 m^3 and each tank is under a pressure of 2.5 - 3.5 kPa. The retention time in ACF is eight minutes. The thickness of the carbon bed is 0.5-0.75 meter and it is made of coconut shells. The coconut shells are used for two years before they are replaced. The filter is backwashed every eight hours for 15 minutes. The back washing and the first filtrate go to the receiving sump.

After the ACF, the clean water goes through a magnetic flow meter (II), which registers TDS and pH. This unit forms the last control of the water before it goes to the field for irrigation. The effluent water has a flow of about 139m³/h, pH around 7.5 and a TDS of 1700mg/l. Finally the water is pumped with a booster pump out to the field for irrigation. The sludge from the bottom of the clariflocculator goes to the sludge sump (12) and then further to the sludge thickener (13). The sludge sump is a tank where the sludge is collected before it goes to the sludge thickener. This tank is essential to achieve a constant flow into the next unit. The sludge sump in the treatment plant has a diameter of 1.5 meters and a depth of 3.0 meters.

The purpose of the thickener (15) is to increase the solids content of the sludge by removing a portion of the liquid fraction. The thickener has a slow speed mixer. The mixer has the function of making air channels in the sludge, which makes it easy for the water to escape. Another function of the mixer is to scratch the sludge into the middle of the tank where the sludge is taken out. In PCETP the sludge thickener has a diameter of 6.0 meters and a depth of 2.0 meters.

After the sludge thickener the sludge can go two different ways. The centrifugation (14) separates liquids from solids by considerably increasing the gravity power. Due to different density between the solids and the liquid the solids go immediately to the periphery and the water stays closer to the centre and can than be separated. PCETP has two centrifuges but only uses one at a time. The centrifuge extracts the water so the outlet DS is 25%. Each day 10-15 tons of sludge is produced. The rest of the sludge goes to the drying beds (16). Sludge-drying beds are used to dewater digested sludge. The bed is similar to slow filtration through sand. The bed is filled up with one meter of sludge and it stays untouched for 20 days. Under the sand layer there are drainpipes to collect the separated water. After drying, the sludge is removed and packed into bags and stored under a roof. The sand has three different fractions to increase the flow speed through the bed. The five drying beds are a complement to the centrifuge. They are used instead of the centrifuge when capacity is not sufficient. The dimensions of each bed are 11 x 5.0 x 1.0 m^3.

As a final point the sludge is packed in sacks and stored under a roof until further notice. PCETP has made an investigation regarding the use of sludge for brick production. The result was very positive (Charlotta Leissner, 2005).

3. Materials and methods

One of the leading woven fabric dyeing unit, SIPCOT, Perunduarai, Erode, visited and information on manufacturing process and waste water quantity were collected. Waste water samples from the wash water collection tanks and dye bath collection tanks, intermediate points and at the outlets effluent plants were collected and analysed laboratory using standard methods.

Following samples were collected and tested:

a) Wash water untreated effluent

b) Dye bath plant feed parameters

c) Wash water treated effluent (Biological – inlet Parameters)

d) Biological treatment – secondary clarifier

e) Tertiary clarifier – DMF (Dual Media Filter) out put

f) Ultafiltration feed parameters

g) Ultrafitration Permeate parameters

h) Ultrafiltration reject parameters

i) Feed parameters of Reverse Osmosis

j) Permeate parameters of Reverse Osmosis

k) Reject parameters of Reverse Osmosis

PCETP – Pretreatment I (Washwater Plant):

Collection Tank

↓

Equalization Tank

↓

Flash Mixing Tank

↓

Clariflocculator

↓

AVGF (Auto Valveless Gravity Filter)

↓

Stabilization Tank

↓

Activated Carbon Filter (ACF)

Pretreatment II (Biological &Tertiary Treatment):

Aeration Tank

↓

Secondary Clarifier

↓

Flash Mixer Tank

↓

Tertiary Clarifier

↓

Collection Tank

↓

DMF (Dual Media Filter)

↓

Ultrafiltration

↓

Organic Scavenger

↓

Reverse Osmosis

4. Result and Discussion

This study was carried out at one of knitted fabric dyeing industry located at SIPCOT, Perundurai, Erode. Seven numbers of soft flow with different capacities are used for dyeing including wetting, bleaching, neutralizing, washing, coloring, washing, etc. Dye bath solution requires dyes alkali and sodium salt in the process quantity of salt (sodium chloride) used usually depends on the requirement of color shade. Effluents are segregated in to dye bath waste water and wash water and treatment is effected accordingly.

Wash water equalized in a holding tank is subjected to primary treatment by flash mixing with lime and ferrous sulfate and are allowed for settling. Primary treatment is followed by the secondary treatment such as biological oxidation through tertiary clarifier, activated carbon bed, Dual media filter, ultrafiltration and reverse osmosis (RO) system. Double stage RO is followed with a feed water flow rate of $50m^3/h$. High pressure pumps used to feed the filters water to the first array of the RO and reject of the first RO to second RO and final reject (5m³/h) in sent for multi effect evaporator. Permeate is used in the recycling process.

Whereas dye bath water is collected in a separate tank and allowed for lime and ferrous sulfate flocculation to remove the color. These light color effluents mixed with the rejects of RO are sent to Multi effect evaporation system. The permeate is used for preparation of dye bath solution. The characteristics of the raw effluents, intermediate effluents and permeate are presented in the (table-1 to table-11) the low hardness of permeate is an added advantages in the process, which was observed in the span of fifteen day.

5. Conclusion

Perundurai Common Effluent Treatment Plant, PCETP implement and recent technology to simplify operation. The plant is well operated and maintains constant effluent as per pollution control board (PCB) norms in water quality.

The study shows the recycling of treated wastewater and zero wastewater discharge concept are found technically feasible and economically viable in the textile dyeing industries located in the area of Erode and Tirupur in Tamil Nadu. By implementing novel technology PCETP, the average of BOD, COD, TDS and Chloride can reduced in the range of 88 – 98%, 91 – 97%, 80 – 97% and 76 – 97% respectively.

Nomenclature

pH – Percentage of Hydrogen

TDS – Total Dissolved Solids

COD – Chemical Oxygen Demand

RO – Reverse Osmosis

BOD – Biological Oxygen Demand

TSS – Total Suspended Solids

TH – Total Hardness

Cl^- – Chloride

So_3 – Sulphide

So_4 – Sulphate

Si – Silica

Cl_2 – Chlorine

Fe – Iron

CETP – Common Effluent Treatment Plant

PCETP – Perundurai Common Effluent Treatment Plant

PCB – Pollution Control Board

PPM – Parts Per Millian

NTU – Nepelometric Turbidity Unit

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Table 1. Wash water (untreated effluent)

Day	pH	TDS ppm	TSS ppm	COD ppm	BOD ppm	Cl^- ppm	Total Alkalinity ppm	Total Hardness ppm
1	10.11	3180	720	830	230	1205	1250	122
2	9.88	1730	830	720	260	854	1300	90
3	8.34	1690	300	750	180	527	1080	140
4	9.45	3340	700	810	405	425	1200	100
5	9.53	2300	700	740	225	947	1060	210
6	9.58	1190	720	730	200	420	1110	160
7	9.10	1580	900	672	279	632	980	180
8	9.20	2310	800	816	315	716	810	170
9	9.10	2210	830	824	280	752	1240	160
10	9.16	2230	710	808	285	815	1040	152
11	8.88	2410	740	820	240	1060	1450	160
12	8.92	2120	880	824	260	996	1320	135
13	9.01	2100	860	816	280	1120	1120	145
14	8.86	2300	710	752	260	1000	1020	140
15	9.10	1950	740	832	275	957	1300	128

Table 2. Dye bath plant feed parameters

Day	pH	TDS ppm	TSS ppm
1	10.47	24000	2950
2	10.39	25900	3400
3	9.97	26800	9950
4	10.50	27600	9900
5	10.42	27800	9000
6	10.44	33900	9900
7	10.40	20100	4600
8	9.92	24200	8800
9	10.26	23600	7600
10	10.40	25100	8200
11	10.38	25800	6900
12	9.93	24300	7350
13	10.18	22900	8200
14	10.02	27100	8450
15	9.96	25300	7690

Table 3. Wash water treated effluent (Biological inlet parameters)

Day	pH	TDS ppm	TSS ppm	COD ppm	BOD ppm	Cl^- ppm	Total Alkalinity ppm	Total Hardness ppm	Turability NTU
1	7.45	2710	520	330	182	1262	250	120	14.4
2	8.09	2480	540	452	190	1056	550	100	16.2
3	7.10	2680	440	420	164	1134	230	116	13.4
4	6.99	2730	330	448	102	1098	460	128	11.0
5	6.78	2430	300	420	140	1106	320	112	13.1
6	6.70	2560	320	344	160	1040	340	138	12.9
7	7.04	2290	310	384	125	1140	360	116	13.2
8	7.10	2380	390	480	188	1210	300	108	11.3
9	7.15	2280	420	384	164	1050	400	96	13.6
10	7.90	2140	380	392	168	1070	420	70	12.5
11	8.02	2120	330	408	192	910	510	82	10.2
12	7.38	2150	320	410	188	751	420	98	11.4
13	7.80	2200	380	400	178	892	490	102	14.8
14	7.88	2120	340	420	186	890	400	112	12.2
15	7.90	2030	380	414	180	920	450	120	10.8

Table 4. Biological treatment (Secondary clarifier)

Day	pH	TDS ppm	TSS ppm	COD ppm	BOD ppm	Cl^- ppm	Total Hardness ppm
1	7.36	2300	50	56	17	990	100
2	7.35	2510	50	88	24	1130	92
3	7.34	2500	60	84	15	1162	94
4	7.34	2510	70	72	32	1066	88
5	7.24	2480	60	76	20	1100	90
6	7.14	2520	46	84	24	1120	92
7	7.25	2500	50	86	26	1120	96
8	7.35	2380	54	74	30	1040	80
9	7.35	2460	48	100	32	1056	82
10	7.30	2400	50	86	24	1116	84
11	7.27	2500	60	70	30	990	88
12	7.30	2420	80	82	26	1020	68
13	7.40	2380	80	84	26	920	72
14	7.30	2390	70	76	32	964	80
15	7.34	2380	60	74	30	980	68

Table 5. Tertiary classifier DMF (Dual Media Filter) output

Day	pH	TDS ppm	TSS ppm	COD ppm	BOD ppm	Cl^- ppm	Total Hardness ppm	Total Alkalinity ppm	Turability NTU
1	6.70	2280	50	48	30	990	125	210	1.0
2	6.96	2520	50	64	26	1130	110	250	0.9
3	7.20	2580	60	60	28	1160	115	200	1.0
4	7.16	2550	70	48	26	1063	104	240	1.0
5	7.20	2570	60	64	26	1098	116	220	1.2
6	7.00	2560	46	60	25	1120	108	260	1.1
7	7.02	2500	50	56	28	1012	120	250	1.0
8	7.04	2420	54	56	30	1230	108	225	0.8
9	7.02	2530	48	64	32	1156	108	200	.07
10	6.90	2470	50	56	26	1116	120	210	1.0
11	6.85	2600	60	48	24	987	80	310	0.9
12	6.90	2500	80	72	28	1028	94	340	0.7
13	7.05	2480	80	64	30	921	92	280	0.6
14	6.92	2400	70	60	32	980	94	270	0.6
15	7.06	2370	60	48	30	974	90	290	0.8

Table 6. Ultrafiltration feed parameters

Day	pH	TDS ppm	Cl^- ppm	Total Hardness ppm	Total Alkalinity ppm	Turability NTU	Free Cl_2 ppm
1	6.74	2450	1100	120	130	0.3	0.380
2	7.30	2500	1200	124	120	0.2	0.392
3	7.18	2400	1220	124	140	0.3	0.390
4	7.13	2450	1210	126	120	0.2	0.398
5	7.33	2540	1191	130	130	0.6	0.370
6	7.22	2600	1210	132	170	0.6	0.778
7	7.30	2460	1200	120	140	0.1	0.340
8	7.40	2510	1190	122	150	0.4	0.360
9	7.11	2540	1210	124	145	0.3	0.380
10	7.25	2460	1220	130	155	0.4	0.398
11	6.91	2620	1220	132	145	0.2	0.480
12	7.16	2510	1190	100	125	0.2	0.220
13	7.38	2440	1210	92	135	0.3	0.325
14	7.40	2420	1240	110	125	0.2	0.330
15	7.32	2400	1250	116	125	0.4	0.200

Table 7. Ultrafiltration permeate parameters

Day	pH	TDS ppm	Cl^- ppm	Total Hardness ppm
1	7.40	2300	1000	120
2	7.43	2450	1010	126
3	7.37	2500	1040	130
4	7.36	2510	1020	132
5	7.30	2550	1070	128
6	7.35	2400	1010	122
7	7.38	2350	980	130
8	7.26	2330	990	100
9	7.30	2540	1010	102
10	7.20	2650	1010	106
11	7.26	2300	1020	110
12	7.24	2500	1000	100
13	7.19	2250	940	88
14	7.20	2310	960	96
15	7.30	2300	1000	98

Table 8. Ultrafiltration reject parameters

Day	pH	TDS ppm
1	7.10	2350
2	7.03	2450
3	7.43	2550
4	7.39	2540
5	7.44	2500
6	7.30	2350
7	7.40	2390
8	7.32	2410
9	7.20	2550
10	7.30	2660
11	7.32	2400
12	7.40	2570
13	7.20	2290
14	7.22	2360
15	7.33	2400

Table 9. Reverse Osmosis feed parameters

Day	pH	TDS ppm	COD ppm	Cl^- ppm	Total Hardness ppm	Total Alkalinity ppm	SO_4 ppm	SO_3 ppm	Free Cl_2 ppm	Si ppm	Fe ppm
1	6.92	2260	48	1127	112	150	228	5.4	Nil	12.2	0.06
2	7.00	2500	52	1170	112	180	224	4.6	Nil	32	0.04
3	6.97	2540	48	1169	136	170	256	6.4	0.025	20	0.05
4	6.99	2550	50	1191	128	210	264	5.6	0.086	10.5	0.06
5	7.00	2520	54	1077	130	200	236	8.1	Nil	9.0	0.05
6	6.87	2580	48	1180	150	200	278	7.4	Nil	10.22	0.06
7	6.80	2490	38	1200	130	160	240	7.0	Nil	12.10	0.06
8	6.80	2490	64	1319	108	150	285	5.4	Nil	9.0	0.08
9	6.91	2540	56	1230	150	120	278	3.3	Nil	8.25	0.11
10	6.69	2580	38	1354	100	150	254	5.0	Nil	11.15	0.06
11	7.25	2560	56	1063	110	150	278	6.2	Nil	22.7	0.07
12	6.88	2500	50	1098	100	140	280	7.8	Nil	10.40	0.08
13	7.04	2500	48	922	88	160	248	7.0	Nil	12.20	0.07
14	7.05	2460	52	1100	84	150	260	6.8	Nil	9.75	0.08
15	6.85	2390	50	1098	86	140	288	2.9	Nil	20.87	0.07

Table 10. Reverse Osmosis Permeate parameters

Day	pH	TDS ppm	Cl^- ppm	Total Hardness ppm
1	6.13	190	85.0	3.0
2	6.12	160	78.6	2.5
3	6.12	130	79.4	3.0
4	6.09	130	81.5	3.0
5	6.23	110	92.0	1.5
6	6.03	110	58.0	1.5
7	5.90	105	64.0	2.5
8	6.00	90	55.0	1.5
9	5.95	90	61.0	2.0
10	6.91	140	71.0	2.0
11	5.94	120	56.0	3.0
12	6.23	100	57.0	6.0
13	6.18	120	50.0	4.0
14	6.20	115	52.0	3.5
15	6.07	110	54.0	3.0

Table 11. Reverse Osmosis Reject parameters

Day	pH	TDS ppm	Cl^- ppm	Total Hardness ppm
1	7.14	20200	9997	965
2	7.20	21800	9394	910
3	7.20	18400	9040	940
4	7.14	18600	8508	1120
5	7.36	21400	9010	800
6	7.20	19000	9020	920
7	7.15	19300	9910	890
8	7.02	19300	9075	850
9	7.09	21400	11340	795
10	7.26	23600	10565	790
11	7.07	22100	9640	810
12	7.02	17100	9580	624
13	7.19	19300	9290	780
14	7.10	20100	9380	790
15	7.09	21400	9480	696

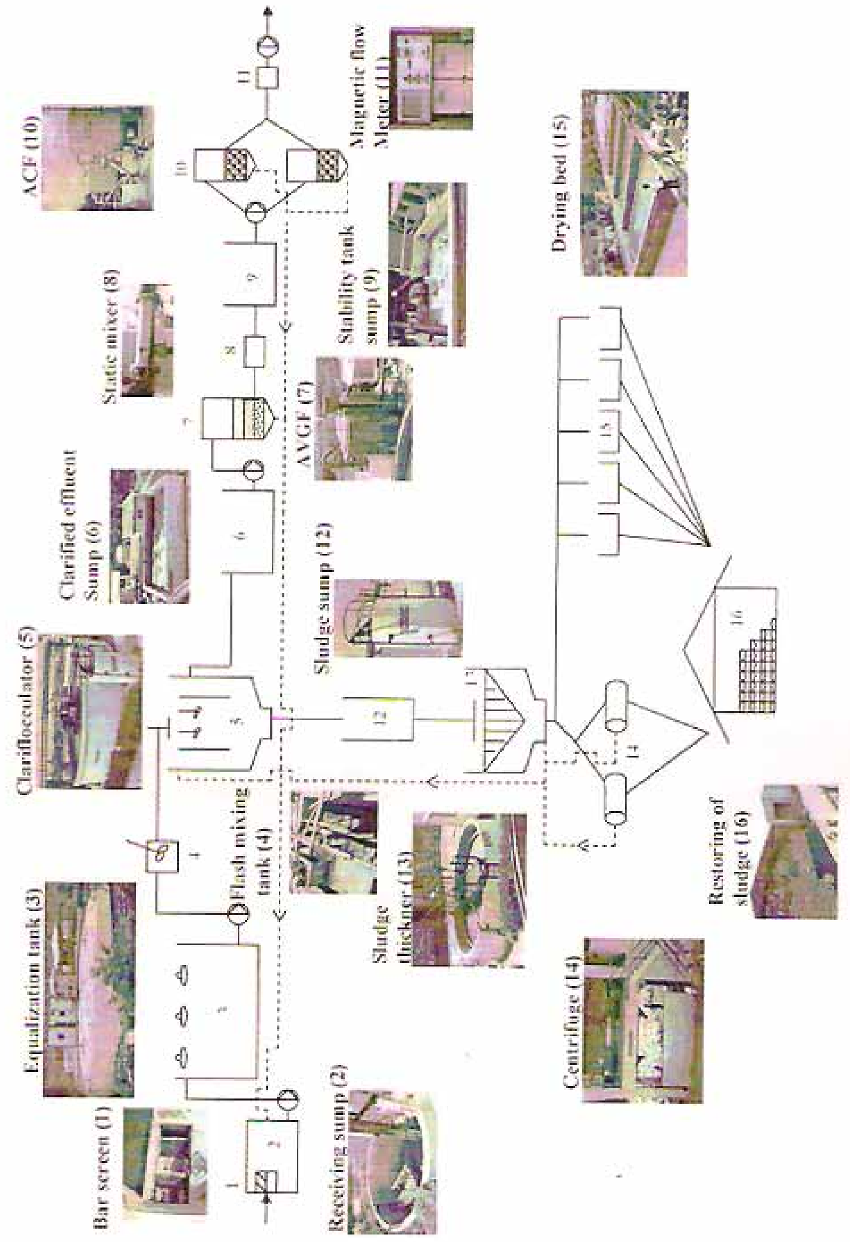

Figure 1. Flowchart of PCETP

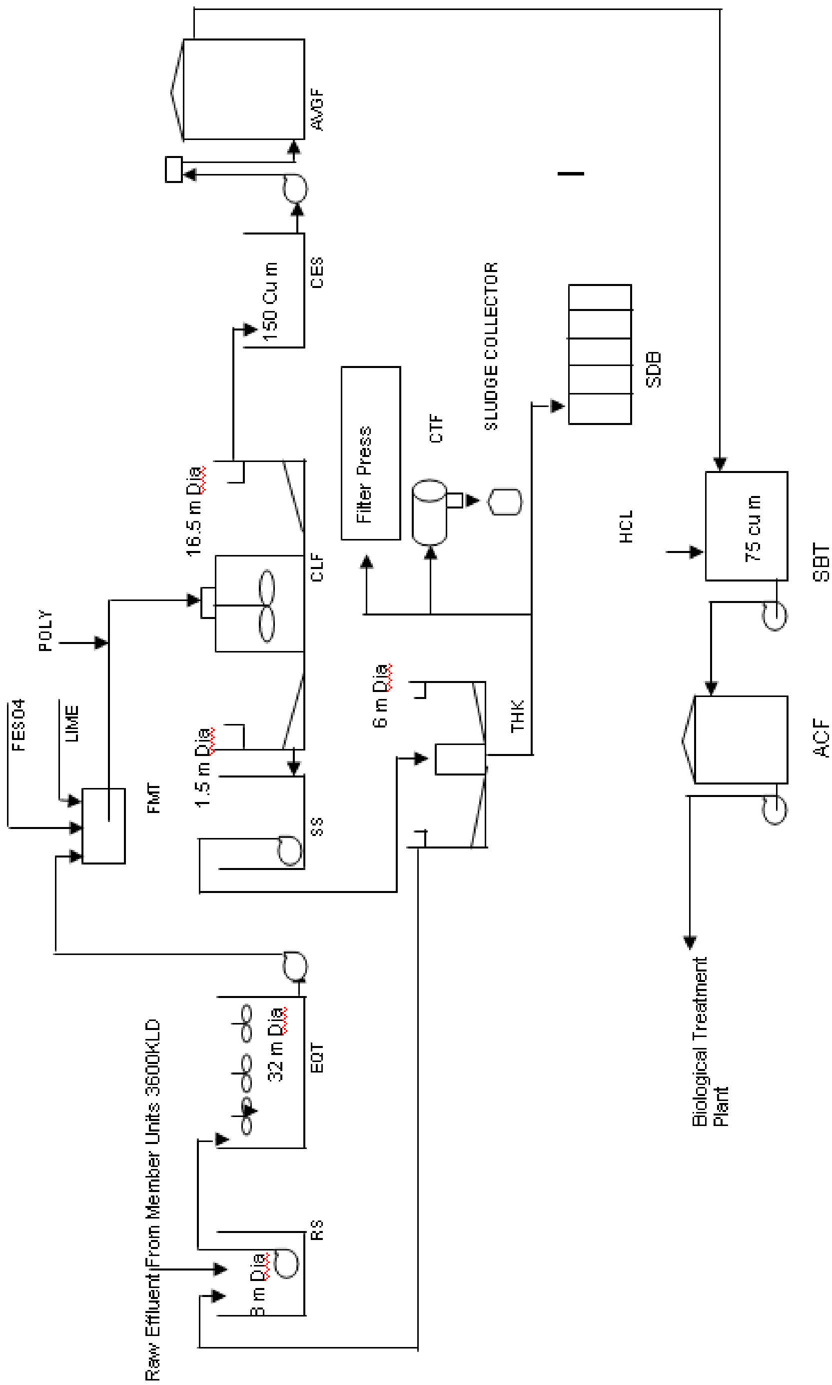

Figure 2, Pre treatment – I (Wash water Plant)

RS	RECEIVING SUMP	**CES**	CLARIFIED EFFLUENT SUMP	**SS**	SLUDGE SUMP
EQT	EQUALISATION TANK	**AVGF**	AUTO VALVELESS GRAVITY FILTER	**THK**	THICKNER
FMT	FLASH MIXING TANK	**SBT**	STABILISATION TANK	**CTF**	CENTRIFUGE
CLF	CLARIFLOCCULATOR	**ACF**	ACTIVATED CARBON FILTER	**SDB**	SLUDGE DRYING BED

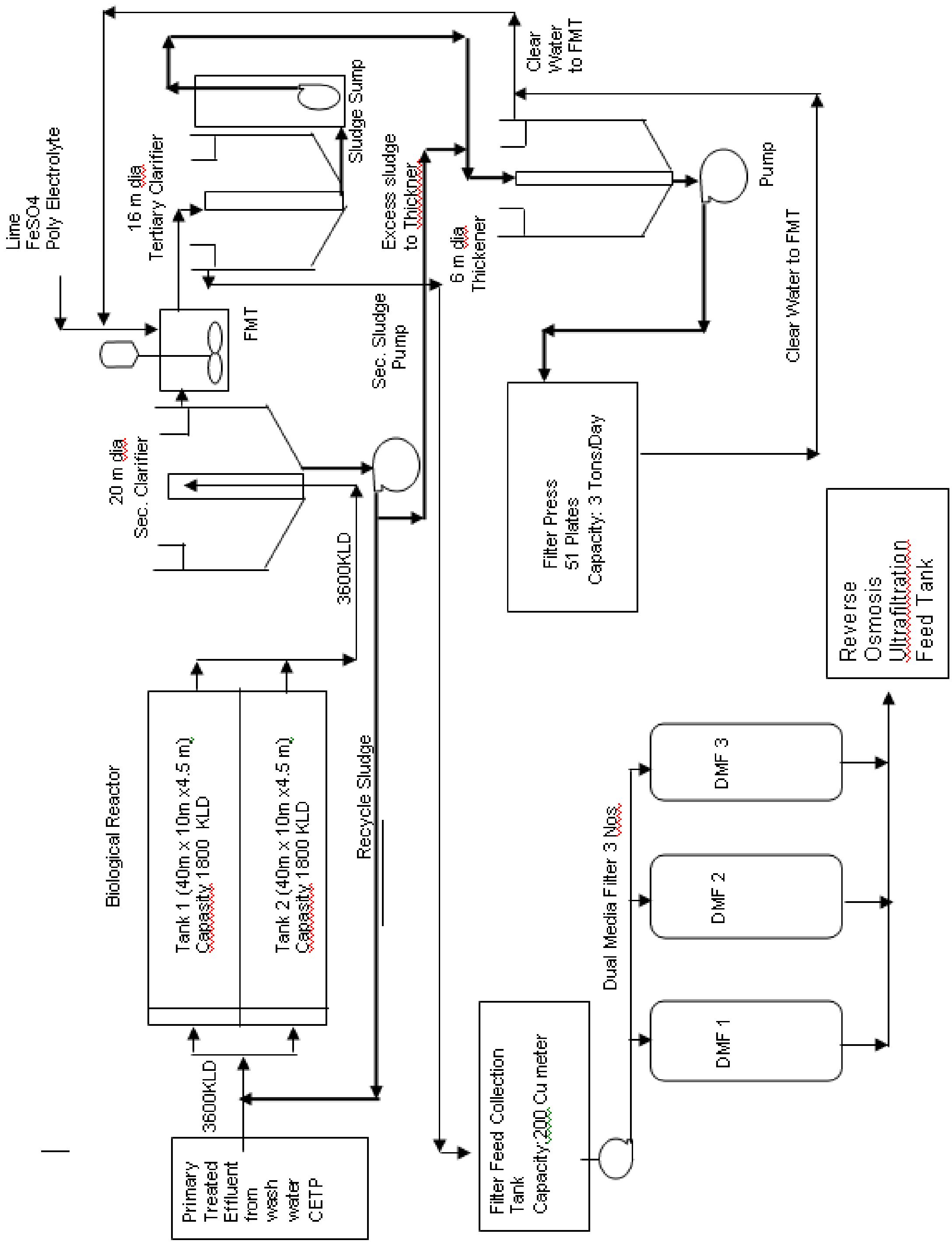

Figure 3, Pretreatment II (Biological, Secondary & Tertiary treatment)