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PERFORMANCE EVALUATION OF A COMMON EFFLUENT TREATMENT PLANT (CETP) TREATING TEXTILE WASTEWATERS IN INDIA

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ABSTRACT

Several small scale industries have formed cooperatives and established Common Effluent Treatment Plants (CETP) to treat wastewater in India. The wastewaters are subjected to primary treatment in the industry and thereafter discharged to be further treated at the CETPs. The management and treatment costs are shared by the member industries. The CETP under study is situated in North Western part of Rajasthan in Pali district. Pali has about 989 synthetic and cotton textile printing and dyeing units. The member industries generate wastewater containing a variety of chemicals, dyes, acids, alkalis besides other toxic heavy metals. In this study, performance of a CETP of capacity 1.5 Million Gallons per day wastewater from synthetic textile mills was evaluated. Four criteria viz. design, operation, maintenance and administration was deployed to evaluate the overall performance of CETP. Design data was collected from each unit operation of the CETP and adequacy of design was assessed using a scoring method. Actual operational efficiency of the CETP was evaluated by collecting samples (16 in all) at each stage of treatment. All samples were analyzed for 16 physico-chemical parameters. Administration capability and adequacy of maintenance systems were evaluated using questionnaires and by conducting staff interviews. The overall performance of the CETP was evaluated considering all the dimensions and accordingly recommendations were made for improving the performance.

INTRODUCTION

Textile industry is the largest industrial employer in the country, contributing to 6% of GDP (Gross Domestic Product), 16% of export and about 18% of industrial production. The textile industry plays an important role in Indian economy. It contributes to 9% of excise collection, 30% of export revenue and 18% of employment in industrial sector. It is one of India's largest foreign exchange earners, accounting for 12% of the country's total exports. Since global trade in textile and clothing is expected to reach US$ 600 Billions in 2010 from the level of US$ 356 Billions; there is an urgent need to augment our textile production capacity. At the same time, it is very essential that the environmental problems associated with industrial development are properly addressed to sustain both industrial as well as economic growth. The index of production for the textile group of industries shows mixed trend. There is a significant increase in textile products (18.6 %) and cotton textiles (10.2%). Only a marginal increase in jute and other vegetable fiber textiles (2.7 %) is witnessed, while wool, silk and man made fiber textiles have declined (-0.1 %). 40% of the industrial wastewater generated in India comes from small size industries. With the

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adoption of the Water Act, those small size industries have in theory the obligation to treat their effluent in order to reach pollution concentration respecting the minimum acceptable standards laid down by the State Pollution Control Boards. Nevertheless, the size of these facilities makes the installation of a standard effluent treatment plant (ETP) unaffordable. Therefore, public authorities have taken the initiative to promote CETP schemes, allowing small industries to gather in order to treat jointly their effluents. The CETP concept was originally promoted by the Ministry of Environment and Forests in 1984. The first CETP in India was constructed in 1985 in Jeedimetlha near Hyderabad, Andhra Pradesh, to treat waste waters from pharmaceuticals and chemicals industries. In 1999, 82 CETPs had been set up in 12 states around the country. Although CETPs are mainly seen as a means to take advantage of scale economies, these schemes also act as subsidies from public powers to small industries in order to allow them to respect the standards. It has been clearly shown that compared to individual ETPs, CETPs are more cost effective in reaching the effluent concentration standards (Pandey and Deb,1998) and (Sankar, 2001)

Several methods of cost distribution for CETPs are being practiced world wide. In India the distribution is as such: state subsidy of 25%, central subsidy of 25%, entrepreneur's contribution of 20%, and loan from financial institutions of 30% of the total project cost (e.g. any nationalized bank, State Industrial Financial Corporation etc.). If the CETP Co. does not desire to have loans from financial institutions / banks they may augment the same out of their own resources / contributions, i.e. the entrepreneurs would then contribute 50% of the project cost. Central assistance up to 25% of the total cost of the CETP would be provided as a grant to the CETP. In the other parts of the world various other systems of cost distribution exist such as Quantity Method, Quantity – Quality method, Malz Formulation, Fukashiba formulation, Roman Formulation, Chemtech Formulation, Graduated Payment Formulation, and Flecksedar Methodology (Pandey and Deb 1998) , (Mathur *et al.* 2005) and (Raj *et al.* 2004)

The CETP in the case study is located in Pali which is in the North-Western State of Rajasthan of India. Pali district is situated on the banks of river Bandi. The total area of this town is about 12,387 Sq. kms. There are around 989 dyeing and printing units. There are 3 CETPs (I, II, III) in operation in Pali and one is in planning stage (IV) (Mathur *et al.* 2005). The CETP of Mandia Road was constructed and commissioned by NEERI in May 1997. Dyeing and printing of cotton fabrics in the major activity of this industrial complex besides other activities such as desizing, mercerising, kiering, bleaching etc. This CETP is based on physico- chemical followed by aerobic biological treatment.

MATERIALS AND METHODS

Design of CETP

The effluent treatment plant is a combination of physico-chemical followed by aerobic biological treatment (Fig 1). The plant consisted of following primary and secondary treatment unit operations: Sump well, Equalization basin, Chemical dosing tank, Primary clariflocculator, Activated sludge basin, Secondary clarifier and Sludge drying bed. The capacity of the existing CETP is about 1.5 MGD.

Treatment process

The treatment plant is based on physico-chemical treatment followed by biological treatment. The combined wastewater is collected in a sump well. The wastewater from sump is being continuously taken up into equalization basin to neutralize qualitative irregularities. The wastewater from equalization basin is treated by ferrous sulphate as chemical coagulating agent. Concentrated sulphuric acid of 98% purity is added for pH adjustment, whenever needed. These chemicals are added from chemical dosing tanks. The contents are held up for 60 seconds in this tank. Ferrous sulphate helps in coagulation and flocculation of colloidal material which is mostly responsible for colour in the wastewater. The agglomerated flocculated material along with wastewater enters into primary clarifier. The colloidal material along with some of inorganics are removed in primary clarifier by coagulation, and sedimentation. The precipitated material comes out as sludge slurry and is finally dried up on sludge drying beds. The clarified liquid enters into activated sludge basin and is treated by acclimatized micro-organisms. The treated effluent from activated sludge basin is then passed through a secondary clarifier to settle waste sludge. Part of the waste sludge is recirculated to activated sludge basin in order to maintain required MLSS. However, the remaining sludge along with sludge from primary clarifier is sent to sludge drying beds for disposal. The clear treated effluent from secondary clarifier passes through the drain which finally disposes into the river. Sludge drying beds are provided at CEPT area. This sludge slurry from primary clarifier along with remaining sludge slurry from secondary clarifier is taken together for dewatering on sludge drying beds. The dried sludge is finally disposed off according to State Pollution Control Board recommendation. The filtrated is finally taken back into activated sludge basin for further treatment.

Evaluation of design eactors

The primary objective of this phase is to determine design adequacy of CETP and explore whether significant improvements in treatment can be achieved without major capital expenditures. Each unit operation was analyzed for design and point score was awarded to the unit operation. The design adequacy was assessed based on overall score. The design score of each unit operation was then computed using a program to obtain the final point score for each of the 3-4 crucial evaluation parameters. The final point scores were compared with the bands of point range (also given) and the unit operations were adjudged Type 1, 2 or 3. Type 1 unit operations are those where design is adequate but there are major problems related to operation, maintenance and administration. Type 2 units are the type where marginal capacity of the unit operation can inhibit good performance and the plant needs physical improvement. Type 3 units are one in which major unit operations are inadequate and require major construction work to improve the performance.

Evaluation of operational factors

The major units were also evaluated for their performance by taking 3 samples from each unit operation viz. inlet, middle and outlet. These 16 samples were analyzed for about 16 parameters. All samples were analyzed within 24 hrs of their arrival and stored below 8 C till then. All samples were analyzed as per Standard Methods of Examination (APHA-AWWA-WPCF, 1989). The parameter values indicate operational efficiency of a particular unit operation and could be corrected to improve performance. Its major benefit is that it optimizes the capability of existing facilities to perform better and to treat more wastewater.

Evaluation of administrative factors

The evaluation of administrative performance - limiting factors is subjective. An idea of the budget, revenue budget etc. can provide some insight, as budget is one of the limiting factors. Improving working condition, lowering costs, and other similar goals could be perused within the realm of first achieving adequate performance. Administration can be judged by the following criteria:

Excellent reliably provide adequate wastewater treatment at lowest reasonable cost; Normal: provides best possible treatment within financial constraints; Poor: spends as little as possible with no consideration for achieving adequate plant performance. Another area in which administrators can significantly, even indirectly, affect plant performance is through personal motivation by training, awards etc. Administrators can be evaluated on the basis of operator training man hours, operator salaries, and their influence on operator morale. The competence of the management staff is also an important criterion.

Evaluation of maintenance factors

General information on maintenance was gathered during the data collection phase**.** However, the evaluation of maintenance performance - limiting factors was done through observations and discussions regarding the reliability and service requirements of equipment critical to process control and thus performance. Observation and documentation is necessary in the approach used to evaluate emergency and preventive maintenance practices. Important aspects are examination and verification of spare parts inventories, record keeping systems and work order procedures etc. Preventive maintenance schedules, predictive maintenance schedules, breakdown service efficiency, availability of spares, stand-by availability are some of the indicators of adequate maintenance which were tracked.

RESULTS AND DISCUSSION

Evaluation of design of CETP

Each CETP has a number of performance limiting problems that are unique to that facility. However, it is important to establish whether minor design changes, process adjustments, operator training and appropriate administrative actions would lead to improving plant performance to the desired level or a major facility upgrade would be necessary. Table 2 gives the important parameters for each unit operation, their calculated evaluation parameters, point score for each parameter and its point range. Based on the above, the units are characterized as Type 1, 2 or 3.

Equalization tank has a capacity of 1808m^3. It is rectangular in configuration. HRT provided is 12.7 hour which is sufficient to take care of the fluctuations in the incoming waste water for mixing of the different streams. 3 agitators of 15 HP each are provided. Mixing power provided is less for the given capacity Overall this unit is of Type 1.

Lime tank is of capacity 30.6m^3. 10% slurry of the lime is prepared. One agitator is provided for mixing. Capacity of the lime tank is 180% of the required capacity. This tank is of Type 2. Dimensions of lime tank II are same as that of lime tank I. This tank is also of Type 2.

Ferrous sulphate dosing tank is of capacity 27.30 m^3 .10% slurry of $FeSO_4$ is made. One agitator is provided for mixing 2 HP, which is less than required as per the capacity of the unit. This unit is of Type 2.

PolyelectrolytetTank capacity is 10m^3, which is 196% of the required capacity. Polyelectrolyte is added as a coagulant. Power provided for mixing is 2 HP Capacity and mixing provided is as per the requirement and this unit is of Type 1.

In flash mixer, different chemicals are mixed to treat the wastewater. HRT provided is 162 second which is sufficient to achieve good mixing of chemicals. Power provided for mixing is 2 HP Capacity and mixing provided are as per the requirement and this unit falls under Type 1.

Clariflocculator consists of clarification zone and flocculation zone. Clarification zone is circular in configuration. HRT provided is 10.5 hrs, which is sufficient to achieve proper settling. Surface overflow rate is 40m^3 / m^2 / day, which is greater than the specified limits. Retention time provided for flocculation zone is 3703 seconds. Data on power provided for flocculation is not available Overall, clariflocculator unit is of Type 1.

Activated sludge tank capacity is around 9000 m^3. Nine no. of agitators with 100 HP are provided for aeration. Organic loading rate is 0.06 kgBOD / m^3 / d and oxygen availability is 9.257 kgO_2 / kg BOD. HRT, organic loading rate and oxygen availability are all as per the requirement and this unit falls under Type 1.

Secondary settling tank Sludge from the aeration tank is passed to settling tank for settling. Capacity of the tank is 1742 m^3 and it is circular in configuration. HRT of the unit is 12.28 hrs, which is sufficient to achieve good settling of sludge.

Sludge drying beds (SDB) are eight in number - four for chemical sludge and four for biological sludge. Total area the beds is 3840 m^3 area provided is 126.35% of the required area. Sludge drying bed is of Type 1. Sludge drying beds for biological sludge are 20% of the required area. This SDB is of Type 3.

Equalization tank, polyelectrolyte tank, flash mixer, clariflocculator, aeration tank, secondary settling tank, and sludge drying beds for chemical sludge are of Type 1. Lime tank (I,II) are of Type 2 and sludge drying bed of biological sludge is of Type 3.

In many ETPs treating textile mill effluents, the mode of treatment is anaerobic followed by aerobic. This system is attractive as it is cost-effective and environment friendly (Moosvi and Madamwar 2007) , (Weber and LeBeof 1999) , (Bortone *et al.* 1995) and (Georgiou *et al.* 2005) . Biological treatment is sensitive to several parameters. Mutagenic compounds are formed in aerobic treatment (APHA-AWWA-WPCF, Standard Methods for Examination for Water and wastewater, 1989) and (Umbuzeiro *et al.* 2005) . Azo dyes cause mutagenicity and carcinogenicity (Alves de Lima *et al.* 2007). Dye carriers can also be highly toxic to the biomass activity (Alaton *et al.* 2006). Nonyphenol is toxic to aquatic life (Servos *et al.* 2003). Many dyes contribute to toxicity to all stages of life (Navarro *et al.* 2001) and (Rozzi *et al.* 1999). High total dissolved solids (TDS) interfere with oxygen transfer necessary for biological metabolism and thereby affecting the efficiency of the activated sludge process. High TDS effluents are more sensitive to hydraulic shock loads and prone to process upsets (Pophali *et al.* 2003).

Another method of removing colour and Chemical oxygen demand (COD) of textile mill effluents is electrochemical oxidation (Zainal *et al.* 2006). Operating current density of 3.1-4.8 mA cm^{-2} is recommended for the treatment of textile mill wastewaters having TDS around 7000 mg / L for reduction of TDS (Chandramowleeswaran and Palanivelu, 2006). TiO_2 photocatalysis is also a promising technology for treating textile mill COD. Photo Fenton is more capable of decolourization and decreasing COD than TiO_2 coupled oxidizer (Lin and Chen, 1997).

Operational performance of the CETP

pH of the common drain and sump was 13 and 11 respectively. It reduced to 7 in the equalization tank. However, a pH of 8 - 8.5 is maintained in the flash mixer. The pH reduced again in the clarifier to 7 and remained around 7 - 8 in the aeration tank. It was 8 in the secondary clarifier and the outlet. Figure 2 gives the change in pH, COD, BOD, Total solids, Total dissolved solids, Total suspended solids, Alkalinity and Total hardness within the unit operations in the CETP.

Chemical Oxygen Demand (COD) of the common drain was 1160 mg/L and was 640 mg/L in the sump well. It reduced to about 600 mg/L in the equalization tank. A further reduction in COD to about 450 mg/L was observed in the primary clarifier. COD reduced to about 400 mg/L in the aeration tank and to 360 mg/L in the secondary clarifier. COD of the final outlet was 320 mg/L.

Biochemical Oxygen Demand (BOD) of the common drain was 420 mg/L and that of the sump well was 260 mg/L. It reduced in the equalization tank to 175 mg/L which further reduced to about 100 mg/L in the primary clarifier. However, BOD again showed a higher value of 300 mg/L in the primary clarifier outlet and the aeration tank which reduced to about 70 mg/L. BOD was 150 mg/L in the final outlet.

Total solids (TS) were 7600 mg/L in the common drain and 6100 mg/L in the sump. TS increased slowly from this value to about 8825 mg/L in the flash mixer and remained at about 8500 mg/L in the primary clarifier. TS increased from 8000 mg/L to about 14,000 mg/L showing an MLSS of 5000 - 6000 mg/L. TS reduced again in the secondary clarifier to 7000 mg/L. TS of the outlet was 9300 mg/L.

Total dissolved solids (TDS) in the common chain are about 7100 mg/L and that in the sump about 6100 mg/L. It increased to 7000 mg/L in the equalization tank with a further increase to 7600 mg/L in the flash mixer. It reduced to 7800 mg/L in the primary clarifier and to 7000 mg/L in the aeration tank. TDS in the secondary clarifier was 7100 mg/L and in the outlet, it was 7000 mg/L.

Total suspended solids (TSS) in common drain was 470 mg/L and in common sump as 265 mg/L. It increased in the equalization tank to about 1000 mg/L and further to 1200 mg/L in the flash mixer. TSS reduced to 500 mg/L in the clarifier, but increased to about 7000 mg/L in the aeration tank. Drastic reduction to 320 mg/L was observed in the secondary clarifier. TSS in the final outlet was only 22 mg/L.

Total hardness in the common drain was 800 mg/L and in the sump, 180 mg/L. It remained at about 500 mg/L in the equalization tank. An increase in hardness was observed to 650 mg/L in the flash mixer followed by a rise to 760 mg/L in the primary clarifier. It decreased to 600 mg/L in the aeration tank. Hardness in the outlet was 500 mg/L.

Calcium hardness continued to increase from 70

Table 1. The characteristics of the CETP influent and pollution control board standards for effluent from Textile Industry

Sr. No.	Parameter	Concentration, all in mg l^{-1} except pH	Concentration, all in mg l^{-1} except pH (CPCB website)
1.	pH	13	5.5-9.0
2.	COD	1160	100
3.	BOD	420	30
4.	Total Solids	7602	250
5.	Total Dissolved Solids	7126	-
6.	Total Suspended Solids	476	-
7.	Total Hardness	800	-
8.	Calcium Hardness	74	-
9.	Calcium	29	-
10.	Magnesium	17	-
11.	Chloride	2127	-
12.	Salinity	3840	-
13.	Alkalinity	130	-
14.	Ammonia	0.7	-
15.	Phosphate	0.029	-
16.	Sulfate	750	-
17.	Total residual chlorine	-	1
18.	Oil and grease	-	10
19.	Total Chromium as Cr	-	2
20.	Sulphide as S	7.3 [22]	2
21.	Phenolic compounds as C_6H_5OH	-	1

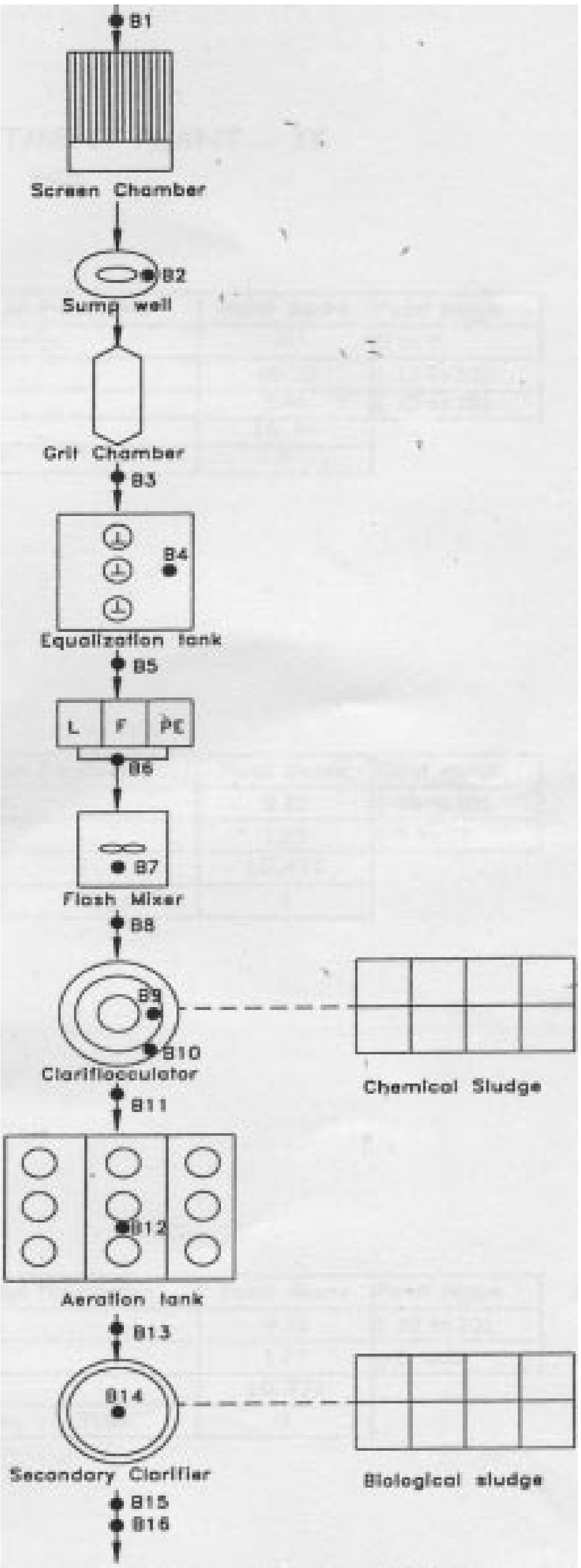

Fig. 1 Flow sheet of CETP showing all the unit operations.

List of sampling point locations

1. Influent from the common drain
2. Sump well
3. Outlet of grit chamber or inlet of equalization tank
4. Equalization tank
5. Outlet of the equalization tank
6. Flash mixer dosing tank
7. Flash mixer
8. Inlet to Clariflocculator
9. Middle of Clariflocculator
10. Outlet of Clariflocculator
11. Inlet of aeration tank
12. Aeration tank middle
13. Aeration tank outlet
14. Middle of secondary clarifier
15. Outlet of clarifier
16. Outlet of unit II

mg/L to 200 mg/L in equalization tank, 400 mg/L in the flash mixer and 500 mg/L in the primary clarifier. Calcium hardness decreased thereafter in the aeration tank to 280 mg/L and in secondary clarifier to 250 mg/L. It was 250 mg/L in the final outlet.

Figure 3 gives the change in Calcium, Calcium hardness, Magnesium, Chloride, Salinity, Phosphate, Sulfate and Ammonia with the unit operations in the CETP. Calcium remained in the range of 16 - 29 mg/L. It increased in the equalization tank to about 90 mg/L and to 160 mg/L in the flash mixer. It continued to increase in the primary clarifier to about 200 mg/L. Calcium reduced in the aeration tank to 110 mg/L and remained at 100 mg/L in the secondary clarifier and the outlet.

Magnesium concentration increased from 33 mg/L to 80 mg/L in the equalization tank and remained in a range of 50 - 100 mg/L in subsequent units. Magnesium was 50 mg/L in the outlet.

Chlorides were high in the drain (2127 mg/L) and in sump well (1700 mg/L). Chlorides increased to 2100 mg/L in the equalization tank and increased further to 2300 mg/L in flash mixer and then 2500 mg/L in the primary clarifier. Chlorides remained at about 2000 mg/L in the aeration tank and secondary clarifier. Chlorides in the outlet were 3000 mg/L.

Salinity in inlet was 3000-3800 mg/L which remained at 3800mg/L in the equalization tank and increased to 4200 mg/L in the flash mixer. It remained in the range of 3300 mg/L to 4200 mg/L in the remaining units. Salinity in the outlet was 6000 mg/L.

Phosphate in the inlet is 0.007 - 0.029 mg/L and increased to 0.052 in equalization tank. A reduction in phosphate concentration was observed in the flash mixer followed by an increase in the clarifier to about

Table 2. Design evaluation sheet for all unit operations.

Evaluation Parameter	Point range	Point Score	Total Score	Remark
Configuration	**Equalization**			
0 to 5		0	16.46	Type-1
HRT	-10 to 15	15		
Mixing	-10 to 10	1.46		
	Chemical House			
Lime Tank-I				
Capacity	-10 to 10	9.21	10.47	Type-1
Mixing	-5 to 5	1.27		
Lime Tank-II				
Capacity	-10 to 10	9.21	10.47	Type-1
Mixing	-5 to 5	1.27		
$FeSO_4$ Tank				
Capacity	-10 to 10	4.02	5.68	Type-2
Mixing	-5 to 5	1.66		
Polyelectrolyte Tank				
Capacity	-10 to 10	9.84	14.84	Type-1
Mixing	-5 to 5	5		
Flash mixer				
Configuration	0-10	0	15.00	Type-1
HRT	-10 to 10	10		
Mixing	-5 to 5	5		
Primary clariflocculator				
Clarification Chamber				
Configuration	-10-10	7	12.27	Type-2
HRT	-10 to 15	15		
SOR	-15 to 10	-10		
Depth at weir	-10 to 10	0.27		
Flocculation chamber				
HRT	-6 to 10	10	10.00	Type-1
Power	-10 to 10	0		
Aeration tank stage I				
HRT	-6 to 10	10	30	Type-1
Organic Loading	-6 to 10	10		
Oxygen Availability	-10 to 10	10		
Secondary clarifier				
Configuration	-10 to 10	7	35.67	Type-1
HRT	-10 to 15	15		
SOR	-15 to 10	10		
Depth at weir	-10 to 10	3.67		
Sludge Drying Beds				
Sludge Handling Capacity	-10 to 25	22.27	22.27	Type-1
Sludge Drying Beds (Biological Sludge)				
Sludge Handling Capacity	-10 to 25	-10	-10	Type-3
TOTAL POINT SCORE			158.87	

0.05 mg/L. It increased further to 0.09 mg/L in the aeration tank, but reduced to 0.04 mg/L in secondary clarifier and outlet.

Ammonia was in the range of 0.05 - 0.7 mg/L which increased to 1.25 - 1.7 mg/L in the equalization tank. However, a decrease in ammonia concentration was observed in the flash mixer to about 0.2 mg/L which reduced to 0.06 mg/L in primary clarifier. Ammonia concentration in rest of the units could not be analyzed due to interference.

Sulphate in the common drain was about 750mg/L. It remained in a narrow range of 600-800 mg/L in the various ETP units.

Alkalinity was about 150 mg/L in the inlet and

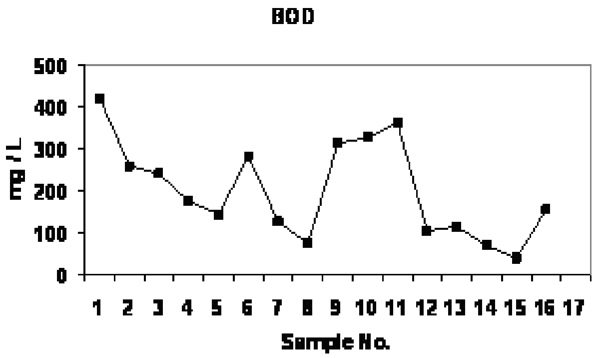

Fig. 2 Change in pH, COD, BOD, Total solids, Total dissolved solids, Total suspended solids, Alkalinity and Total hardness with the unit operations in the CETP.

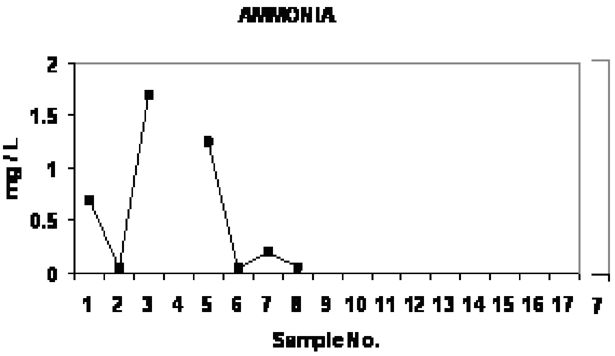

Fig. 3 Change in Calcium, Calcium hardness, Magnesium, Chloride, Salinity, Phosphate, Sulfate and Ammonia with the unit operations in the CETP.

remained between 100 - 180 mg / L in the ETP.

CONCLUSION

Performance evaluation of the CETP based on design, operation, administration and maintenance was carried out. Most of the units are designed well. Some improvements like better mixing in equalization tank, modifications in SOR in the clariflocculator can be achieved by changing operational parameters. The $FeSO_4$ tank has inadequate capacity and mixing which therefore needs improvement. Existing biological sludge drying beds are only 20% of the area required and therefore need further construction.

The COD and BOD in the outlet exceeded the standards for effluents from textile industries. The aeration tank needs to improve in terms of performance. This can be achieved by improving the biomass in the aeration tank and increasing the HRT. Other standards were met by the treated effluents.

REFERENCES

Alaton, I.A., Insel, G., Eremektar, G., Babuna, F.G. and Orhon, D. 2006. Effect of textile auxiliaries on the biodegradation of dye-house effluents in activated sludge. *Chemosphere.* 62 : 1549-1557.

Alves de Lima, R.O., Bazo, A.P., Salvadori, D.M.F., Rech, C.M., Oliviera, D.P. and Umbuzeiro, G.A. 2007. Mutagenic and carcinogenic potential of a textile azo dye processing plant effluent that impacts a drinking water source. *Mutat. Res. Genetic Toxicology and Environmental Mutagenesis.* 626 : 53-60.

APPHA-AWWA-WPCF, *Standard Methods for Examination for Water and Wastewater*, 17th Edition, 1989. American Public Health Association, Washington D.C.

Baban, A., Yediler, A., Liener, D., Kemerdere, N. and Kettrup, A. 2003. Ozonation of high strength segregated effluents from a woolen textile dyeing and finishing plant. *Dyes Pigments.* 58 : 93-98.

Barredo-Damas, S., Iborra-Clar, M.I., Bes-Pia, A., Alcaina-Miranda, M.I., Mendoza-Roca, J.A. and Iborra-Clar, A., Study of pre-ozonation influence on the physical–chemical treatment of textile wastewater. Presented at the conference on *Desalination and the Environment , Santa Margherita , Italy,* 22-26 May 2005. European Desalination Society.

Bortone, G., Cech, J.S., Bianchi, R. and Tilche, A. 1995. Effects of an anaerobic zone in a textile wastewater treatment plant. *Water Sci. Technol.* 32 : 133-140.

Chandramowleeswaran, M. and Palanivelu, K. 2006. Treatability studies on textile effluent for total dissolved solids reduction using electrodialysis. *Desalination.* 201 : 164-174.

Georgiou, D., Hatiras, J. and Aivasidis, A. 2005. Microbial immobilization in a two stage fixed bed reactor pilot plant for on-site anaerobic decolorization of textile wastewater. *Enzy. Microbial Technol.* 37: 597-605.

Lin, S.H. and Chen, M.L. 1997. Purification of textile wastewater effluents by a combined Fenton process and ion exchange. *Desalination.* 109 : 121-130.

Lin, S.H. and Chen, M.L. 1998. Treatment of textile wastewater by chemical methods for reuse. *Water Research.* 31 : 868-876.

Lopez, A., Ricco, G., Ciannarella, R., Rozzi, A., DiPinto, A.C.D. and Passino, R. 1999. Textile wastewater reuse: Ozonation of membrane concentrated secondary effluent. *Water Sci. Technol.* 40: 99-105.

Marcucci, M., Nosenzo, G., Capannelli, G., Ciabatti, I., Corrieri, D. and Ciardelli, G. 2001. Treatment and reuse of textile effluents based on new ultrafiltration and other membrane technologies. *Desalination.* 138 : 75-82.

Mathur, N., Bhatnagar, P. and Bakre, P. 2005. Assessing mutagenicity of textile dyes from Pali (Rajasthan) using AMES bioassay. *Appl. Ecol. Environ. Res.* 4 : 111-118.

Mathur, N., Bhatnagar, P., Mohan, K., Bakre, P., Nagar, P. and Bijarnia, M. 2006. Mutagenicity evaluation of industrial sludge from common effluent treatment plant. *Chemosphere.* 67 : 1229-1235.

Ministry of Textiles. http://texmin.nic.in/welcome.asp

Moosvi, S. and Madamwar, D. 2007. An integrated process for the treatment of CETP wastewater using coagulation, anaerobic and aerobic process. *Bioresour. Technol.* 98 : 3384-3392.

Nandy, T., Manekar, P., Dhodapkar, R., Pophali, G. and Devotta, S. 2007.Water conservation through implementation of ultrafiltration and reverse osmosis system with recourse to recycling of effluents in textile industry: A case study. *Resour. Conserv. Recycl.* 51 : 64-77.

Navarro, A.V., Ramirez, M, Y., Salvador-S.B., M.S. and Gallardo, J.M. 2001. Determination of wastewater LC_{50} of the different process stages of the textile industry. *Ecotoxicol. Environ. Safety.* 48 : 56-61.

Newsletter Parivesh, November 2000. http://www.cpcb.nic.in/News%20Letters/Archives/Common%20 Effluent/contactCE.html

Pala, A. and Tokat, E. 2002. Color removal from cotton textile industry waste water in an activated sludge system with various additives. *Water Res.* 36 : 2920-2925.

Pandey, R. and Deb, S. 1998. CETP's and Pollution abatement in SSIs. National Institute of Public Finance and Policy.

Pophali, G.R., Kaul, S.N. and Mathur, S. 2003. Influence of hydraulic shock loads and TDS on the Performance of large-scale CETPs treating textile effluents in India. *Water Res.* 37 : 353-361.

Raj, D.S.S., Chary, N.S., Bindu, V.H., Reddy, M.R.P. and Anjaneyulu, Y. 2004. Aerobic oxidation of common effluent treatment plant wastewaters and sludge characterization studies. *Int. J. Environ. Stud.* 61 : 99-111.

Rozzi, A., Ficara, E., Cellamare, C.M. and Bortone, G. 1999. Characterization of textile wastewater and other industrial wastewaters by respirometric and titration biosensors. *Water Sci. Technol.* 40 : 161-168.

Sankar, U. 2001. Common Effluent Treatment Plants: An Institutional Arrangement for Pollution Control on Small Scale Tanneries in India. *Madras School of Economics.*

Sapari, N. 1996. Treatment and reuse of textile wastewater by overland flow. *Desalination.* 106: 179-182.

Servos, M.R., Maguire, R.J., Bennie, D.T., Lee, H.B., Cureton, M., Davidson, N., Sutcliffe, R. and Rawn, F.K. 2003. An Ecologial risk assessment of nonylphenol and its ethoxylates in the aquatic environment. *Human and Ecological Risk Assessment.* 9 : 569-587.

Shaw, C.B., Carliell, C.M., Wheatley, A.D., 2002. Anaerobic/ aerobic treatment of coloured textile effluents using sequencing batch reactors. *Water Res.* 36 : 1993-2001.

Stern, S.R., Szpyrkowicz, L. and Grandi, F.Z. 1996. Treatment of silk and lycra printing wastewaters with the objective of water reuse. *Water sci. Technol.* 33 : 95-104.

Treffry-Goatley, K., Buckley, C.A. and Groves, G.R. 1983. Reverse osmosis treatment and reuse of textile dyehouse effluents. *Desalination.* 47 : 313-320.

Umbuzeiro, G.A., Freeman, H.S., Warren, S.H., Oliveira, D.P.D., Terao, Y., Watanabe, T. and Claxton, L.D. 2005. The contribution of azo dyes to the mutagenic activity of the cristais river. *Chemosphere.* 60 : 55-64

Vedavyasan,C.V.2000. Combating water shortages with innovative uses of membranes. *Desalination.* 132 : 345-347.

WeberJr., W.J., LeBeof, E.J. 1999. Processes for advanced Treatment of water. *Water Sci. Technol.* 40 : 11-19

Zainal, Z., Lee, C.Y., Hussein, M.Z., Kassim, A. and Yusof, N.A. 2006. Electrochemical - assisted photodegradation of mixed dye and textile effluents using TiO_2 thin films. *J. Hazard. Mater.* 146 : 73-80.