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Efficiency of effluent treatment plant and assessment of water quality parameters in tannery wastes

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ABSTRACT

In India, tanning is a small-scale industry. Throughout the tanning process, massive amount of wastewater is generated and in most cases it pollutes the environment. The waste materials from the tannery industry are characterized by high oxygen demand, total dissolved solids and hazardous inorganic chemical waste, etc. The design of the Effluent Treatment plant under study, involves a combination of primary, secondary and tertiary treatment processes. The relative proportion of effluent generated in different stages of tanning was found to be high in de-liming and baiting (26%) while lower in pickling (4%), which produced semi-finished leather product. The study was performed regarding the analysis of water quality parameters. Primary treatment possesses maximum values while compared to the final stage such as tertiary treatment. The pH ranged from 10 to 6.6; temperature from 27.6 to 28.3°C; TSS from 1582 to 26.3 mg/L; TDS from 2558 to 2500 mg/L; chlorides from 1476 to 1407 mg/L; oil & grease from 65.8 to nil mg/L; COD from 1819 to 157 mg/L and BOD from 810 to 55 mg/L respectively. Therefore a critical study on the nature of industrial wastes, treatment processes and it is essential features was assessed to maintain a sustainable environment.

Key words: ETP, tannery waste, water quality, semi-finished leather

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INTRODUCTION

Heavy metals are considered to be a serious threat to the environment and human health all over the world because of their persistence and cumulative tendency in the environment and their associated toxicity to biological organisms [1, 2, 3, 4]. Moreover, the presence of contaminated sites in populated areas is a major concern for urban development because costs of soil remediation pose significant liabilities and financial burdens on landowners and other stakeholders.Tiruchirappalli is one of the active centers for tanning industries in Tamilnadu. Out of 13 functioning tanning industries of Tiruchirappalli, 10 have established their own individual effluent treatment plant and remaining 3 tanneries are connected to CETP for waste water treatment. Tanning industries are one of the chief manufacturing processes which are responsible for tremendous pollution of water resources [5-7]. Tanning is a process by which animal hides and skin is converted into a stable material which is resistant to microbial attack and has enhanced resistance to wet and dry heat. During leather processing the hides and skin undergoes a series of pre-tanning, tanning, and post tanning operations [8]. The collagen of the skin reacts with plant materials containing polyphenols (vegetable tanning) or chromium (chrome tanning). In addition about 130 different chemicals including surfactants, acid and metal organic dyes, natural or synthetic tanning agents, sulfonated oils, salts, etc are employed in leather making process [9]. Synthetic tanning agents are high molecular organic compounds which are used to make hides and skin into an imputrescible material called leather [10]. Most of the syntans are manufactured by the condensation of aromatic compounds like phenol, phenol sulphonic acid or naphthalene sulphonic acid with formaldehyde [11]. In these industries, animal hides are transformed into leather through many multifarious stages, consuming large quantities of water and chemicals such as ammonium sulfate, lime, sodium sulfide, sodium

chloride, bactericides, vegetable tannins and chrome salts [12]. These wastewaters are generally characterized by elevated levels of salinity and organic loading and specific pollutants such as sulfide and chromium [13,14]. The initial processing of raw hides release organic waste and sulfide contents in the environment. The tanning process uses very high concentration of inorganic salts of chloride, ammonia, chromium and sulfate, which may responsible to cause pollution [15]. The tannery effluent, if not treated, can cause severe damage to water bodies. Since all the physico-chemical treatment processes of tannery wastewater are associated with the operational problems and maintenance cost, new methods have been developed mostly the biological methods [16]. Tanneries in India, numbering over 3000 are capable of processing about 500,000 tonnes of hides and skins per day. This means that about 15 million cubic meters of waste water is generated [17]. Likewise, exposure of these heavy metals to soil as a result of industrial and anthropogenic activities is a serious threat to human health and ecosystem [18]. Therefore the present investigation has been focused about the environmental issues of tanneries and to eradicate the toxicity caused by the industrialization and evaluation of the effluent after succeeding treatments, with possible cost-effective remedies to solve these problems.

MATERIALS AND METHODS

Prime Tanning industry was the study area chosen for the work, situated in Sembattu in Trichy. The tannery has installed an Effluent Treatment Plant at the cost of 1.5 crores to treat the tannery waste water. This plant is designed to treat the effluent at the rate of 400 M^3/day. The effluent treatment plant has primary, secondary and tertiary treatment systems. The primary treatment system includes Pretreatment Chamber, Equalisation Tank, Flash Mixture Tank and Clariflocculator and the secondary treatment system consists of Aeration tank - I, Clarifier - I, Aeration Tank - II and Clarifier - II. The tertiary treatment is carried out in two units, namely Pressure Sand Filter and Activated Carbon Filter.

Waste Water Generation from Tannery

The waste water is generated from various tanning operations such as soaking, liming, deliming and tanning. The first one is the soaking process in which the raw skins and hides arc soaked in water in order to remove the common salt used in the skins for preservation purpose.

The second one is the liming process. In this process the skins are soaked in 35% lime solution for a period of 24 his and this facilitates the removal of flesh and hairs. After deliming with ammonium salts the material is pickled with sulphuric acid and common salt. The final process is tanning with tree extract in which the skin are treated with extract of chincona tree bark and myroblam nut extract. In this stage the material is called semifinished leather.

The applied tanning process to convert the raw material into semifinished leather is called East Indian Tanning Method, Most of the chemicals used in the process are organic in nature extracted from tree bark and nuts. The waste water generated from soaking and pickling process having high salt content. Hence it was discharged into solar evaporation pans. The waste water generated from the other units of processing is diverted in to ETP consisting of 3 units, i.e., primary, secondary and tertiary treatment. Total waste water generated at the maximum processing capacity (13000 kg skins) is 350 M^3/day. The average quantities of water used for I kg of raw skin at each stage of tanning are given in Table 1 and 2.

Design of Effluent Treatment Plant

Effluent Treatment Plant is designed to treat 400 M^3 waste water per day. The plant has been constrhcted in about 1 acres of land. The plant has different units such as pretreatment chamber, equalization tank, clariflocculator. aeration tanks, clarifiers, filters, sluk e thickener, sludge collection sump and beds for drying sludge.

The treatment plant design involves a combination of physical, chemical and biological processes (Fig. I). The raw waste water flows by gravity and passes through several screens before it is collected in pretreatment chamber. Pretreatment chamber is constructed in the shape of Imhoff cone for the removal of suspended solids. The screened effluent flows into equalisation tank for achieving uniform water characteristics. The constant flow of equalised effluent is transferred to the flash mixture tank where alum solution is added to coagulate the suspended particles. The raw effluent after flash mixture flows to the clariflocculator, where polyelectrolytes are added to flocculate the suspended particles. The apparent effluent flows to the biological system (secondary treatment).

A two stage aerobic biological process is employed in the aeration tank for the degradation of the organic pollutant load based on the activated sludge process. Activated sludge generally consists of microorganisms like bacteria, protozoa, rotifiers, etc. in the presence of dissolved oxygen. The process involves the degradation of organic matter by the action of various microorganisms.

The first stage aeration system is designed with a food to micro organisms ratio of 0.15 (F/M) and mixed liquid suspended solids (MLSS) concentration of 4000 mg/L and the required oxygen is transferred to the system through mechanical surface aerators. The desired F/M ratio and MLSS levels are maintained by the recirculation of the sludge settled in the first stage clarifier. A portion of sludge that settles in the first stage clarifier shall be continuously pumped back to the first stage aeration tank and excess sludge to the sludge thickener.

The second stage aeration system is designed with F/M ratio of 0.15 and MLSS concentration of 3000 mg/L. Two mechanical surface aerators shall provide the oxygen necessary for the process. The effluent from the second stage aeration flows by gravity to the second stage clarifier. A portion of sludge that settles down on the bottom of clarifier is continuously pumped back to the second stage aeration tank and the excess sludge is pumped to sludge thickener. Clarifier II overtlow is collected in filter feed sump.

The bio treated water is pumped to pressure sand filter followed by activated carbon filter. The clear water from the filters flows to final disposal sump. The filtrate water of sludge drying beds, over flow of sludge thickener and back wash water from filter are routed back to the equalisation tank.

Efficiency of Effluent Treatment Plant

To evaluate the performance of the effluent treatment plant at the Tanning Industry, monthly samples were collected for a period of three months (May 2014 to July 2014) from outlets of four units namely Raw effluent, Primary treatment chamber, Secondary treatment and Tertiary Treatment. The samples were analysed for the water quality parameters such as pH, temperature, total suspended solids, total dissolved solids, chlorides, oil & grease, chemical oxygen demand and biochemical oxygen demand. The waste water analyses were carried out following the methods described by [19].

RESULTS

To assess the efficiency of ETP of Prime Tanning Industry, monthly water samples were collected from the outlets of different units such as raw effluent, pretreatment chamber, clariflocculator, clarifier-I, clarifier-II and tertiary treatment unit for three months (from May 2014 to July 2014). These samples are subjected to analysis for assessing the efficiency of primary, secondary and tertiary treatment. The mean quantity of water used to produce 1 kg of semifinished leathers and the quantity of waste water generated per day at different stages are given in Table 1 and 2 and fig 1. To assess the treatment Efficiency of ETP, water quality parameters were analysed and its results were presented in Table 3. The mean values of water quality parameters from May 2014 to July 2014 were presented in table 4. The mean values of water quality parameters of untreated, treated effluent of primary, secondary and tertiary treatments are presented in Table 5 and Fig. 2, 3 and 4. Table 1 shows the mean quantity of water used for the production of 1 kg of semifinished leather at different stages are soaking 5.0 L, liming 4.0 L, fleshing 2.0 L, deliming and bating 6.0 L, pickling 1.0 L, pretanning and tanning 4.0 L and washing 3 L. The percentage of water utilized with regard to above stages were 22%, 14%, 8%, 26%, 4%, 16% and 10% respectively.

Table 1: Mean quantity of water used at different stages of Tanning for the production of 1 kg of Semi finished leather

S. No.	Two Stage Aerobic System	Utilised water 1 kg	Percentage of utilized water (%)
1	Soaking	4.5	22%
2	Liming	3.5	14%
3	Fleshing	2.5	8%
4	Deliming and Bating	6.5	26%
5	Pickling	2.0	4%
6	Pretanning& Tanning	4.5	16%
7	Washing	3.5	10%

Table 1 and Fig. 1 provide data of mean quantity of waste water generated per day at different stages. The soaking process generates 50 M^3/day, liming 40 M^3/day, fleshing 20 M^3/day, deliming and baiting 60 M^3/day, pickling 10 M^3/day, pre-tanning and tanning 40 M^3/day and washing 30 M^3/day.

In May the pH ranged from 10.5 to 6.4; Temperature from 28 to 28.1°C; TSS from 1593 to 29 mg/L; TDS from 2560 to 2500 mg/L; Chlorides from 1480 to 1405 mg/L; Oil & grease from 65.8 to nil mg/L; COD from 1821 to 158mg/L and BOD from 811 to 56 mg/L respectively.

During June the pH ranged from 10 to 6.6; Temperature 27.9- 28ºC; TSS from 1580 to 26 mg/L; TDS from 2558 to 2501 mg/L; Chlorides from 1475 to 1409 mg/L; Oil & grease from 65 to nil mg/L; COD from 1818 to 157 mg/L and BOD from 810 to 54 mg/L respectively. In July the pH ranged from 10.2 to 6.9; Temperature ranged from 27 to 29

°C; TSS from 1570 to 24 mg/L; TDS from 2556 to 2500 mg/L; Chlorides from 1475 to 1408 mg/L; Oil & grease from 64.5 to nil mg/L; COD from 1818 to 157 mg/L and BOD from 809 to 55 mg/L respectively.

Table 2: Water quality parameters of Tannery effluent at different units of ETP during May 2014 to July 2014

Month	Parameters	Secondary Treatment			Tertiary Treatment		
		Raw Effluent	Pre Treatment Chamber	Clari Flocculator	Clarifier-I	Clarifier -II	
May	pH	10.5	9.4	8.8	7.1	6.9	6.4
	Water Temp. (°C)	28.0	28.0	28.5	28.8	28.5	28.1
	TSS	1593	635	327	203	131	29
	TDS	2560	2540	2530	2518	2507	2500
	Chloride	1480	1469	1454	1433	1428	1405
	Oil &grease	68	56	44	26	14	Nil
	COD	1821	1546	1261	1079	173	158
	BOD	811	635	428	264	149	56
June	pH	10.0	9.5	8.7	7.3	6.5	6.6
	Water Temp. (°C)	27.9	28.5	28.7	28	28.6	28
	TSS	1580	622	324	201	129	26
	TDS	2558	2532	2528	2516	2505	2501
	Chloride	1475	1468	1456	1436	1426	1409
	Oil & grease	65	54	42	25	1	Nil
	COD	1818	1545	1260	1077	172	157
	BOD	810	633	430	265	148	54
July	pH	10.2	9.9	8.7	7.9	6.8	6.9
	Water Temp. (°C)	27	28.9	29.5	29.0	29.7	29.0
	TSS	1570	628	321	209	127	24
	TDS	2556	2537	252 8	2514	2505	2500
	Chloride	1475	1467	1454	1438	1421	1408
	Oil &grease	64.5	51	41	23	11	Nil
	COD	1818	1548	1264	1076	171	157
	BOD	809	636	432	266	148	55

All the values are in mg/L except pH.

Fig: 1 Relative Proportion of effluent generation in different stages of tanning

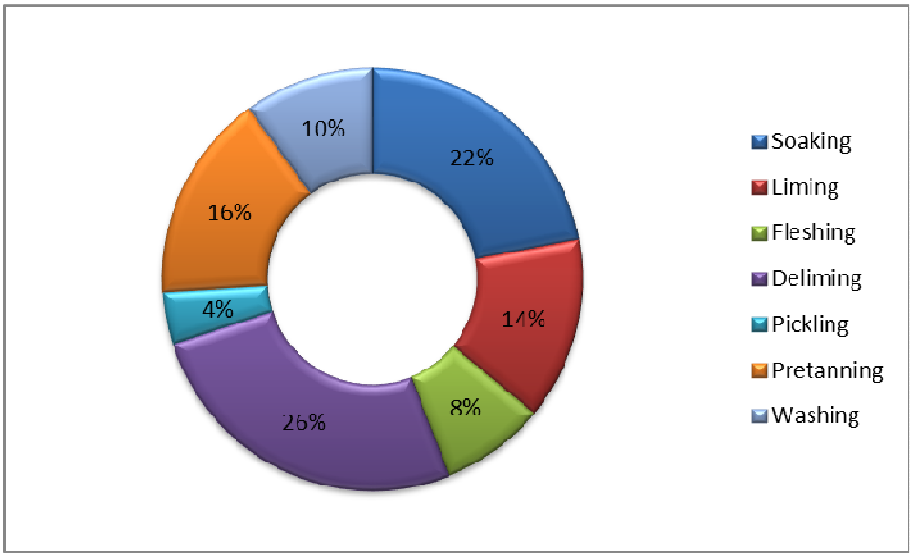
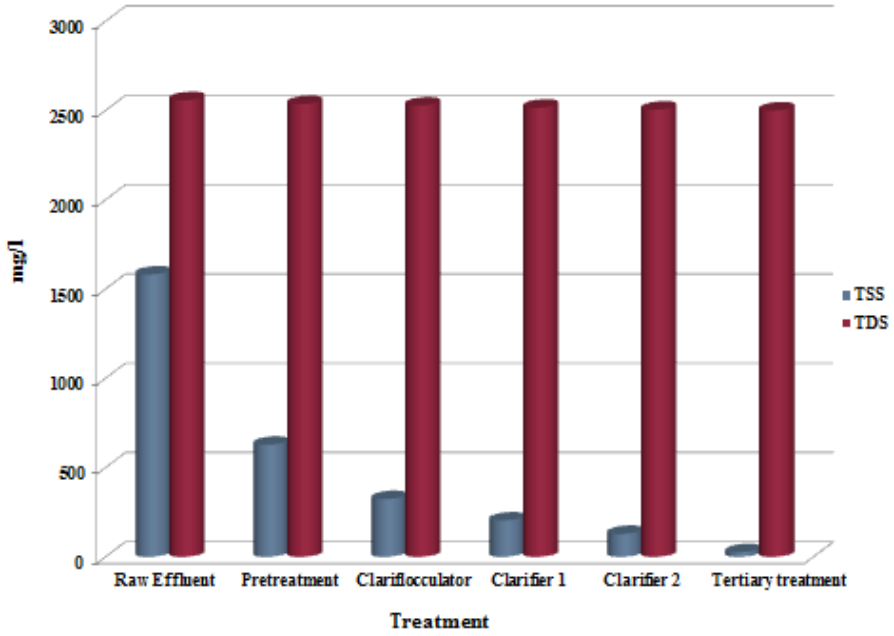
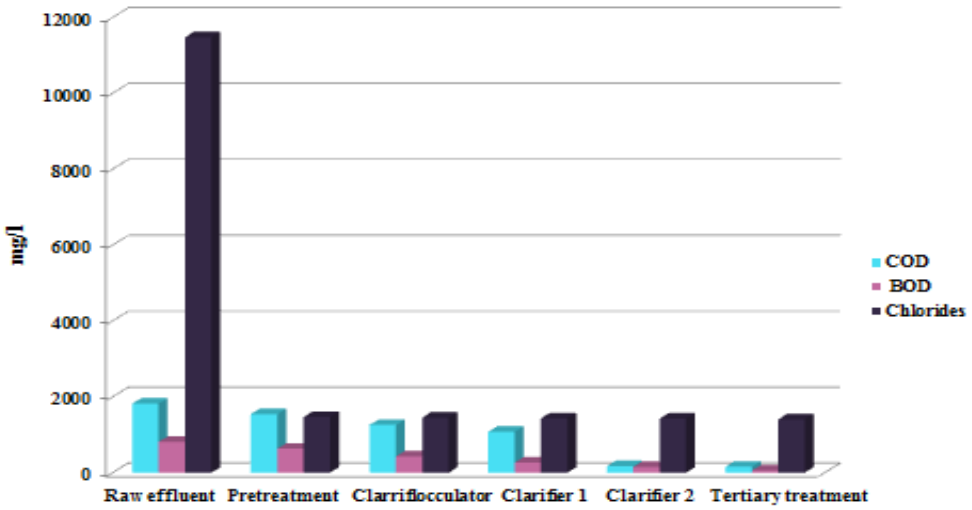


Fig. 2 Reduction in the levels of TSS and TDS in different stages of Effluent treatment plant



TDS- Total dissolved solids; TSS- Total soluble sugar

Fig.3 Reduction in the levels of BOD, COD and Chlorides in different stages of Effluent treatment plant



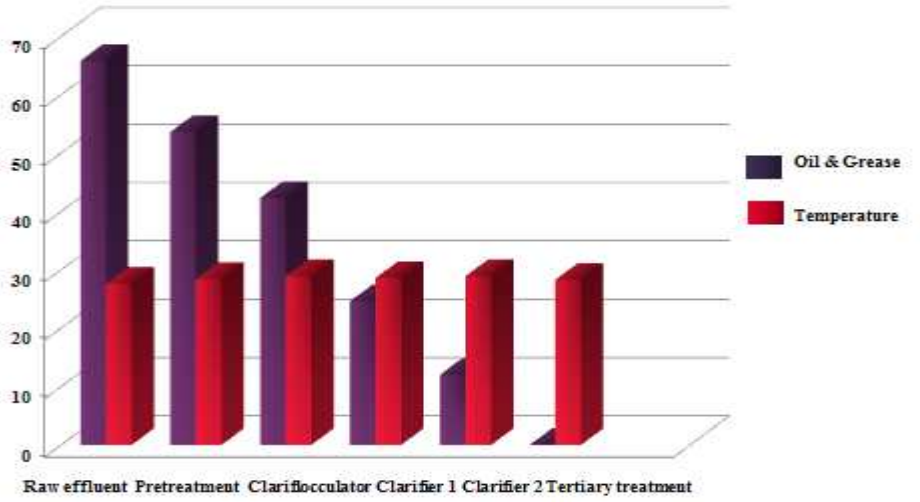
COD- Chemical oxygen demand; BOD- Biochemical oxygen demand

Table 3: Mean value of water quality parameters at different units of ETP from May 2014 to July 2014 (Mean ± SD)

Parameters	Primary Treatment			Secondary Treatment		Tertiary Treatment
	Raw Effluent	Pre Treatment Chamber	Clari-flocculator	Clarifier I	Clarifier II	
pH (Range)	1 10.2 ±0.2	9.6 ± 0.2	8.7 ± 0.0	7.4±0.4	6.7±0.2	6.6 ±0.2
Water temperature (t)	27.6±0.5	28.4 ±0.4	28.9±0.5	28.6±0.5	28.9±0.6	28.3± 0.5
TSS	11582±9.2	628.3 ± 6.5	324 ± 3	204 ± 4.1	129±2	26.3±2.5
TDS	22558±2	2536 ± 4	2528 ± 1	2516±2	2505 ± 1	2500±0.5
Chlorides	11476± 2.8	1468 ± 1	1455 ± 1	1435 ± 2.5	1425±3.6	1407± 2
Oil & grease	65.8 ± 1.8	53.6 ± 2.5	42.3± 1.5	24.6	12 ± 1.7	Nil
COD	1819±1.7	1546±1.5	1261±2	1077±1.5	172±1	157±0.5
BOD	810±1	634±1.5	430±2	265±1	148±0.5	55±1

All the values are in mg/L except pH.

Fig. 4. Reduction in the levels of Temperature and oil & grease in different stages of Effluent treatment plant



DISCUSSION

Tannery and metal industries causes depletion of surface and ground water quality [20]. Several processes of tanneries like bathing, pickling, tanning, dyeing and fat liquoring leads to severe water pollution. Tanning may be defined as the treatment of skin for preservation. Chrome tanning uses chromium sulphate as tanning agent. Tanning process starts with pickling which is the treatment of skin with acids and salts to bring it to desired level of pH. To prepare limed skin for tanning, the skins are delimed using Ammonium Sulphate and then skins are washed. Baiting is done for further purification of hide. Subsequently degreasing is done with the help of detergents. The release of effluent into streams from all the tanneries under investigation was within the extreme permissible limits of pH 6.0-9.5, which affects the availability of plant nutrients [21]. Water with a low pH is corrosive to water-carrying systems and can lead to metal dissolving in the water. The high pH in water can cause scaling in the sewers. Also large fluctuation in the pH value is detrimental to some aquatic species. The large quantities of proteins and their degrading products forming a major part of the wastewater can affect Biochemical Oxygen Demand (BOD). The high value of BOD in extreme cases can kill natural life in the affected area. Tanneries discharge water having 10-190 times the recommended value of BOD by NEQS. In present investigation the TS content was found to decrease from the month of May (1593 mg/L), June (1580 mg/L) and July (1570 mg/L); whereas comparing with the existing report [22] predicted that the TS were found to be higher in T5 (raw effluent treated with alum and ferric chloride - 3833.33 mg/L) followed by T1 (raw effluent treated with alum- 4333.33 mg/L) and highest in T0 (raw effluent - 12333.33 mg/L). TSS, BOD and COD was moderate in tertiary treatment plant, indicate the presence of some chemicals in the treatment plant. Dissolved oxygen is one of the most essential factor for survival of an aquatic organism in water [23]. It is a vital factor in natural water which indicates the metabolic process of biotic community and aquatic health. Govindasamy *et al*., 2006 reported that BOD content was maximum in Equalisation treatment (1380 mg/ml), decreased in raw effluent-1100 mg/L, chemical-650 mg/L, secondary-31 mg/L, and tertiary treatment-27 mg/L [24], whereas the obtained results was found to be 810 mg/L in raw effluent, 634 mg/L in primary treatment, 265 mg/L in secondary treatment, 55 mg/L in tertiary treatment. Previous results predicted that COD was found to be in extreme level in raw effluent(1819mg/L), whereas minimized after several treatment, the tertiary treatment value was found to be 250 mg/L, whereas the present investigation reveals the COD content of 157 mg/l. The maximum absorption of TSS, BOD, COD, chloride and metals in waste water were observed in the summer season, as soil, porosity, inorganic matter and metals were generally found higher. From prior analysis, the DO content has drastically reduced from 4.4 mg/L to 0.7mg/L, therefore it indicates that microorganisms requires oxygen for degradation of organic waste [25]. Sahu *et al*., 2008 reported that Chloride 925 mg/ L, 675 mg/ L, while in prevailing work chloride content remained higher in raw effluent during the month of May- 1480 mg/l and lower in tertiary treatment 1405 mg/L, followed by June- 1475-1409 mg/L and July- 1475-1408 mg/L [26]. Chlorides significantly increases the soil salinity within a short period of time. In the tannery industry complications aggravating due to chromium and sulfide have been threatened and resolved, i.e., sulfides are detached by precipitation or transformed by chemical oxidation and chromium is precipitated or recovered and recycled due to tanning process [27, 28]. The improvement of the CETP mainly executes the reverse osmosis (RO) plant, which would optimize the level of TDS and applicable for the reuse of treated water for gardening.

Therefore the present work signified the fact that the pollutants are drastically reduced during the susequent treatment of effluent.

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