

## Upgradation of Wool Scouring Plant for Efficient Wastewater Treatment

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### ABSTRACT

The paper emphasized the manufacturing processes of the wool scouring plant, study of the wastewater characteristics generated from the plant in the laboratory, performance evaluation of the existing effluent treatment plant (ETP) with the present pollution load. On their basis, an approach and flow sheet for the treatment of wastewater obtained from wool scouring is suggested to improve the performance and treatment of wastewater.

**Keywords:** wastewater, effluent treatment plant, performance evaluation, upgradation.

### INTRODUCTION

The biological wastewater treatment systems, like the activated sludge process or trickling filters, have been widely used for treating wastewater from textile manufacturing industries to satisfy stringent effluent limitations. However, unlike other textile wastewater, the wool scouring wastewater contains a large amount of suspended solids (SS), organic matter, and grease, which regularly cause malfunction of the biological treatment system (Srebrenkoska et al., 2014). Investigation of the biological treatment of wastewater from wool scouring was conducted in an activated sludge system owned by the plant. They found that the biologically treated effluent failed to meet the imposed effluent limitations because the wastewater treatment system was overloaded. They implemented an in-plant separation technique of the concentrated component streams that comprise 6% of the whole rate from the entire discharge as a pre-treatment choice to alleviate the overloading situation. It was discovered that the proposed system could reduce 65% of grease, 38% of Chemical Oxygen Demand (COD), 24% of 5-day Biological Oxygen Demand (BOD), and 38% of SS from the overall discharge from the

wool scouring process, improving the standard of the treated effluent (Chao & Wang, 1981). They investigated the ways of reducing the grease substance of the wastewater obtained from wool scouring. The pre-treated wool scouring wastewater might be fed to a particular high rate anaerobic digester. Different variants of coagulants, flocculants, and utilizing sulfuric acid for pH adjustment of the wastewater were used in an attempt to remove the amount of grease and COD.

The experiment was conducted within the range starting from 20 to 45 °C. It was discovered that sulfuric acid of pH two to three and a temperature of 20 °C remove up to 98% of the grease and 79% of COD (Ang & Himawan, 1994). The treatment study of wool scouring wastewater by Immobilized Chitosan Bio-Membrane discovered that a composite bio-membrane containing immobilized *Aspergillus sojae* had excellent degradation ability when treating the wool scouring wastewater. Following treatment, the COD and SS of the wastewater were reduced to 198 mg/l from 12000 mg/l and 125 mg/l from 1935 mg/l (Laijiu & HeZeshou, 2013). They investigated the effect and efficiency of two inorganic coagulants, PAC (poly-aluminum chloride) and PFS (poly-ferric sulfate), before adding PAM (polyacrylamide)

for improved wool scouring effluent treatment. It investigates, calculates, and compares such parameters as linear alkylbenzene sulfonate (LAS) concentration, COD, colloid size, and aggregate size. The results showed that PAC could more completely remove emulsified colloid and free LAS. When the dosage increased beyond a particular point, PFS showed some dis-aggregating effect on aggregates (Dong et al., 2005).

It was discovered that centrifugation could easily remove the de-emulsified wool wax, proof against biodegradation. In 12-day batch experiments, gentle centrifugation at 200 g removed 97% of wool wax and 87% of COD, compared to only 6% and 8%, respectively, for sterile controls. Under optimum conditions, steady-state chemo-stat experiments yielded essentially complete removal of wool wax and 90% removal of COD in but 40 hours, demonstrating that the mechanism of pollutant removal was by bioflocculation instead of aerobic degradation (Poole & Cord-Ruwisch, 2004). The Australian and New Zealand Environmental and Conservation Council developed the Effluent Management Guidelines for Aqueous Wool Scouring and Carbonizing in Australia and New Zealand to ensure a nationally consistent approach to effluent management for the wool scouring industry throughout Australia. The removal of natural and other impurities from wool is accomplished by treating it with a hot chemical solution containing soaps, alkali, detergents, and washing soda. Scouring is finished within the first stage with soap and alkali (usually sodium carbonate) at 52 to 54 °C. The alkali saponifies the fatty acids within the wool fat. The soap dissolves the lanolin and creates suspensions of sunshine dirt particles. Following that, detergent and soap/soda are used. A second scouring follows this with soap and alkali, a detergent and washing soda treatment, and a final rinsing with water (National Water Quality Management Strategy, 1999). Discussion of the way and means to cut back the liquid waste load from textile mills by including physical, chemical, and biological methods applied. It considered close control wet processes, process modification, recovery of usable products for reuse, replacement of low BOD chemicals for higher BOD removal, and good housekeeping practices (Souther & Alspaugh, 1957). Nonylphenol ethylene oxide anionic is extracted from lanolin by methanol under reflux and estimated from the infrared absorption at 1510 cm<sup>-1</sup>. The strategy estimates between 90

and 100% of the detergent present and is independent of the sort of grease. The commercial wool greases recovered from non-ionic-detergent wool scouring liquors contained between 0.5% and 2.4% detergent (Anderson et al., 1996). The rules focused on preserving the environmental values of surface and ground waters, including their ecology, by minimizing effluent discharges containing organic matter, nutrients, and salts. Moreover, minimizing the effect of effluent addition to land may lead to soil structure degradation, salinization, water-logging, chemical contamination, or erosion; and avoiding off-site nuisance or irradiation. Safeguarding surface waters, groundwaters, soils, vegetation, and public amenity is necessary (BIS 10495, 2009).

A critical literature review of the typical and fundamental properties of textile effluents was carried out. The chemical constituents, including the chemicals, were used to prepare simulated textile effluents containing dyes also identified. It helps to collect various information referring to artificial textile wastewater constituents and provides help to the researchers who are required to arrange synthetic wastewater (Yaseen & Scholz, 2019). They discussed a process to support a mixture of the coagulation-flocculation processes which followed by a membrane separation technology to enhance the removal efficiency. The optimum operating conditions for the coagulation-flocculation process were pH 4 and 500 mg/l in ferric chloride as coagulant (Labanda & Llorens, 2008). It was observed that the scouring process generates high pollutant wastes in two forms, an effluent liquid phase, and a solid phase. Both phases contain an outsized amount of grease (wool wax) which can be recovered and purified to obtain lanolin, a highly valued product by introducing a modified recovery loop process (Madara & Namango, 2014). An integrated effluent treatment process capable of treating the worst polluted effluent from wool scour “heavy flow-down”, to the purpose where it can either be economically discharged to local trade waste sewer or directly discharged to the river or ocean outfall with minimal environmental impact, was developed. The prevailing proprietary chemical flocculation process, Sirolan CF™, was improved by the addition of a bio-flocculation stage and turbidity monitoring and control, and also the product from this process was fed to an aerobic biological treatment system based upon the standard activated sludge process (Savage, 2002). The disposal of

wool scouring sludge is becoming more problematic, because of the requirement to satisfy environmental legislation concerning what is considered hazardous waste, as well as the increasing cost of landfills and therefore the scarcity of landfill sites. Composting the sludge to provide a secure, saleable product may be a viable alternative (Pearson et al., 2004). The results of the study indicated that anaerobic biological and chemical treatment of wool scour effluent may be a promising alternative treatment system compared to other chemical or natural (lagooning) treatment systems (Merz & Cord-Ruwisch, 1997). Laboratory experiments using samples of 11 Australian wool's representing five different classes (merino fleece, lambs, merino pieces, crossbred pieces, and pieces and bellies) showed that dirt can be selectively removed during a warm (35 °C) suint bowl containing non-ionic surfactant and alkaline builder (Bateup, 1988).

Treatment of the wool scouring waste is a critical because of its high BOD, COD, SS, and grease concentrations. In Mumbai, Maharashtra, a wool scouring plant was visited to study the manufacturing process, wastewater quantification, and characterization. Its entire manufacturing process, wastewater generation, and effluent treatment plant (ETP) were studied in detail. An approach for the treatment of the wastewater generated from the plant was suggested. The entire manufacturing process, wastewater characteristics, philosophy of treatment, performance evaluation, and modification told for up-gradation of the plant was discussed in the subsequent paragraphs.

## MANUFACTURING PROCESS

Raw wool (Keratin) consists of suint (the water-soluble secretion of the sudoriferous gland) and wool grease (the secretion of the sebaceous gland) along with excretal matter from sheep. It also contains dirt, straw, and vegetable matter. Removal of natural impurities by an aqueous washing process is termed as scouring. Some pesticides or drugs may also be present in raw wool. Wool is insoluble in water, but fiber expands on wetting and contracts after drying; being a natural protein, it can be damaged by caustic or alkali chemicals. In soap/soda scouring, the scouring temperature is kept less than 55 °C because of the possibility of alkaline damage to the wool at higher temperatures.

With non-ionic detergents, higher temperatures of 60 to 65 °C are usually used. Although the efficiency of grease removal increases with temperature the bowl, temperatures should be kept below 70 °C to reduce wool damage and limit energy wastage.

Degumming of raw silk is the primary process, while the use of detergents, alkalis, and hot water result in the release of gum, silt, and sericine (hydrolysis of polypeptide chains). Degummed silk waste is then thoroughly rinsed and dried. Each roller machine has a liquid holding capacity of 1100 liters. Fiber batches are operated per day, with each machine giving rise to 22 m<sup>3</sup>/day of wastewater discharge at the end of the degummed operation. At the time of visit to the plant, four roller machines were operational, generating around 90 m<sup>3</sup>/day of wastewater. If 8 to 10 roller machines operated, the total quantity of wastewater generated would be 180 to 220 m<sup>3</sup>/day. The manufacturing process is presented in the form of a flowchart, as presented in Figure 1. The manufacturing process indicated that the factory pollution load is equivalent to the number of rollers in operation. If four rollers remain in operation, the wastewater quantity amounts to 90 m<sup>3</sup>/day. If additional four rollers were running, the amount would increase to 180 m<sup>3</sup>/day. At the same time, the further additional two rollers would raise the wastewater generation to 210 m<sup>3</sup>/day.

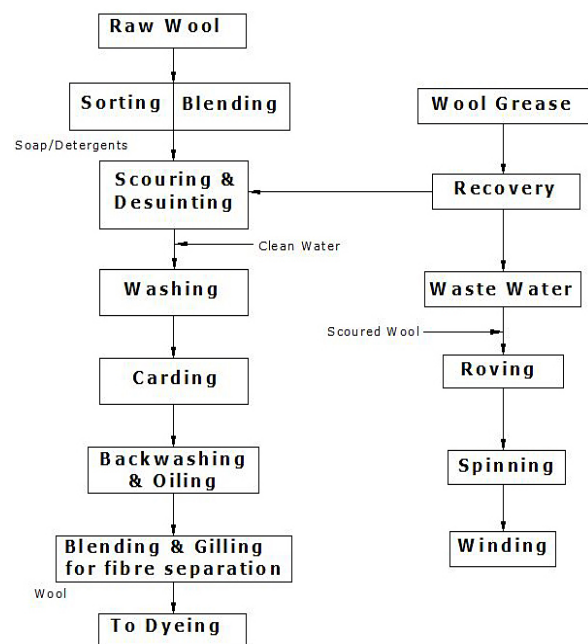


Figure 1. Process flow chart for wool scouring plant

**Table 1.** Wastewater characteristics before upgradation

Sr. No.	Parameter	Range / Values
1	pH	6.5–8.0
2	BOD (mg/l)	6000–7500
3	COD (mg/l)	8000–10000
4	Total suspended solids (mg/l)	1000–1600
5	Total dissolved solids (mg/l)	5000–7000
6	Total solids (mg/l)	6000–8600
7	Oil & Grease (mg/l)	20–30
8	Temperature °C	65–75
9	Colour	Light Brown

**Table 2.** Pollution load

Sr. No.	Pollution Load	Existing (At visit's time) Kg/day	Future (After all rollers would run) Kg/day
1	BOD load	1350	1620
2	Total suspended solids load	290	345
3	Oil and grease load	5.5	6.5

## WASTEWATER CHARACTERISTICS AND POLLUTION LOAD

The wastewater of a wool scouring plant at Mumbai, Maharashtra, India was collected and tested in the institute's Environmental Engineering laboratory and confirmed with standards (BIS 10495, 1983). Laboratory test results are presented in Table 1.

Pollution load is calculated by flow multiplied by pollutant concentration in mg/l. At Mumbai, the total flow at the time of visit was 180 m<sup>3</sup>/day. Hence, pollution load is computed and presented in Table 2.

## PHILOSOPHY OF TREATMENT

Any treatment scheme for wastewater management depends on the type of pollutant and effects they would have on the environment. In the wool scouring wastewater, it can be classified as biodegradable waste with excessive oil and grease. The BOD/COD ratio was more than 0.3, which indicated the biodegradability of this wastewater. It means that biological processes, preferably aerobic, could treat wastewater. Anaerobic systems would be challenging to maintain because of oil and grease and variability in wastewater characterization. Unnecessary

suspended matter load to be removed from wastewater to reduce the load on the suspended matter's secondary treatment is inorganic. In this case, if the suspended matter is organic, it would probably be due to emulsified greasy matter. Any removal would undoubtedly reduce the organic load. However, it may create another disposal problem of organic sludge. Aerobic biological treatment means the supply of oxygen in the form of air to increase the rate of organic matter consumption which is food for micro-organisms. Mixed Liquor Suspended Solids (MLSS) concentration of micro-organisms in mg/l in the aeration tank is evaluated. It usually has to be maintained between 1500–4000 mg/l depending on the design. The design of any biological system depends on several factors like BOD in kg/m<sup>3</sup>, MLSS concentration, food to microorganism ratio, cell residence time, hydraulic loading, etc.

## UNITS OF EFFLUENT TREATMENT PLANT AT THE TIME OF VISIT

The wastewater originating from the roller machines, degumming process was conducted in an ETP consisting of primary treatment, followed by two stage biological treatment process. It was comprised of the following treatment units:

1. Medium bar screen.
2. Oil and grease trap.
3. Holding tanks (four nos.)
4. Equalization cum neutralization tanks (two nos. of 40 m<sup>3</sup>).
5. Flash mixing followed by dissolved air flotation.
6. Primary settling tank.
7. First stage biological treatment in aerated lagoon (540 m<sup>3</sup> capacity).
8. Second stage biological treatment in extended aeration activated sludge unit.
9. Secondary settling with sludge re-circulation.
10. Sludge drying beds.
11. Chemical dosing systems.

## PERFORMANCE EVALUATION IN TERMS OF EFFICIENCY OF EXISTING ETP

The existing ETP designed based on the parameters is depicted in Table 1. The increased flow of wastewater and subsequent COD/BOD load has reduced the efficiency of the ETP. During the studies conducted for Mumbai site, it was

observed that the existing ETP was not capable of treating the increased wastewater flow. The entire ETP was hydraulically overloaded, since it was treating wastewater in the amount of about 180 m<sup>3</sup>/day. The existing Primary Settling Tank (PST) had less detention time. Due to less detention time in PST, the sludge did not settle well, and it carried over to the aerated lagoon. Sludge production after Krofta DAF was also very high. Head losses in the settling tanks had disturbed the basic function of settling. Settling tanks had inadequate settling time. Hence, mixed liquor solids were seen escaping with the effluent. Therefore, the design and commissioning of new settling tanks were found inevitable. However, Krofta dissolved air flotation unit was functioning better with 60–70% oil and COD removal. The observed sludge formation was heavy. The chemical sludge produced during the Krofta operation was disposed of on drying beds. The effluent from the Krofta flotation unit was allowed to settle in a settling tank. Due to increased flow, it provided less detention time, and therefore the chemical sludge particles escaped with the effluent from Primary Settling Tank (PST) to the aerated lagoon. The escape of chemical sludge particles in the aerated lagoon disturbed the microbiology of the aerobic reactor and subsequently caused the death of microorganisms. It might be the reason for the depletion of microbiological mass in the aeration tank. During the site visit to Mumbai, MLSS concentration in the aerated lagoon was found almost nil.

## UPGRADATION OF EFFLUENT TREATMENT PLANT

When all installed eight roller machines started functioning, the flow was estimated to be 225–240 m<sup>3</sup>/day. The efficiency of the Krofta Dissolved Air Flotation (DAF) unit was 60–70% concerning the removal of oil, SS, and COD. One of the major problems faced during ETP operation was sludge handling. The Krofta flotation unit generated a substantial quantity of sludge. The existing sludge drying beds were inadequate to meet the required drying period. Hence, a mechanical vacuum filter for sludge thickening and drying was proposed.

## MODIFICATIONS SUGGESTED FOR UPGRADATION

The following are modified dimensions suggested over existing dimensions to various units of ETP to handle detention time, BOD, MLSS concentration, food to microorganism ratio, cell residence, hydraulic load, sludge production after Krofta DAF. Modified dimensions for upgradation of ETP are presented in Table 3. Flow sheet for the treatment of wool scouring waste presented in Figure 2.

The main function of the equalization tank is acting as a buffer and gathering the raw incoming sewage that comes at widely fluctuating rates and pass it on to the remainder of the

**Table 3.** Modified dimensions for upgradation of ETP

Unit of ETP	Existing dimensions at the time of visit	Modified dimensions of upgradation	Remarks
Primary settling tank	1.5 m width x 2.0 m side depth with 0.25 m Free Board (FB)	1.5 m dia. x 2.8 m Side Water Depth (SWD) + 0.5 m FB with a centrally driven sludge scraping mechanism	After PST, wastewater was proposed to be subjected to a two-stage extended aeration process.
Aerated lagoon	18.5 x 11.5 x 2.4 m SWD + 0.3 m FB	18.5 x 11.5 x 3.0 m SWD + 0.5 m FB	Provide two no. 15 HP surface aerators or three nos. of 10 HP surface aerators.
Aeration tank	4.0 m dia x 1.5 m SWD + 0.3 m FB	4.0 m dia x 2.0 m SWD + 0.5 m FB	Peripheral driven sludge scraping mechanism needed for sludge re-circulation and sludge wasting.
Second stage aeration tank	6.8 m x 6.5 m x 2.5 m SWD + 0.3 m FB	8.8 m x 6.5 m x 3.0 m SWD + 0.5 m FB	10 HP required for surface floating aerator.
Secondary settling tank	3.0 m dia x 1.5 m SWD + 0.3 m FB	4.0 m dia x 2.0 m SWD + 0.5 m FB	Peripheral driven sludge scraping arrangements needed for sludge wasting arrangements.
Sludge drying beds	3.0 m x 2.0 m (03 Nos.)	3.0 m x 2.0 m (05 Nos.)	Mechanical vacuum filtration with existing sludge drying beds

effluent treatment plant at a gentle rate. The tank is allowed with a detention period of 8 hours to treat weak effluent and robust effluent separately to produce placement of air diffusers for full floor coverage. When strong and weak effluents permitted to react with  $H_2SO_4$  for treating alkali wastes enter a grease trap, the rate is reduced sufficiently so that the effluent is provided enough time to cool down and separate into 3 layers. The grease rises to the highest inside the interceptor and is trapped employing a system of baffles. Solids settle at the underside and therefore the separated clear water is permitted to suffer the solvent extraction plant for recovery. Flash Mixer is employed to evenly distribute coagulating  $FeSO_4$  and lime within the water, allowing micro-flocs to create because the precursor to flocculation, flash mixing increases the efficiency of flocculation and reduces chemical wastage. Clarifloculator is a combination of flocculation, and clarification in an exceedingly single tank. Within the clarifloculator, the water enters the flocculator, where the flocculating paddles enhance flocculation of the feed weak and powerful effluent. As heavy particles settle to the underside, the liquid flows radially upward within the clarifier zone. The settled heavy particles are allowed to sludge drying beds after treating through a chemical sludge chamber. Chemical sludge digestion could be a process during which aerobic treatment of organic solids is decomposed into stable substances with a detention time of 6 days. The sludge then flows

into a secondary settling tank, where the dissolved matter is converted by other bacteria into biogas, a combination of greenhouse gas and methane. The biological treatment of the wastewater takes place in the aeration tank. Before the wastewater reaches the current tank, it is mixed with activated sludge. This contains countless microorganisms, like bacteria, that are ready to break down the colloidal, organic contaminants dissolved within the wastewater. Secondary settling is the final step of the activated sludge-based biological wastewater treatment. Secondary settling tanks (SSTs) are therefore a necessary unit for generating a transparent effluent. Secondary treatment consisting of biological treatment by aerobic treatment processes for BOD reduction, either on the traditional pattern or the low-cost biological treatment methods. Sludge recycle was allotted from secondary settling tank for further treatment into aeration tanks.

### OPERATION AND MAINTAINANCE TIPS FOR PERFORMANCE

#### MLSS built up

The soil on which the wastewater is discharged is likely to suspend in an empty oil barrel. During the study, 20% slurry was prepared, mixed well, and allowed to settle overnight. The supernatant was decanted with wastewater. This supernatant

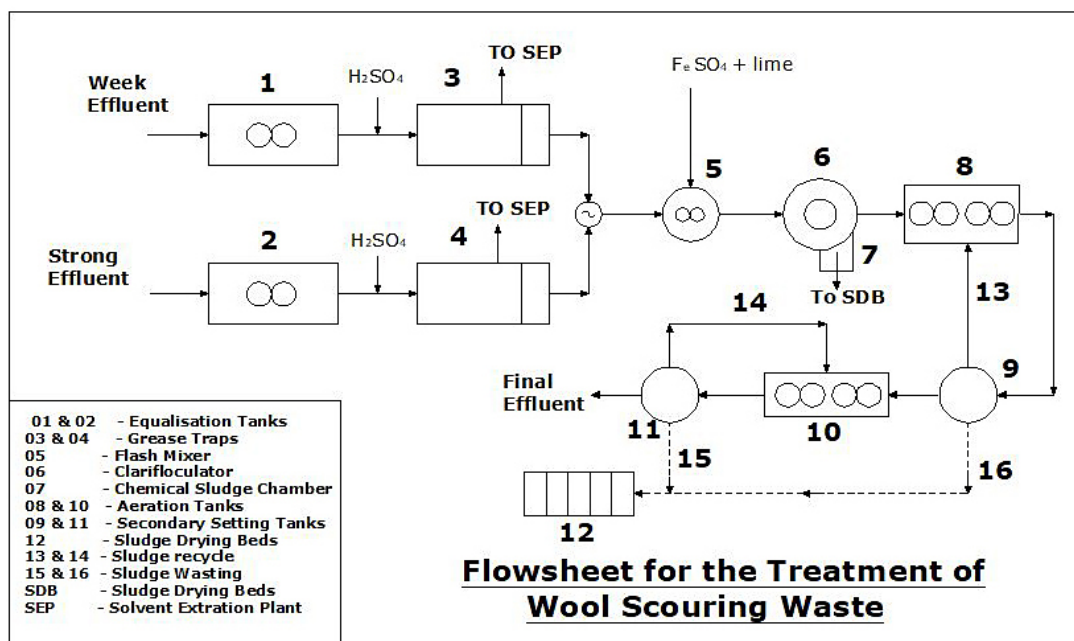


Figure 2. Flow sheet for the treatment of wool scouring waste

was mixed with wastewater in 1:1 proportion and aerated till biomass indicated by suspended solids was seen. The concentration of suspended solids should be about 1500 to 2000 mg/l with BOD loading rate of 0.075 kg/kg MLSS. The bacterial culture that is built up separately. Once the full barrel of biomass developed, it was transferred to the aeration tank. Continuous aeration of collected biomass with wastewater was carried out. Di-ammonium Phosphate, commonly known as DAP, is a preferred fertilizer in India because it contains both Nitrogen and Phosphorus which are primary macro-nutrients. Di-ammonium Phosphate was added regularly for the development of bacterial culture. This process was continued for about one month. If the soil was not available, cow dung slurry was used instead of soil slurry. Alternatively, cow dung was added directly to the aeration tank by preparing its 20% slurry.

## RESULTS AND DISCUSSIONS

Various coagulants like calcium chloride, lime + ferrous sulfate, alum, copperas (green crystals of hydrated ferrous sulfate), ferrous sulfate, sulfuric acid + ferric chloride tried to obtain optimum COD/BOD reduction.  $\text{FeSO}_4$  and lime combination gave better results of BOD removal. The percentage reduction of BOD for various chemicals used is presented in Table 4.

After studying the characteristics of the wastewater emanating from upgraded wool scouring plant and carrying out the treatability studies, it was concluded that the waste could be treated by physico-chemical followed by biological treatment. The results of wastewater after upgradation using  $\text{FeSO}_4$  as coagulant are presented in Table 5.

$\text{FeSO}_4$  was suggested as coagulant because re-adjustment of pH not necessary during treatment. It is essential to maintain the pH at 7–8 for efficient biological treatment. By comparing results

**Table 4.** Results of chemical used for BOD reduction

Chemical used	Percentage reduction in BOD
Calcium chloride	40–70
Lime + ferrous sulfate	75
Alum	20–56
Copperas	20
Ferrous sulfate	50–80
Sulphuric acid + ferric chloride	59–84

**Table 5.** Wastewater characteristics after upgradation

Parameter	Range / Values
pH	6.5–8.5
BOD (mg/l)	1500–2200
COD (mg/l)	2000–2750
Total suspended solids (mg/l)	500–750
Total dissolved solids (mg/l)	1800–3000
Total solids (mg/l)	2000–3500
Oil & Grease (mg/l)	12–16
Temperature °C	45–54
Colour	Creamy white

of Tables 1 and 5, it was observed that BOD and COD reduction reached around 70–75% after chemical treatment and settling. Total suspended solids were reduced by 50% after upgradation. The total dissolved solids and total solids removed by 57–64% and 60–67%, respectively. Oil and grease removal increased by 57–64% after implementation of ferrous sulfate as coagulant. Thus, with the help of treatability studies carried out, the upgradation scheme was given to the wool scouring plant in Mumbai. The upgraded ETP started functioning in October'2020 and gave satisfactory BOD/COD, oil and grease removal performance.

Using an upgraded design of scouring machine in which all the pollutants of the wool are periodically dropped to drain, a relatively clean wool of 22  $\mu\text{m}$  diameter normally utilizes 10 tons of fresh water per kg of raw material. At a production rate of 1000 kg greasy wool per hour, 120 kg grease, 80 kg suint and 80 kg dirt removed per hour, producing a COD load of 474 kg/hour by including a settler and centrifuges in the above-mentioned system, and introducing a counter-flow of liquor from clean bowls to the dirtier bowls, a regular discharge of effluent can be obtained and the pollution load can be reduced by about one third by removing about 30% of the grease in a one-pass system.

## CONCLUSIONS

On the basis of the experimental study of the wool scouring plant upgradation, it was concluded that it is essential to decide the type of pollutants present in the strong and weak effluent before treatment. As the ratio of BOD/COD of wastewater after upgradation is more than 0.3, adopting an aerobic digestion process to remove oil and grease is recommended. Aerobic

biological treatment helps to provide oxygen from the air to increase the rate of consumption of organic matter, which is food for an organism. Krofta dissolved air flotation unit recommended for 60–70% oil and COD removal of wastewater. A provision of two-stage extended aeration activated sludge process would facilitate 90 to 95% of the residual BOD after chemical treatment. Recovery of lanolin and raw material for detergents was also found possible after physico-chemical treatment. The temperature of wastewater should be between 45–54 °C to reduce residual moisture on the scoured wool before drying, thereby decreasing the drying cost and overall energy usage of the treatment process. It is required to maintain 0.075 kg/kg MLSS by developing a suitable bacterial culture to treat suspended solids with the concentration of 1500–2000 mg/l. It is important to observe the effect of other chemicals found effective for percentage removal of BOD from strong and weak effluent regularly. With the upgraded treatment units, the capacity of handling pollution load per day increased by 20%, 19%, and 18% for BOD load, total suspended solids, and oil & grease load, respectively. Finally, it was observed that the upgradation of various ETP units was found effective in handling strong and weak effluent.

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