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Investigation of stabilization of common effluent treatment plant at Calcutta Leather Complex: A case study

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Common Effluent Treatment Plant (CETP) of Calcutta Leather Complex (CLC), South 24-Parganas, West Bengal, India was installed for final treatment of wastewater generated from cluster of tannery units located there. In this study, treatment stage wise as well as overall performance efficiency for removal of TSS, COD, BOD, sulfide (S^{2-}) and total Cr from tannery wastewater were analyzed for evaluating the performance of CETP. Also, during performance analysis of activated sludge process, various aspects like parameters of MLSS, MLVSS, F/M and SVI of aeration tank are discussed to judge stability of CETP. Finally, statistical correlations among removal efficiency of wastewater parameters were carried out using SPSS (Version 17.0) in order to establish relation between removal efficiencies of treatment stages and CETP overall. To perform this study, the concentration level of TSS, COD, BOD, sulfide (S^{2-}) and total Cr in wastewater of CETP at its different treatment stages is obtained from data of West Bengal Pollution Control Board (WBPCB), environmental regulatory agency of West Bengal.

Keywords: CETP, tannery, wastewater, parameter, stability.

Introduction

Tannery process is a water intensive industry which involves a variety of chemicals such as sodium sulfide (Na_2S), basic chromium sulfate [$Cr_2(SO_4)_3$], non-ionic wetting agents, bactericides, soda ash, calcium oxide, ammonium sulfate, ammonium chloride, enzymes, sodium bisulfate, sodium chlorite, sodium hypochlorite, sodium chloride, sulfuric acid, formic acid, sodium formate, sodium bicarbonate, vegetable tannins, syntans, resins, polyurethane, dyes, fat emulsions, pigments, binders, waxes, lacquers and formaldehyde etc. resulting generation of highly polluted wastewater. This wastewater containing high level of total dissolved solid (TDS), total suspended solid (TSS), chloride, biological oxygen demand (BOD), chemical oxygen demand (COD), sulfide (S^{2-}), total chromium as major polluting parameters cause water pollution if discharged without treatment. Considerable quantum of highly polluted wastewater generated from cluster of such type of industries requires common effluent treatment plant (CETP) for proper treatment. For treatment of wastewater generated from cluster of tannery units located at Calcutta Leather Complex (CLC), South 24-Parganas,West Bengal, India, CETP of 20 MLD capacity was installed. This CETP has four parallel modules of capacity 5 MLD each. Equalization tank, flash mixer, flocculation tank, primary clarifier, aeration tank and secondary clarifier are successive treatment stages of each module of this CETP. Physico-chemical treatment of this CETP consists of flash mixer, flocculation tank and primary clarifier. Aeration tank and secondary clarifier of CETP form activated sludge process. In flash mixer, wastewater is mixed with coagulants (poly aluminium chloride) to enhance the separation of solids and chromium from wastewater. Then in flocculation tank, the flocs of coagulated solids grow into larger and heavier particles with the addition of anionic polyelectrolyte. In primary clarifier, wastewater flows from the centre to the perimeter of the circular tank under a baffle and over a V-notch weir of this tank and suspended solids settle at the bottom of the tank as mainly inorganic sludge. Wastewater in aeration tank is mixed with flocs of aerobic microorganisms (activated sludge) under aerobic condition where sludge containing active aerobic microorganisms adsorbs suspended materials of wastewater and biodegrades organic matter. In secondary clarifier, sludge of sludge and wastewater mixer settles at the bottom and clear wastewater flows out of the tank from it's surface at the top. Part of the sludge is recirculated to the aeration tank to maintain a concentration of the activated sludge[3]. Flow sheet diagram of CETP at CLC is presented in Fig. 1.

In this study, treatment stage wise as well as overall performance efficiency for removal of total suspended solid (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD), sulfide (S^{2-}) and total Cr from tannery wastewater were analyzed and assessed for evaluating the performance of this CETP at CLC as no other literature till date is available for analyzing the performance of this CETP. Also, during performance analysis of aeration tank, various aspects like parameters of mixed liquor suspended solid (MLSS), mixed liquor volatile suspended solid (MLVSS), food to monomer ratio (F/M) and sludge volume index (SVI) are discussed to judge stability of activated sludge process in the CETP. Finally, statistical correlations among removal efficiency of treatment stages and CETP for wastewater parameters were carried out using SPSS (Version 17) in order to establish relation between removal efficiencies of treatment stages and CETP overall.

Materials and methods

Wastewater characteristics at common inlet to CETP, outlet of primary clarifier of each module, outlet of secondary clarifier of each module and finally common outlet of CETP were regularly monitored by West Bengal Pollution Control Board[8], the environmental regulatory agency of Govt. of West Bengal for concentration level of major water quality parameters such as TSS, COD, BOD, S^{2-} and total Cr using standard method[1]. Additional parameters of MLSS, MLVSS, F/M and SVI at wastewater outlet of aeration tank were also considered. Removal efficiency of a treatment stage for each of TSS, COD, BOD, S^{2-} and total Cr is obtained utilizing its inlet and outlet concentrations. For each pollutant, removal efficiencies of primary clarifier, activated sludge process and CETP overall are calculated and outlet wastewater concentration of CETP for all parameters is compared with environmental discharge standard to evaluate performance of CETP. A number of cases were taken for present work for all polluting parameters of wastewater. Using SPSS (Version 17.0),

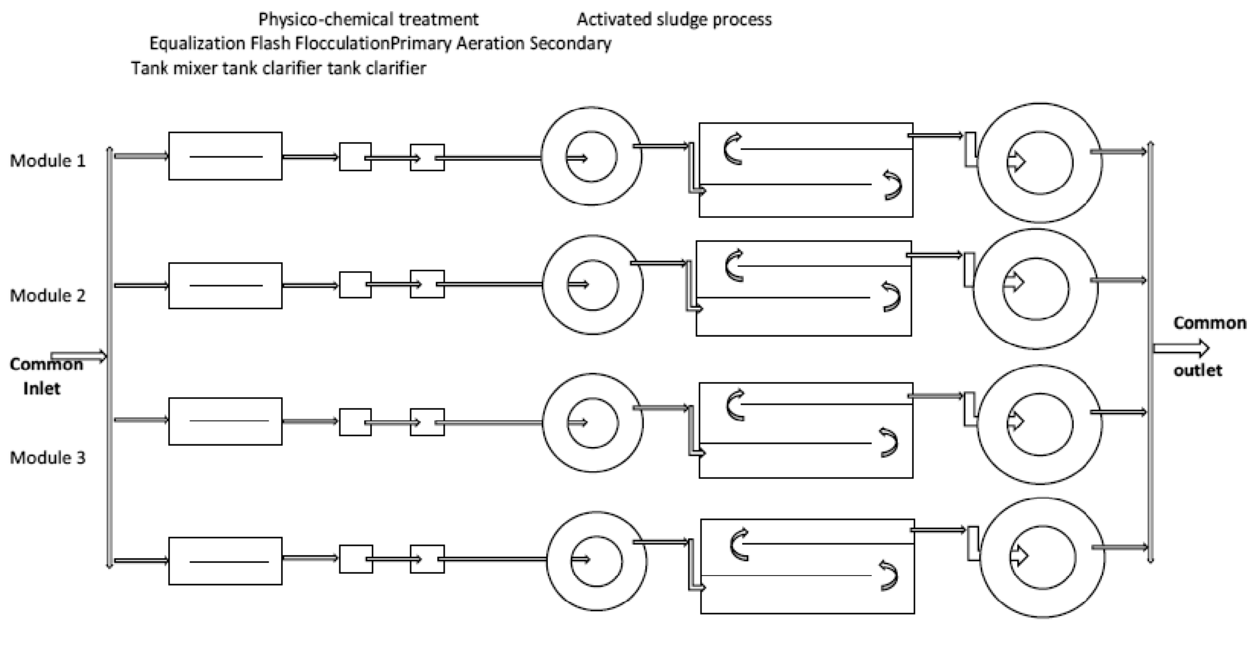

Fig. 1. Flow sheet diagram of CETP at CLC.

Pearson and Spearman correlations were carried out for treatment stage wise as well as overall CETP removal efficiencies of different parameters.

Results and discussion

At inlet to CETP, concentrations of TSS, COD, BOD, S^{2-} and total Cr were varying in the range from 530 mg/L to 8090 mg/L, 1474.4 mg/L to 3980.8 mg/L, 622.5 mg/L to 2051 mg/L, 47.1 mg/L to 276.73 mg/L and 1 mg/L to 34.45 mg/L respectively.

TSS removal efficiency of primary clarifier and activated sludge process for CETP at CLC considering all four modules were evaluated in the range of 33.33 to 98.96% and 28.33 and 96.19% respectively. Also, the extent of TSS removal by primary clarifier was higher than that in the activated sludge process. The overall treatment performance of the CETP for TSS was varied in the range of 87.10 to 98.24%. In most of the cases for CETP at CLC, TSS level at CETP outlet wastewater attained environmental standard (100 mg/L)[2]. In the available literature, Govindasamy *et al.*[6] showed that treatment performance of TSS in the primary clarifier and the secondary clarifier were 84.40 and 62.72% respectively for satisfactory operation of the CETP for tanneries located at Pallavaram, Tamilnadu, India having inlet TSS level of 1410 mg/L These findings are comparable with the present study of the CETP at CLC. This literature also informed the overall removal efficiency of the CETP including tertiary treatment as 97.02%. In another literature, Vasudevan *et al.*[5] stated that the overall removal efficiency of the CETP at Pammal, Tamilnadu, India having inlet TSS load of 2000 mg/L had attained a value of 96.63%. The overall TSS removal efficiency of the CETP in CLC, Kolkata is observed to be comparable with these two study.

Considering all four modules, COD removal efficiencies in the primary clarifier were varied between 9.24 and 66.10%, while it was varying from 58.61 to 97.69% in the activated sludge process. The overall removal efficiency of the CETP was varied in the rage of 70.75 to 96.59% and COD level at outlet of activated sludge process did not attain compliance of environmental discharge standard (250 mg/L)[2] for 11% cases. Probable reasons for these non-compliances are low removal efficiency of primary clarifier for three cases, low removal efficiency of activated sludge process in one case and finally low removal efficiencies of both primary clarifier and activated sludge process in one case. As per available literature mentioned earlier, Govidaswami *et al.*[6] mentioned the removal efficiencies of the primary clarifier and the aeration tank along with the secondary clarifier were 60.72 and 71.42% respectively for inlet COD concentration of 4117 mg/L for CETP at Pallavaram. They also reported the overall removal efficiency of the CETP including tertiary treatment as 93.92%. In another work mentioned earlier, Vasudevan *et al.*[5] observed that the treatment performance of CETP at Pammal for COD removal having inlet COD load of 5940 mg/L, was observed as 96.93%. The removal efficiencies of primary clarifier, activated sludge process and CETP are comparable with the treatment performance of the CETP at CLC under study.

For BOD, treatment performance of primary clarifier, activated sludge process and CETP at CLC were recorded as 5.99% to 63.89%, 52.43% to 99.22% and 85.78% to 99.77% respectively. In 9% cases, non-compliance of environmental standard (above 100 mg/L)[2] for BOD level at CETP outlet sample was obtained. In the cases where BOD level at activated sludge process outlet did not attain compliance, low removal efficiency of primary clarifier in three cases and low removal efficiency of activated sludge process in one case were observed. Govidaswami *et al.*[6] reported for CETP at Pallavaram that the removal efficiencies of the primary clarifier and the aeration tank along with the secondary clarifier were 40.91 and 95.23% respectively for inlet BOD concentration of 1100 mg/L. They also reported the overall removal efficiency of the CETP including tertiary treatment as 97.54%. Vasudevan *et al.*[5] informed that the overall BOD removal efficiency of the CETP at Pammal was obtained in the range of 95 to 98.5% having inlet BOD load of 1400 mg/L. The removal efficiencies of above mentioned two literatures are comparable with the observed values of the CETP at CLC. Non-attainment of BOD level at CETP discharge for different cases can be assessed from different parameters of aeration tank culture condition: (1) Poor culture (low MLVSS/MLSS value, 0.14) of aeration tank during its new or growing stage can not be able to treat wastewater having high BOD level (high F/M value, 1.55). In the literature, Vasudevan *et al.*[5] informed that treated wastewater quality is achieved by maintaining MLVSS/MLSS value of 0.6 and value of F/M ratio as 0.18. In the present study, 33% data were comparable with MLVSS/MLSS value of 0.6 which signifies that the activated sludge process of CETP at CLC was stable to the extent of 33%. (2) Though activated sludge contained higher population of microorganism (high MLVSS/MLSS value, 0.82) and high compactness of culture (low SVI value, 87.57 ml/g), but very high F/M ratio (0.29) may cause lower efficiency of activated sludge process. (3) Very high F/M ration (5.67), poor culture (low MLVSS value, 150 mg/L) and unsettled sludge (high SVI value, 189 ml/g) may cause non-attainment of BOD concentration at wastewater outlet of secondary clarifier. In a study, Nandy *et al.*[7] stated that the activated sludge process was stabilized by maintaining MLVSS value in the range of 2245 to 2680 mg/L and SVI parameter of 105 mL/g. (4) Inferior active biological solid (low MLVSS/MLSS value, 0.2) and high F/M value (0.87) cause non-attainment of BOD level at CETP outlet wastewater. (5) High F/M value (0.29) and high SVI value (126.68 ml/g) were unfavorable to remove BOD in wastewater. (6) Very high F/M value (2.59), low microorganism concentration (MLVSS value, 440 mg/L) and compact sludge (low SVI value, 65.9 ml/g) cause improper BOD removal from wastewater. (7) Though MLVSS/MLSS was stable (0.68), low SVI value (25.28 ml/g) and very high F/M value (0.51) cause less BOD removal efficiency.

In the aeration tank of CETP at CLC, volumetric BOD load was obtained to vary from 0.396 to 1.419 kg BOD/m^3d. In literature, Metcalf and Eddy[4] informed about the normal range of volumetric BOD load from 0.30 to 0.70 kg BOD/m^3d. In CETP of CLC, 21.8% values were attained with in the normal range of volumetric BOD load as stated by literature.

S^{2-} removal efficiencies of primary clarifier, activated sludge process and CETP were evaluated with ranges as 14.99% to 78.70%, 63.95% to 99.95% and 95.52% to 99.92% respectively. In 16.7% cases, S^{2-} value at CETP outlet wastewater did not attain environmental standard (1 mg/L)[2] due to low removal efficiency of primary clarifier in two cases and low removal efficiencies of both primary clarifier and activated sludge process in two cases.

Treatment performances of primary clarifier, secondary clarifier and CETP for total Cr were maintained with ranges as 19.39% to 98.44%, 53.92% to 98.11% and 90.00% to 99.63% respectively resulting compliance of total Cr level at CETP outlet with environmental discharge standard (2 mg/L)[2] in all cases.

Strong Pearson correlation (0.924) (linear relation) is obtained for BOD removal efficiency between activated sludge process of module 3 and CETP interpreting that only activated sludge process of module 3 was stable for BOD removal of CETP. There exists strong Pearson (0.884) as well as Spearman (0.842) correlation for total Cr removal efficiency between activated sludge process of module 1 and CETP reflecting activated sludge process of module 1 only was related with overall total Cr removal efficiency of CETP. Only strong Pearson correlation (0.931) is exhibited for S^{2-} removal efficiency between activated sludge process of module 3 and CETP and thus S^{2-} removal of CETP was connected with activated sludge process of module 3. No strong statistical correlation was observed for COD removal between either primary clarifier or activated sludge process of any module and CETP. Similar observation was derived for TSS removal efficiency of CETP. For CETP being properly functional, it is expected that there exists strong statistical correlation between every treatment stage of each module and CETP for every polluting parameter.

Conclusions

As a case study, stage wise treatment performances of CETP at CLC for every polluting parameter is discussed. Probable cause for non-attainment of BOD level at CETP discharge point is discussed explicitly. Considering MLVSS/MLSS ratio, activated sludge process of CETP at was stable for 33% cases to maintain higher BOD removal efficiency. In 21.8% cases, volumetric BOD load was achieved from 0.30 to 0.70 kg BOD/m^3d as stable condition of activated sludge process for this CETP. Statistical correlation is established between activated sludge process of module 3 and CETP for both BOD and total Cr removal efficiency.

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