Biological Treatment of Tannery Wastewater Using Activated Sludge Process

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Abstract

A study was conducted to evaluate the feasibility of Activated Sludge Process (ASP) for the treatment of tannery wastewater and to develop a simple design criteria under local conditions. A bench scale model comprising of an aeration tank and final clarifier was used for this purpose. The model was operated continuously for 267 days. Settled tannery wastewater was used as influent to the aeration tank. Five days Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD) of the influent and effluent were measured to find process efficiency at various mixed liquor volatile suspended solids (MLVSS) and hydraulic detention time (θ). The results of the study demonstrated that an efficiency of above 90% and 80% for BOD_5 and COD, respectively could be obtained if the ASP is operated at an MLVSS concentration of 3500 mg/L keeping an aeration time of 12 hours.

Key words: Activated sludge; Biological treatment; Tannery wastewater treatment; BOD_5; COD.

1. Introduction

The operation of tanneries in Pakistan is causing severe environmental degradation due to the disposal of untreated effluent on land and in water bodies. There is urgent need for the treatment of tannery effluent prior to their disposal. To this effect suspended growth biological processes can be employed for effective water pollution control. Facultative waste stabilization ponds have been employed as pretreatment facilities in Kasur to treat the effluent from local tanning industry. The use of waste stabilization ponds, however, requires large land areas that may not be available in a particular situation. On the other hand, fully aerobic processes, such as ASP, require significantly less land area.

Treatment of tannery effluent through the use of activated sludge process has been reported by many research workers [1-6]. All these studies indicate a BOD_5 removal of 90 to 97% for the tannery effluent concluding activated sludge process as highly useful for the purpose.

The characteristics of tannery effluent vary considerably from tannery to tannery depending upon the size of the tannery, chemicals used for a specific process, amount of water used and type of final product produced by a tannery. In 1998, Federation of Pakistan Chambers of Commerce and Industries conducted a survey in Pakistan and determined the quality characteristics range of effluent from tanneries processing raw goat and sheep skins to finished leather as given in Table 1[7].

The range of quality parameters indicates very high concentration of organic matter, solids, sulfates, sulfide and chromium in tannery effluent. Such wastewaters can be treated by employing physical and biological treatment processes. High concentrations of chromium may pose adverse impact on biological activity in the reactor and hence it would be desirable to remove chromium before subjecting the wastewater to biological treatment. Most of the chromium is removed in primary sedimentation tanks [1,8].

Many factors affect the performance of activated sludge process. Various parameters of importance relating to growth of microorganisms and substrate utilization on which the operation of the reactor is based include mean cell residence time (θ_c) in days, mixed liquor volatile suspended solids (MLVSS) concentration expressed as X in mg/L, hydraulic

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Table 1: Range of Tannery Effluent Quality Parameters [7]

Parameters	Range
pH (unsettled effluent)	7.3 – 10
BOD_5, mg/L (30 minute settling)	840 – 18,620
COD, mg/L (30 minute settling)	1320 – 54,000
Suspended Solids, mg/L (30 minute settling)	220 – 1610
Settleable Solids, ml/L (30 minute settling)	11 – 40
Total K. Nitrogen, mg/L (unsettled effluent)	236 – 358
Sulfates, mg/L (unsettled effluent)	800 – 6480
Sulfides ,mg/L (at 0 time settling)	800 – 6480
Chromium, mg/L (unsettled effluent)	41 – 133

detention time (θ) i.e aeration time in hours, food to microorganism (F:M) ratio in kg BOD_5/kg MLVSS/day, and the dissolved oxygen (DO) in mg/L in the reactor.

The present research work was carried out at the Institute of Environmental Engineering and Research. The objectives were to study the feasibility of ASP for the treatment of settled tannery effluent and to develop general guidelines for the process design under local conditions.

2. Materials and Methods

A bench scale continuous flow activated sludge reactor was used in this study (Figure 1). It consisted of an aeration tank of 3.15 litres capacity and a settling portion of 1.1 litre capacity. Composite tannery wastewater fed as influent to the reactor was brought from East Pakistan Tannery, 27 Km Lahore-Sheikhupura Road.

The influent was subjected to settling in a 20 liters bottle. A peristaltic pump of variable capacity was used to pump the settled influent to the aeration tank. The reactor had to operate at different MLVSS concentrations. Due to non-availability of mechanical return sludge facility, 100% of the settled sludge was daily removed from the final clarifier in a beaker and manually

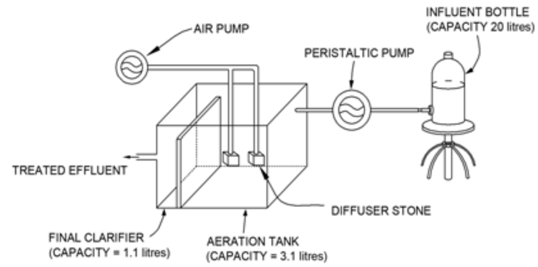

Figure 1: Bench Scale Model of Activated Sludge Reactor

returned to the aeration tank. In order to maintain the desired MLVSS concentration in the reactor the calculated fraction of the volume of the aeration tank (ranging from one third to one tenth) was removed manually on daily basis and the tank was filled to the original volume by the treated effluent. No external nutrients were added to the influent.

Filtered air was supplied through diffuser stones to maintain a DO level of more than 2 mg/L. Flow, temperature and pH values for settled influent and effluent were measured daily while MLVSS in the reactor, COD and BOD_5 of influent and effluent were measured thrice a week. The analytical determinations were made in accordance with the Standard Methods [9].

The two chosen operating parameters i.e. MLVSS concentration and θ were varied during the course of the study keeping into consideration the generally applied range in activated sludge process for industrial effluent treatment. The reactor was operated for an MLVSS concentrations range of 1500, 2000, 2500, 3000 and 3500 mg/L and θ value of 4, 6, 8, 10 and 12 hours, respectively.

During the course of study, the pH of the reactor varied between 7 and 8.5 which is a suitable range for biological treatment [10-11]. DO of the reactor was maintained above 2 mg/L which is required for satisfactory biological treatment [11-12].

Experimental work was performed for a period of 267 days. The bench scale reactor was seeded with the acclimatized sludge prepared in the laboratory from domestic sewage.

3. Results and Discussion

The treatment efficiency of the reactor in terms of BOD_5 and COD removals was studied for MLVSS concentrations of 1500, 2000, 2500, 3000 and 3500 mg/L at θ of 4, 6, 8, 10 and 12 hours. It was noted that the process efficiency improved with increase in MLVSS concentration and θ. The removal efficiencies at different MLVSS and θ are given in Table 2.

Thus the results indicate that for optimal operation, ASP should be operated at MLVSS concentration of 3500 mg/L and θ value of 12 hours. As already discussed, wastewater characteristics vary from tannery to tannery, therefore, the optimal values obtained for MLVSS and θ during present studies may hold good only for East Pakistan Tannery. It is thus proposed to carry out bench scale studies for obtaining optimal values of the said parameters for a specific tannery before designing a biological treatment system.

The data in Table 2 are graphically presented in Figures 2 and 3, which reveal that a maximum removal efficiency of 93.9% and 84.2% was achieved at MLVSS concentration of 3500 mg/L and θ of 12 hours for BOD_5 and COD, respectively. Furthermore, residual values of BOD_5 and COD at this MLVSS and θ are 54 mg/L and 233 mg/L, respectively. It shows that BOD_5 meets National Environmental Quality Standards (NEQS) limits, which is 80 mg/L whereas COD does not qualify NEQS, which is 150 mg/L.

COD and BOD_5 relationship for influent and effluent was determined. As indicated in Table 3, an average COD/BOD_5 ratio of 1.57 was established for settled influent on the basis of data collected during the course of investigations.

The correlation between the two parameters for influent was found out by plotting data for influent COD and BOD_5 and fitting a linear regression line to the plotted data as shown in Figure 4. The correlation obtained may be expressed as:

$$BOD_5 = 0.636\ COD - 1.1958 \qquad (1)$$

It may, therefore, be concluded that a reasonably good approximation of BOD_5 can be obtained from a COD measurement once a relationship has been established between the two parameters from the available data.

Table 2: BOD_5 and COD Removal Efficiency at various MLVSS concentrations and θ[2].

MLVSS (mg/L)	θ (hours)	Mean Influent BOD_5 (mg/L)	Mean Effluent BOD_5 (mg/L)	Removal Efficiency %	Mean Influent COD (mg/L)	Mean Effluent COD (mg/L)	Removal Efficiency %
3500	12	882	54*	93.88	1475	233**	84.2
	10	878	78*	91.12	1464	248	83.1
	8	875	114	86.97	1325	317	76.1
	6	884	166	81.22	1370	364	73.4
	4	872	265	69.61	1316	394	70.1
3000	12	905	84	90.72	1459	290	80.1
	10	901	107	88.12	1476	344	76.7
	8	904	145	83.96	1445	420	70.9
	6	910	198	78.24	1506	440	70.7
	4	907	276	69.57	1499	460	69.3
2500	12	810	110	86.42	1203	277	76.9
	10	812	133	83.62	1208	280	76.8
	8	801	178	77.78	1289	306	74.3
	6	817	312	61.81	1289	430	66.1
	4	811	332	59.06	1292	433	66.5
2000	12	1078	160	85.16	1614	363	77.5
	10	1092	325	70.24	1661	476	71.3
	8	1075	398	62.98	1654	514	68.9
	6	1081	456	57.82	1662	531	68.1
	4	1057	520	50.80	1621	523	67.7
1500	12	798	240	69.92	1270	418	67.1
	10	802	320	60.1	1252	470	62.4
	8	794	345	56.55	1308	499	61.8
	6	784	368	53.06	1269	464	63.4
	4	797	401	49.69	1221	398	67.4

* *NEQS for BOD_5 = 80 mg/L*
** *NEQS for COD = 150 mg/L*

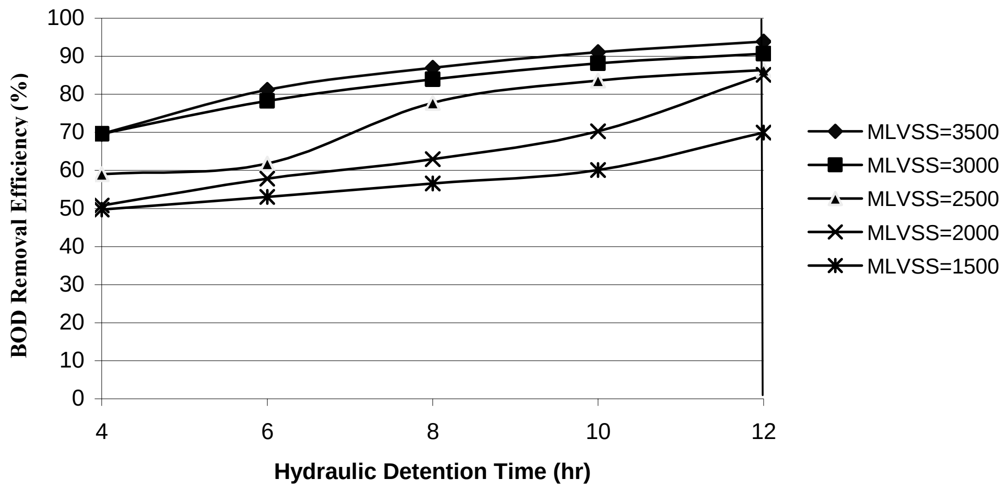

Figure 2: Relationship among Hydraulic Detention Time, MLVSS and BOD_5 Removal (%)

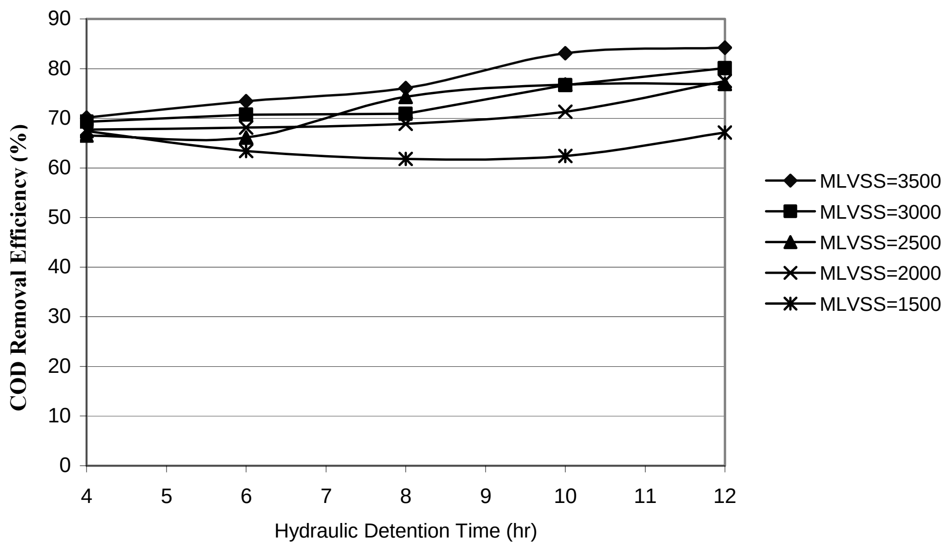

Figure 3: Relationship among Hydraulic Detention Time, MLVSS and COD Removal (%)

Equation 1 must be used with caution. A substitution of 'zero' for COD in the said equation yields a value of –1.195 mg/L for BOD_5, which is not possible. Its application is, therefore, restricted and valid only when COD falls in a range of 1203 – 1662 mg/L (Table 3). The relation cannot be generalized for COD values other than the specified range.

The F:M ratio for the optimal values of MLVSS and θ that qualified BOD_5 limit for NEQS for the present study came out to be 0.4 $KgBOD_5/KgMLSS/day$. Studies on biological treatment of wastewater of Saddiq Leather Works, 12 Km Lahore-Shakhupura road, were carried out using bench scale model of aerated lagoon [8].

Table 3: Influent COD and BOD_5 Ratio

Average COD (mg/L)		**Average BOD_5 (mg/L)**		**Average COD/BOD_5**
Range	Mean	Range	Mean	
1203 – 1662	1405	784 – 1092	893	1.57

The studies showed that an F:M ratio of 0.44 $KgBOD_5/KgMLSS/day$ satisfied NEQS for BOD_5 with an effluent concentration of 67 mg/L. However, NEQS limit for COD could not be satisfied even at a very low F:M ratio of 0.18 $KgBOD_5/KgMLSS/day$ as the effluent at this F:M ratio contained COD content of 187 mg/L [8].

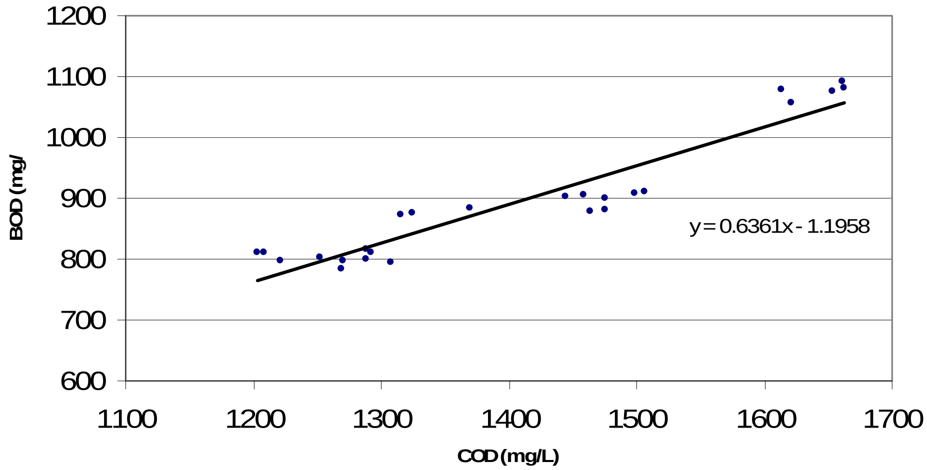

Figure 4: COD and BOD_5 relationship for Influent.

Table 4: Effluent COD Standard in Some Developing Countries [13]

Sr No.	Country	**COD limit (mg/L)** (In surface waters)	COD > 150 mg/L
1	Argentina	250	**Yes**
2	China	300	**Yes**
3	Costa Rica	600	**Yes**
4	Czech Republic	300	**Yes**
5	India	250	**Yes**
6	Indonesia	300	**Yes**
7	Nepal	250	**Yes**
8	Nicaragua	250	**Yes**
9	Philippines	250	**Yes**
10	Sri Lanka	250	**Yes**
11	Turkey	200	**Yes**
12	Venezuela	350	**Yes**
13	Tunisia	90	No
14	Vietnam	100	No
15	Zambia	90	No

If COD/BOD_5 value of 1.57 is looked into, it clearly reveals that substantial portion of the organic matter is non-biodegradable. Owing to large quantities of non-biodegradable matter in tannery wastewater, the NEQS limit of 150 mg/L seems to be stringent. Furthermore, when NEQS limit for Pakistan is compared with other developing countries as given by Bosnic (2000), it clearly appears to be conservative (Table 4). Out of the fifteen countries given in Table 4, twelve have COD limits higher than 150 mg/L, whereas only three have lower than it. Therefore, keeping in view this comparison, it appears that effluent COD standard in Pakistan is on the conservative side.

4. Conclusions

ASP is a feasible treatment technology for tannery wastewater especially where limited space restricts the use of other biological methods. ASP for East Pakistan Tannery may be operated with MLVSS concentration of 3500 mg/L and θ value of 12 hours in order to obtain optimal removal efficiencies with respect to BOD_5 and COD. However, for a specific tannery, bench scale studies to find out the optimal values of these parameters are needed prior to the design of biological unit. The effluent met NEQS for BOD_5 at the above stated MLVSS concentration and θ value. However, COD limit for NEQS could not be qualified. A COD/BOD_5 ratio of 1.57 for the tannery wastewater shows that a substantial portion of organic matter is non-biodegradable. Owing to large quantities of non-biodegradable matter in tannery wastewaters, the NEQS limit of 150 mg/L for COD seems to be stringent. NEQS for COD should therefore be revised for specific wastewaters having appreciable quantities of non-biodegradable organic matter. Furthermore, NEQS for COD also appear to be on conservative side when compared with other developing courtiers. Pakistan Environmental Protection Council may therefore consider modifying the NEQS for COD. Based upon this research, further work is proposed to study the nitrogen removal in addition to BOD_5 and COD in ASP. In addition, effect of different MLVSS concentration and detention time on the efficiency of settling tank may be investigated.

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