EFFICIENCY OF WASTEWATER TREATMENT PLANT IN THE PUNJAB TANNERY SECTOR: A CASE STUDY OF DADA TANNERY

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ABSTRACT

Tanning industry of Pakistan contributes significantly towards foreign exchange earnings of the country. Growing concern of international buyers on environmental compliance, during tanning process, has forced this sector to install wastewater treatment plants to address the issue. This study aims to evaluate the performance of wastewater treatment plant (WWTP) of a local tanning industry. Raw wastewater showed high concentration of organic matter and Chromium. Phosphorous concentration was found deficient for satisfactory biological treatment. WWTP showed overall removal efficiency of 88.81, 84.54 and 62.31% for total suspended solids (TSS), five day biochemical oxygen demand (BOD) and chemical oxygen demand (COD), respectively. Whereas, the mean effluent concentrations of TSS, BOD and COD were 216 mg/L, 199 mg/L and 1023 mg/L, respectively. The effluent from WWTP exceeded the National Environmental Quality Standards (NEQS) for TSS, BOD and COD. It was due to the low concentration of Mixed Liquor Suspended Solids (MLSS) in aeration tank and low Phosphorous concentration in wastewater. NEQS limits for BOD and COD could be met by adding Phosphorous and increasing the MLSS in aeration tank.

KEYWORDS: *tannery wastewater, treatment plant, activated sludge,*

INTRODUCTION

Leather industry is one of the major contributors in the foreign exchange of Pakistan. About 90% of its products are exported in finished form[1]. The leather exports of Pakistan increased from US$ 672 million in 2002 to US$ 1.13 billion in 2007, which indicates an increase of 68% in a period of 5 years[2]. Formal tanning sector, in Pakistan, comprises of 656 tanneries and equally large number of tanneries exists in the informal sector. In Pakistan, major clusters of tanneries are located in Kasur, Karachi, Sialkot, Sheikhupura, Multan, Lahore and Gujranwala[3].

The tanning process includes number of steps during which large quantities of water and chemicals are applied to the raw skins. These steps can be divided into four major classes i.e. (1) pretanning; (2) tanning; (3) wet finishing and (4) finishing. Groundwater is used as the major source of water[4]. During manufacturing process, about 130 different types of chemicals are used which ranges from common salt to a very expensive chrome salt. Most widely used tanning method in Pakistan is by using chrome salts and is referred as "chrome tanning"[5,6].

The recommended water consumption in tanneries is 50 liter/kg of raw hide, however, it has been observed that tanneries generally consume more water and in some cases it is as high as 150 liter/kg[7]. Wastewater that is drained out after the completion of the process, is the same in quantity as is used in the process. Tanneries are generally disposing their wastewater into the drains, which ultimatly find their way to the natural water bodies. The large quantities of proteins and their degrading products, in tannery wastewater, result in high biochemical oxygen demand (BOD) values. The high value of BOD in extreme conditions can kill natural life by depleting oxygen present in the natural waters. Similarly, other pollutants present in tannery wastewater like Sulphides, Sulphates and Chromium can also harm the aquatic life. Table 1 illustrates wastewater characteristics of tannery effluent that has been reported previously by a number of researchers[8-12].

End of pipe effluent treatment in tanneries, at least, requires two levels of treatment; primary and secondary. Mechanical screening, pH equalization and physicochemical processes fall in the category of primary treatment. Coarse particulate, flesh and hair are removed by means of perforated screens which also reduce the BOD load. The amplitude of pH fluctuation is reduced to manageable range by equalization. Coagulation, flocculation and sedimentation are applied to remove suspended solids. In secondary treatment, biological processes are used to remove most of the organic matter, from wastewater, by converting it into different gases and cell tissues[1].

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Treatment of tannery effluent by using activated sludge process has been used extensively and it has been observed that a BOD removal of 90-97% is achieved[12].

Dada Enterprises Limited (DEL), the tannery understudy, is located at Ferozpur road, Lahore. In Dada tannery, finished leather is manufactured from raw hides and skins of goat/sheep. Ninety percent of the leather produced, is exported. All operations are carried out on batch basis. Average wastewater flow from the tannery is 454 m3/day and maximum flow is 839 m3/day (from DEL's available flow sheets). The tannery employs conventional tanning process using chromium salts and is one of the largest tanneries in Pakistan. DEL is also committed to sustainable development through effective implementation of environmental management systems[13].

Primary treatment plant was constructed by DEL in year 1999, while secondary treatment at Dada Tannery was completed in 2007. The targets fixed for this combined primary and secondary treatment were to achieve TSS, BOD and COD removal efficiencies up to 87%, 91% and 94%, respectively and achieve NEQS compliance[14]. Ever since the establishment of primary and secondary treatment units at Dada Tannery, no systematic study has been conducted to evaluate whether or not it is achieving its targeted efficiencies with respect to major pollution parameters, mentioned above, and the compliance of NEQS. Therefore, the present study is the first ever one undertaken to gauge the performance of the treatment plant and to suggest corrective measures if the targets fixed are not met.

MATERIAL AND METHODS

Plant Layout

DEL is equipped with primary and secondary wastewater treatment units. Primary unit comprises of settling chamber, equalization tank, primary sedimentation tank and 4 number of sludge drying beds. Secondary unit comprises of two overlapped aeration tanks, secondary sedimentation tank, sludge thickener and 8 number of sludge drying beds (Figure 1).

Primary sedimentation tank is circular in shape with a diameter of 6 m. The sludge from the primary sedimentation is sent to primary sludge drying beds for drying. The effluent after primary treatment is discharged into two aeration tanks. To maintain the required dissolved oxygen concentration of 2 mg/L in wastewater, two surface aerators are installed in the aeration tank. DEL operates its aerators continuously for 20 hours per day to produce favorable environment for the microorganism growth and to maintain the required dissolved oxygen levels. The wastewater from aeration tank goes to secondary settling tank from where it is disposed in a seepage drain, which finally joins Rohi Nullah and

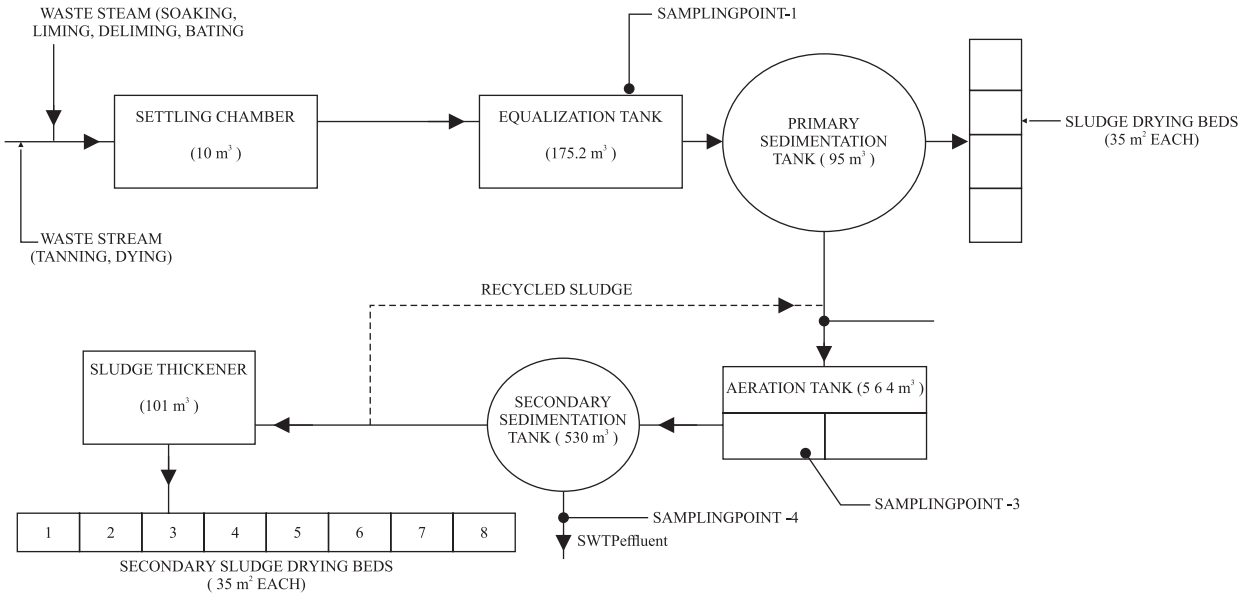

Figure 1: Schematic Diagram of DEL treated effluent

Table 1: Wastewater Characteristics of Raw Unsettled Tannery Effluent

Sr. No	Parameters*	(Iqbal,1998) Range	(Cheda,1984) Mean	(PTA,1995) Range	(Tare,2003) Mean	(Haydar and Aziz, 2008) Range
1	pH	7.35-7.67	7.5	8.2-9	-----	7.55-9.66
2	TSS	820-1920	2560	3430-6500	750	568-2132
3	Chlorides	------	2000	10770-14900	----	1000-4548
4	Sulfates	800-860	-----	1540-3300	1500	564-2121
5	Chromium	41	60	160-275	50	22.98-122
6	BOD	1020-2640	1500	1950-3100	1500	390-1320
7	COD	1600-4080	3800	4500-7500	3600	1760-3320
8	Phosphorous	----	----	1.9-5	---	0.5-1.1

*All parameters are in mg/L, except pH

Table 2: Sampling points and test conducted on the samples

Sampling Point	Sample location	Tests conducted					
1	Equalization tank	COD	BOD	TS	TDS	TSS	N & P
2	Effluent of Primary Sedimentation Tank	COD	BOD	TS	TDS	TSS	------
3	Aeration tank	-----	------	TS	TDS	TSS	------
4	Effluent of Secondary Sedimentation Tank	COD	BOD	TS	TDS	TSS	------

(TS=Total Solids; TDS=Total Dissolved Solids; TSS=Total Suspended Solids; N=Nitrogen; P=Phosphorous)

ultimately finds its way to River Ravi. Figure 1 shows schematic diagram of the treatment plant and sampling points for the evaluation of efficiency of wastewater treatment plant (WWTP).

Sampling Locations

Four grab samples each of 1.5 liter were collected from the sampling points (Figure 1) of primary and secondary treatment units. Sampling point-1 was selected to take homogenized sample and was used to characterize the DEL wastewater. Sampling point-2 was selected to evaluate the efficiency of primary sedimentation tank. Sampling point-3 was fixed at aeration tank in order to find out the MLSS concentration in the tank. While sampling point-4 was used to evaluate the efficiency of secondary treatment as well as the overall efficiency of the entire WWTP.

Sampling Schedule:

Wastewater sampling was extended over a period of 10 months. This sampling duration incorporates all the possible fluctuations that normally occur in a tannery. Each sampling point was sampled 14 times during 10 month period. Hence the total numbers of samples collected and tested were 56 (4x14).

Tests Conducted

Various tests were conducted on the collected samples. The purpose of these tests was (1) to characterize the wastewater; (2) to evaluate the performance of primary and secondary units and also the overall performance of WWTP and (3) to estimate/determine the values of important parameter used for the control of Activated Sludge Process. Tests conducted on sample from each location have been indicated in Table 2.

Sufficient amount of nutrients like Nitrogen (N) and Phosphorous (P) are necessary for the satisfactory growth of the microbial cell in the secondary treatment unit and

strongly affect the performance of secondary unit. Hence 'N' and 'P' tests were also performed on three samples from sampling point 1.

All of the above tests were carried out in the laboratories of "Institute of Environmental Engineering and Research (IEER), University of Engineering and Technology (UET), Lahore". Test procedures, as laid down in the Standard Methods for the Examination of water and wastewater (1998), were used and are shown in Table 3A. For the sake of performance evaluation of WWTP, three parameters i.e. TSS, BOD and COD were selected. WWTP was also designed for these three parameters.

RESULTS AND DISCUSSION

Raw wastewater characteristics of DEL

Test results of grab samples collected from sampling point 1 were used to characterize DEL raw wastewater. Table 4 shows the characteristics of raw wastewater reaching equalization tank.

It can be observed in Table 4 that significant variations occur in the equalized tannery wastewater. During the study period pH varied from 6.2 to 10.4, TSS varied from 376 to 3590 mg/L, BOD varied between 600 to 2280 mg/L and COD varied between 1360 to 4120 mg/L. The average concentrations of TSS, BOD, and COD of equalized wastewater were 1754, 1361and 2960 mg/L, respectively. This shows high suspended solid load and high organic contents in equalized wastewater of DEL. High coefficient of variation (CV) values for TSS, BOD and COD show large variations in these parameters.

Quantities of nutrients in DEL wastewater

To determine nutrients, nitrogen and phosphorous tests were performed on three samples of equalized wastewater. The results showed that the mean values of BOD: N: P for DEL wastewater was 100:18:0.13 as against the desirable ratio of 100:5:1.[15] It shows that sufficient amount of nitrogen was present in the wastewater but phosphorous was deficient. However, it was noted that no Phosphorous supplement was being added by DEL management to meet this deficiency. Furthermore, the domestic wastewater generated in the tannery from public toilets was separately disposed off. Since domestic wastewater contains high amounts of Phosphorous, therefore, this wastewater could have been added to the tannery wastewater to meet the Phosphorous deficiency. However, no such effort was made by DEL management to evaluate this possibility.

Performance evaluation of primary sedimentation tank

Characteristics of samples taken from sampling point-1 (SP-1) and sampling point-2 (SP-2) could give an insight into the performance of primary sedimentation tank. The data has been shown in Table 5.

TSS concentrations at SP-2 varied from 60 mg/L to 600 mg/L during the study period with a mean value of 277mg/L. The data is variable with its Standard Deviation of 20.5 and Coefficient of Variation of 24.3%. The removal efficiency for TSS varied greatly from 26 to 94% with an average value of about 84.2%. Mean TSS removal in PST was higher than that reported in the literature i.e. 30 to 60%[16].

BOD concentrations at SP-2 varied from 570 mg/L to 1980 mg/L with a mean value of 1097mg/L. The data is variable with its coefficient of variation of 60.7%. Removal efficiency for BOD in PST varied from 4% to 38% with average removal of about 21.2%. BOD removal in PST was somewhat lower than reported in the literature i.e. around 30%[16]. COD concentrations at SP-2 varied from 1100 mg/L to 3200 mg/L with mean value of 2164 mg/L. Removal of COD in PST varied from 3% to 68% with mean removal of 32.3%. It is also evident from Table 4 that TSS removal efficiency is higher than BOD and COD, showing that most of the suspended solids are removed in primary sedimentation tank.

Performance evaluation of secondary treatment unit

Characterization of samples from sampling point-2 (SP-2) and sampling point-4 (SP-4) was used to gauge the removal of pollutants in the secondary unit (aeration tank + secondary sedimentation tank). The data are shown in Table 6.

TSS concentrations at SP-4 varied from 106 mg/L to

Table 3: Testing procedures used

Sr. No.	Test	Test Procedure
2.	pH	4500 – H^+ B
3.	Total Solids (TS)	2540 B
4.	Total Suspended Solids (TSS)	2540 B
5.	Total Dissolved Solids (TDS)	2540 C
18.	Five Day Biochemical Oxygen Demand (BOD)	5210 B
20.	Chemical Oxygen Demand (COD)	5220 B
22.	Phosphorus (P)	4500 – PC
23.	Nitrogen (N)	4500-$_{Norg}$B

Table 4: Raw wastewater characteristics of DEL

Sample	pH	TSS	BOD	COD
1	10.2	626	720	2560
2	8.9	1208	1125	3200
3	9.2	3590	1185	3840
4	8.7	2298	600	2560
5	9.8	850	1185	2240
6	6.2	376	622	1360
7	8.9	1178	1380	3280
8	9.4	2368	2070	4120
9	10.4	2270	1950	4000
10	9.1	444	1260	2000
11	7.0	2530	1500	3400
12	7.4	2330	1320	3040
13	8.3	2260	2280	3120
14	8.3	2224	1860	2720
Range	6.2-10.4	376-3590	600-2280	1360-4120
Average	8.7	1754	1361	2960
SD	1.2	962.9	528.3	782.7
CV	13.7 %	54.9 %	38.8%	26.4%

*S.D=Standard Deviation; **C.V=Coefficient of Variation

Table 5: Performance evaluation of primary sedimentation tank (PST)

Sample No.	TSS			BOD			COD		
	SP-1	SP-2	% removal	SP-1	SP-2	% removal	SP-1	SP-2	% removal
1	626	358	42.81	720	660	8.33	*	*	*
2	1208	432	64.24	1125	1000	11.11	3200	3100	3.12
3	3590	278	92.26	1185	750	36.71	3840	1840	52.08
4	2298	176	92.34	600	570	5.00	2560	1520	40.62
5	850	240	71.76	1185	1140	3.80	*	*	*
6.	376	278	26.06	*	*	*	1360	1240	8.82
7.	1178	314	73.34	1380	855	38.04	3280	1960	40.24
8.	2368	600	74.66	2070	1620	21.74	4120	2720	33.98
9.	2270	338	85.11	1950	1605	17.69	4000	3200	20
10.	444	60	86.49	*	*	*	*	*	*
11.	2530	182	92.81	1500	960	36.00	3040	1100	63.81
12.	2330	176	92.45	1320	930	29.55	3120	2800	10.25
13.	2260	140	93.81	2280	1980	13.16	*	*	*
14.	2224	310	86.06	*	*	*	*	*	*
Range	376-3590	60-600	26-94	600-2280	570-1980	4-38	1360-4120	1100-3200	3-68
Average	1754	277	84.2	139	1097	21.2	3169	2164	32.3
S.D	963	135	20.5	530	449	12.9	846	807	22.1
C.V (%)	54.9	48.7	24.3%	38	40.9	60.7%	26.7	37.2	68.2%

* not measured

252mg/L during the study period with a mean value of 203 mg/L. The data is highly variable with its coefficient of variation of 55.9%.The removal efficiency for TSS varied greatly from 9.4% to 79% with an average value of about 46.2%.

BOD concentrations at SP-4 varied from 90 mg/L to 375 mg/L with a mean value of 199 mg/L. The data appears to be consistent with its coefficient of variation of 12.7%. Removal efficiency for BOD in secondary unit varied from 59% to 94% with average removal of about 83.6%.

COD concentrations at SP-4 varied from 500 mg/L to 1960mg/L with a mean value of 1085 mg/L. The data were variable with its coefficient of variation of 31%. Removal of COD in secondary unit varied from 25% to 85.9% with mean removal of about 58.3%.

Overall performance of WWTP

Overall performance of WWTP could be obtained from comparison of the characteristics of sampling point-1 (SP-1) and sampling point-4 (SP-4) as shown in Table 7.

It can be observed from the Table 7 that TSS removal varied from 55.8% to 92.9% with an average value of 88.8%. BOD removal varied from 60.9% to 89% with an average value of 84.5%. While COD removal varied from 33.8% to 83.5% with an average value of 62.3%. Mean effluent concentrations for TSS, BOD and COD were 220 mg/L, 199 mg/L and 1067 mg/L. The values are higher than the NEQS limits i.e. TSS= 200 mg/L; BOD = 80 mg/L and COD = 150 mg/L. The major

Table 6: Performance evaluation of secondary treatment unit

Sample No.	TSS			BOD			COD		
	SP-2	SP-4	% removal	SP-2	SP-4	% removal	SP-2	SP-4	% removal
1	*	*	*	660	270	59.09	2720	1960	27.94
2	432	226	47.68	1000	209	79.10	3100	1140	63.23
3	278	252	9.35	750	144	80.80	1840	900	51.09
4	*	*	*	570	168	70.53	1520	1140	25.00
5	240	204	15	1140	126	88.95	2760	900	67.39
6.	*	*	*	765	90	88.24	1240	500	59.68
7.	314	250	20.38	855	324	62.11	1960	1340	31.63
8.	600	168	72	1620	277	82.90	2720	1620	40.44
9.	338	198	41.42	1605	302	81.18	3200	1700	46.88
10.	*	*	*	1410	375	73.40	2200	1040	52.73
11.	506	106	79.05	2040	120	94.12	3520	600	82.95
12.	*	*	*	960	132	86.25	1100	560	49.09
13.	*	*	*	930	144	84.52	2800	860	69.29
14.	*	*	*	1980	162	91.82	3600	1020	71.67
15.	310	220	29.03	1920	150	92.19	4800	1000	79.17
Range	240-600	106-252	9.35-79.05	570-2040	90-375	59.09-94.12	1100-3600	500-1960	25-85.92
Average	377	203	46.2	1213	199	83.6	2605	1085	58.9
S.D	124	47.9	25.9	506	87	10.6	993	421	18.1
C.V	32.9	23.6	55.9	41.7	43.8	12.7	38.11	38.8	31.0

reason was low phosphorous concentration in wastewater which resulted in low microbial growth and hence low MLSS concentration in aeration basin.

pH and MLSS in aeration tank

MLSS concentration and pH in the aeration tank plays important role in the performance of activated sludge process, therefore, these were also evaluated using samples from sampling point-3 (SP-3). The results are shown in Table 8.

Table 8 shows that pH value varied from 7.5 to 8.4 in the aeration tank. This value is suitable for the growth of microorganisms. MLSS concentration in aeration tank varied from 572 to 2216 mg/L with an average value of 1346 mg/L. This value is low as compared with the generally reported value of 2000 to 4000 mg/L[17]. In order to maintain the desired value, the sludge re-circulation from secondary sedimentation tank should be increased.

From the above results, it can be concluded that non-compliance of WWTP with NEQS for the test parameters may be due to low MLSS concentration in the aeration tank and low value of the nutrient i.e. Phosphorous for satisfactory biological treatment.

COD/BOD ratio

The mean value of COD/BOD for the equalized wastewater is shown in Table 9. The value varies from

Table 7: Overall performance of WWTP

Sample No.	TSS			BOD			COD		
	SP-1	SP-4	% removal	SP-1	SP-4	% removal	SP-1	SP-4	% removal
1	*	*	*	720	270	62.50	2560	1690	33.98
2	1208	226	81.29	1125	209	81.42	3200	1140	64.38
3	3590	252	92.98	1185	144	87.85	3840	900	76.56
4	2298	282	87.73	600	168	72.00	2560	1140	55.47
5	850	204	76.00	1185	126	89.37	2240	900	59.82
6.	*	*	*	622	90	85.53	1360	500	63.24
7.	1178	250	78.78	1380	324	76.52	3280	1340	59.15
8.	2368	168	92.91	2070	277	86.62	4120	1620	60.68
9.	2270	198	91.28	1950	302	84.51	4000	1700	57.50
10.	444	196	55.86	1260	375	70.24	2000	1040	48.00
11.	*	*	*	300	120	60.00	1040	600	42.31
12.	2530	232	90.83	1500	132	91.20	3400	560	83.53
13.	2330	210	90.99	1320	144	89.09	3040	860	71.71
14.	2260	198	91.24	2280	162	92.89	3120	1020	67.31
15.	2224	220	90.11	1860	150	91.94	2720	1000	63.24
Range%	444-3590	168-282	55.86-92.98	300-2280	90-375	60-92.89	1040-4120	500-1700	33.98-83.53
Average %	1963	220	88.8	1290	199	84.5	2832	1067	62.3
S.D	871.9	30.9	10.8	578	87.9	10.7	902.5	385.7	12.6
C.V	44.4	14.1	12.2	44.8	43.8	12.7	31.8	36.1	20.2

*Values not determined

1.8 to 3.4 with a mean value of 2.2, which indicates that large portion of organic matter is non biodegradable or very slowly biodegradable.

Experimental data of COD and BOD, for equalized raw wastewater, is plotted and correlated as shown in Figure 2.

The correlation between COD and BOD was obtained from the equation of the linear regression line fitted to the plotted data and may be expressed as:

$$\mathbf{BOD = 0.41\ COD + 141.6} \qquad \mathbf{(1)}$$

Correlation coefficient (R) has a value of 0.37 which shows moderate positive correlation between the two parameters for wastewater understudy. In spite of the criticism that Equation (1), which is obtained from linear regression, is subject to considerable error[18] yet it is used as a quick way to find BOD at wastewater treatment plants for process monitoring and control[19]. Equation (1) must be used with caution. A substitution of zero for COD in equation (1) yields a value of 141.6 for BOD which is not possible. Therefore, the use of this equation is restricted and valid only when COD falls in the range of 1360-4120 mg/L (Table 4).

Statistical distribution of pH, TSS, BOD and COD in the treated effluent

Table 8: pH and MLSS concentration in aeration tank

Sample No.	pH	MLSS (mg/L)
1.	8.4	572
2.	8.34	772
3.	8.3	882
4.	7.92	1376
5.	8.35	*
6	8.33	1202
7.	7.97	2216
8.	8.11	2150
9.	8.1	1970
10.	7.54	1450
11.	7.78	1762
12.	7.73	1172
13.	7.63	1160
14.	7.59	1070
15.	8	1090
Range	7.5-8.4	572-2216
Average	8	1346
S.D	.30	507.5
C.V	3.8%	37.7 %

Table 9: COD/BOD Ratio for Equalized wastewater

COD (mg/L)		BOD (mg/L)		Average COD/BOD
Range	Mean	Range	Mean	2.2
1360-4120	2960	600-2280	1361	

The statistical distribution of pH, TSS, BOD and COD of the treated effluent (SP-4) is shown in Figure 3 to 6.

It is clear from Figure 3 that 50% of the time, pH in treated effluent remained equal to or less than 8. For about 90% of the time pH remained equal to or less than 8.3.These values are within the permissible limits of NEQS.

It is evident from Figure 4 that for about 50% of time BOD of treated wastewater concentration was equal to or less than 200mg/L and 90% of the time it reminded equal to or less than 310 mg/L. Almost all of these values are more than the limits of NEQS (80 mg/L).

Figure 5 illustrates that 50% of the time, TSS concentration in treated effluent remained equal to or less than 216 mg/L and 90% of the time remained equal to or less than 275 mg/L. All of these values are above the permissible limits of NEQS (200 mg/L).

It is clear from Figure 6 that 50% of the time COD is equal to or less than 1090 mg/L value and 90% of the time it remained equal to or less than 1630 mg/L

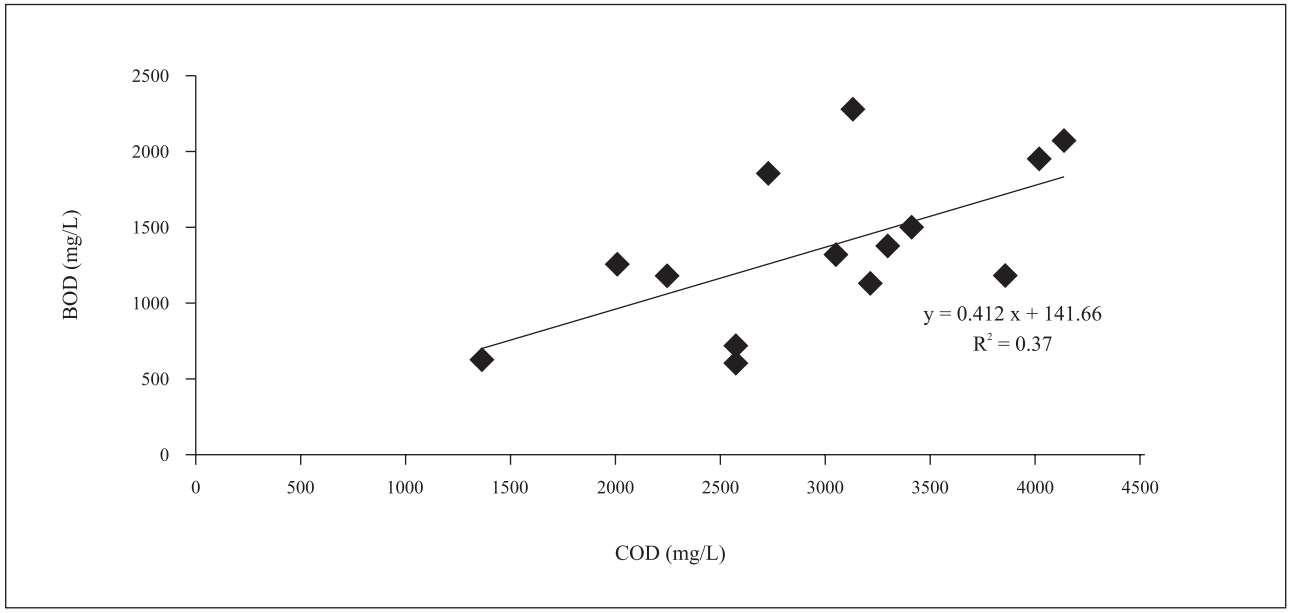

Figure 2: Correlation between COD and BOD for raw DADA tannery wastewater

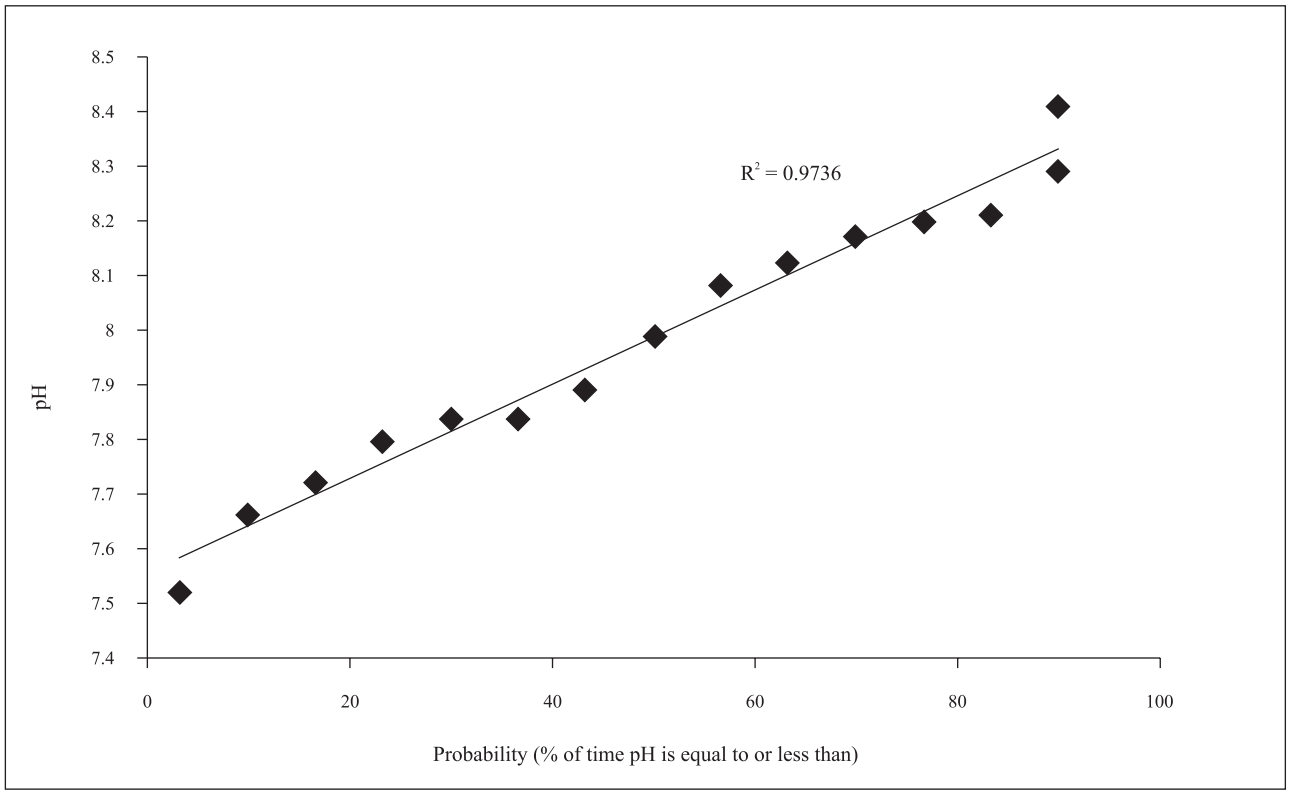

Figure 3: pH probability graph for treated effluent

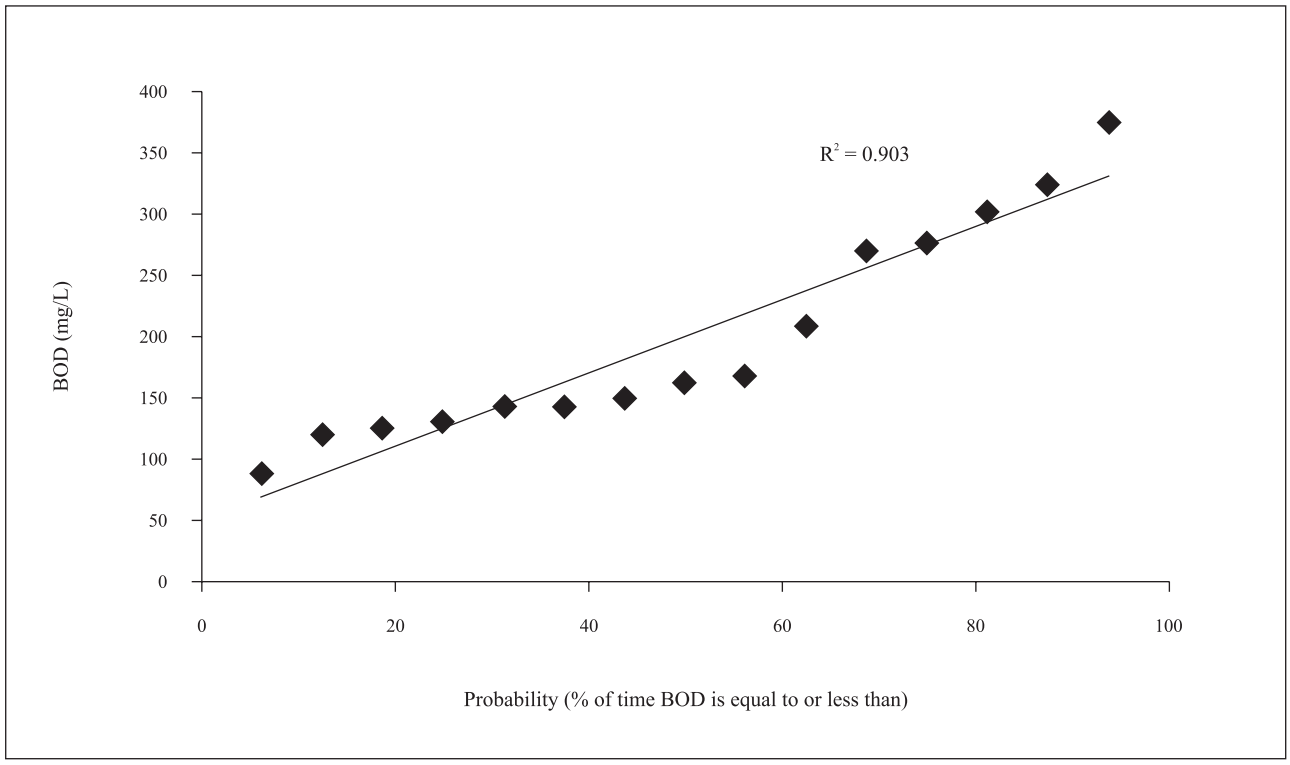

Figure 4: BOD probability graph for treated effluent

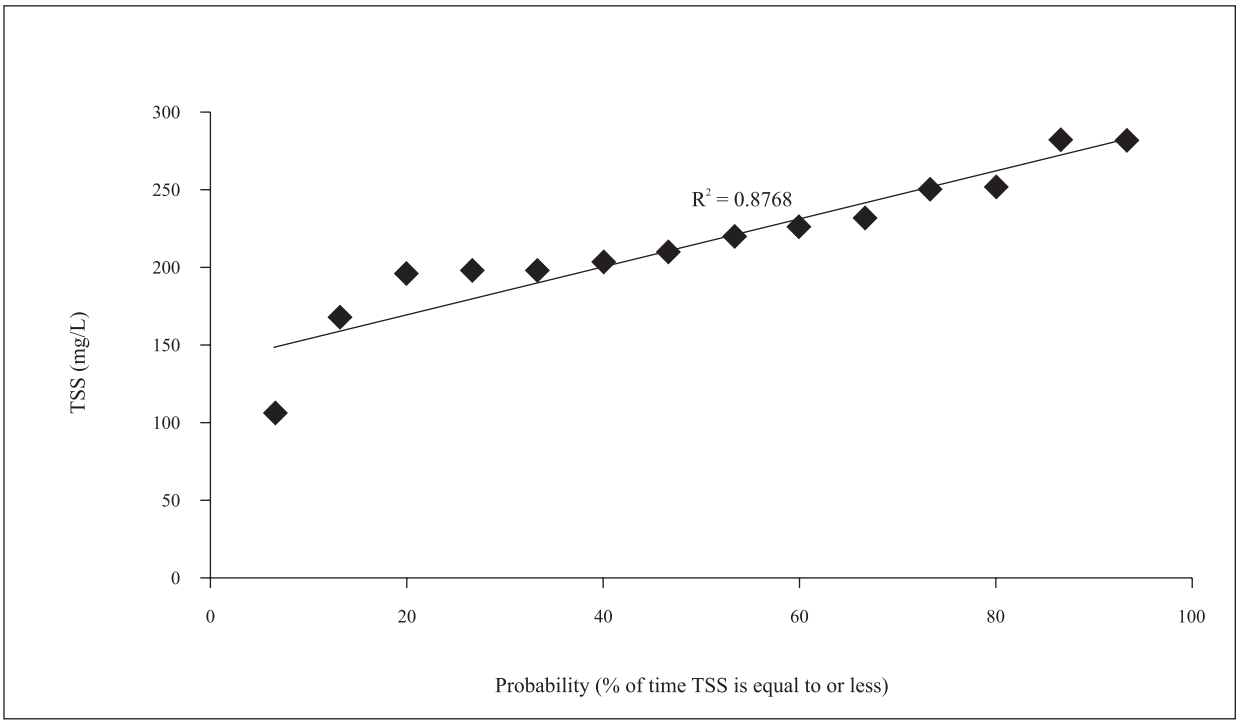

Figure 5: TSS probability graph for treated effluent

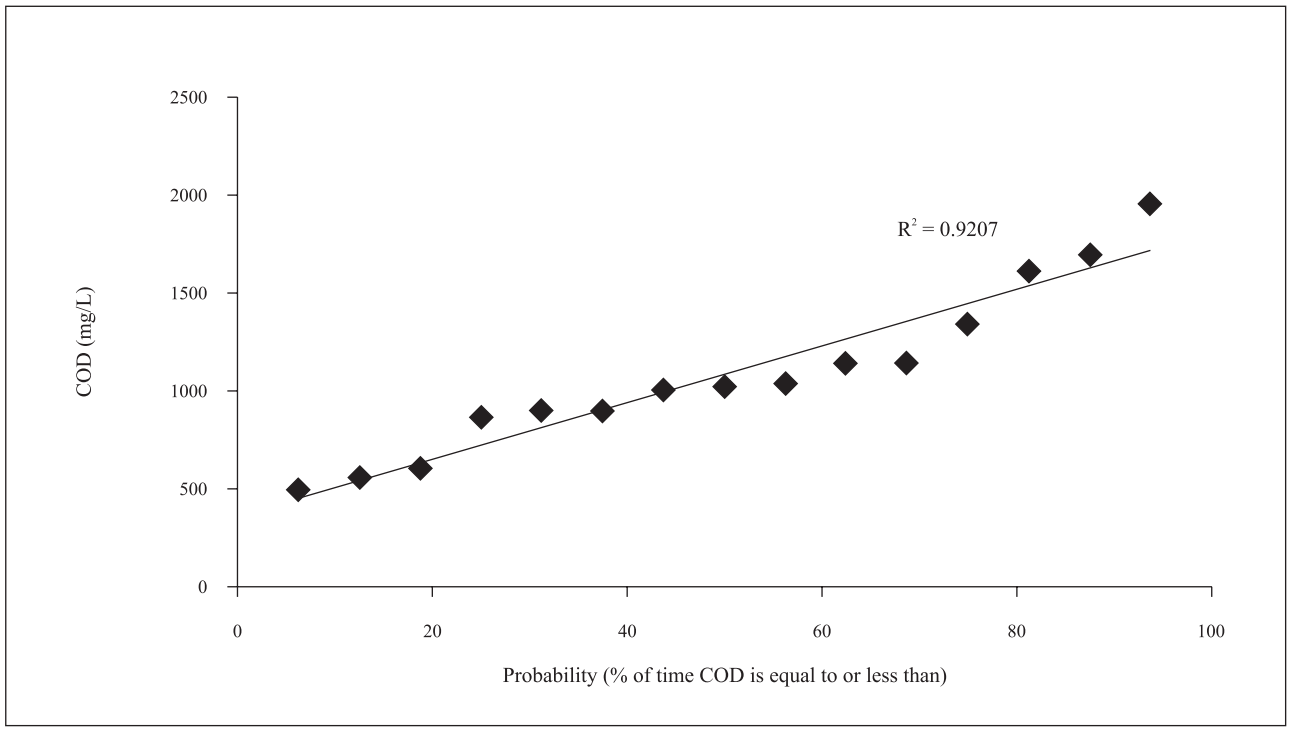

Figure 6: COD probability graph for treated effluent

Almost all of these values are more than the permissible limits of NEQS (150 mg/L).

CONCLUSIONS

1. Raw wastewater of DEL constantly varied in character. It was due to the routine processes involved in leather production and changing proportions of wastewater from these processes.

2. High BOD values in tannery wastewater indicates high organic contents and need of biological treatment.

3. DEL wastewater was deficient in phosphorous concentration which is an essential nutrient for satisfactory biological treatment.

4. Average removal of TSS, BOD and COD, in the primary treatment unit, was 84.19%, 21.19% and 32.36%, with average effluent concentrations of 277mg/L, 1097mg/L and 2164 mg/L respectively. Major portion of the suspended solids gets removed in PST unit.

5. Average removal of TSS, BOD and COD, in secondary treatment unit, was 46.2%, 83.6% and 58.3% with average effluent concentrations of 203 mg/L, 205mg/L and 1085 mg/L respectively.

6. The overall average removal, in both primary and secondary units, for TSS, BOD and COD were 88.8%, 84.5% and 62.3%, with the effluent concentration of 216 mg/L, 199 mg/L and 1023 mg/L, respectively. The effluent WWTP did not meet the NEQS for TSS, BOD and COD.

7. A mean COD/BOD value of 2.2, for raw wastewater of Dada tannery, indicated that a large portion of organic matter was non biodegradable or very slowly biodegradable.

8. Low values of MLSS in aeration tank and deficiency of phosphorous could be the possible reasons of unsatisfactory treatment efficiency of WWTP and non-compliance with NEQS. It is recommended to add a phosphorous compounds to enhance the efficiency of WWTP and hence meet NEQS.

REFERENCES

1. *Responding to Environmental Challenge, Pakistan's Leather Industry, 1999, A Brochure Published by Federation of Pakistan Chambers of Commerce and Industry under Environmental Technology Program for Industry (ETPI) Project. [available at : http:// www.p2pays.org/ref/18/17863.pdf]*

2. *Haydar, S. and Aziz, J.A., 2008, "Characterization and correlations of various pollution parameters in the tannery effluent", Mehran University Research Journal of Engineering & Technology, volume 27, No.4, pp.441-449*

3. *United Nations Industrial Development Organization (UNIDO), 1991, Conference on Ecological Sustainable Industrial Development", Copenhagen,14-18.ID/ WG.516/10 V.91-27636 7767T, Denmark.*

4. *Tunay, O., Orhan, D. and Kabdasli, I.,1994, "Pretreatment requirement for leather tanning industry wastewater", Water Science and Technology, Volume 19, No.9, UK, pp.121-128*

5. *Ahmed, J. and Shaukat, M., 2000, "An assessment of environmental concern in the leather industry and proposed remedies; Case Study of Pakistan". [available at: http://www.environmental-expert.com/ Files/0/articles/2226/2045.pdf]*

6. *Gumen, R. 2002,"Waste generation in tanning industries", proceedings of the International Conference on Pollution Control in Tanning Industry of Pakistan*

7. *National Environmental Consulting (NEC), 2007, "DEL WWTP Process Design Report", pp. 9-15*

8. *Iqbal, M., Haque, I. and Berns, J.A.S., 1998, "Draft environmental report on the leather sector in Pakistan", Environmental Technology Program for Industries Published by Federation of Pakistan, Chamber of Commerce and Industries, Federation House, Karachi, Pakistan.*

9. *Cheda, P.V., Mandledar, U.V., Handa,B.K. and Khanna, P., 1984, "Joint wastewater management for a cluster of tanneries at Kanpur", 39th Purdure Industrial Waste Conference, Lafayatte, Indiana, USA, pp.151-162*

10. *Pakistan Tanners Association (PTA),(1995), "Techno-economic study of combined effluent treatment plant for tannery clusters in Punjab", National Management Consultants, Karachi, Pakistan*

11. *Tare, V., Gupta , S. and Bose ,P.,2003, "Case studies on biological treatment of tannery effluents in India", Journal of Air and Waste Management Association, Volume 53, India ,pp.97-982*

12. *Haydar, S., Aziz, J.A. and Ahmad, M.S., 2007, "Biological treatment of tannery wastewater using Activated Sludge process" Pak. J. Engg. &Appl. Sci.Vol.1,pp.61-66*

13. *DADA Tannery, 2009. Data obtained through personal communication from the records maintained at DADA Enterprises Limited, Lahore.[available at : http://www.dada.com.pk/corporate.html]*

14. *Ali, M., 2004, " Reduction of chemical oxygen demand from tannery wastewater by oxidation", Electronic Journal of Environmental, Agricultural and Food Chemistry,Vol.3(1),pp.625*

15. *Metcalf and Eddy, Inc., 2004, "Wastewater Engineering, Treatment and Reuse",4th Edition, Mc Graw Hill, New York, USA, pp.684*

16. *Steel, E. W. and McGhee. T. J. (1991) "Water Supply and Sewerage, 6th Edition, McGraw-Hill, New York*

17. *Davis, Leo M., and David A.,2008, " Introduction to Environmental Engineering", McGraw-Hill Companies,pp.468*

18. *Berthouex, P.M. and Brown, L.C., 2002 "Statistics for environmental engineers", Lewis Publishers,USA,pp.281-287*

19. *Fair, C., 2005, "BOD: COD Correlation provides operations, laboratory benefits". [available at: http://www.pennnet.com/display_article/2307064/41/ ARTCL/none]*