Characterization and Study of Correlations among Major Pollution Parameters in Textile Wastewater

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ABSTRACT

Wastewater characterization is an integral part of treatment and management strategies for industrial effluents. This paper outlines the results of detailed wastewater characterization studies conducted for a textile mill in Lahore, Punjab. The results of this study demonstrated that the composition of textile wastewater could change continuously due to inherent nature of textile operations. In general, textile wastewater was high in temperature and alkaline in nature. It was highly polluted in terms of solids and organic content. Most of the portion of solids and organic load was in the soluble form. On the basis of mean values, temperature, pH, TDS (Total Dissolved Solids), BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) were above the limits set by NEQS (National Environmental Quality Standards) while chlorides and sulfates were below the limits set by NEQS. Prior neutralization of wastewater with an acid and addition of phosphorus and nitrogen is imperative for its effective treatment.

Key Words: **Textile Wastewater, Characterization, Biochemical Oxygen Demand, Chemical Oxygen Demand, Solids**

1. INTRODUCTION

Textile processing sector is one of the most important and largest industrial sectors of Pakistan with regard to production, source of foreign exchange and labour force employment. It alone accounts for 65% of the country's export, 46% of industrial production and 38% of employed industrial manpower [1]. There are approximately 670 textile mills in Pakistan, of which 300 are in Karachi while rest in the Punjab [2]. Textile sector earned a foreign exchange of US$ 10.56 billion in 2007-2008 [3]. For cloth production, locally available cotton is used. Textile industry is characterized by the large quantity of water consumption and the variety of chemicals used. Water is used in wet process and lies in a range of 80-150 m^3 per 1000 kg of the product [4]. Wet processes generate wastewater. Liquid wastes tend to dominate over air emission and solid wastes in terms of severity of environmental impacts [4]. In Pakistan textile industries discharge their highly polluted wastewater into the fresh water bodies adversely affecting the aquatic life and human health.

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Full-scale implementation of environmental standards (ISO-14001) in 2005 and growing concern of foreign buyers to adopt environmental friendly practices during textile production processes have forced local industry to treat their wastewater and comply with NEQS [5]. This activity is witnessed in local textile industries, especially those which are export oriented.

Reliable wastewater characterization is a prerequisite for the selection of an appropriate treatment technology and an effective design of treatment facilities. Characterization is also needed for assessing the performance of individual unit operations and processes. This is especially true for textile industry which exhibits significant differences in their processing activities generating effluents of very specific and complex nature.

The objective of this study was to carry out detailed characterization of wastewater from a local textile mill (Nishat Textile Mill), find relationship between major pollution parameters and propose a treatment methodology.

2. MATERIALS AND METHOD

For the characterization of wastewater, grab samples were collected from a suitable place inside the textile mill where wastewater from all the individual processes combined and sufficient homogenization occurred.

For the complete delineation of the quality of textile wastewater, twenty two different parameters (Table 1) were tested in the laboratories of the IEER (Institute of Environmental Engineering and Research), University of Engineering and Technology, Lahore, Pakistan. Test procedures outlined in the "Standard Methods" were used [6]. Whatman GF/C filter with pore size 1.2µm was used for TSS (Total Suspended Solids) and VSS (Volatile Suspended Solids) determinations. Five days BOD and COD tests were conducted on both raw and filtered samples to find out the total and soluble portion of organic matter in the wastewater.

SS (Settleable Solids) were measured on both volume and weight basis as described in section 2540F of the "Standard Methods". SS on volume basis is often reported in the literature. Results of SS on weight basis were used to compare it with the results obtained for other solids tests, which are usually defined on weight basis. NSS (Non Settleable Solids) were determined by subtracting the values of SS (on weight basis) from TSS. NSS actually represent colloidal solids less than 10µm size, which can not be normally removed through sedimentation process under normal surface overflow rates [7].

Wastewater sampling was extended over a period of 5 months from March-July 2008. This period was sufficient to take into account all possible fluctuations in the production process and all types of working routines in the textile mill, which ultimately affect the wastewater quality. Fifteen samples of raw wastewater were taken during the above mentioned period.

3. RESULTS AND DISCUSSION

3.1 Wastewater Characteristics

Raw wastewater characteristics of Nishat Textile Mill are shown in Table 1. The table shows the minimum and maximum value of a parameter along with the mean value and standard deviation. NEQS have also been mentioned for the purpose of comparison.

A number of important observations can be made regarding the quality of raw wastewater from the analysis of Table 1. It can be observed that variations occurred in all the parameters. Variations are inherent in textile wastewater because all production processes involved are batch processes. Timings of discharge for these processes keep varying and thus effluent composition keeps on changing. This variation can however be sufficiently narrowed down by using an equalization tank. Detention time of equalization tank is important in this respect. If a textile mill runs for 24 hours then ideally an equalization tank with a detention time of 24 hours should be provided. However, if it is not possible, then the detention time should not fall below 30% of total daily flow capacity [4]. The decision generally is governed by the space limitations and the availability of funds.

Raw wastewater had high temperature with a mean value of 38.8ºC which is more than the limit allowed by NEQS. Raw wastewater was highly alkaline in nature with a pH lying in a range of 11.2-12. It is mainly due to chemicals used in bleaching, mercerizing and dying process.

Raw wastewater was high in solids. The mean value of total solids was 4802.6 mg/L while that of settleable solids was only 102.5 mg/L, which showed that sufficiently large portion of solids was in the dissolved or colloidal form. Total alkalinity was quite high with a mean value of 2750.3 mg/L while mean values of total and calcium (Ca^{+2}) hardness was found to be 179.6 and 71.6 mg/L, respectively.

A low concentration of chlorides and sulfates was encountered in raw textile wastewater with mean values of 118.8 and 142.6 mg/L, respectively. Mean BOD and COD values of 920.7 and 2053.2 mg/L, respectively exhibited high organic contents in textile wastewater.

Phosphorus and nitrogen are needed in sufficient amounts for satisfactory biological treatment. A BOD: N: P of 100:5:1 is required [8]. For Nishat textile wastewater, this ratio, based upon average values of these parameters from Table 1, was 100:3.5:0.07. This showed that nitrogen and phosphorus were deficient and their addition was imperative for effective biological treatment.

The statistical distribution of BOD and COD data was also evaluated and is plotted in Figs. 1-2, respectively.

From Fig. 1 it can be seen that for 50% of the time BODt remained less than or equal to 940 mg/L and BODs remained 700 mg/L. For 70 percentile the BODt value was 1160 mg/L, which can be used as a design value for biological unit [9]. Similarly, in Fig. 2 it can be seen that for 50% of the time CODt remained less than or equal to 2050 mg/L and CODs remained equal to or less than 1550 mg/L. It can be observed from the value of correlation coefficient (R^2) from Figs. 1-2 that a stronger fit is depicted for the data of soluble BOD and COD.

3.2 Relationship Among Major Parameters

Experimental data regarding raw wastewater quality were further evaluated to obtain useful relationships among major parameters as shown in Table 2.

TABLE 1. CHARACTERISTICS OF RAW WASTEWATER AT NISHAT TEXTILE MILL FOR A PERIOD OF 5 MONTHS

No.	Parameter[1]	N[2]	Minimum	Maximum	Mean + SD[3]	NEQS
1.	Temperature (Centigrade)	15	33.9	42.4	38.8+2.7	37ºC
2.	Turbidity	15	56.5	289.0	177.6+63.9	-
3.	pH	15	11.2	12.0	11.6+0.2	6-9
4.	Total Solids	15	2602.0	8858.0	4802.6+1519.8	-
5.	Total Dissolve Solids	15	2575.0	8584.0	4670.8+1483.7	3500
6.	Total Suspended Solids	15	70.0	300.0	186.7+82.7	200
7.	Settleable Solids (mL/L)	15	00.0	25.0	1.9+6.6	-
8.	Settleable Solids	15	12.0	192.0	102.5+67.1	-
9.	Non Settleable Solids	15	00.0	148.0	84.2+39.5	-
10..	Volatile Suspended Solids	15	14.0	160.0	92.6+49.1	-
11.	Fixed Suspended Solids	15	28.0	238.0	95.7+59.5	-
12.	Total Alkalinity ($CaCO_3$)	15	1408.0	5000.0	2750.3+917	-
13.	Total Hardness ($CaCO_3$)	15	60.0	300.0	179.6+72	-
14.	Ca Hardness ($CaCO_3$)	15	40.0	220.0	71.6+45.8	-
15.	Chlorides	15	50.0	150.0	118.8+29.8	1000
16.	Phosphates	15	00.1	001.6	0.7+0.5	-
17.	Total Kjeldhal Nitrogen	15	14.0	110.0	32.5+23.8	-
18.	Sulfates	15	71.0	307.6	142.6+65.9	600
19.	Total Biochemical Oxygen Demand	15	300.0	1740.0	920.7+401.8	80
20.	Soluble Biochemical Oxygen Demand	15	157.5	1170.0	680.7+298.8	-
21.	Total Chemical Oxygen Demand	15	1000.0	4000.0	2053.2+778.6	150
22.	Soluble Chemical Oxygen Demand	15	700.0	3200.0	1541.4+736.7	-

[1]All Parameters in mg/L if Not Specified, [2]Number of Samples, and [3]Standard Deviation

It is evident from Table 2 that particulate BOD varied between 6.4-47.5% (of total BOD) with a mean value of 26.7%. Similarly, particulate COD varied from 12.99-46.97% (of total COD) with a mean value of 26.94 %. This showed that most of the organic matter present in textile wastewater was in the soluble form. This characteristic could have a positive effect on the biological treatment process [10].

The ratio of CODt/BODt varied between 1.28-4.0 with a mean value of 2.48 , which indicated that large portion of organic matter is non-biodegradable or very slowly biodegradable. From the experimental data correlation between these two parameters for raw wastewater were plotted as shown in Figs. 3-4.

The correlation between total COD and BOD was obtained from the equation of the linear regression line fitted to the plotted data in Fig. 3 and may be expressed as:

$$BOD_t = 0.43\,COD_t + 21.75 \quad (1)$$

An approximate value of BODt could be obtained from CODt measurement thus avoiding lengthy BOD procedure once such a relationship is established for a specific waste

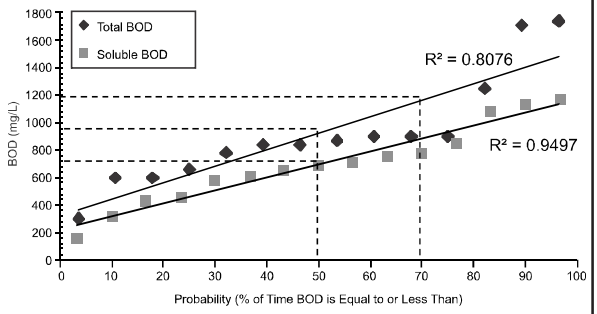

FIG. 1. STATISTICAL DISTRIBUTION OF TOTAL AND SOLUBLE BOD FOR RAW NISHAT WASTEWATER

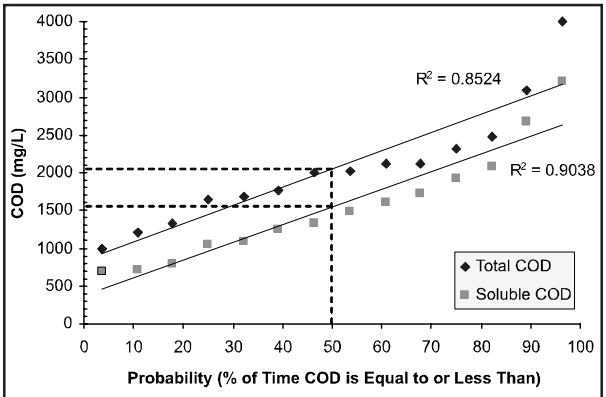

FIG. 2. STATISTICAL DISTRIBUTION OF TOTAL AND SOLUBLE COD FOR RAW UNSETTLED NISHAT WASTEWATER

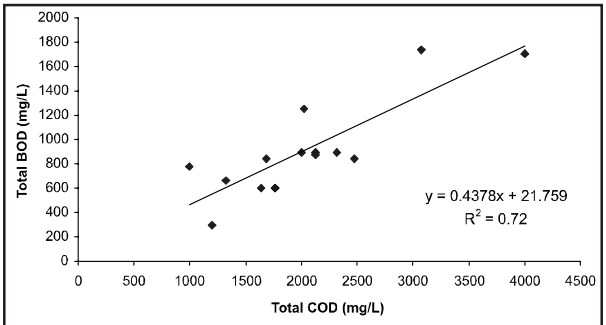

FIG. 3. CORRELATION BETWEEN TOTAL COD AND TOTAL BOD FOR RAW NISHAT WASTEWATER

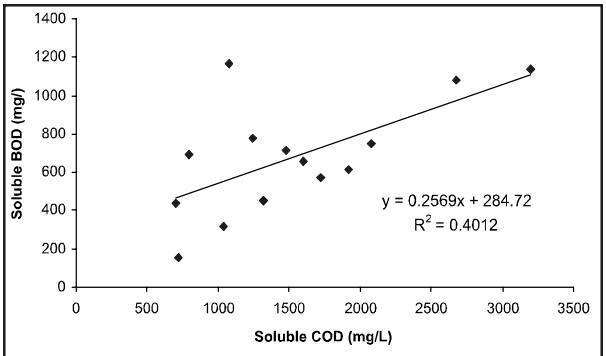

FIG. 4. CORRELATION BETWEEN SOLUBLE COD AND SOLUBLE BOD FOR RAW NISHAT WASTEWATER

TABLE 2. RELATIONSHIP AMONG MAJOR PARAMETERS FOR RAW NISHAT WASTEWATER

No.	Parameter/Relationship	Minimum	Maximum	Mean
1.	Particulate[1] Biochemical Oxygen Demand (%)	06.40	47.50	26.70
2.	Particulate Chemical Oxygen Demand (%)	12.99	46.97	26.94
3.	Chemical Oxygen Demand/Biochemical Oxygen Demand	01.28	04.00	02.37
4.	Chemical Oxygen Demand/Biochemical Oxygen Demand	00.92	04.57	02.48
5.	Volatile Suspended Solids/Total Suspended Solids (%)	11.00	07.00	52.00
6.	Total Dissolve Solids/Total Solids (%)	92.00	99.00	97.00

[1]Particulate Biochemical Oxygen Demand=Total Biochemical Oxygen Demand-Soluble Biochemical Oxygen Demand

from experimental data. Correlation coefficient (R^2) has a value of 0.72 which shows moderately strong positive correlation between the two parameters for the wastewater under study. In spite of the criticism that Equation (1), which is obtained from linear regression , is not valid due to the fact that these two tests are subject to considerable error [11] yet it is used as a quick way to find BOD_t at wastewater treatment plants for process monitoring and control [12]. Equation (1) must be used with caution. A substitution of "zero" for COD_t in the said equation yields a value of 21.75 mg/L for BOD_t, which is not possible. Therefore, the use of this equation is restricted and valid only when COD_t falls in a range of 1000-4000 mg/L (Table 1). The correlation between CODs and BODs is moderate (R2=0.4) when compared with that for COD_t and BOD_t.

It is also evident from Table 2 that in total solids, sufficiently large portion was available in the dissolved form, which varied from 92-99% with a mean value of 97% (Serial No. 6). Of the TSS, 11-70% were volatile (organic) with a mean value of 52% (Serial No. 5).

Correlations were also determined between TSS and various other parameters and are summarized in Table 3. It can be seen in Table 3 that a moderately strong correlation exists between TSS and SS while correlation of TSS with other parameters varied from very weak to moderate.

3.3 Pollution Loads

Yearly load of major pollution parameters, generated in Nishat textile, was also calculated. For this purpose mean value of wastewater flow (1000 m^3/day) and mean values of parameters reported in Table 1 were used. Nishat textile operates for 24 hours. Working days in a year was taken as 270 based upon the information supplied by the mill management [13]. The yearly load has been shown in Table 4.

It is evident from Table 3 that pollution load of various pollutants e.g. 48.6 tons of TSS, 1260.9 tons of TDS, 248.4 tons of BOD_t and 553.5 tons of COD_t is generated in the textile mill, which necessitates the provision of wastewater treatment before its final disposal in a water body. Among these BOD would cause oxygen depletion, TDS impart taste to water and restrict the use effluent for irrigation purposes. TSS on the other hand cause turbidity in stream waters.

4. CONCLUSIONS

Following conclusions can be drawn from the present study.

(i) Raw textile wastewater constantly varied in character. It was due to the routine processes involved in textile production and changing proportions of wastewater from these processes. The wastewater was highly alkaline and polluted in terms of organic and solids content.

(ii) A mean COD_t/BOD_t value of 2.37 for raw wastewater of Nishat textile indicated that sufficient amount of organic matter was non-biodegradable or very slowly biodegradable.

(iii) On the basis of average values: 97% of total solids were in the dissolved form; around 52% of TSS were volatile i.e. organic in nature.

(iv) On average, 26.7% of total BOD and 26.9% of total COD was in particulate form and rest in the soluble form.

(v) Nishat textile wastewater was deficient in nitrogen and phosphorus for effective biological treatment.

(vi) Strong correlation existed between TSS and SS.

(vii) Keeping in view the characteristics of Nishat Textile Mill wastewater, following treatment

TABLE 4. YEARLY LOAD OF PRIMARY POLLUTANT FROM NISHAT TEXTILE MILL

Pollutant	Mean Value (mg/L)	Pollution Load (Tons/Year)
Total Dissolve Solids	4670.8	1260.9
Total Suspended Solids	0186.7	0048.6
Biochemical Oxygen Demand	0920.7	0248.4
Chemical Oxygen Demand	2053.2	0553.5
[1]Ton=1000 Kg		

TABLE 3. CORRELATION OF VARIOUS PARAMETERS WITH TSS

Parameter	Biochemical Oxygen Demand	Chemical Oxygen Demand	Settleable Solids	Total Solids	Volatile Suspended Solids
R^2	0.265	0.252	0.77	0.004	0.315
Correlation	Weak	Weak	Strong	Very Weak	Moderate
R^2=Correlation Coefficient					

scheme is proposed: omit primary sedimentation tank (due low concentration of TSS), add acid to bring down the pH to about 7 and directly take the wastewater to biological treatment unit. This would be the most economical and effective treatment methodology to control pollution from textile.

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