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PRETREATMENT OF TEXTILE PROCESSING WASTEWATERS

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ABSTRACT

In this paper, the pretreatment approaches in the textile processing industry are discussed and two case studies which have been carried out in two textile processing plants are delineated. Case studies include the phases of process and pollution profiles, treatability study, conceptual design and evaluation of one-year actual treatment plant performances. One of the treatment schemes applied was chemical coagulation while the other was activated sludge. Therefore a comparison of two main types of pretreatment has been realised. Results indicate that biological treatment is more efficient and reliable in terms of organic matter removal as compared to chemical coagulation. Comparisons of cost of initial investment, cost and ease of operation, and sludge production are also made and discussed.

KEYWORDS

Textile waste treatment; pretreatment; treatment cost.

INTRODUCTION

Textile processing is one of the most common industry types in the world as well as in Turkey. Textile processing industry wastewaters have a considerable pollution load in terms of both conventional and toxic parameters. The structure of the industry varies widely. This variation gives rise to marked differences in pollutional characteristics. The textile industry has been grouped into generally more than ten subcategories for the assessment of pollutional characteristics and definition of pollution control measures suitable for each subcategory, EPA (1978). Treatment of textile wastewaters to meet direct discharge standards requires the use of combinations of preliminary treatment, biological treatment and chemical treatment. Volumes of textile wastewaters are considerable. On the other hand retention times employed in the biological treatment which is generally an extended aeration type activated sludge, are rather long (in the magnitude of days) due to the low rate of degradation and stabilization, EPA (1978). Therefore the selection of treatment system and its design parameters are of importance as far as both performance and initial and operating cost of the system are concerned. System selection is required to be based on well defined wastewater characterization and treatability data which can best be obtained from tests on the wastewaters to be treated or, especially if the factory has not been installed, can be obtained from the literature. These evaluations are even more important for pretreatment applications, because, selective and partial treatment of pollutant parameters are considered and of course the optimization of the cost and operating conditions are more important.

This paper attempts to evaluate the pretreatment approaches for the textile processing wastewaters. Two case studies in which different treatment schemes have been employed are delineated and compared considering the design approaches, performance, cost and operating factors.

PRETREATMENT ALTERNATIVES FOR TEXTILE PROCESSING WASTEWATERS

Pretreatment approaches have radically changed since 1970. The conventional pretreatment approach can be summarized as: to protect sewer and treatment systems and receiving media by limiting conventional parameters in which toxic parameters such as heavy metals, phenol are included. The limitations vary depending on whether the joint treatment system is a biological treatment or an ocean outfall with a preliminary treatment.

In this system the starting point is to combine the wastewaters in a single system so as to provide more economic treatment and ease of control while taking advantage of increasing rate of degradation of some industrial wastewaters as they are diluted with sewage. Therefore in this system organic matter loads of industries are preferred to be treated in the joint treatment. However, excessive loads may be controlled by pretreatment, especially when combined wastewaters are biologically treated. For ocean outfall systems organic matter control, although it can be based on dilution, may be more stringent than needed due to the ease of control. Sometimes organic matter and nutrients are limited to the level of domestie wastewater for the ease of control however this may give rise to difficulties for some category of industries. Toxics are controlled to protect sewer systems, sewer workers and biological treatment systems. The control is based on dilution so as to satisfy safe limits for the systems. The effects of toxics on the receiving media are not of primary concern and generally no specific criteria are applied. When biological treatment exists toxics are first pretreated to meet the safe limits to protect the systems and then are treated in the biological treatment with varying efficiencies. However in the ocean outfall systems the pretreatment limitations for toxics are rather less stringent and the control of their effects on receiving medium relies solely on dilution.

Since 1970 industrial pollution control approaches placed the emphasis on micropollutants. Both direct discharge and pretreatment standards are modified to control micropollutants. The effects and permissible concentrations of micropollutants on the receiving media are not well defined. Therefore their control is generally based on treatment technologies which are determined considering the effects of micropollutants on the sewer system, on the joint treatment, on the quality and removability of sludge produced in the joint treatment, on the removability of micropollutants in the joint treatment (pass-through) as well as on the receiving medium. Since the control basis is the treatment technology, discharge and pretreatment standards are categorical. In Europe the directives of EC require the control of dangerous substances and this control is on a sectoral basis. In U.S.A. pretreatment regulations are categorical for the industries which are of importance as far as the priority pollutants are concerned. The textile industry is controlled by the categorical pretreatment standards (WPCF, 1981).

The above discussion may help the evaluation of pretreatment applications for the textile industry. As mentioned above the full treatment of textile industry wastewaters necessitates the application of several stage treatment. Primary steps involve equalization, screening, neutralization, chemical coagulation. Second stage is a type of biological treatment. Final stage is a polishing step which involves chemical treatment and other physical-chemical processes. For most of the pretreatment purposes, except the removal of a specific substance existing in considerable concentration in the wastewater which is limited by the regulations, final stage is not needed. Then the basic alternatives for the pretreatment are primary treatment and a combination of primary and secondary treatment. In the conventional pretreatment approach, if organic matter is not limited and if the toxicity or toxic matter content of wastewaters satisfies the limits, equalization, screening and neutralization may be adequate. If toxicity removal or organic matter removal or both are required then a primary treatment involving chemical coagulation or biological treatment following screening and neutralization can be selected depending on the treatability of wastewaters and other parameters of selection i.e. cost. The same approach is valid for the categorical pretreatment needs. This result often brings the requirement of comparison of chemical coagulation and biological treatment. Below are given the main factors which can be taken as the basis of comparison.

Organic matter removal performance of chemical coagulation varies widely depending on wastewater composition. Removal, in general, is between 40 and 70 percent in terms of COD. However BOD_5 removal may be less and sometimes negative values can be obtained especially if acclimated seed is not used. Removal degree depends strictly on wastewater composition so that minor changes in wastewater characteristics can affect the efficiency. If organic matter limitation of a pretreatment process aims at domestic wastewater level, only weak wastewaters, such as that of wool finishing, which requires only a minor reduction, can be treated by chemical coagulation. For other wastewaters, chemical coagulation can only be applied after obtaining extensive treatability data representing all possible character of wastewaters. On the other hand, organic matter removal of biological treatment is well documented. Treatment efficiency is over 80 percent steadily in terms of both COD and BOD_5 and generally over 90 percent especially if extended aeration type of activated sludge process is employed (EPA, 1978).

Toxics removal efficiencies of both processes have not yet been fully determined. Conventional toxic parameters such as heavy metals can be efficiently removed by chemical coagulation depending on the pH of operation. Priority pollutant removal efficiencies vary. Biological treatment detoxifies wastewaters especially dyeing wastewaters and seems to be more effective as compared to chemical coagulation. However, toxics removal efficiencies for both systems can be predicted on a case by case basis by conducting treatability tests.

One of the most important factor in system selection is the initial investment cost of the system. Initial investment cost of biological treatment is at least 40 percent higher than that of chemical coagulation. Cost increase depends on the rate of degradation, in other words the volume of the aeration tank and degree of stabilization required and sludge production rate.

Cost of operation for biological treatment consists of neutralization agent and nutrient additions and electricity requirement. However chemical coagulation operating costs are mainly due to chemicals and on a unit wastewater volume basis these are much higher than total operating cost of biological treatment.

Ease and reliability of operation is another factor of selection. Biological treatment generally copes with changing influent quality without significant loss of efficiency especially if it is an extended aeration type. For conventional systems adequate equalization must be provided. Operation of biological treatment does not require much care and any type of intervention, provided that the pH is within the acceptable limits and nutrients are fed properly. Chemical treatment cannot work without continuous adjustments and follow-ups. For proper operation especially if the equalization is not adequate, which is the case for many chemical coagulation systems because it adds much to investment cost, optimum dose of chemicals must be set at least once or twice a day. The efficiency of the system for varying influent quality cannot be predicted even though the optimum dosages are found.

Sludge production of biological treatment depends on organic loading. For extended aeration systems sludge production is 0.2 kg/kgBOD removed or lower.

Sludge is stabilized and easy to handle and dewater. Chemical coagulation produces considerably higher amounts of sludge. Amount of sludge is a function of influent suspended solids content and dosages of chemicals. An average coagulant dosage for most of the textile processing wastewaters is about 500 mg/l ferric or ferrous salt. Lime is added to provide alkalinity. For this condition the sludge production is about 3 kg/m^3 wastewater treated. This amount is roughly 30 times greater than biological sludge production. Generally volume of chemical sludge is more than 10% of the wastewater being treated. Dewatering is not easy and may require polyelectrolyte addition.

CASE STUDIES

Two textile factories both located in Istanbul are the subject of study. Case studies include production and pollution profiles, treatability studies, treatment plant design and performance testing and evaluation.

Plants

Erdoğan Dye-House treats cotton and synthetic blend knit fabrics employing sodium chlorite and hydrogen peroxide bleaching and dyeing operations. Reactive and direct dyes are used. Capacity of the plant is 300 ton fabric/year.

Kom Textile Plant treats synthetic and cotton knit fabric. Synthetics are dyed using acid, metal complex and disperse dyes. Cotton blends are mercerized, bleached with hydrogen peroxide and dyed with reactive dyes. Capacity of the plant is 5000 ton/year.

Wastewater Amount and Characterization

Erdoğan Dye-House works alternately with reactive and direct dyes while chlorite bleaching is continuous. For the 2 modes the process and pollution profiles differ. Based on the production data and a source-based wastewater characterization study a pollution profile of the plant is prepared. This profile is given in Table 1.

TABLE 1-Pollution Profile of Erdoğan Dye-House

Process	Production	Wastewater		BOD_5			COD		
	ton/day	m^3/day	m^3/ton	mg/l	kg/ton	kg/day	mg/l	kg/ton	kg/day
Chlorite bleaching	2.25	14.0	6.2	1800	11.2	25.1	4430	27.5	61.8
H_2O_2 bleaching	0.72	36.0	50.0	250	12.5	9.0	500	25.0	18.0
Reactive dyeing	0.72	54.0	75.0	250	18.8	13.5	670	50.3	36.2
TOTAL A	2.97	104.0	35.0	458	16.0	47.6	1115	39.0	116.0
Chlorite bleaching	2.25	14.0	6.2	1800	11.2	25.1	4430	27.5	61.8
Direct dyeing	2.20	23.5	10.7	707	7.5	16.6	1750	18.7	41.1
TOTAL B	4.45	37.5	8.43	1112	9.4	41.7	2744	23.1	102.9

Kom Textile Plant had not been installed at the time of treatment plant selection. Therefore the determination of wastewater amounts and characterization was realised using production data and the data from the literature. Prepared pollution profile is given in Table 2. This profile predicts a 390 mg/l BOD_5 for total wastewaters. This evaluation was checked after the plant had started. Actual characterization for total wastewaters yields a BOD_5 range of 240-320 mg/l with an average value of 300 mg/l.

TABLE 2-Pollution Profile of Kom Textile Plant

Process	Production	Wastewater		BOD5	
	ton/day	m^3/day	m^3/ton	kg/day	kg/ton
Nylon dyeing (acid dye)	1.5	100.0	66.7	15.0	10.0
Nylon dyeing (metal complex dye)	0.3	14.4	48.0	1.5	5.0
Nylon dyeing (disperse dye)	0.6	36.0	60.0	7.9	13.2
Polyester dyeing	1.2	48.0	40.0	28.0	23.3
Mercerizing	4.8	96.0	20.0	72.0	15.0
Bleaching	5.6	89.6	16.0	25.2	4.5
Reactive dyeing	6.4	36.0	5.6	3.8	0.6
Washing	6.4	96.0	15.0	38.4	6.0
Color removal	0.3	25.0	83.3	20.0	66.7
		541.0		211.8	

Treatability

Treatability studies were carried out on Erdoğan Dye-House total wastewaters for both working modes. Biological treatability was investigated using a bench scale batch activated sludge unit. Sludge is acclimated to direct dyeing mode total wastewaters. Wastewaters are screened through 0.5 mm sieve, neutralized and nutrients are added before feeding. Istanbul Water and Sewerage General Directorate pretreatment regulations are taken as the basis for treatability. Pretreatment limits are given in Table 3.

TABLE 3-Pretreatment Limits (Partial List)

Parameter	Limit (mg/l)
BOD5	250
COD	800
TSS	350

Table 4 shows the results of biological treatability tests for direct dyeing mode, B.

TABLE 4-Biological Treatability Results of Direct Dyeing Mode, B

q	BOD5 (mg/l)		COD (mg/l)	
day^{-1}	Initial	End	Initial	End
0.16	1050	410	2850	624
0.26	1050	260	2850	326

Extrapolation of the above results gives the organic loading of 0.125 day^{-1} to obtain 200 mg/l BOD5 effluent concentration. Reactive dyeing wastewaters are fed to direct dyeing treating system without acclimation. At the beginning of the experiment the removal is over 80% and full performance is achieved within 10 days. Table 5 shows the results of biological treatability tests for reactive dyeing mode, A.

TABLE 5-Biological Treatability Result of Reactive Dyeing Mode, A

q	BOD5 (mg/l)		COD (mg/l)	
day^{-1}	Initial	End	Initial	End
0.15	540	40	1170	300

Chemical treatability studies are run on jar test equipment. Two samples of Direct Dyeing mode were used. For the first sample, which had a COD of 2930 mg/l, alum and ferric and ferrous salts were tried. Alum was tried up to 600 mg/l dosages at pH between 5-7 with polyelectrolyte addition however the results were not satisfactory. Ferrous sulphate does not work up to 500 mg/l even at high pH. Ferric chloride was found to be the best coagulant which provided 40% COD removal at the optimum dosage of 400 mg/l at pH 9. pH correction was made using lime. Second sample, which had 3320 mg/l COD and 1150 mg/l BOD_5, was tested in a similar manner and best result was obtained again with ferric chloride with non-ionic polyelectrolyte of 5 mg/l which gave 30% COD and 25% BOD_5 removal at 500 mg/l dosage and pH of 9.0. Chemical treatability test on a weak Reactive Dyeing mode had a better performance. Results of the studies are shown in Table 6 for optimum dosages.

TABLE 6-Chemical Treatability Test Results for Reactive Dyeing Mode, A

Chemical	Dosage mg/l	Polyelectrolyte (anionic), mg/l	pH	COD mg/l			BOD_5 mg/l		
				Inf.	Eff.	%Rem.	Inf.	Eff.	%Rem.
Alum	400	5	6	300	202	33	170	90	47
$FeCl_3$	250	5	9	300	148	50	170	60	65

Conceptual Design

Poor results of chemical treatability for Direct Dyeing mode wastewaters led to the adoption of biological treatment for Erdoğan Dye-House. Considering the lowest organic loading required for Direct Dyeing mode which also provides satisfactory removal for Reactive Dyeing mode an organic load of 0.085 day^{-1} was selected. This loading is assumed to satisfy the pretreatment limits at influent BOD_5 of 1200 mg/l and meets the organic loading value of Reactive Dyeing mode for influent concentration of 500 mg/l BOD_5.

Treatment scheme of Erdoğan Dye-House is given in Figure 1. Design data are outlined in Table 7.

Wastewater characterization of Kom Textile Plant indicates a relatively low treatment requirement. On the other hand wastewater treatability of similar plants in the literature predicts adequate efficiency. Therefore chemical coagulation was selected as the basic system for the pretreatment of Kom Textile Plant. Treatment scheme and design data are given in Figure 2 and Table 8 respectively.

TABLE 7-Design Data of Erdoğan Dye-House Treatment Plant
Design Flow: 37.5 - 104 m^3/day

Unit	Specification
Equalization	181 m^3 net volume
Screening	Opening 0.5 mm
Neutralization	retention time: 38.4 - 14 min
Aeration tank	retention time: 1.4 - 3.92 days
Settling tank	surface loading: 2.3 - 6.5 m^3/day

TABLE 8-Design Data of Kom Textile Treatment Plant
Design Flow: 700 m^3/day

Unit	Specification
Equalization	450 m^3 net volume
Flash mixing	retention time: 5.5 min
Flocculation	retention time: 39 min
Settling	parallel plate
Neutralization	retention time: 25 min

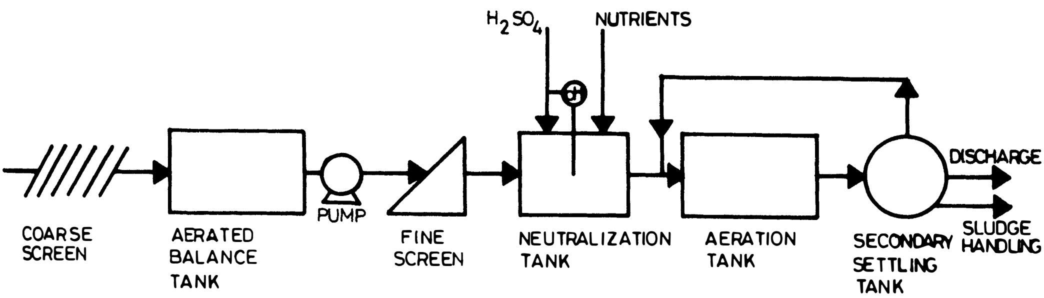

Figure. 1. Treatment scheme of Erdoğan Dye-House

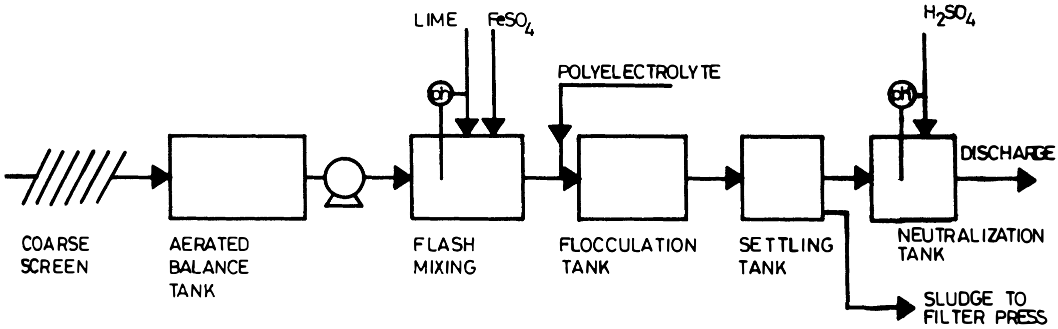

Figure. 2. Treatment scheme of Kom Textile

Performance

Performance of Kom Textile treatment plant was monitored with four experimental programs. Each program covered two consecutive days. For all programmes the difference between COD and BOD_5 values of two days was not greater than 10% . Samples are 24 h composite. Table 9 shows the results of the program where the two-day averages are given.

TABLE 9-Kom Textile Treatment Plant Performance

Program	COD (mg/l)			BOD_5 (mg/l)		
	Inf.	Eff.	%Rem.	Inf.	Eff.	%Rem.
1	422	263	38	146	246	-
2	647	345	47	238	206	13
3	756	448	41	307	243	21
4	513	367	28	269	255	5

As shown on the table the pretreatment limits are satisfied except for only Program 4 BOD_5. Removal efficiencies of COD are in the order of predicted values. However, BOD_5 removal is erroneous. The peculiarity of BOD_5 removal is due to toxicity. COD/BOD_5 ratio of the effluent is always lower than the influent. Although the ratio for the influent does not indicate a high toxicity it significantly affects the BOD_5 values. Thus, it may be concluded that chemical coagulation provided a low degree of organic matter removal together with some degree of toxicity removal.

Performance of Erdoğan Dye-House was tested with two sampling programs as the plant is working with direct dye. Samples are again hourly composite for 24 hours. Results are given in Table 10.

TABLE 10-Performance of Erdoğan Dye-House Treatment Plant

Program	COD (mg/l)			BOD_5 (mg/l)		
	Inf.	Eff.	%Rem.	Inf.	Eff.	%Rem.
1	1432	563	60	876	184	82.6
2	1015	607	40	754	142	80.5

The above results were obtained at the organic loading of 0.1 day^{-1}. Therefore the results are very close to treatability indications and the system is not overdesigned.

Sludge production of Kom treatment plant as an average of one year is 2.9 kg/m^3 water treated. The volume of the sludge is 13% of treated wastewater. Sludge production of Erdoğan Dye-House treatment plant is slightly lower than 0.2 kg/kg BOD_5 removed.

Electricity consumption of Kom and Erdoğan treatment plants are 0.9 and 2.3 kWh/m^3 water treated respectively.

CONCLUSIONS

Evaluation of the literature data and results of case studies indicate that the selection of pretreatment system of textile processing wastewaters must be on a case by case basis. Selection and design basis can best be deduced from treatability data. If wastewaters have not been produced, a synthetic waste may be produced in the laboratory for treatability tests. Chemical coagulation provides removal of organic matter. Degree of removal varies with influent quality but generally is not more than 50 % in terms of COD for especially the textile plants employing soluble dye stuffs. BOD_5 removal, however, is unpredictable. Biological treatment on the other hand is a proven and reliable technology for textile wastewaters and provides the desired efficiency for organic matter removal if designed properly. Toxics removal of biological treatment can also be predicted. Comparison of the two systems based on case study data is given below.

Area requirements are 1.9 m^2/m^3.d wastewater for Erdoğan Dye-House and 0.4 m^2/m^3.d wastewater for Kom Textile. Initial investment of chemical treatment is 150,000.-TL/m^3 wastewater while it is 250,000.-TL/m^3 wastewater for biological treatment.

Sludge production of chemical treatment is 2.9 kg dry matter/m^3 wastewater. Biological treatment results in 0.12 kg dry matter/m^3 wastewater. Chemical sludge is high in volume and difficult to handle.

Operating costs including chemicals and electricity are 850 TL/m^3-day for chemical coagulation and 390 TL/m^3-day for biological treatment. Personnel requirement or attendance is higher for chemical coagulation.

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