Pollutants of Textile Industry Wastewater and Assessment of its Discharge Limits by Water Quality Standards

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Abstract

Textile industry is one of the most important and rapidly developing industrial sectors in Türkiye. It has a high importance in terms of its environmental impact, since it consumes considerably high amounts of processed water and produces highly polluted discharge water in large amounts. Textile mills in Türkiye are required to control their discharge and therefore have started installing treatment plants in the name of environmental protection.

The wastewater treatment plants of 11 textile mills in the woven fabric and knit fabric finishing industry were investigated in this study. Performances of the treatment plants were evaluated by in situ inspections and analyses of influent and effluent samples. The cost of the existing treatment plants is also evaluated.

For the treatment of textile industry wastewater, biological treatment, chemical treatment and combinations of these are used. Plants utilizing biological treatment rather than chemical processes claim that their preference is due to less excess sludge production, lower operational costs and better COD removal in biological treatment.

Waste water parameters in the effluent of biological treatment plants were in compliance with the ISKI (Istanbul Water and Sewerage Administration) discharge standards.

However, if sodium sulphate in dyeing process and sulphuric acid in neutralization processes are used before a biological treatment, sulphate in the effluent exceeds 1700 mg/l. This problem can be avoided by using HCl or CO_2 rather than H_2SO_4 in neutralization and NaCl instead of Na_2SO_4, if the use of Na_2SO_4 is not necessary.

Key words: Phytoplankton, estuarine, pollution, tide, floodwaters, creek.

Introduction

The textile industry uses vegetable fibres such as cotton, animal fibres such as wool and silk, and a wide range of synthetic materials such as nylon, polyester, and acrylics. The production of natural fibres is approximately equal to the amount of production of synthetic materials (of which polyester accounts for about half) (Commission, 2002). Because textile operations produce so much wastewater, mills may be tempted to assume that they cannot avoid large volumes of wastewater, and therefore, they may become lax in pollution prevention. In practice, mills vary considerably in the amount of water and wastewater pollutants they discharge. One essential and often difficult step in water pollution prevention is to accurately and realistically assess the current status of mill and its potential for improvement. This assessment is necessary to target specific waste streams that will maximize pollution prevention. The first step in a pollution prevention strategy for water is a thorough audit and characterization of wastewater from textile operations (Wood, 1992). Comparing the information from this audit with benchmark data allows for realistic goal-setting and economic projections for water pollution reduction activities. Several options exist for benchmarking an operation and, hence, for identifying pollution prevention targets. Fibres used in the textile industry can be divided into two main categories: natural fibres (e.g. wool, hair, silk, cotton, flax etc.) and synthetic fibres (e.g. rayon, nylon etc.) (Sahin, 1996). Pollutants in wastewater from textile factories vary greatly and depend on the chemicals and treatment processes used. Pollutants that are likely to be present include suspended solids, biodegradable organic matter, toxic organic compounds (e.g. phenols), and heavy metals (URL 1).

Many studies have been published on water pollution from textile operations. Brown and Anliker summarised the effects of textile effluent on the environment and the toxicity with respect to fish and other aquatic organisms, sewage bacteria and plants (URL 2). For example, suspended solids can clog fish gills, either killing them or reducing their growth rate. Other important impact, they also reduce light penetration. This reduces the ability of algae to produce food and oxygen (URL 3).

The other parameter, sulphates ($SO_4^{=}$) can be naturally occurring or as a result of municipal or industrial discharges. Point sources include sewage treatment plants and industrial discharges such as tanneries, pulp mills and textile mills. Sulphates are not considered toxic to plants or animals at normal concentrations. In humans, small concentrations cause a temporary laxative effect. However, doses of several thousand units cause all long-term illness effects. Sulphates are toxic at very high concentrations. Problems caused by sulphates are most frequently related to their ability to form strong acids which changes the pH. In this way, phosphates are not toxic to humanbeings or animals unless they are present at very high levels. Digestive problems could occur from extremely high levels of phosphate (URL 1).

Textile industry in Türkiye is concentrated in Istanbul where there exist 116 plants that are specifically treating wastewaters of textile industry. Seventeen of these treatment plants are biological, 83 are chemical, 14 are chemical and biological, and 2 are physical and chemical (Ucar, 1995).

The discharge standards for the textile industry in Istanbul are set by Istanbul Water and Sewerage Administration (ISKI), which also controls and inspects the industrial wastewater discharges. Industries are required to pretreat their wastewaters to meet the standards set by ISKI, according to which they are allowed to be discharge to the city sewer system (ISKI, 1994).

In this study, 11 textile mills that have treatment facility were chosen to investigate their material production, use of processed water, wastewater production, and treatment facility. The cost of treatment from these plants is also investigated. The products and processes of these 11 mills are summarized in Table 1.

When these industries were selected, waste water treatment plants that included different treatment methods were considered. The chemical and/or biological treatment methods used in the treatment of textile industry wastewater were characterized, problems in treatment plants were explained and solutions were proposed.

Materials and Methods

The most important parameters in wastewater from textile industry are COD (Chemical Oxygen Demand), BOD_5 (Biological Oxygen Demand), pH, fats, oil, nitrogen, phosphorus, sulphate and SS (suspended solids) (Tufekci *et al*., 1998). The influent

Table 1. Production and wastewater flow rates of the mills investigated

Mill	Material	Process	Dyeing	Wastewater Flow (m^3/day)
A	Cotton	• Cotton Knitting • Dyeing • Washing • Kasar	• 90% Reactive • 10% Direct	Dyeing: 150 Washing: 90 Total: 240
B	Cotton	• Cotton Knitting • Kasar • Dyeing	• 90% Reactive • 10% Direct	300
C	Cotton	• Weaving • Jeans Dyeing • Jeans Washing		Dyeing: 100 Washing: 240 Total: 340
D	Cotton	• Kasar • Dyeing • Washing	• Reactive	400
E	Polyester	• Socks Knitting • Dyeing • Washing		20
F	Cotton	• Kasar • Dyeing	• 85% Reactive • 10% Direct • 5% Pigment	300
G	Cotton	• Jeans Washing • Cloth Making		250
H	Cotton Polyester	• Kasar • Dyeing • Cloth Printing	• 80% Reactive • 10% Direct • 10% Pigment	300
I	Polyester	• Cord Production • Cord Dyeing	• Dispersive	60
K	Polyester Wool Acrylic	• Cord Production • Dyeing	• 40% Acrylic • 20% Polyester • 40% Wool	95
L	Cotton Polyester	• Cord Production • Mercerized • Kasar • Dyeing	• Reactive • Direct	Polyester Dyeing:20 Cotton Dyeing:150 Total: 170

and effluent characteristics and efficiencies of treatment plants of the mills, most of which are cotton-fabric refining mills and polyester, wool, acrylic, were investigated in this study. The effluents values are average of at least 6 samples taken at arbitrary times (Table 2). The effluent concentrations of BOD_5, COD, SS, TKN (Total Kjeldahl Nitrogen), TP (Total Phosphor) and Grease were analyzed according to Standard Methods (APHA, 1998).

Results

These analyses along with the discharge standards set by ISKI and indicated in the Water Pollution Control Regulation (SKKY) (ITKIB, 1995) are also presented in Figure 1 to 8.

It is seen in Table 2 that all the parameters from mill A are under the discharge limits, except for BOD_5 and sulphate. The results of analysis however imply that the treatment plant is operated only when it is inspected by the authorities. When the effluent characteristics of mill B are examined closely, the treatment efficiency is close to 90%. The fact that effluent suspended solids (SS) and BOD_5 values are quite low implies that the sample might have taken from the supernatant of the final sedimentation tank. Despite some violations of the limits for BOD_5 COD, total sulphur and pH, it is seen that the treatment facility of mill C was operated efficiently enough.

The treatment facility at mill D treats 300 m^3/day industrial wastewater on top of 100 m^3/day municipal wastewater. It works with high efficiency. However, the raw water characteristics of this treatment plant are not above the discharge limits. When the influent and effluent values are compared, it seems that a two-stage treatment may not be necessary for this mill. The analysis carried out at the treatment plant of mill E shows that TKN, COD and SS were above the discharge limits of ISKI at 50% of all times. It is seen in Table 2 that the treatment plant of mill F was one of the low efficiency facilities. However, this did not pose a significant problem for the firm, except for BOD_5 and COD. Apart from SS, there was not a single parameter that caused a problem for mill G, which is a jeans-washing facility.

When the values given in Table 2 are compared to the discharge limits, it is seen that the additional activated carbon unit to the prefabricated chemical treatment facility is not really necessary for this mill. The effluent values of mill H is one of the lowest. When the effluent analysis from mill K is examined, it is seen that they have a chronic nitrogen problem. The treatment efficiency for the other parameters is not very satisfactory either. For this mill, where wool

Table 2. Measured influent and effluent values and removal efficiencies

Mill	A			B			C			D		
Parameter	Inf	Eff.	Rem.	Inf	Eff.	Rem.	Inf	Eff.	Rem.	Inf	Eff.	Rem.
BOD_5 (mg/l)	293	42	86	370	26	93	600	152	75	420	30.3	93
COD (mg/l)	614	120	80	714	92	87	1200	518	57	980	200	80
SS (mg/l)	56	22	60	120	9	92	300	96	68	300	32	89
TKN (mg/l)	10	7.4	26	10	8	20	30	15.2	49	20	11.3	43
TP (mg/l)	1.3	0.7	46	2	0.8	60	2	0.34	83	4	3.6	10
Grease (mg/l)	34	4	88	40	4	90	50	13	74	40	6.7	83

Mill	E			F			G			H		
Parameter	Inf	Eff.	Rem.	Inf	Eff.	Rem.	Inf	Eff.	Rem.	Inf	Eff.	Rem.
BOD_5 (mg/l)	1140	181	84	715	363	49	520	162	69	410	48	88
COD (mg/l)	1960	877	55	1130	780	31	1030	599	42	900	129	86
SS (mg/l)	653	247	62	420	109	74	670	431	36	230	10	95
TKN (mg/l)	60	49	18	43	27	37	37	17.6	52	19	14.6	23
TP (mg/l)	11	3	73	9	4	55	2,8	0.7	75	2.4	0.2	92
Grease (mg/l)	133	62	53	97	31	68	71	19.4	73	48	6	87

Mill	I			K			L		
Parameter	Inf	Eff.	Rem.	Inf	Eff.	Rem.	Inf	Eff.	Rem.
BOD_5 (mg/l)	974	186	81	615	242	61	280	112	60
COD (mg/l)	1740	636	63	1605	800	50	720	298	59
SS (mg/l)	600	77	87	470	288	39	180	33	82
TKN (mg/l)	11	1,8	84	92.5	53	43	17	9	47
TP (mg/l)	3	0,33	89	4	0.3	92	3	1	66
Grease (mg/l)	120	65	46	127	32	75	52	9.2	82

Inf.: Influent
Eff.: Effluent
Rem.: Removal Efficiency (%)

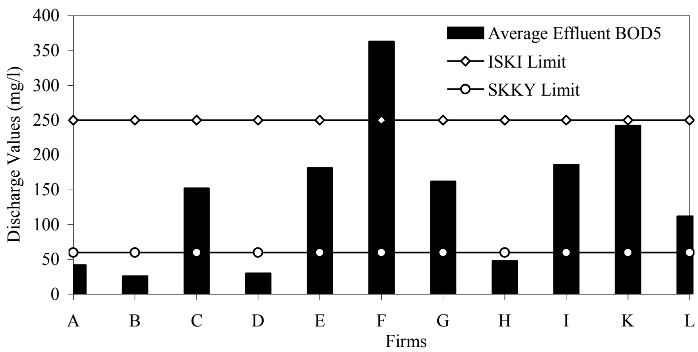

Figure 1. Average effluent BOD_5 from the mills.

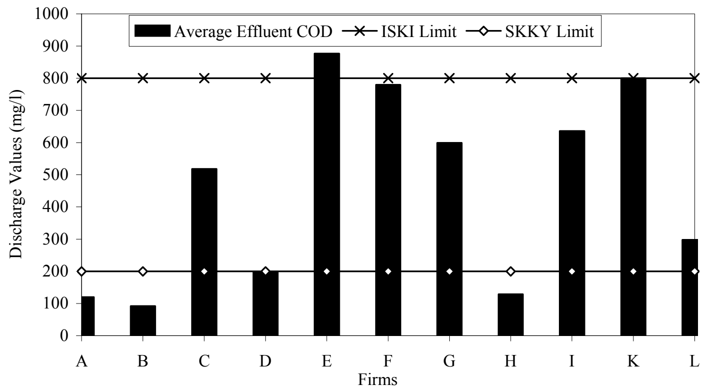

Figure 2. Average effluent COD from the mills.

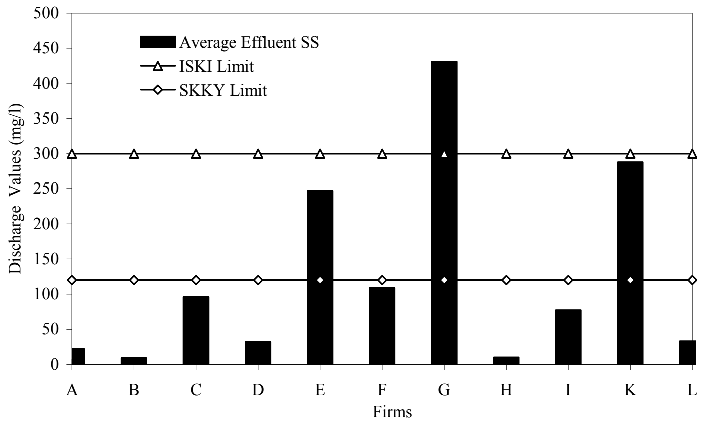

Figure 3. Average effluent SS from the mills.

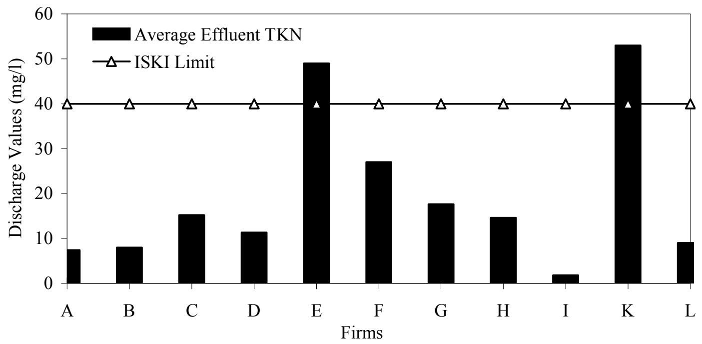

Figure 4. Average effluent TKN from the mills.

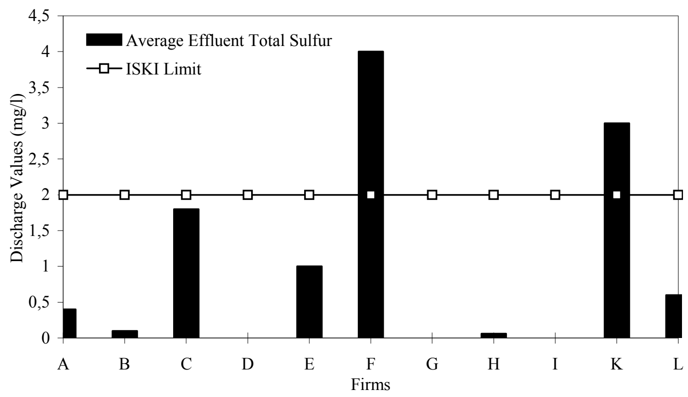

Figure 5. Average effluent total sulphur from the mills.

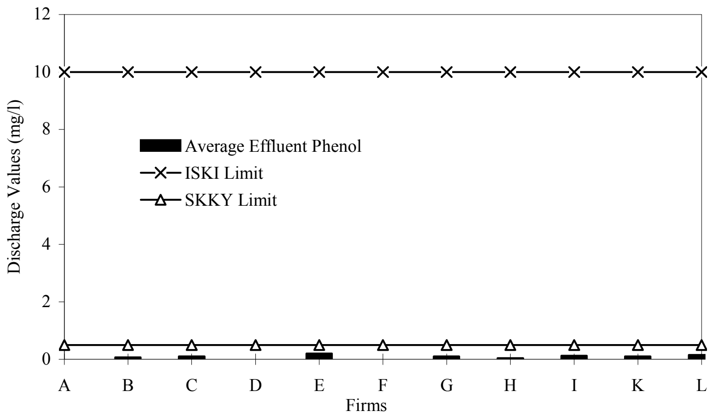

Figure 6. Average effluent phenol from the mills.

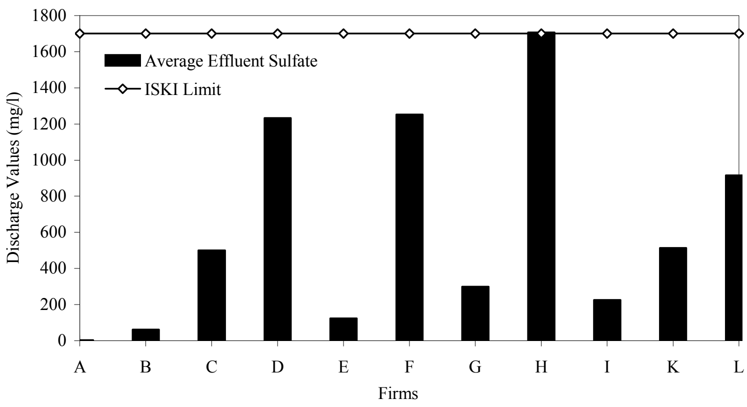

Figure 7. Average effluent sulphate from the mills.

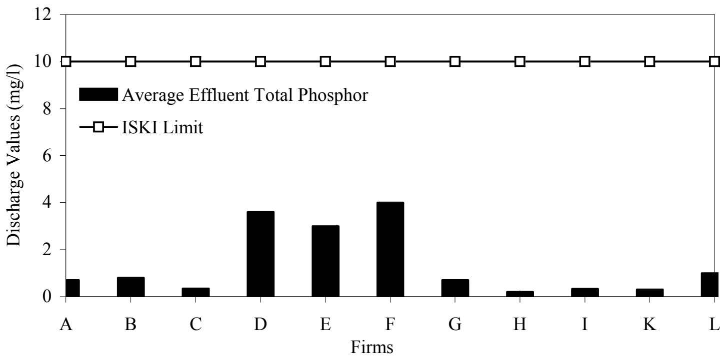

Figure 8. Average effluent phosphorus from the mills.

dying with acrylic is also carried out, a combination of chemical and biological treatment should produce better results. The influent values of mill L, which also have a mercerizing unit, are relatively low. However, the treatment efficiency of this plant is satisfactory.

Cost of Treatment

The cost of the treatment facilities of the textile industries investigated in this study is given in Figure 9. The cost of the chemicals included in calculations in Figure 9 is based on the unit prices as of April 2005.

The cost of electricity is based on the present motor power of the facility and the assumption that the treatment facility is operated 24 hours. The mills that do not have maintenance cost declared that they carry their maintenance on their own.

The yearly equivalence of the capital cost is calculated by assuming a 10-year operational life and 20% yearly interest. The total cost per unit wastewater for each mill includes the capital and operational costs.

Discussion

It is observed in this study that 11 textile mills that carry refining of knit and woven fabric have mostly chemical treatment facilities. In addition, some mills prefer biological or biological/chemical treatment. Polyethylene (PE), $FeSO_4$, Alum, Lime, $FeCl_3$ and several modifications of these chemicals are used in chemical treatment facilities (Sahin, 1996; Ucar, 1995). Because of the mandatory use of $SO_4^{=}$ based chemical in several process of textile industry, high sulphate concentration in effluent is observed. It will be beneficial to modify some processes in a way that it would be possible to use less salt for dyeing, to prefer chlorine instead of sulphate and to use HCl or CO_2 for neutralization. When the effluent values and discharge standards by national authority are compared, the parameters other than BOD_5, COD and SS do not require high degree of treatment. If it was desired to discharge the effluent to receiving environments rather than to the sewer system, additional treatment units would require SKKY would in order to meet their standards. It is possible that advanced treatment technologies might be used to treat the wastewater from these industries to a quality that could allow reuse of wastewater. By this way, the reduction in the use of processed water along with the less costly treatment through reuse might contribute to the faster amortization. It is a priority to consider the advanced treatment technologies along with the source reduction of waste rather than limiting the treatment to single-stage. Like in the European countries, many firms in textile industry are concentrated on the use of environmentally friendly chemicals and processes that use less water (Barclay and Buckley, 2000). It is imperative for us to carry out similar studies and to keep up with the technological developments.

In addition, it is necessary to have educated operators to run the treatment facilities. ISKI and similar authorities should provide more strict mechanisms of control based on the scientific methods. Moreover, the firms that need to pay the maximum attention to prevent pollution should be encouraged by the local and central authorities. As explained above, if more economical local treatment facilities are opened, firms which do not require high degree of treatment can control the pollution more easily. And these firms should pretreat pH, SS and temperature before they discharge them into the local treatment plants. This is a much better approach than having unfunctional or unoperating treatment facilities. Between 1986 and 1989, ISKI and mostly textile industry firms, wastewater of which is conventional, signed a contract that required these firms to pay their share in capital and operational cost of treatment. The purpose was to build a central treatment facility with this money that would treat both municipal and industrial wastewater. However, later on this plan was cancelled and each firm was required to have its own treatment facility. However,

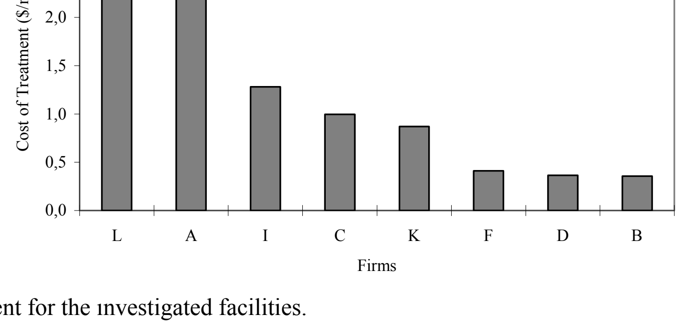

Figure 9. The cost treatment for the ınvestigated facilities.

it is becoming harder in Istanbul to inspect whether these facilities are operated properly. The effluent phosphor, sulphate, and phenol values are below the limits set by ISKI and it makes it necessary not to use such parameters for control. The cost of effluent analysis at ISKI laboratories will be reduced by these means.

Conclusion

Certain pollutants in textile wastewater are more important to target for pollution prevention than others. For example, most dyeing machines have lint filters and other primary control measures to keep lint out of heat exchangers and off of the cloth; therefore, total suspended solids (TSS) levels are low in raw textile dyeing wastewater compared to many other industries. On the other hand, biological oxygen demand (BOD) and chemical oxygen demand (COD) are relatively high in slashing, fabric formation, and wet processing and therefore, are more important pollution prevention targets. The aquatic toxicity of textile industry wastewater varies considerably among production facilities. Data are available showing that some facilities have fairly high aquatic toxicity, while others show little or no toxicity. If the discharge of these facilities is assessed according to EC criteria, additional treatment units would be required to meet the standards. Despite the fact that it is not a common practice in our country, the advanced treatment technologies might be used to treat the wastewater from these industries to such an extent of a quality that could allow reuse of wastewater. By these means, the reduction in the use of processed water along with less costly treatment through reuse might contribute to fast amortization. In addition, it is necessary to have educated operators to run the treatment facilities. Local and other authorities should provide more strict regulations and directives like the EC (EPA, 1996).

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