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AN OVERVIEW OF THE TEXTILE INDUSTRY IN TURKEY — POLLUTION PROFILES AND TREATABILITY CHARACTERISTICS

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ABSTRACT

In this study, a large number of textile plants in Turkey have been studied and evaluated in terms of characteristics and treatability of wastewaters involved as related to relevant production parameters, exhibiting significant differences for each plant. Certain industrial groups have been identified to possess different pollution profiles and treatability specifications within the same subcategory. The results observed lead to conclude that the subcategorization now in use for the textile industry needs to be reformulated by taking care of the significant components defining the nature of this industry, and it has to show more connection with treatability evaluations.

KEYWORDS

Textile industry; sub-categorization; wastewater characterization; pollution profile; treatability.

INTRODUCTION

Textile industry, which plays an important role in the economy of most developed and developing countries, has a very complex nature in terms of raw materials used, techniques employed, chemicals applied and products. Different techniques and a variety of operations and processes are involved within this industry. Because of the dynamic structure of the industry, it is meaningless to speak of a typical textile effluent. The amount of wastewater and its quality in plants show a wide range of values. It is impracticable to attempt to explain the differences between effluents from different sources without reference to the essential characteristics of the effluent-producing process in this industry. So, at that point the necessity of a sound pollution-based subcategorization is considered.

Industrial pollution control calls for a systematic evaluation based on pollutional characteristics, treatability tests and actual treatment performance data leading to a proper characterization, treatment technology and to rational discharge standards. Despite an abundance of related data, this systematic approach can hardly be considered adequately defined for the textile processing industry, mainly because the subcategorization criteria are not identified in adequate detail due to the complexity of the problem.

In this study, 14 different textile plants were evaluated in 4 different already established subcategories, namely, wool finishing, woven fabric finishing, knit fabric finishing, stock and yarn dyeing and finishing;these were evaluated both in terms of wastewater characteristics and treatability studies. The experimental output has been evaluated by comparing the values or ranges of the wastewater parameters indicated for subcategories in the literature.

The aim of subcategorization is to set out the differences between the wastewaters of plants which produce the same product by different methods or processes, or plants which have

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different ways of production, although they are in the same category. The subcategories established by EPA (EPA, 1978) for textile industry are as follows: Wool Scouring, Wool Finishing, Dry Processing, Woven Fabric Finishing, Knit Fabric Finishing, Carpet Finishing, Stock and Yarn Dyeing and Finishing.

In this study, the following subcategories which are essentially important in pollution are evaluated.

Wool Finishing. This subcategory covers wool finishing including carbonizing, fulling, dyeing, bleaching, rinsing, fire-proofing etc.

Woven Fabric Finishing. This subcategory generally covers the processes that are applied to woven fabrics, such as: desizing, scouring, bleaching, mercerizing, dyeing, printing, resin treatment, water-proofing, flame-proofing, soil repellency application and application of special finishes.

Knit Fabric Finishing. This subcategory covers bleaching, dyeing, printing, resin treatment, water-proofing, flame-proofing etc. processes that are applied to knit fabrics.

Stock and Yarn Dyeing and Finishing. This subcategory covers cleaning, scouring, bleaching, mercerizing, dyeing and special finishing processes applied to fibre stock and yarn.

EVALUATION OF TEXTILE EFFLUENT

Wastewater Characteristics

Comprehensive studies on wastewater characteristics have been undertaken by a number of sources. This study reviewed the study done by Göknil et al. (1984) reflecting the overview of textile industry in Turkey, together with American Textile Manufacturers Institute; ATMI, Carpet and Rug Institute; CRI, and National Commission on Water Quality; NCWQ studies. The last three studies have been extensively reviewed in EPA (EPA, 1978).

Wool Finishing Subcategory. Within this subcategory two plants are investigated, plant No.1 (Orhon et al., 1985) and plant No.2 (Tünay et al, 1986,a). In wool finishing subcategory, given values in literature for the daily wastewater flowrates vary within a very wide range of values. This is due to the different plant capacities and different equipment used in the wool finishing processes. As unit wastewater flowrates are considered, a narrow range which is consistent with the unit water use range in the ATMI-CRI study is observed. But the unit water use values given in ATMI-CRI and NCWQ are quite different from each other. Unit wateruse of the NCWQ reference values are higher than those reported in the ATMI-CRI one. For one of the plants investigated, the unit wastewater flowrate is even lower than the lower limit of the range given in literature. This low value is obtained because, in this factory, processes that require less water are applied more than the processes which use a lot of water, such as dyeing.

As BOD_5 concentrations and loads are concerned, the three literature studies are consistent with each other, since slight changes are not considered. Although the BOD_5 concentration of one of the plants is within the literature range, it is higher than the average value given in literature. However, the BOD_5 load of this plant is lower than the minimum value indicated in the literature.

In literature, a wide range of values is given for the COD concentrations. The COD concentrations of the plants investigated are of the same level as the average COD concentrations in the literature.

In textile wastewaters, generally chromium is generated from the chemical materials used in dyeing processes. According to the frequency of application of the dyeing processes, the type and the concentration of the dye used, the chromium concentrations can take high values. The inconsistency between the literature shows itself in the total chromium concentrations. In Göknil et al. (1984), the given values are much lower than the values in the NCWQ study. In general, heavy metal concentrations given in literature have values of 1 mg/l or below for the textile industry subcategories. But, in NCWQ, only one value, 4 mg/l , is reported for chromium concentration.

Woven Fabric Finishing Subcategory. In this subcategory 5 plants are investigated, namely; plant No 2. (Tünay et al, 1986,a), plant No.3 (Tünay et al., 1987a), plant No 4. (Polkon, 1984),

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TABLE 1 Wool Finishing Subcategory Wastewater Characterization

Parameter	Göknil et al.(1984)		ATMI-CRI		NCWQ				Plant No.1		Plant No.2***	
	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$) Range Average	Concentration ($mg\ l^{-1}$) Standard Deviation	Concentration ($mg\ l^{-1}$) Range Average	Concentration ($mg\ l^{-1}$) Arith. Mean	Concentration ($mg\ l^{-1}$) Use	Load ($kg\ t^{-1}$) Range Average	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)
BOD_5	66-750	22-140	125		(150-700) 300	300	300	(50-233) 100			565	8.8
TSS	17-240	9.5-97	31		(45-300) 130	130	130	(15-100) 43	66		298	9.9
COD	280-2000	97-440			(280-5000) 1041	1041	1040	(93-1670) 347	1050		1874	62.4
Oil and Grease												
Total Chrome	0.19-0.88				4	4	4	1.3				
Phenol	0.09-0.16				0.5	0.5	0.5	0.17				
Sulfide	1.1-6.0				0.1	0.1	0.1	0.03				
Color	1000-2000 (APHA)				(500-1700) (ADMI)		1000 (ADMI)					
pH (units)			6.92		(6-11)		7		7.4			
Water use ($m^3\ t^{-1}$)			(76-168) 116	38.6	336	336		336				
Wastewater Flowrate	190-16000*	115-130**							1000*		66.6*	45**

* : in $m^3\ d^{-1}$

** : in m^3 per ton of product $mg\ l^{-1}$

*** : A part of this plant's production is included in Woven Fabric Finishing Subcategory.

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TABLE 2 Woven Fabric Finishing Subcategory Wastewater Characterization

Parameter	Göknil et al. (1984) Concentration ($mg\ l^{-1}$)	Göknil et al. (1984) Load ($kg\ t^{-1}$)	ATMI-CRI Concentration ($mg\ l^{-1}$) Range Average	ATMI-CRI Concentration ($mg\ l^{-1}$) Standard Deviation	NCWQ Concentration ($mg\ l^{-1}$) Range Average	NCWQ Concentration ($mg\ l^{-1}$) Arith. Mean	NCWQ Concentration ($mg\ l^{-1}$) Use	NCWQ Load ($kg\ t^{-1}$) Range Average	Plant No.3 Concentration ($mg\ l^{-1}$)	Plant No.3 Load ($kg\ t^{-1}$)	Plant No.4 Concentration ($mg\ l^{-1}$)	Plant No.4 Load ($kg\ t^{-1}$)	Plant No.5*** Concentation ($mg\ l^{-1}$)	Plant No.5*** Load ($kg\ t^{-1}$)	Plant No.6*** Concentration ($mg\ l^{-1}$)	Plant No.6*** Load ($kg\ t^{-1}$)	Plant No.7**** Concentration ($mg\ l^{-1}$)	Plant No.7**** Load ($kg\ t^{-1}$)
BOD_5	19-2600	5.9-220	(134-1800) 592	392	(80-465) 300	550	650	(28-95.7) 62	750	35.4	580	84.7	710	23.6			564	13.3
TSS	1-2400	0.2-220	(0-2180) 313	533	(50-360) 150	185	300	(5.1-53.5) 21	330	15.5	330	48.2	1280	42.6	93	6	105	2.5
COD	200-5100	10-800	(378-2288) 1093	513	(320-2000) 950	1850	1200	(47.9-162) 95.7	1500	70.7	2390	348.9	1410	46.9	896	58	1257	29.5
Oil and Grease	5-1400	0.4-150	14				14		82	3.9	1425	208			78	5		
Total Chrome	0.001-12	0.0001-1.5	(0.31-10.81) 4.3	4.23		0.04	0.04	0.0045	3.9	0.2								
Phenol	0.01-1.2	0.0009-0.15	(0-0.02) 0.01	0.01		0.04	0.04	0.0045							0.2	0.013		
Sulfide	0.02-5.6	0.0006-0.13	(0-8) 2.72	4.57		2.72	3.0	0.31	4.9	0.2					920	59.8		
Color	20-4000 (APHA)					325 (ADMI)	325 (ADMI)											
pH(Units)			(7.5-13.2) 11.62	2.89	(6-11)		10		12.1-12.6		9-10		11.5		12			
Water use ($m^3\ t^{-1}$)			(32.5-342.4) 152.5	83.5	12.6	113.5	113.5	113.5										
Wastewater Flowrate	42-29000 *	110-150 **							1885.5 *	47.1 **	3200 *	146 **	100 *	33.3 **	1300 *	65 **	182 *	23.5 **

* in $m^3\ d^{-1}$

** in m^3 per ton of product

*** The wastewater of this plant contains a slight amount of yarn dyeing and rinsing wastewaters.

**** A part of this plants' production is included in Wool Finishing Subcategory

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TABLE 3 Knit Fabric Finishing Subcategory Wastewater Characterization

Parameter	Göknil et al.(1984)		ATMI-CRI		NCWQ				Plant No.7		Plant No.8		Plant No.9		Plant No.10		Plant No.11	
	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)		Concentration ($mg\ l^{-1}$)			Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)
			Range Average	Standard Deviation	Range Average	Arith. Mean	Use	Range Average										
BOD_5	60-1900	4.4-140	(80-800) 335	303	(80-250) 140	250	350	(15-97.6) 37.5	325	8.13	65	0.5	1000	59.5	503	10.9	500	
TSS	18-2200	1.3-110	(40-332) 115	123	(500-1000) 550	300	300	(6.0-72.8) 45	488	12.2	35	0.27	234	13.9	140	3		
COD	340-19000	18-500	(869-1501) 1105	345	(1500-3000) 1900	850	1000	(67.6-255) 127.6	1273	31.8	900	7.02	2690	160	1233	26.6	1150	
Oil and Grease	6-460	0.4-46	53				53											
Total Chrome	0.01-0.6	0.0006-0.085				0.05	0.05	0.0072	1.3	0.03	<0.05							
Phenol	0.001-1.7	0.0014-0.4	23			0.24	0.24	0.04	2.7	0.07								
Sulfide	0.02-7.1	0.0031-0.77				0.20	0.20	0.03										
Color	37-1500 (APHA)		(625-2500) 1295 (ADMI)	1046 (ADMI)	800 (ADMI)	400 (ADMI)	400 (ADMI)											
pH (units)			6.9	2.05	(6-9)		8						12.6				11.3	
Water use ($m^3\ t^{-1}$)			(50.2-338) 168.6	82.1	12.6	151.3	151	151.3										
Wastewater Flowrate	11-13000 *	150-155 **							1147*	25**	33.2*	7.8**	1190*	59.5**	127.5*	21.6**	2640*	

* in $m^3\ d^{-1}$

** in m^3 per ton of product

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TABLE 4 Stock and Yarn Dyeing and Finishing Subcategory Wastewater Characterization

Parameter	Göknil et al. (1984)		ATMI-CRI		NCWQ				Plant No.12		Plant No.13		Plant No.14	
	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)		Concentration ($mg\ l^{-1}$)			Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)	Concentration ($mg\ l^{-1}$)	Load ($kg\ t^{-1}$)
			Range Average	Standard Deviation	Range Average	Arith. Mean	Use	Range Average						
BOD_5	43-1600	0.8-110	(73-600) 240	166	(100-650) 250	200	250	(11.3-51.0) 30	240	105.6	294	13.1	593	5.9
TSS	2-4200	0.1-480	(22-160) 77	69	(40-485) 300	50	75	(3.8-11.3) 7.35	43	18.9	30	1.3	227	2.3
COD	140-4800	2.5-380	(363-1400) 882	733	(450-1500) 850	524	800	(33-151.6) 78.7	330	145.2	470	21	5049	50.5
Oil and Grease	1-180	0.1-22							71	31.2				
Total Chrome	0.004-1.6	0.0008-0.36	0.27		0.05	0.013	0.27	0.002	< 0.5					
Phenol	0.003-0.62	0.0005-0.083			0.27	0.12	0.12	0.018	< 0.1					
Sulfide	0.001-4.4	0.0006-0.17			0.2		0.09		4	1.8				
Color	57-3000 (APHA)				400 (ADMI)	600 (ADMI)	600 (ADMI)							
pH (units)			(4.52-11.8) 8.93	2.60	(7-12)		11		10-11		7.35		3.8	
Water use ($m^3\ t^{-1}$)			(14-668) 187	146	151	151		151						
Wastewater Flowrate	45-9600*	150-180**							1000-1200*	400-500**	350*	44.7**	100*	10**

* in $m^3\ d^{-1}$

** in m^3 per ton of product

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Plant No 5. (Polkon, 1986), Plant No 6. (Kare, 1986). Since the unit wastewater flowrate range given only in Göknil et al. (1984) is too narrow, the water use data reported in ATMI-CRI and NCWQ studies are used for a healthier evaluation of investigated plant's wastewater flowrates. Within this frame, unit wastewater flowrates of the plants are in the lower range of ATMI-CRI. So they are consistent with the literature.

According to BOD_5 concentrations, the values for the plants studied are close to ATMI-CRI values. BOD_5 unit values are also consistent with the literature.

COD concentrations and loads in literature are consistent with each other. Similarly, the plants' COD values are within the ranges of the literature.

Apart from one exceptionally high value, the oil and grease values of the plants are consistent with the literature.

Knit Fabric Finishing Subcategory. In this subcategory 5 plants are investigated; Plant No 7. (Tünay et al., 1987b), Plant No 8. (Talınlı et al., 1987), Plant No 9. (Polkon, 1985), Plant No 10. (Tünay et al., 1986,b), Plant No 11. (Polkon, 1983). By the same reasoning as in woven fabric finishing subcategory, unit water use values in literature are used rather than the unit wastewater flowrates in evaluating the plants' unit wastewater flowrates. The unit wastewater flowrates of the plants are very low. Even the highest of these values can only reach the lower limit of the literature. There are several reasons for this. First of all, the factories in Turkey mostly operate as dyehouses, and the major process applied in these plants is dyeing rather than rinsing. Finally, scouring process is applied very seldom in Turkey due to lack of oil usage in knit fabric sizing.

BOD_5 concentrations and loads in literature are consistent, and the plants' values are within the literature limits. BOD_5 concentrations of most of the factories have values that are above the average of literature values, since the wastewaters are concentrated, as a result of facts mentioned above on wastewater flowrates.

COD values are consistent in literature. The investigated plants COD loads are variable and are above the literature averages.

Stock and Yarn Dyeing and Finishing. Three plants are investigated within this subcategory, namely; Plant No 12. (Kare, 1984), Plant No 13. (Kare, 1985), Plant No 14. (Polkon, 1987). As was mentioned in knit fabric finishing and woven fabric finishing subcategories, it is healthier to compare the water use values in literature with the studied plants' unit wastewater flowrates. The unit wastewater flowrate values of the plants cover the two limits of the literature. The literature and plants' flowrate values vary within a very large range.

Except from a plant which has a very high BOD_5 load, still in the range, BOD_5 loads and concentrations are consistent.

COD concentration and load values from the literature and the plants investigated are consistent with each other, except for one plant, in which an extreme concentration value is observed. This factory has a COD/BOD_5 ratio of 8.5; the COD concentration of this factory even exceeds the upper limit given in the literature.

Treatability Studies

Biological Treatability. Biological treatment is a standard method applied to almost all subcategories in textile industry. A specific removal efficiency is achieved whether activated sludge or extended aeration is used.

Biological treatability studies are performed on a variety of wastewaters from different subcategories.

It is observed that the important thing in biological treatment is the type of wastewater rather than the subcategories. In the textile industry, the effecting factor for the determination of the type of wastewater is the toxicity which in turn is a function of the dyeing agents used.

The biological treatability results are consistent with literature. The values in literature vary according to the type of wastewater. Because the flowrates are high in textile wastewaters, even small differences in residence times cause a change in design and a significant increase in cost. For this reason, the biological treatability experiments are

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very important in design. For example in an investigated plant (Plant No.2) BOD_5 removal of 80% is achieved for 0.2 organic loading, whereas the removal is 86% under 0.09 organic loading.

In biological treatment high BOD_5 removal efficiencies are achieved. On the other hand, COD removal percentages are lower and approximately 300 mg/l residual COD values are observed.

TABLE 5 Results of Biological Treatability Studies

SUBCATEGORY	Plant	q (day^{-1})	COD ($mg\ l^{-1}$) in	COD ($mg\ l^{-1}$) out	COD removal %	BOD ($mg\ l^{-1}$) in	BOD ($mg\ l^{-1}$) out	BOD removal %
Woven Fabric Finishing	Plant No.3	0.052	1750	350	80.0	830	40	95.2
		0.058	1750	354	79.8	830	70	91.5
		0.059	1750	340	80.5	830	60	92.7
Knit Fabric Finishing	Plant No.7	0.06	1140	280	75.4	280	4	98.5
	Plant No.10	0.16*	2850	624	78.1	1050	260	75.2
		0.26*	2850	326	88.6	1050	410	60.9
		0.15**	1170	300	74.4	540	40	92.6
Wool Finishing + Woven Fabric	Plant No.2	0.2	602	216	64.0	430	90	79.1
		0.09	3010	400	86.7	620	85	86.3

* Wastewaters from direct dyeing process

** Wastewaters from reactive dyeing process.

Chemical Treatability. If the chemical treatability results are evaluated in a very general sense, they are contained within the limits of literature, but, according to the studies, a wider removal range than given in literature is observed.

The investigated plants' removal efficiencies are very variable. Therefore, whether chemical treatment alone is sufficient or not must be determined by running chemical treatability experiments.

TABLE 6 Chemical Treatability Results with $FeSO_4$

Subcategory	Plant	Initial COD ($mg\ l^{-1}$)	$FeSO_4$ Trial Interval ($mg\ l^{-1}$)	COD Removal Interval (%)	Optimum Polyelectrolyte Dosage ($mg\ l^{-1}$)	Optimum $FeSO_4$ Dosage ($mg\ l^{-1}$)	COD Removal at Optimum Dosage (%)
Knit Fabric Finishing	Plant No.7	1530*	10-400	68-83	-	100	83
		1100	-	-	7.5	100	92
Wool Finishing + Woven Fabric Finishing	Plant No.2	700	100-500	35-45	4	300	45

* pH is adjusted with Lime

** Optimum coagulant dosage is obtained by using different polyelectrolyte dosages.

The use of polyelectrolytes in chemical treatability studies increases the removal efficiency. Also lime usage improves the percent removals and aids the pH adjustments.

When chemical treatability results are evaluated according to the wastewater characteristics, different removal percentages are obtained. Removal efficiencies from 60 to 86% can be observed in knit fabric finishing subcategory. This is true for other subategories too. Therefore, it is impossible to evaluate the chemical treatability results on the basis of subcategorical approach now in use. Chemical treatability results have to be evaluated either according to the existing processes such as dyeing etc. or the subcategorization must must be rearranged in a way so as to emphasize the processes.

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TABLE 7 Chemical Treatability Results with Alum

Subcategory	Plant	Initial COD ($mg\ l^{-1}$)	Alum trial Interval ($mg\ l^{-1}$)	COD Removal Interval (%)	Optimum Polyelectrolyte Dosage ($mg\ l^{-1}$)	Optimum Alum Dosage ($mg\ l^{-1}$)	COD Removal at Optimum Dosage (%)
Knit Fabric Finishing	Plant No.10	300	50-400	-	5	400	33
Stock and Yarn Dyeing and Finishing	Plant No.13	470	-	-	-	50	33.6
Wool Finishing + Woven Fabric Finishing	Plant No.2	700**	-	9-32	4	400	32

* pH is adjusted with lime.
** Optimum coagulant dosage is obtained by using different polyelectrolyte dosages.

TABLE 8 Chemical Treatability Results with $FeCl_3$

Subcategory	Plant	Initial COD ($mg\ l^{-1}$)	$FeCl_3$ trial Interval ($mg\ l^{-1}$)	COD Removal Interval (%)	Optimum Polyelectrolyte Dosage ($mg\ l^{-1}$)	Optimum $FeCl_3$ Dosage ($mg\ l^{-1}$)	COD Removal at Optimum Dosage (%)
Wool Finishing	Plant No.1	1050*	75-300	58.7-91.4	4	150	91.4
Woven Fabric Finishing	Plant No.5	1410	200-800	verylow-59.6	-	800	59.6
Knit Fabric Finishing	Plant No.7	1530*	10-400	75-86.3	-	200	86.3
		1100	-	-	7.5	200	93.0
	Plant No.8	862	50-400	74-87	15	400	87.0
	Plant No.9	2690	75-600	39-62.3	4	600	62.3
		2690*	75-600	39-60.7	4	600	60.7
	Plant No.10	300	-	30-50	5	250	50.0
Stock and Yarn	Plant No.12	330*	-	63.9-68.8	-	500	68.8
Dyeing and Finishing	Plant No.13	470**	-	33.6-47.7	5	400	47.7
Wool Finishing +	Plant No.2	3590	400-800	46-66	4	800	66
Woven Fabric Finishing		700	100-300	41-44	4	300	44
		400.	400-800	48-53	4	400	53

*pH is adjusted with lime
**Optimum coagulant dosage is obtained by using different polyelectrolyte dosages.

GENERAL CONSIDERATIONS

Due to the nature of the textile industry, it is difficult to define specific limits for the water use and wastewater flowrates.

For BOD_5 and COD loads and concentrations, the ranges are narrower when compared with the water uses. Except for wool scouring, no significant difference is observed between the subcategories for these parameters, but their treatability results are very different.

Wastewater characteristics are very similar between the subcategories. Therefore the application of the subcategorization now in use is meaningless. This is emphasized in COD/BOD_5 ratios and treatabilities. As can be seen easily from the experimental studies, the COD/BOD_5 ratios and treatability results are not similar within same subcategories.

The ultimate goal is to control the pollution; on the other hand, pollution control depends on the definition of the treatment technology. Therefore, subcategorization should be made in such a way that for each subcategory there should be a corresponding specific wastewater characterization and this should result in the identification of a particular treatment

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technology for every subcategory. New ways should be defined to promote more relevant bases, such as the type of processes concerned, to establish meaningful subcategorization. This subject should be discussed in detail in another paper.

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