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THE TEXTILE INDUSTRY

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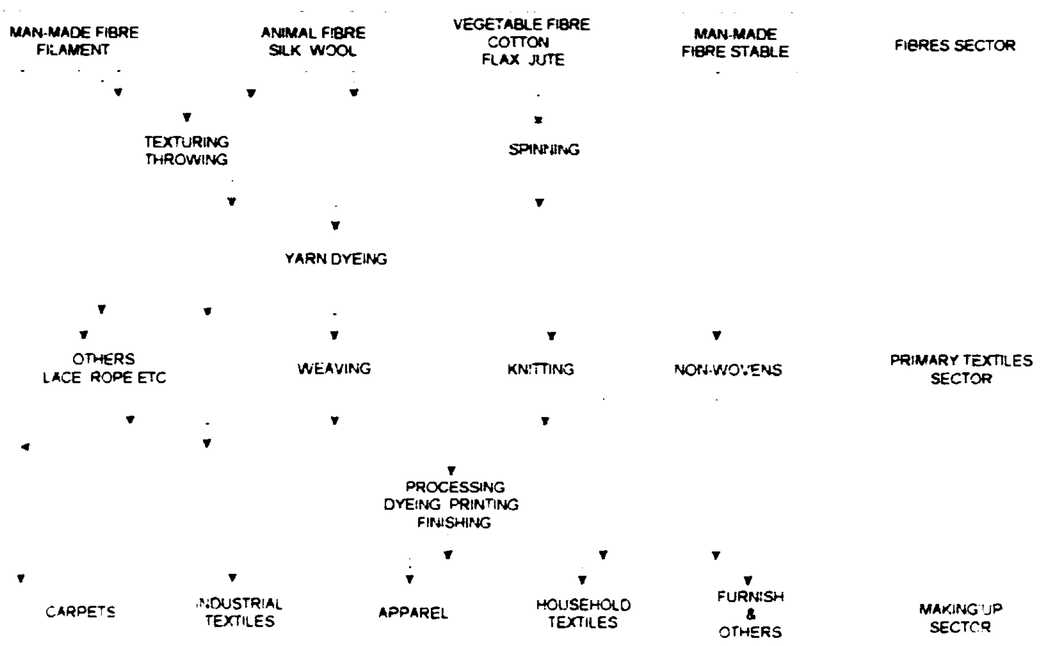
1. INTRODUCTION

The textile industry is a group of related industries which uses a variety of natural (cotton, wool, etc.) and/or synthetic fibers to produce fabric. It is a significant contributor to many national economies, encompassing both small and large-scale operations worldwide. The sequence of the manufacture of textiles is illustrated in the flow diagram in Figure 1.

Figure 1: Structure and Material Flow of the Textiles Industry



Traditionally, the textile industry is very energy, water, and chemical-intensive. About 60% of the energy is used by dyeing and finishing operations [14]. Environmental problems associated with the textile industry are typically those associated with water pollution. Natural impurities extracted from the fibre being processed along with the chemicals used for processing are the two main sources of pollution. Effluents are generally hot, alkaline, strong smelling and colored by chemicals used in dyeing processes. Some of the chemicals discharged are toxic. Other environmental issues now considered equally important and relevant to the textile industry include air emissions, notably Volatile Organic Compounds (VOC) [10].

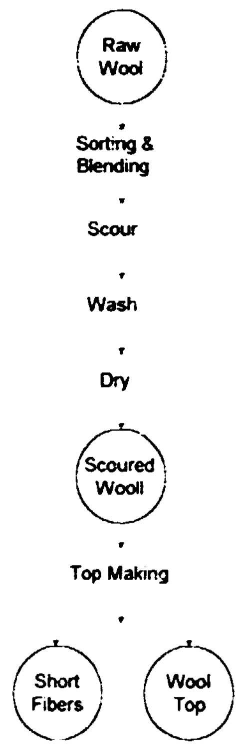
Textile Industry Organization

Subdivision of the textile industry into its various components can be approached form several angles. The classical method of categorizing the industry involves grouping the manufacturing plants according to the fiber being processed, that is, cotton, wool, or synthetics. The modern approach to textile industry categorization, however, involves grouping the manufacturing plants according to their particular operation.

- Wool Scouring
- Wool Finishing
- Dry Processing
- Woven Fabric Finishing
- Knit Fabric Finishing
- Carpet Manufacture
- Stock and Yarn Dyeing and Finishing

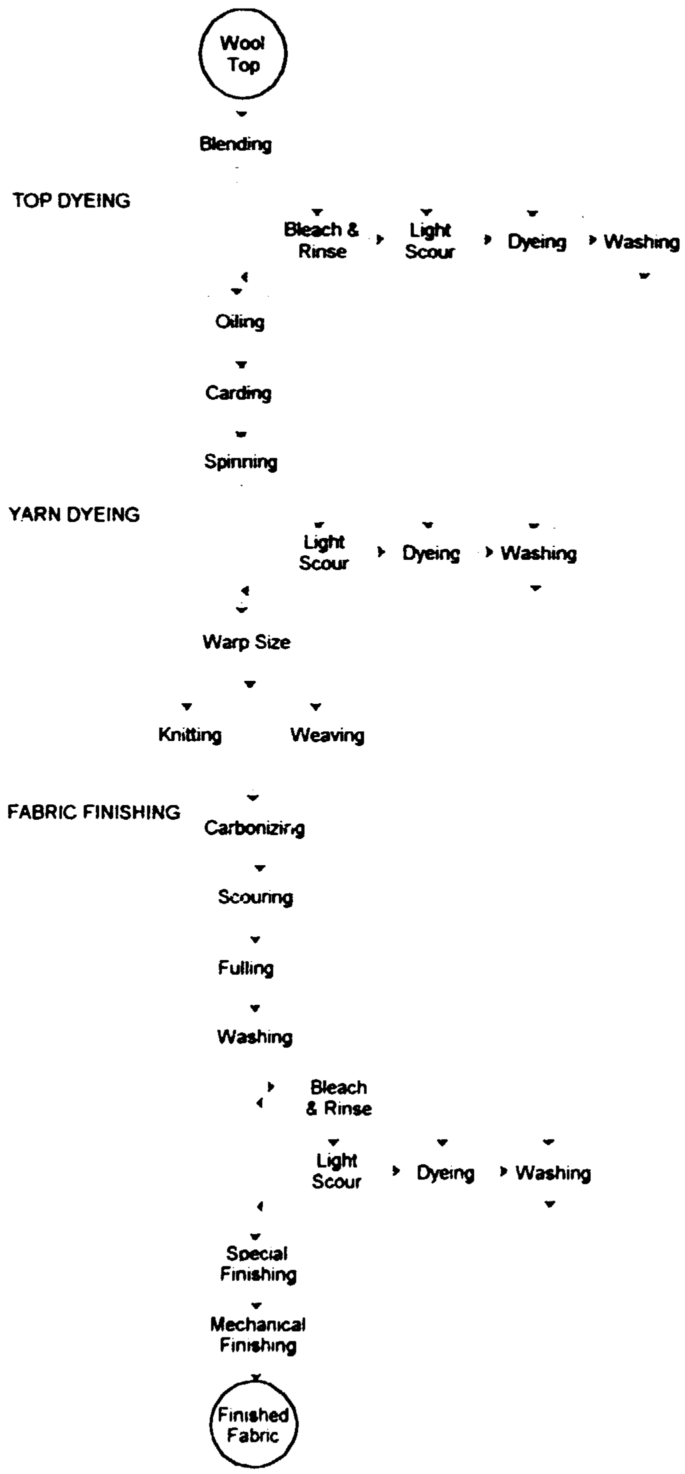
1.1 Wool Scouring Mill

This category of the textile industry includes mills such as wool scouring, top making and general raw wool cleaning. Raw wool must be cleaned by wet processes before the fibre can be dry processed to produce fibre, yarn or fabric. Neither cotton nor synthetic fibers require this initial wet cleaning before processing. Scouring begins with sorting the fleece and feeding it to a hopper. The wool is then carried through a series of scouring bowls where scour liquor flows counter-current to it. Detergent is added in the third and forth bowls to emulsify the grease and oils. The scoured wool is then dried. In mills where the cleaned wool is converted into wool top, the wool is combed and gilled. The products are short fibers (used for wool yarn) and long fibers (used for wool top). Figure 2 shows the manufacturing processes of a wool scouring mill [10].



1.2 Wool Finishing

This category of the textile mill includes wool finishing along with processes such as carbonizing, fuiling, dyeing, bleaching, rinsing, fire proofing, etc. This category is differentiated from other fabric finishing categories by the wide variety of chemicals used to process wool fabrics. These operations generate a high effluent load including toxic pollutants such as chromium and phenols. The wool finishing process is shown in figure 3. The three distinct finishing processes shown in this diagram are stock, yarn and fabric finishing. Waste generated by the fabric finishing operation is similar to that generated by all three, therefore only this process will be described. If the greige goods are 100% wool, then they are first cleaned to remove vegetable matter by carbonizing. Later, spinning oils and any weaving sizes are removed with the use of a light scour. The fabric is then dyed, in batches, in vessels called becks, washed and then taken to dry finishing operations. In this stage, the only dry finishing operation of concern for waste generation is mothproofing [10].

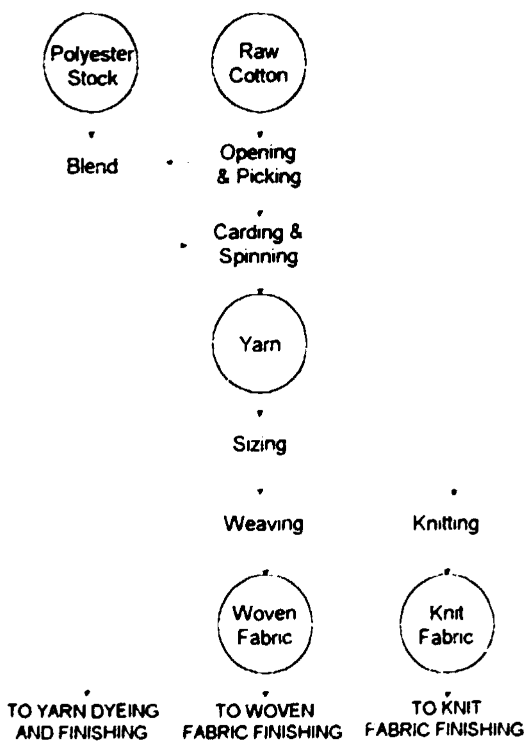


1.3 Dry Processing

This category of the textile mill includes yarn manufacturing, yarn texturing, unfinished fabric manufacturing, fabric coating, fabric laminating, tire cord and fabric dipping, carpet tufting and carpet backing. The majority of dry processing mills are usually greige mills. Weaving textile yarns into a fabric requires application of size to the warp yarns, to resist the abrasive effects of the filling yarns as they are positioned by the shuttle action of the loom. Greige mills apply the size and complete the weaving. Many greige mills operate as completely independent facilities. Figure 4 shows operations generally performed at this type of greige mill.

Mills within the dry processing category typically carry out dry-type operations, however, some waste is produced by spillage and vessels of floor cleaning. Some textile greige mills produce a wide variety of woven goods, each requiring a specially formulated size. In mills of this type, the size boxes may be dumped and cleaned several times a day depending upon the production schedule. In unusual cases such as this, operations may produce a large effluent volume.

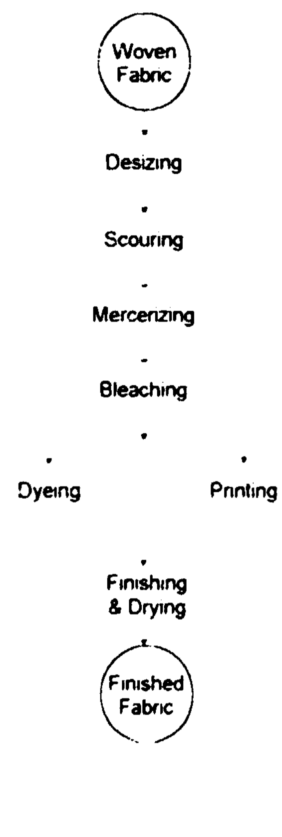
Weaving is a dry operation, but is normally done in buildings maintained at high humidity. Cooling and humidifying water used in a greige mill represents a substantial portion of the total water usage. Effluent generated from knit greige goods is generally nil. If any wastes are generated through spills, clean-up or possible washing of the final products, the only pollutant would be knitting oils [10].



1.4 Woven Fabric Finishing

This category of operational unit used to finish woven greige fabric is one of the most important because of the significant effluent load generated from the removal of foreign matter during cleaning and from various chemicals used in finishing. This category may be divided into two groups. The first removes impurities, cleans or modifies the cloth (desizing, scouring, bleaching, mercerizing). The second group involves dyeing, printing, resin treatment, water or flame proofing, soil repellency and a few special finishes. These all generate various effluents, mostly those chemicals and additives washed off in the processing. This category also includes integrated woven fabric finishing mills, although the greige goods section contributes only a small amount of the overall effluent load form an integrated mill.

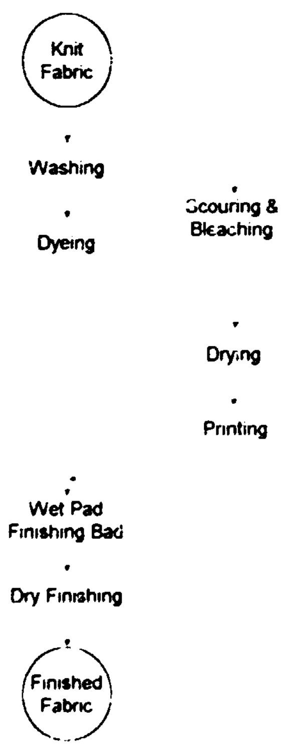
Certain fabrics, including denims and some drapery goods, are loom finished. To make these goods, the warp yarns are dyed, woven into a fabric, and then fabric-finished with a permanent size. For these fabrics the first group of processes listed above (i.e.cleaning and preparing the cloth) is avoided entirely. The degree of finishing necessary to provide fabric ready for sale depends significantly on the fibre(s) being processed. The natural fibers (cotton and wool) contain substantial impurities, even after they have been woven as greige goods, and require special treatment to convert them to the completely white, uniformly absorbent form essential for dyeing, resin treatment, etc. Synthetic fibers contain only those impurities that were necessary for manufacture of the fibre and spinning to obtain the yarn. A flow sheet of woven fabric finishing is given in Figure 5 [10].



1.5 Knit fabric Finishing

The knit fabric industry is characterized by a large number of plants and organized structure, including specialized products segments such as knit fabric goods, hosiery, outwear and underwear. This category is characterized by operational units such as bleaching, dyeing, printing, resin treatment, water proofing, flame proofing, and the application of soil repellency or special finishes. The wet processing operations performed in knit fabric finishing are shown schematically in Figure 6. This is only a generalized flow sheet, as the specific operations employed in a given facility will vary form plant to plant. In general, yarns are purchased in the undyed state, with a knitting oil finish to provide lubrication for the knitting operation. Lubricants (knitting oils) that can be applied to knitting yarns include mineral oil, vegetable oil, synthetic ester-type oil or waxes. These lubricants may also contain anti-static agent, antioxidants, bacteriostat and corrosion inhibitors. The amount of oil applied varies with the type of yarns. Knitting oils are also injected into the needles of knitting machines in order to lubricate and lower the temperature of the needles. The knitting oil present in knit greige goods is readily emulsified or soluble in water and is scoured or washed out as an effluent. After the yarn has been knitted into fabric, the fabric may be processed by one or more of the alternative routes indicated in figure 6.

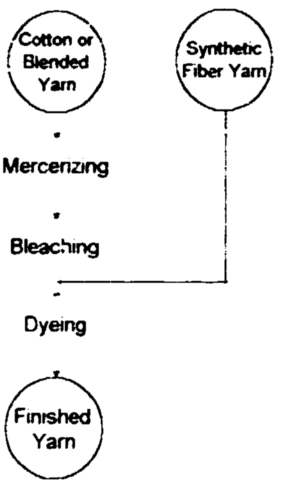
The main difference between woven and knit fabric finishing is that the sizing/desizing and mercerizing operations are not required for the knit so the generation of effluent load is relatively low. Here the knit yarn is treated with lubricants rather than with the starch or polymeric sizes used for woven goods [10].



1.6 Stock and Yarn dyeing and finishing

Yarn dyeing and finishing are different from woven fabric finishing because there are no sizing and desizing operation. They are different from knit fabric finishing because of their mercerizing operations and water use.

This category is typically characterized by operational units such as cleaning, scouring, bleaching, mercerizing, dyeing and special finishing. This category includes plants which clean, dye and finish fibre stock or yarn. Sewing thread, textile and carpet yarn are typical products in this category. Several techniques are available for processing raw yarn into the finished product. The most common process is probably package dyeing, but other processes, such as space dyeing, are widely used. In package dyeing, yarn wound on perforated tubes is placed in a large vessel, which is sealed. The dye solution, at an appropriate temperature, is circulated through the yarn. The dyed yarn is washed, rinsed and dried. In space dyeing, yarn is knitted and the fabric is dyed or printed, washed, rinsed and dried. The fabric is then unraveled and the yarn is wound on cones for subsequent use by other mills. Figure 7 represents typical operation of a stock and yarn dyeing and finishing mills [10].



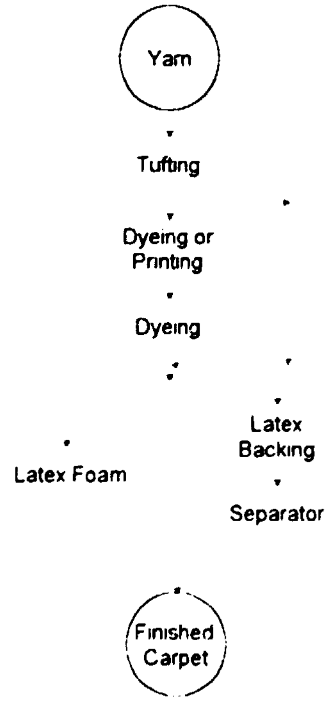
1.7 Carpet Manufacture

Carpet mills form a distinct part of the industry although their effluents are similar in many ways to those of the knit fabric finishing mill. Figure 8 shows the various process details of a Carpet Manufacture Mill.

Carpet mills use mostly synthetic fibers (nylon, acrylic and polyesters), but some wool and cotton are also processed. This category is characterized by any or all of the following operational units: bleaching, scouring, carbonizing, dyeing, printing resin treatment, water proofing, flame proofing, soil repellency, backing with foamed and unfoamed latex or jute. Carpet backing without other carpet manufacturing operation may be included in the dry processing mill category. Some carpet is backed with latex in a separate plant. Other carpet mills do latexing in the same plant with the finishing. Tufted carpets consist of face yarn that is looped through a woven mat backing (mostly polypropylene, some jute), dyed or printed, and then backed with either latex foam or coated with latex and a burlap-type woven fabric baking put over the latex.

The dominant face yarn is nylon, followed by acrylic, modacrylic and polyester. The latter two groups taken together are about equal to nylon. Since dyeing of these fibers in carpets differs little from dyeing fabric, the dyeing descriptions for these fibers given in other categories applies here as well.

The yarn is tufted into a woven or synthetic non-woven polypropylene or jute primary backing in a dry operation. Following this, the tufted carpet can be either printed or dyed. If printed, a semicontinuous screen printing operation is performed, followed by a wash and rinse step in the same machine. If dyed, the most common method is beck dyeing, in a manner quite similar to that described in previous categories for yarn goods. The continuous dyeing appears very similar to the continuous pad stream process used for cotton/synthetic blend broad woven finishing. After it is dyed, the carpet is dried in a tunnel drier. The carpet is then ready for application of adhesive and secondary backing [10].



2. PROCESS DESCRIPTION

2.1 Process stages description

•Carding
Is the preliminary process in spun yarn manufacture. The fibers are separated, distributed, equalized, and formed into a thin web and condensed into a continuous, untwisted strand of fibers called a sliver. This process also removes impurities and a certain amount of short, broken or immature fibers.

•Spinning
Is the process of making yarn from fibers by a combined drawing out and twisting operation or from filament tow by the combination of cutting/breaking with drafting and twisting in a single series of operations.

•Slashing (Sizing)
The thread is run through a starch solution and then dried so that it has the strength and stiffness required to withstand the abrasion and friction generated in the weaving operation.

•Weaving
Is the process of interlacing two yarns of similar materials so that they cross each other at right angles to produce woven fabric.

•Knitting
Is the process of constructing fabric by an interlocking series of loops of one or more yarns.

•Tufting
Is the process of making carpets and involves a wide multiple-machine needle process that sews pile yarns to a broad fabric baking.

•Desizing
Removes the sizing compounds applied to yarns to impart tensile strength. The starch sizing compounds are solubilized with alkali, acid or enzyme, and the fabric is washed thoroughly. Alkaline desizing utilizes a weak alkaline solution to facilitate size removal, while acid desizing employs a dilute acid solution to hydrolyze the size and render it water soluble. Enzyme desizing utilizes vegetable or animal enzymes to decompose size. After solubilizing the size, the fabric is rinsed clean.

•Scouring
Removes natural and acquired impurities form fibers and fabric. Synthetic fibers require less scouring than does cotton or light wool. Scouring agents include detergents, soaps, and various assisting agents, such as alkalis, wetting agents, formers, defoamers, and lubricants. After scouring, the goods are thoroughly rinsed (or washed) to remove excess agents.

•Wool Carbonizing

Removes burrs and other vegetable matter from loose wool or woven fabric goods. The process consists of acid impregnation, baking and mechanical agitation. A dilute solution of sulfuric acid is used to degrade cellulosic impurities to hydrocellulose without damaging the wool. The excess acid is squeezed from the wool and the wool is baked to oxidize the contaminants to gases and a solid carbon residue. The material then passes through pressure rollers to crush the solid residue and into a mechanical agitator to shake loose the crushed material. The acid content in the material remains high after agitation, requiring neutralization and rinsing before further processing.

•Mercerizing
is usually used in cotton processing to increase the tensile strength, luster, dye affinity, and abrasion resistance of the goods. In this operation, the cotton, usually in fabric form, is impregnated with a cold sodium hydroxide solution. The solution causes the cotton fibers (cellulose) to swell. After the desired contact period, the alkali is thoroughly washed out, sometimes with the use of a dilute acid bath to ensure neutralization. It has been normal practice to recover the caustic solution for concentration and reuse in scouring or mercerization.

•Bleaching
is a common process used to whiten cotton, wool and some synthetic fivers by removing the natural coloring. It is usually performed after scouring and prior to dyeing or printing. Bleaching chemicals include sodium hypochlorite, hydrogen peroxide, and sodium perborate, as well as optical brighteners. Batch bleaching is done in dyers (continuous processes use J-boxes) where fabric is tacked for a given period to allow the chemical to work before goods are withdrawn from the bottom of the box. Bleaching is followed by thorough rinsing.

•Dyeing
can be performed in the stock, yarn or fabric state, and single or multiple-fiber types can be dyed. Multiple-fiber may require multiple or sequential steps.
Stock dyeing is performed before the fiber is converted to the yarn state and can be a batch or continuous process. Yarn dyeing is performed on yarns used for woven goods, knit goods, and carpets. Usual methods include skein, package, and space dyeing.
Fabric dyeing is the most common method in use today because it can be continuous or semicontinuous, as well as a batch process. Methods employed include becks (winch), jet, jig, beam, and continuous range.

•Printing
is similar to dyeing, except that print color is applied to specific areas of the cloth. Dyes and dyeing assists are similar to those used in fabric dyeing; however, the color application techniques are quite different. Textiles are usually wet-printed by roller, rotary screen or flatbed screen methods.

•Finishing
involves the application of a wide range of chemicals to add properties to a fabric. Finishes can be applied, for example, to make a fabric wrinkle resistant, crease retentive, water repellant, flame resistant, mothproof, mildew resistant, bacteriostatic and/or stain resistant.

2.2 Process Diagrams

Table 1: Textile Industry- Wool Scouring Mill
Basis 1 tonne of scoured wool

Inputs: Raw materials	Inputs: Water	Inputs: Energy	Process	Wastes: Liquid	Wastes: Solid	Wastes: Gas
Wool 1300-4000 Kg [10] (3)		E. N.A. (1)	Sorting & Blending			
Soap N.A. Sodium Carbonate N.A.	66-100 m^3 [8]	E N.A. (1) S N.A. (2)	Scouring	pH 9.0-10.4 BOD 104.5-221.4 Kg [8] TS 1129-64448 ppm (3) Flow 46-100 m^3	N.A.	
		E N.A. (1) S N.A. (2)	Dry			vapors N.A. particulate N.A.

(1) E:Electricity
(2) S:Steam
(3) Raw sheep wool contains from 25 to 75% suint, which includes water soluble excretions of the sheep such as urine, feces, blood, dirt, grease, etc. Because of this, the scouring process contributes to more than half or even up to two-thirds of pollution load in terms of BOD [10]. See Table 1.1
(4) O&G: Oil and Grease

Table 2a: Textile Industry- Wool Finishing Mill. Fabric
Basis 1 tonne of wool fabric

Inputs: Raw materials	Inputs: Water	Inputs: Energy	Process	Wastes: Liquid	Wastes: Solid	Wastes: Gas
Wool Top N.A. Olive Oil N.A.		E N.A. (1)	Oiling			
		E N.A. (1)	Carding & Spinning		N.A.	
Starch N.A.	N.A. (2)	E N.A. (1) S N.A. (1)	Sizing	N.A. (2)		
		E N.A. (1) S N.A. (1)	Knitting or Weaving			Vapors N.A.

(1) Electricity (E) and Steam (S) consumption for the process stages is not available. The energy consumption for a Wool Finishing Mill is given in Table 2.b
(2) Individual data not available. Table 2.1 shows the global discharge from a Wool Finishing Mill and the water used.

Table 2b : Textile Industry- Wool Finishing Mill. Fabric Finishing
Basis 1tonne of finished cloth

Inputs			Process	Wastes		
Raw materials	**Water**	**Energy**		**Liquid**	**Solid**	**Gas**
H_2SO_4 N.A. (1)	30 m³ [10] (5)	N.A	Carbonize	N.A.	N.A.	Fine carbon particles N.A. Fumes (SO_2) N.A. ODP (6) N.A. [12]
Na_2CO_3 N.A.	N.A. (5)	N.A.	Neutralization	pH 1.9-9.0 BOD 1.7-2.1 Kg [8] TS 1241-4830 ppm (5) FLOW 1200-4800 m³		
(4)	N.A (5)	N.A.	Fulling			
Soap N.A Synthetic Detergent N.A	N.A (5)	S N.A E N.A	Washing	pH 7.3-10.3 BOD 31-94 Kg [8] TS 4800-19300 ppm (5) FLOW 330-840 m³		
SO_2 or N.A H_2O_2 N.A	N.A (5)	S N.A. E N.A.	Bleaching	pH 6.0 BOD 1.4 Kg [8] TS 908 ppm (5) FLOW 2.5-22.4 m³		
Acid Dye N.A (3) Metalized dye N.A (3)	N.A (5)	S N.A E N.A.	Dyeing	pH 4.8-8.0 BOD 9.0-34.3 [8] TS 3800-8300 ppm (5) FLOW 15.9-22.4 m³		Vapors N A
(2)	N.A (5)	N.A	Special Finishing	N.A. (2),(5)		Vapors N A Particulate N A
N.A		N.A	Mechanical Finishing			Particulate N A

(1) Carbonizing is applied only if the greige goods are 100% wool
(2) The only dry finishing operation of concern for waste generation is moth-proofing [10].
Table 2.4 shows the wastewater discharged if a permethrin-based mothproofing agent is used
(3) Table 2.2 lists the chemicals present in the woolen fiber dye baths
(4) There are two common methods of fulling, alkali fulling and acid fulling. See Table 2.3
(5) Table 2.1 shows wastewater generation of a Wool Finishing Mill as reported in Ref.[10]
(6) ODP: Organic decomposition products

Table 2.1: Effluent Generation Load Factors in a Wooll Fabric Finishing Mill
Basis: 1 tonne of woll fabric [10].

Amounts of Waste Load (Kg)			Water Used (m^3)		
BOD	COD	TSS	Minimum	Median	Maximum
59.8	204.8	17.2	110.9	283.6	657.2

Table 2.2: Chemicals Present in the woolen fiber dyebaths
Basis: 1 tonne of finished wool fabric [?]

Dye Type	Chemicals Present	Quantity (Kg)
Acid Dyes	Dye	N.A.
	Sulfuric or Acetic Acid or Ammonium Sulphate	N.A.
	Glauber Salt	N.A.
Metalized Dyes	Dye	N.A.
	Acetic Acid or Sulfuric Acid or Ammonium Sulphate	N.A

Table 2.4: Effluent characteristics for different mothproofing methods, using a permethrin-based Mothproofing Agent.
Basis: 1tonne of wool [21].

Method	Permethrin Load (g)	Wastewater discharge (m^3)
Hank Dyebath	8.0	50
Conventional tape scour	30.0	0.75
Mini-bowl tape scour	4.0	0.1
Modified centrifuge	1.7	0.05

Table 2.3: Chemicals Used for different fuling methods
Basis: 1 tonne of finished wool fabric [?].

Fulling Method	Chemicals Present	Quantity (Kg)
Alkali	Soap or Synthetic detergent	N.A.
	Sodium Carbonate	N.A.
	Sequestering agent	N.A
Acid (1)	Sulfuric Acid	N.A.
	Hydrogen peroxide	N.A
	Metallic Catalyst (Cromium, Copper and Cobalt)	N.A.

(1) Acid fulling is always followed by alkali fulling

Table 3 : Textile Industry- Dry Processing Mill
Basis 1000 Kg of woven/knit fabric

Inputs: Raw materials	Inputs: Water	Inputs: Energy	Process	Wastes: Liquid	Wastes: Solid	Wastes: Gas
Raw cotton [20] (3) 1050-1150 Kg		N.A	Opening & Picking			Waste lint [12] 50-80 Kg
Mineral Oil N.A. Non-ionic emulsifier N.A. Soluble Fatty Ester N.A.		3125-5400 KWh [7],[14]	Carding & Spinning		N.A.	
Starch or modified starch compounds (2) [19] 100-150 Kg	6.4 m³ [22]	N.A.	Sizing	pH 7.0-9.5 BOD 0.5-5.0 Kg TS 47-67 Kg [8] FLOW 0.8-140.1 m³ (4) [10]		Vapors N.A. Particulate N.A.
		3680-4760 KWh [14]	Weaving			
		1290-1750 KWh [14]	Knitting			

(1) Energy required for spinning only. Value for carding is not available
(2) For cotton and cotton blends. From 30 to 50 Kg if synthetic filaments are the raw materials
(3) Cotton may contain 4-12% by weight of impurities [3].
(4) Average wastewater discharge: 9.2 m³/t [10]

Table 4 : Textile Industry- Woven Fabric Finishing
Basis 1000 Kg of woven fabric

Inputs: Raw materials	Inputs: Water	Inputs: Energy	Process	Wastes: Liquid	Wastes: Solid	Wastes: Gas
Enzymes or H_2SO_4 N.A Yarn N.A.	14.6 m³ [12] (3)	5 GJ (1) [13]	Desizing	pH N.A. BOD 14.8-16.1 Kg (2) TS 66-70 Kg [8] FLOW 2.5-9 m³ (3)		Vapors N.A
(8)	28.4 m3 [12] (3)	5-11 GJ (1)(4) [13]	Scouring	pH N.A. BOD 1.4-3.0 Kg TS 47-67 Kg [8] FLOW 19.2-42.6 m³ (3)		
NaOH N.A	250 m3 [12] (3)	N.A (1)	Mercerize	pH 5.5-9.5 BOD 10.5-13.5Kg TS 185-450 Kg [8] FLOW 232-308 m³ (3)		
H_2O_2 or N.A NaOCl N.A	2.5 m3 [12] (3)	10 GJ (1)(5) [13]	Bleach	pH 8.5-9.6 BOD 5.0-14.8 Kg TS 38-290 Kg [8] FLOW 2.50-124 m³ (3)		Vapors N.A
See Table 6.4	N.A (3)	N.A (1)	Dyeing	Function of the dye used (3) (7)		
N.A	37.5 m3 [12] (3)	N.A (1)	Printing	N.A. (3)		VOC?
Finishing Agent N.A Starch resin N.A	N.A (3)	1.9-3.7 GJ [13] (1) 2.6-7.1 GJ [17] (6)	Finishing & Drying	N.A. (3)		Vapors Particulate N.A

(1) Total Energy requirement for Woven Fabric Finishing 10770-18670 KWh per tonne of finished fabric [14]
(2) Ref. [10] 60 Kg BOD per tonne of fabric
(3) Table 4.1 shows the global discharge for a Woven Fabric Finishing Mill and the water used
(4) Scouring process consumes about 5-6 GJ t. Subsequent washing-off requires a further 5 to 6 GJ t [13]
(5) The energy required for bleaching may amount5 GJ t. Washing-off is an important part of the processing and again is found to require about 6 GJ t
(6) Energy required for drying only
(7) Table 6.3 shows the waste load of cotton dyeing for different dyes
(8) There are two common methods of scouring, Kier boil and continuous scouring. See Table 4.2

Table 4.1: Effluent Generation Load Factors in a Woven Fabric Finishing Mill
Basis: 1 tonne of woven fabric [10].

	Amounts of Waste Load (Kg)							Water Used (m^3)		
	BOD	COD	TSS	O&G	Phenol	Cr	Sulphide	Minimum	Median	Maximum
Simple processing (1)	27.7	81.1	6.3	4.0	8.7	7.8	13.0	12.5	78.4	275.2
Complex processing (2)	22.1	115.4	6.9	3.5	12.0	4.7	14.0	10.8	86.7	276.9
Complex processing plus desizing	45.1	122.6	14.8	4.1	13.1	20.9	N.A.	5	113.4	507.9

(1) Processes such as desizing, fibre manufacturing preparation and dyeing
(2) Simple manufacturing with additional operations such as printing and dyeing

Table 4.2: Chemicals Used in the scouring process
Basis: 1 tonne of finished fabric [12].

Scouring Method	Chemicals Present	Quantity (Kg)
Kier Boil	NaOH	10-80
	Na_2CO_3	10-30
	Na_2SiO_3	2.5-10
	Pine Oil Soap	N.A.
	Fatty alcohol sulfates	N.A.
Continuous Scour	Caustic Soda	N.A.
	Wetting Agent	N.A.

Table 4.3: Pollution effect of cotton dyeing for different dyes
Basis 1000 Kg of finished cloth [8].

Wastewater characteristics	Aniline black	Basic	Developed Colors	Direct	Naphthol	Sulfur	Vats
pH	N.A	6.0-7.5	5-10	6.5-7.6	5-10	8-10	5-10
BOD (Kg)	5-10	15-50	15-20	1.3-11.7	2-5	2-250	12-30
TS (Kg)	100-200	150-250	325-650	25-250	200-650	300-1200	150-250
FLOW (m^3)	124-190	149-298	74-207	14-53	19-139	24-212	8.3-166

Table 4.4: Chemicals present in cotton dyebaths
Basis: 1 tonne of finished fabric [12].

Dye Type	Chemicals Present	Quantity (Kg)
Aniline Black	Aniline hydrochloride	N.A.
	Sodium Ferrocyanide	N.A.
	Sodium Chlorite	N.A.
	Pigment	N.A.
	Soap	N.A.
Developed	Dye	N.A.
	Penetrant	N.A.
	Sodium chloride	N.A.
	Sodium Nitrate	N.A.
	Hydrochloric Acid or Sulphuric Acid	N.A.
	Developer (Beta-Naphtol)	N.A.
	Soap or Sulfated Soap or Fatty Alcohol	N.A.
Direct	Dye	N.A.
	Sodium Carbonate	N.A.
	Sodium Chloride (1)	0-300
	Wetting Agent or Soluble Oil or Sodium Sulfate	N.A.
Naphthol	Dye	N.A.
	Caustic Soda	N.A.
	Soluble Oil	N.A.
	Alcohol	N.A.
	Soap	N.A.
	Soda Ash	N.A.
	Sodium Chloride	N.A.
	Base	N.A.
	Sodium Nitrate	N.A.
	Sodium Nitrite	N.A.
	Sodium Acetate	N.A.
Sulfur	Dye	N.A.
	Sodium Sulfide	N.A.
	Sodium Carbonate	N.A.
	Sodium Chloride	N.A.
Vat	Dye	N.A.
	Caustic Soda	N.A.
	Sodium Hydrosulfite	N.A.
	Soluble Oil	N.A.
	Gelatine	N.A.
	Perborate or Hydrogen Peroxide	N.A.

(1) Function of the dye used. Amount of NaCl required for 50% dye exhaustion [20]

Table 5 : Textile Industry- Knit Fabric Finishing
Basis 1000 Kg of Knit Fabric

Inputs			Process	Wastes		
Raw materials	Water	Energy		Liquid	Solid	Gas
Knit Greige Goods N.A Detergents N.A	N.A (3)	N.A (1)	Washing	N.A.(3)		
Dye N.A Additives N.A	N.A (3)	42.7 GJ [22] (2)	Dyeing	N.A.(3)		Vapors N.A
Scour N.A Bleach Agents N.A	N.A (3)	N.A (1)	Kier Scouring & Bleaching	N.A.(3)		
		N.A (1)	Drying	N.A.(3)		N.A
N.A	N.A (3)	N.A (1)	Printing	N.A.(3)		N.A
N.A	N.A (3)	N.A (1)	Wet Pad Finishing Bad			N.A
N.A	N.A (3)	N.A (1)	Finishing & Drying			Vapors N.A Particulate N.A

(1) Energy consumption for knitted Fabric Finishing: 13680-20710 KWh per tonne of finished knit fabric [14]
(2) Energy required for combined Disperse reactive dyeing of Polyester Cotton Knit Fabric
(3) Table 5.1 shows the effluent Generation Load Factors and the water requirement in a Knit Fabric Finishing Mill.

Table 5.1: Effluent Generation Load Factors in a Knit Fabric Finishing Mill
Basis: 1 tonne of woven fabric [10].

		Amounts of Waste Load Kg							Water Used m^3		
		BOD	**COD**	**TSS**	**O&G**	**Phenol**	**Cr**	**Sulphide**	**Minimum**	**Median**	**Maximum**
Simple processing	(1)	27.7	81.1	6.3	4.0	8.7	7.8	13.0	8.3	135.9	392.8
Complex processing	(2)	22.1	115.4	6.9	3.5	12.0	4.7	14.0	20.0	83.4	377.8
Hosiery Products	(3)	26.4	89.4	6.7	6.6	4.2	6.4	23.8	5.8	69.2	289.4

Table 6 : Textile Industry- Stock and Yarn Finishing Mill
Basis 1 tonne of yarn

Inputs			Process	Wastes		
Raw materials	**Water**	**Energy**		**Liquid**	**Solid**	**Gas**
Cotton or Cotton Blend Yarn or Stock N.A N.A NaOH N.A	N.A (1)	N.A	Mercerise	N.A (1)		
H_2O_2 N.A NaOCl N.A	N.A (1)	N.A	Bleaching	N.A (1)		Vapors N.A
Dye N.A Chemicals N.A	N.A (1)	9120-11810 KWh [14] 11.74 GJ (2) [22]	Dyeing	N.A (1)		Vapors N.A

(1) Individual data not available. Table 5.1 shows the effluent load and the water consumption for a Stock and Yarn Finishing Mill
(2) Energy required for Pressure Package Dyeing of Polyester Yarn

Table 6.1: Effluent Generation Load Factors in a Stock and Yarn Finishing Mill
Basis: 1 tonne of yarn [10]

Amounts of Waste Load (Kg)							Water Used (m^3)		
BOD	**COD**	**TSS**	**O&G**	**Phenol**	**Cr**	**Sulphide**	**Minimum**	**Median**	**Maximum**
20.7	62.7	4.6	1.6	15.0	12.0	27.8	3.3	100.1	557.1

Table 7 : Textile Industry- Carpet Mill
Basis: 1 tonne of Carpet

Inputs			Process	Wastes		
Raw materials	Water	Energy		Liquid	Solid	Gas
Synthetic yarn N.A.		N.A.	Tufting			
Dye N.A. Additives N.A.	N.A. (2)	17.7 GJ [23](3)	Dye or Print	N.A (2)		Vapor N.A.
		N.A.	Dry	N.A (2)		Vapors N.A. Particulate N.A.
(1)	N.A. (2)	N.A.	Finishing	N.A (2)	N.A (2)	Vapor N.A.

(1) For wool and wool blends, mothproofing may be applied. See Table 2.4
(2) Effluent characteristics for each step not available. Table 7.1 shows the wastewater characteristics and the amount of water needed for a carpet mill.
(3) Energy required for dyeing

Table 7.1: Effluent Generation Load Factors in Carpet Finishing Mill
Basis: 1 tonne of carpet [10].

Amounts of Waste Load (Kg)							Water Used (m^3)		
BOD	COD	TSS	O&G	Phenol	Cr	Sulphide	Minimum	Median	Maximum
25.6	62.7	4.6	1.6	15.0	12.0	27.8	8.3	46.7	162.6

3. WASTES AND ADD-ON TECHNOLOGY

3.1 Wastewater

Textile process effluents, have a high BOD high total dissolved solids and a high temperature and are generally grey in color. Natural impurities extracted form the type of fibre being processed along with the chemicals used for processing are the two main sources of pollution. Other factors which determine effluent quantity and quality include the unit operations used and the degree to which water and chemicals are preserved in a particular manufacturing plant.

Typical textile processing operations can include the use of several non-process chemicals such as machine cleaners, shop chemicals, biocides, insecticides and boiler treatment, the use of which is rarely as well controlled as that of most process chemicals.

Textile mill wastes are also highly colored due to the application of dyes with color units ranging between 300 to 1000 for non-wool operations and as high as 2000 in the case of effluents form wool scouring.

• Organic priority pollutants expected to be found in textile effluents (at the ppb level) are substituted phenol (i.e. toluene, ethylbenzene and chlorobenzenes), naphthalene, phenol, substituted phenol (i.e. chlorophenol, methylphenol and nitrophenol), chloroethylenes, chloroethanes, chloroform and phtalates such as bis (2-ethylhexyl) phthalate and di-n-butylphtalate. These pollutants may come as trace or additives in dyes, dye carriers and raw materials as well as form their uses in the wet processing.

• If 'total phenols' is used as a surrogate measure for the control of organic priority pollutants in textile effluents, as suggested by the EPA, effluents form the mills surveyed all had a loading of total phenols below 0.05 Kg per 1000 kg of products. This is below the limit set by the EPA Textile Mill Effluent Guidelines. The potential sources for organic priority pollutants are related to the varied application of these dyes as detailed below:

- Those that may be present in commercial dyes or dye carriers as trace impurities or additives include toluene, ethylbenzene, dichlorobenzene, naphthalene, phenol, nitrophenol, 2,4-dimethylphenol, pentachlorophenol and p-chloro-m-cresol.
- Those that may be used as cleaning solvents or scouring agents are 1,1,1-trichlorcethane, trichloroethane, tetrachloroethylene, chloroform and 1,2-dichloroethane.
- Those that may be used as a plasticiser or in coating formulations are bis (2-ethylhexyl) phthalate and di-n-butylphtahalate
- Those that are ubiquitous and may be present in rawwater supplies or raw material are chloroform, 1,2-dichlorethane, phenol and bis (2-ethylhexyl) phthalate.

• Metal priority pollutants commonly found in textile effluents are zinc, copper chromium, lead and nickel; individual concentration of these metals tends to be below 1mg/l, the discharge limit set by local municipal sewer by-law. Dyes used in processing are the main sources of these metal pollutants.

• If Chromium is used as a surrogate measure for the control of all heavy metals in textile effluents, effluents form the mills surveyed had a pollution loading of chromium less than 0.05 Kg per 1000 Kg of product, below the monthly average limit set by EPA Textile Mill Effluent Guidelines.

Wool effluents are characterized by high BOD, high solids concentration and a high grease content. Cotton finishing effluents are not as strong as those produced by the wool industry but may have a high color content due to cotton dyeing operations. They also have

Table 8: Overview of Effluent Treatment Technologies [10]

Type of effluent	Processes Normally Employed	Strategy
Wool Scouring	Screening-Equalization (1)-Flotation-Chemical Assisted Sedimentation (2)-Biological Treatment	Segregation of rinse water for volume reduction
Wool Finishing	Screening-Equalization (1)-Biological Treatment-Residual Chromium Removal by Chemically Assisted Sedimentation (2)	Segregation and pretreatment of chrome bearing streams
Dry Processing	Screening-Equalization (1)-Biological Treatment	Segregation of latex stream for separate treatment
Woven and Knit Fabric Finishing	Screening-Equalization (1)-Biological Treatment-Residual COD removal by Chemical Assisted Sedimentation (2)	
Carpet Mill	Screening-Equalization (1)-Biological Treatment	Segregation of latex stream for separate treatment
Stock & Yarn Dyeing	Screening-Equalization (1)-Biological Treatment	

(1) Equalization may include neutralization for the adjustment of pH

(2) Chemically assisted sedimentation is normally performed with lime and alum. Use of polyelectrolytes has proved beneficial in some instances

Table 9: Anticipated Treatment Removal Efficiencies [10]

Treatment Process Unit	Range of Removal Efficiency in %				
	BOD_5	COD	TSS	Grease	Color
Primary Treatment					
Screening	0-5	-	5-20	-	-
Equalization	0-20	-	-	-	-
Neutralization	-	-	-	-	-
Chemical Coagulation (2)	40-70	40-70	30-90	90-97	0-70
Flotation	30-50	20-40	50-60	90-98	-
Secondary Treatment					
Conventional Activated Sludge and Clarification	70-95	50-70	85-95	0-15	(2)
Extended Aireation and Clarification	70-94	50-70	85-95	0-15	(2)
Aerated Lagoon and Clarification	60-90	45-60	85-95	0-10	(2)
Aerobic Lagoon	50-80	35-60	50-80	0-10	(2)
Packed Tower	40-70	20-40	-	-	(2)
Roughing Filter	40-60	20-30	-	-	(2)
Tertiary Treatment					
Chemical Coagulation	40-70	40-70	30-90	90-97	0-70
Mixed Media Filtration	25-40	25-40	80	-	-
Carbon Adsorption	25-40	25-60	25-40	-	80-90
Chlorination	0-5	0-5	-	0-5	0-5
Ozonization	-	30-40	50-70	-	70-80
Advanced Treatment					
Spray Irrigation	90-95	80-90	95-98	-	-
Evaporation	98-99	95-98	99	-	-
Reverse Osmosis	95-99	90-95	95-98	-	-

(1) Removals vary with chemicals and dosages used
(2) 20% color removal for biological treatment units

US EPA BPT AND BAT EFFLUENT LIMITS FOR THE TEXTILE INDUSTRY

Table 10a: US EPA BPT and BAT effluent limits for Wool Scouring Mills

	BPT Limitations Kg/1000 Kg of Fibre		BAT Limitations Kg/1000 Kg of Fibre	
	Daily Maximum	**Monthly Average**	**Daily Maximum**	**Monthly Average**
BOD	10.6	5.3		
COD	138.0	69.0	138.0	69.0
TSS	32.2	16.1		
Sulphide	0.20	0.10	0.20	0.10
Phenols	0.10	0.05	0.10	0.05
Total Chromium	0.10	0.05	0.10	0.05
Oil & Grease	7.2	3.6		
pH	6-9	6-9		

Table 10b: US EPA BPT and BAT effluent limits for Wool Finishing Mills

	BPT Limitations Kg/1000 Kg of Fibre		BAT Limitations Kg/1000 Kg of Fibre	
	Daily Maximum	**Monthly Average**	**Daily Maximum**	**Monthly Average**
BOD	22.4	11.2		
COD	163.0	81.5	163.0	81.5
TSS	35.2	17.6		
Sulphide	0.28	0.14	0.28	0.14
Phenols	0.14	0.07	0.14	0.07
Total Chromium	0.14	0.07	0.14	0.07
pH	6-9	6-9		

Table 10c: US EPA BPT and BAT effluent limits for Woven Fabric Finishing Mills

	BPT Limitations Kg/1000 Kg of Fibre		BAT Limitations Kg/1000 Kg of Fibre	
	Daily Maximum	**Monthly Average**	**Daily Maximum**	**Monthly Average**
BOD	6.6	3.3		
COD	60.0	30.0	60.0	30.0
TSS	17.8	8.9		
Sulphide	0.20	0.10	0.20	0.10
Phenols	0.10	0.05	0.10	0.05
Total Chromium	0.10	0.05	0.10	0.05
pH	6-9	6-9		

Table 10d:	**US EPA BPT and BAT effluent limits for Knit Fabric Finishing Mills**			
	BPT Limitations Kg/1000 Kg of Fibre		**BAT Limitations Kg/1000 Kg of Fibre**	
	Daily Maximum	**Monthly Average**	**Daily Maximum**	**Monthly Average**
BOD	5.0	2.5		
COD	60.0	30.0	60.0	30.0
TSS	21.8	10.9		
Sulphide	0.20	0.10	0.20	0.10
Phenols	0.10	0.05	0.10	0.05
Total Chromium	0.10	0.05	0.10	0.05
pH	6-9	6-9		

Table 10e:	**US EPA BPT and BAT effluent limits for Carpet Finishing Mills**			
	BPT Limitations Kg/1000 Kg of Fibre		**BAT Limitations Kg/1000 Kg of Fibre**	
	Daily Maximum	**Monthly Average**	**Daily Maximum**	**Monthly Average**
BOD	7.8	3.9		
COD	70.2	35.1	70.2	35.1
TSS	11.0	5.5		
Sulphide	0.08	0.04	0.08	0.04
Phenols	0.04	0.02	0.04	0.02
Total Chromium	0.04	0.02	0.04	0.02
pH	6-9	6-9		

Table 10f:	**US EPA BPT and BAT effluent limits for Stock and Yarn Finishing Mills**			
	BPT Limitations Kg/1000 Kg of Fibre		**BAT Limitations Kg/1000 Kg of Fibre**	
	Daily Maximum	**Monthly Average**	**Daily Maximum**	**Monthly Average**
BOD	6.8	3.4		
COD	84.6	42.3	84.6	42.3
TSS	7.4	8.7		
Sulphide	0.24	0.12	0.24	0.12
Phenols	0.12	0.06	0.12	0.06
Total Chromium	0.12	0.06	0.12	0.06
pH	6-9	6-9		

3.2 Air pollution

The conventional source of air pollution form a textile mill is the boiler stack. These emissions normally consist of pollutants such as suspended particulates and sulphur dioxide. Regulations often specify the type and composition of fuel used as well as the minimum stack height for satisfactory pollutant dispersal. Air missions control methods commonly installed at textile mills include cyclone separators, bag filters and wet scrubbers

Oil mist and VOC emissions to air are less conventional and more difficult to control. Reductions can be achieved by controlling the application of spinning oils and finishing agents to fabrics and by checking the heat input to evaporators.

Proper air ducting system and the installation of mist eliminators are another important control technique. Oil mist elimination generally consists of four steps:
1.- Pre-removal of lint and dust. This is accomplished either with fabric filters or high energy mist eliminators.

2.- Condensation of vapors to mist prior to collection by cooling the contaminated air. This step may be performed either by direct contact cooling or heat recovery via a heat exchanger. Examples of direct contact cooling techniques are low energy scrubbers, spray towers and packed towers. These methods all generate some additional effluent which must eventually be taken at the effluent treatment plant.

3.- Mist removal form air, using equipment such as electrostatic precipitators. When oil mists contain water, high efficiency fibre mist eliminators are better than electrostatic precipitators. Incineration with heat recovery is also popular. In this case no pre-cooling or condensation is necessary. Virtually everything in the exhaust is destroyed and the final emissions are odorless.

4.- Collection and disposal of the contaminant.

The other major source of air emissions is form organic solvent vapor releases during and after drying, finishing and solvent processing operations. These vapors cannot be treated by scrubbing because they have a limited solubility in water. Incineration is expensive and emissions form incineration also need to be handled separately. The only effective way to solve this problem is to use activated carbon for vapor adsorption and attempt some form of solvent recovery.[10]

-Lint filtration form spinning, drawing, carding and twisting operations
-fumes from wool carbonizing
-odor form dyeing and finishing operations. Odors of acetic acid, formaldehyde, acids, dyes and other organics may exist [12].
Possible emissions form textile processing includes:
-Oil mists and organic emissions produced when textile materials containing knitting and lubricating oils, plasticizers, and other materials that can volatilize or be thermically degraded into volatile substances, are subjected to heat. Processes that can be the sources of oil mists include tentering, calendaring, heat setting, drying and curing
-Acid mists produced during the carbonizing of wool
-Solvent vapors released during and after solvent processing operations such as dry cleaning
-Dust and ling produced by the processing of natural fibers and synthetic staples prior to and during spinning, as well as by napping and carpet shearing.2??

4. ALTERNATIVE TECHNOLOGIES

4.1 Chemicals: conservation, reuse, recovery and substitution

- Automated chemical dispensing [10]
- Optimize processing sequence and recipes [24]
- Substitution of low BOD process chemicals for those having high BOD values [10]

- Synthetic Sizes (1-3% BOD) for starch (50% BOD) and gelatins (100% BOD)
- Ammonium Sulphate/Chloride or mineral acids (0%BOD) for Acetic Acid (33-62% BOD)
- Low BOD Synthetic Detergent (0-22% BOD) for Soaps (140% BOD)
- Olive Oil applied in Wool Carding (100% BOD) for Mineral Acids with Non-ionic emulsifier (20% BOD)
- Substitute Formic Acid (0.12 Kg BOD/kg) for Acetic Acid (0.64 KgBOD/Kg) in dye baths

- H_2O_2 instead of enzymes to desize the starch. When the starch is degraded by oxidation using hydrogen peroxide, the BOD is much lower in the effluent because the starch is degraded fully to carbon dioxide and water [10].
- Use of enzymes that degrade the starch size to ethanol instead of anhydroglucose. The ethanol can be recovered by distillation for use as a solvent or fuel, thereby reducing the BOD load in the desized effluent considerably [10].
- Eliminate phosphates wherever possible
- Re-use of dye solutions from the dyebath [10]. 34% flow reduction and 33% COD reduction
- Recovery of Caustic in Mercerizing [10]
- Recovery of size in cotton processing, if a sintethyc size is used [10]

4.2 Process modifications, operational modifications

• Single-stage desizing-scouring-bleaching for the processing of cotton and their blends with synthetics [10]
• Sovent-aided scouring and bleaching processes [10]
• Hot mercerization in place of conventional cold mercerization (often enabling the elimination of separate scouring treatment [10]
• Batch Operation for Dyeing [10]:

-Winch Dyeing: By dropping the dye bath and avoiding overflow rinsing, water consumption could be reduced by 25%.
-High and Low: By replacing the overflow with Pressure Jet Dyeing batchwise rinsing, water consumption can be cut by approximately 50%.
-Beam Dyeing: About 60% of the water consumption may be reduced by preventing overflow during soaking and rinsing. Automatic controls proved to be quite economical with a payback period of about four months.
-Jig Dyeing: A wide range of reductions (from 15% to 79%) are possible by switching form the practice of overflow to stepwise rinsing
-Cheese Dyeing: reduction of around 70% is possible following intermittent rinsing.

•Continuous operation in dyeing: 20-30% savings by introducing automatic water stops[10]
• Liquid ammonia mercerization instead of caustic [6]
• Use of low volume, high pressure nozzles for cleaning printing screens. Water usage reduction by 30% [24]
• Reuse of final rinse water from dyeing for dye bath make-up [6]
• Reuse scouring rinses for desizing [6]
• Reuse of mercerizing or bleach washwater for scouring or desizing [6]
• Recycle reuse of water jet weaving wastewater. Impurities and oils must be removed by in-line filters [6]
• Foam processing
• Segregate water use for cooling purposes

4.3 Energy conservation

ACTION	Typical Saving (MJ/t cloth)
• Water Using Processes [15]	
Avoid under loading	proportional to loading
Reuse of hot water	1900
Use counterflow	1370
Limit idling losses	950
Reduce rinsing water	1370
Reduce water temperature	950
Recover heat where possible	35% of total
• Drying and Heating Processes [15]	
Maximize mechanical drying	211
Avoid over-drying	475
Minimize setting and dye-fixation times	211
Reduce exhaust air to practical minimum. Monitor humidity of drying processes	25% of total
Examine thermal efficiency of forced convection systems	Small
Reduce idling losses, e.g., by switching off exhaust air	475
Recover heat form exhaust air	25% of total

5. REFERENCES

[1] Industrial Pollution Prevention and Abatement Chapter on Textiles Industry
The World Bank, United Nations Industrial Development Organization, United Nations Environmental Programme. March 1994
Anil Somani, Ralph Luken, Fritz Balkau, Frank Van den Akker and Martyn Riddle

[2] Industrial Prevention in the Textile Industries
L.J. Snowden-Swan
In: Industrial pollution prevention Handbook
Harry M. Freeman
Ed. McGraw Hill. New York. 1995

[3] Industrial Water use and treatment practices
J.B. Carmichael and K.M. Strezepek
UNIDO. Cassell Tycooly, 1987

[4] Natural Fiber Textile Industry
Anthony J. Buonicore
In: Air Pollution Engineering Manual
Ed. Air & Waste Management Association. A.J. Buonicore, W.T. Davis
Van Nostrnd Reinhold. New York 1992

[5] Industrial Water Pollution. Oringins, characteristics and treatment
Nelson L. Nemerow
Addison-Wesley Publishing Company, 1978

[6] Pollution Prevention and Technology Handbook
Ed. Robert Noyes. Noyes Publications. New Yersey, 1993

[7] Textile Industry. Handy Manual. Output of a Seminar on Energy Conservation in Textile Industry
UNIDO, 1992

[8] Pollution Control in the Textile Industry
Pollution Technology Review No.2
Noyes Data Corporation. New Yersey, 1973

[9] Energy Conservation in Textile and Polymer Processing
Ed. T.L. Vigo and L.J. Nowacki. ACS Symposium Series 107.
Ameriacan Chemical Society. Washington, 1979
Chapter 11: Sizing and Desizing Textiles with Degraded Starch and Ultrasonic Techniques to Conserve Energy
Elgal G. M., Ruppenicker G.F., and Knoepfler N.B.

[10] Environmental aspects of the textile industry. A Technical Guide
Prasad Modak
Es el manual de la UNEP. Publicacio no16
United Nations Environment Programme. Industry and Environment Office 1990

[11] Case Studies in pollution control measures in the textile dyeing and finishing industries.
M.H. Atkins and J.F. Lowe
Pergamos Press 1979

[12] Industrial Pollution Control Handbook
Ed. H.F. Lund
New York, Mc Graw Hill 1971
Chapter 15, pp 15.1-15.30. Pollution Control in Textile Mills

[13] Low energy preparation of cotton and cotton Blends
J.G. Roberts and B.C. Burdett
International seminar on energy conservation in industry
Ed.Strub A.S. and Ehringer H.
Comission of the European Comunities
Dusseldorf: Verlag des Vereins Deutscher Inginieure, 1984

[14] Energy consumption and Conservation in the Fibre-producing and Textile Industries
Kim S.Y., Grady P.L., Hersh S.P.
Textile Progress, Volume 13, Number 3,1983

[15] Industrial energy conservation: a Handbook for engineers and managers
Reay D.A
Oxford; New York: Pergamon Press, 1979

[14] Energy Cost.ervation in Cotton Ginning
Baker R.V., McCaskill O.L. Energy Conservation in Textile and Polymer Processing
Ed. T.L. Vigo and L.J. Nowacki. ACS Symposium Series 107.
American Chemical Society. Washington, 1979

[15] Energy use in the textile finishing sector
Industrial Energy Thrift Scheme
Department of Industry
Report No 20
1980

[16] Water use and wastes in the textile industry
Environmental Science & Technology

[17] Energy Consumption and Conservation: Textile Drying
David Brookstein. Chapter 17
In: Energy Conservation in Textile and Polymer Processing
Ed. T.L. Vigo and L.J. Nowacki. ACS Symposium Series 107.
American Chemical Society. Washington, 1979

[18] Low Energy preparation processes for textiles
J.G. Roberts
In: Energy conseration in industry applications and techniques. Proceedings of the contractors meeting held in Brussels on 1982
Ed. Ehringer H., Hoyaux G., Pilavachi P.A.
Publisher????

[19] Handbook of chemical specialties. Textile Fiber Processing Preparation and Bleaching
Nettles J.E.
John Wiley & Sons, New York,1983

[20] Textile Processing and Properties. Preparation, Dyeing, Finishing and Performance.
T.L. Vigo
Elsevier Science, 1994. Amsterdam

[21] Environmental Issues in Wool Processing
T. Shaw
In: Are textiles finishing the environment?
Conference of the Textile Institute Finishing Group. 28-29 March 1990
Textile Institute.Manchester, 1990

[22] Handbook of Environmental Control
Volume III. Water Suply and Treatment
Richard G. Bond
Conrad P. Straub
CRC Press 1973

[23] Dyebath and Auxiliary Bath Reuse for Energy and Mass Conservation
F.L. Cook and W.C.Tincher
In: Energy conservation in textile and polymer processing
Ed. T.L. Vigo and L.J. Nowacki
ACS Symposium Series 107
Washington DC 1979
American Chemical Society

[24] Wealth ourt of Waste
Waste Minimization Group. Vol 2 1994