Textiles

Industry Description and Practices

The textile industry uses vegetable fibers such as cotton; animal fibers such as wool and silk; and a wide range of synthetic materials such as nylon, polyester, and acrylics. The production of natural fibers is approximately equal in amount to the production of synthetic fibers. Polyester accounts for about 50% of synthetics. (Chemical production of the polymers used to make synthetic fiber is not covered in this document.)

The stages of textile production are fiber production, fiber processing and spinning, yarn preparation, fabric production, bleaching, dyeing and printing, and finishing. Each stage generates wastes that require proper management.

This document focuses on the wet processes (including wool washing, bleaching, dyeing, printing, and finishing) used in textile processing.

Waste Characteristics

Textile production involves a number of wet processes that may use solvents. Emissions of volatile organic compounds (VOCs) mainly arise from textile finishing, drying processes, and solvent use. VOC concentrations vary from 10 milligrams of carbon per cubic meter (mg/m^3) for the thermosol process to 350 mg carbon/m^3 for the drying and condensation process. Process wastewater is a major source of pollutants (see Table 1). It is typically alkaline and has high BOD—from 700 to 2,000 milligrams per liter (mg/l)—and high chemical oxygen demand (COD), at approximately 2 to 5 times the BOD level. Wastewater also contains solids, oil, and possibly toxic organics, including phenols from dyeing and finishing and halogenated organics from processes such as bleaching. Dye wastewaters are frequently highly colored and may contain heavy metals such as copper and chromium. Wool processing may release bacteria and other pathogens. Pesticides are sometimes used for the preservation of natural fibers, and these are transferred to wastewaters during washing and scouring operations. Pesticides are used for mothproofing, brominated flame retardants are used for synthetic fabrics, and isocyanates are used for lamination *The use of pesticides and other chemicals that are banned in OECD countries is discouraged and in general, is not acceptable.* Wastewaters should be checked for pesticides such as DDT and PCP and for metals such as mercury, arsenic, and copper.

Air emissions include dust, oil mists, acid vapors, odors, and boiler exhausts. Cleaning and production changes result in sludges from tanks and spent process chemicals, which may contain toxic organics and metals.

Pollution Prevention and Control

Pollution prevention programs should focus on reduction of water use and on more efficient use of process chemicals. Process changes might include the following:

- Match process variables to type and weight of fabric (reduces wastes by 10–20%).
- Manage batches to minimize waste at the end of cycles.
- Avoid nondegradable or less degradable surfactants (for washing and scouring) and spinning oils.
- Avoid the use, or at least the discharge, of alkylphenol ethoxylates. Ozone-depleting substances should not be used, and the use of organic solvents should be minimized.

Table 1. Wastewater Characteristics in the Textiles Industry

Process and unit (U)	*Waste volume (m^3/U)*	*BOD (kg/U)*	*TSS (kg/U)*	*Other pollutants (kg/U)*	
Wool processing (metric ton of wool)[a]					
Average unscoured stock[b]	544	314	196	Oil	191
Average scoured stock	537	87	43	Cr	1.33
Process-specific				Phenol	0.17
Scouring	17	227	153	Cr	1.33
Dyeing	25	27		Phenol	0.17
Washing	362	63			
Carbonizing	138	2	44	Oil	191
Bleaching	12.5	1.4		Cr	1.33
				Phenol	0.17
Cotton processing (metric ton of cotton)					
Average compounded[c]	265	115	70		
Process-specific					
Yarn sizing	4.2	2.8			
Desizing	22	58	30		
Kiering	100	53	22		
Bleaching	100	8	5		
Mercerizing	35	8	2.5		
Dyeing	50	60	25		
Printing	14	54	12		
Other fibers (metric ton of product)					
Rayon processing	42	30	55		
Acetate processing	75	45	40		
Nylon processing	125	45	30		
Acrylic processing	210	125	87		
Polyester processing	100	185	95		

a. The pH varies widely, from 1.9 to 10.4.
b. The average compounded load factors listed are based on the assumption that only 20% of the product is mercerized (only nonwoolen components are mercerized) and 10% is bleached.
c. The average compounded load factors listed are based on the assumption that only 35% of the product is mercerized, 50% of the product is dyed, and 14% of the product is printed.
Source: Economopoulos 1993.

- Use transfer printing for synthetics (reduces water consumption from 250 l/kg to 2 l/kg of material and also reduces dye consumption). Use water-based printing pastes, when feasible.
- Use pad batch dyeing (saves up to 80% of energy requirements and 90% of water consumption and reduces dye and salt usage). For knitted goods, exhaust dyeing is preferred.
- Use jet dyers, with a liquid-to-fabric ratio of 4:1 to 8:1, instead of winch dyers, with a ratio of 15:1, where feasible.
- Avoid benzidine-based azo dyes and dyes containing cadmium and other heavy metals. Do not use chlorine-based dyes.
- Use less toxic dye carriers and finishing agents. Avoid carriers containing chlorine, such as chlorinated aromatics.
- Replace dichromate oxidation of vat dyes and sulfur dyes with peroxide oxidation.
- Reuse dye solution from dye baths.
- Use peroxide-based bleaches instead of sulfur- and chlorine-based bleaches, where feasible.
- Control makeup chemicals.
- Reuse and recover process chemicals such as caustic (reduces chemical costs by 30%) and size (up to 50% recovery is feasible).
- Replace nondegradable spin finish and size with degradable alternatives.
- Use biodegradable textile preservation chemicals. Do not use polybrominated diphe-

nylethers, dieldrin, arsenic, mercury, or pentachlorophenol in mothproofing, carpet backing, and other finishing processes. Where feasible, use permethrin for mothproofing instead.
- Control the quantity and temperature of water used.
- Use countercurrent rinsing.
- Improve cleaning and housekeeping measures (which may reduce water usage to less than 150 m^3/t of textiles produced).
- Recover heat from wash water (reduces steam consumption).

Target Pollution Loads

Implementation of cleaner production processes and pollution prevention measures can yield both economic and environmental benefits. The following production-related waste load figures can be achieved by implementing measures such as those described above. The figures are the waste loads arising from the production processes before the addition of pollution control measures.

Air Emissions

VOC emissions should be less than 1 kilogram carbon per ton of fabric.

Wastewater

Wastewater load levels should preferably be less than 100 cubic meters per ton of fabric, but up to 150 m^3 is considered acceptable.

Treatment Technologies

VOC abatement measures include using scrubbers, employing activated carbon adsorbers, and routing the vapors through a combustion system. A common approach to wastewater treatment consists of screening, flow equalization, and settling to remove suspended solids, followed by biological treatment. Physical-chemical treatment is also practiced: careful control of pH, followed by the addition of a coagulant such as alum before settling, can achieve good first-stage treatment. Further treatment to reduce BOD, if required, can be carried out using oxidation ponds (if space permits) or another aerobic process; up to 95% removal of BOD can be achieved. Average effluent levels of 30–50 mg/l BOD will be obtained. Anaerobic treatment systems are not widely used for textile wastes. Carbon adsorption is sometimes used to enhance removal. In some cases, precipitation and filtration may also be required. Up to 90% recovery of size is feasible by partial recycling of prewash and additional ultrafiltration of diluted wash water. Disinfection of wastewaters from wool processing may be required to reduce coliform levels.

Residues and sludges often contain toxic organic chemicals and metals. These should be properly managed, with final disposal in an approved, secure landfill. Sludges containing halogenated organics and other toxic organics should be effectively treated by, for example, incineration before disposal of the residue in a secure landfill.

Emissions Guidelines

Emissions levels for the design and operation of each project must be established through the environmental assessment (EA) process on the basis of country legislation and the *Pollution Prevention and Abatement Handbook*, as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group.

The following guidelines present emissions levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance. Any deviations from these levels must be described in the World Bank Group project documentation. The emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems.

The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable.

All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

Air Emissions

VOC emissions should be reduced to less than 1 kg carbon per metric ton of fabric, or 20 milligrams per normal cubic meter (mg/Nm^3), by implementing measures such as routing the extracted air from the solvent usage areas through a combustion system (such as a boiler).

Liquid Effluents

The effluent levels presented in Table 2 should be achieved.

Sludges

Sludges containing chromium or other toxics should be treated and disposed of in a secure landfill. Incineration of toxic organics should effectively destroy or remove over 99.99% of toxic organics.

Ambient Noise

Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 decibels (measured on the A scale) [dB(A)]. Measurements are to be taken at noise receptors located outside the project property boundary.

Receptor	Maximum allowable log equivalent (hourly measurements), in dB(A)	
	Day (07:00–22:00)	Night (22:00–07:00)
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Table 2. Effluents from the Textiles Industry
(milligrams per liter, except for pH, temperature, and bacteria)

Parameter	Maximum value
pH	6–9
BOD	50
COD	250
AOX	8
TSS	50
Oil and grease	10
Pesticides (each)	0.05
Chromium (total)	0.5
Cobalt	0.5
Copper	0.5
Nickel	0.5
Zinc	2
Phenol	0.5
Sulfide	1
Temperature increase	< 3°C[a]
Coliform bacteria	400 MPN/100 ml

Note: Effluent requirements are for direct discharge to surface waters. Mercury should not be used in the process. The liquid effluent should not be colored. MPN, most probable number.
a. The effluent should result in a temperature increase of no more than 3° C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge.

Monitoring and Reporting

Frequent sampling may be required during start-up. Once a record of consistent performance has been established, sampling for the parameters listed above should be done at least weekly. Only those metals that are detected or are suspected to be present should be monitored. If the presence of other heavy metals such as arsenic, cadmium, lead, mercury, and nickel is suspected, those substances should be included in the monitoring program and treated to achieve the levels mentioned in the "General Industry Guidelines" in this volume.

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be kept in an acceptable format. The results should be reported to the responsible authorities and relevant parties, as required.

Key Issues

The key production and control practices that will lead to compliance with emissions guidelines can be summarized as follows:

- Avoid the use of less degradable surfactants (in washing and scouring operations) and spinning oils.
- Consider the use of transfer printing for synthetics. Use water-based printing pastes, where feasible.
- Consider the use of pad batch dyeing.
- Use jet dyers instead of winch dyers, where feasible.

- Avoid the use of benzidine-based azo dyes and dyes containing cadmium and other heavy metals. Chlorine-based dyes should not be used.
- Do not use mercury, arsenic, and banned pesticides in the process.
- Control the makeup of chemicals and match process variables to the type and weight of the fabric.
- Recover and reuse process chemicals and dye solution.
- Substitute less-toxic dye carriers wherever possible. Avoid carriers containing chlorine.
- Use peroxide-based bleaches instead of sulfur- and chlorine-based bleaches, where feasible.
- Adopt countercurrent rinsing and improved cleaning and housekeeping.

References and Sources

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