



Environmental, Health, and Safety Guidelines for Textile Manufacturing

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)¹. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them.

The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are

¹ Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

Applicability

The EHS Guidelines for Textile Manufacturing include information relevant to textile manufacturing projects and facilities for natural fibers, synthetic fibers (made entirely from chemicals), and regenerated fibers (made from natural materials by processing these materials to form a fiber structure). This document does not include polymer synthesis and natural raw materials production. Annex A contains a full description of industry activities for this sector.

This document is organized according to the following sections:

- Section 1.0 — Industry-Specific Impacts and Management
- Section 2.0 — Performance Indicators and Monitoring
- Section 3.0 — References
- Annex A — General Description of Industry Activities

1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with textiles manufacturing, which occur during the operational phase, along with recommendations for their management. Recommendations for the management of EHS issues common to most large industrial facilities during the construction and decommissioning phases are provided in the **General EHS Guidelines**.

1.1 Environment

Environmental issues during the operational phase of textile manufacturing primarily include the following:

- Hazardous materials management
- Wastewater
- Emissions to air
- Energy consumption
- Solid and liquid waste

Hazardous Materials Management

Chemical Selection and Use

Textile manufacturing activities may include the use of hazardous chemicals in pretreatment, dyeing, and other processes to provide the final product with desired visual and functional properties. Recommendations to avoid or, where avoidance is not possible, to minimize the use of hazardous materials include the following:

- Potentially hazardous surfactants should be replaced with biodegradable / bioeliminable compounds that do not generate potentially toxic metabolites;
- The use of non-biodegradable and bioeliminable tensides and complexing agents in pretreatment and dyeing processes should be avoided (e.g. through the selection of

less hazardous compounds or process modifications that allow removal of iron and alkaline cations);

- The use of non-permanent flame retardants and cross-linking agents with high formaldehyde levels should be avoided;
- Toxic and persistent organic and inorganic textile preservation chemicals (e.g. brominated and chlorinated compounds, dieldrin, arsenic, and mercury) used in mothproofing, carpet bicking, and other finishing processes, should be replaced with biodegradable agents;
- The use of potentially impacting antifoaming agents should be avoided or minimized, through recycling, preventing fabric rotation, or selecting biodegradable / bioeliminable agents.

The following chemicals should be avoided:

- Chemicals prohibited by the Oeko-Tex Standard 1000;²
- Heavy benzene compounds used in emulsion concentrations of the pigment print process;
- Dichromates as oxidizing agents, unless replacement is not possible due to fabric characteristics and color fastness requirements;
- Chlorinated and fluorochlorinated solvents in open systems.

Wastewater

Industrial Process Wastewater

Industry-specific wastewater effluents are related to wet operations, which are conducted during different parts of the textile manufacturing process. Process wastewater from textile manufacturing is typically alkaline and has high BOD (from 700 to 2,000 mg/l) and COD loads. Pollutants in textile effluents

² The prohibited chemicals are listed in Section 6.2.1 of the Oeko-Tex Association Standard 1000 (Oeko-Tex Association, 2006c).

include suspended solids, mineral oils (e.g. antifoaming agents, grease, spinning lubricants, non-biodegradable or low-biodegradable surfactants [alkylphenol ethoxylates APEO, nonylphenol ethoxylates], and other organic compounds, including phenols from wet finishing processes (e.g. dyeing), and halogenated organics from solvent use in bleaching. Effluent streams from dyeing processes are typically hot and colored and may contain significant concentrations of heavy metals (e.g. chromium, copper, zinc, lead, or nickel).

Industrial process wastewater from natural fiber processing may contain pesticides used in prefinishing processes (e.g. cotton growing and animal fiber production), potential microbiological pollutants (e.g. bacteria, fungi, and other pathogens), and other contaminants (e.g. sheep marking dye, tar). This is particularly significant for animal fiber processing. Recommendations for the management of specific wastewater streams in textile manufacturing are discussed below.

Scouring: Fiber (especially wool) scouring involves the use of hot water and detergents to remove soil, vegetable impurities, grease (lanolin) and other contaminants from fibers. Wool scouring typically uses water and alkali, although scouring with an organic solvent is also possible. Scouring with alkali breaks down natural oils and surfactants and suspends impurities in the bath. The scouring effluent is strongly alkaline, and a significant portion of BOD₅ and COD loads from textile manufacturing arises from scouring processes. The recommended pollution prevention and control techniques include the following:

- Design of scouring systems to remove heavy settleable solids continuously; increase recovery of wool grease (for sale); recover heat from the final facility effluent; and control water usage;³

³ An example of this approach is the Wool Research Organization of New Zealand (WRONZ) Comprehensive Scouring System, which is a modified form of emulsion scouring.

- Use of readily biodegradable detergents / surfactants that do not give rise to toxic metabolites. (e.g. APEO should be replaced with alcohol ethoxylates);
- Optimization of mechanical removal of water prior to the drying process;
- Adoption of low volatile organic compound (VOC) emitting solvent wash for removal of water insoluble oils.

For water-based wool scouring, dirt removal / grease recovery loops lead to low water consumption (2-4 l / kg of greasy wool) and a reduction of organic load in the effluent.

Water temperature control (optimum at 65° C) and dryer automatic humidity control using sensors typically leads to energy reduction.

Wool scouring using organic solvents leads to low energy consumption and an almost complete removal of pesticides from the wool, however, fugitive emissions and water contaminated with solvents may be generated and require treatment.

Finishing operations: Wet processing or finishing processes include the main processes of fabric preparation, namely desizing, bleaching, mercerizing, dyeing, printing, and other specific treatments. These phases treat fabrics with chemical and liquor baths and often require several washing, rinsing, and drying steps, generating significant wastewater effluents.

The recommended pollution prevention and control techniques for the finishing pretreatment steps include the following:

- Selection of water soluble and biodegradable lubricants for knitted fabrics instead of mineral oil and wash them with water;
- Use of organic solvent washing for non water soluble lubricants;
- The thermofixing step may be performed before the washing step. Air emissions generated from the stenter

should be treated by dry electrofiltration. The oil separated should be collected to limit effluent contamination;

- Residual liquor should be minimized through reduced application, reduced tank volumes and padding liquor recycling;
- using mechanical dewatering equipment to reduce water content of the incoming fabric and reduce energy consumption in stenter frame.

Desizing: Desizing operations may generate effluents with significant concentrations of organic matters and solids. BOD₅ and COD loads from desizing may be significant (35 to 50 percent of the total load), and COD concentrations up to 20,000 mg/L may be generated.⁴ Recommended pollution prevention and control techniques include the following:

- Selection of raw material with low add-on techniques (e.g. pre-wetting of the warp yarn);
- Selection of more bioeliminable sizing agents (e.g. modified starches, certain galactomannans, polyvinyl alcohol, and certain polyacrylates);⁵
- Application of enzymatic or oxidative desizing with starch and modified starch sizing agents, followed by washing systems;
- Integration of desizing / scouring and bleaching in a single step to reduce effluent generation (e.g. reuse of bleach rinse water in desizing);
- Recovery and reuse of specific water-soluble synthetic sizing agents (e.g. PVA, polyacrylates, and carboxymethyl cellulose) by ultrafiltration.

Bleaching: Common bleaching reagents include hydrogen peroxide, sodium hypochlorite, sodium chlorite, and sulfur

dioxide gas. Hydrogen peroxide is the most commonly used bleaching agent for cotton and is typically used with alkali solutions. The use of chlorine-based bleaches may produce organic halogens (due to secondary reactions) and cause significant concentrations of adsorbable organic halogens (AO_x), particularly trichloromethane, in the wastewater. Sodium hypochlorite bleaching represents the most significant concern, and lower AO_x formation should result if sodium chlorite bleaching is used. The wastewater is alkaline. Recommended pollution prevention and control techniques include the following:

- Use of hydrogen peroxide bleaching agent, instead of sulfur- and chlorine-based bleaches;
- Reduce the use of sodium hypochlorite⁶;
- Control of stabilizers employed, using biodegradable products where possible and avoiding products with poorly bioeliminable complexing agents (e.g. ethylenediaminetetraacetic acid [EDTA], diethylenetriaminepentaacetic acid [DTPA]).

Mercerizing: During mercerizing, cotton fiber reacts with a solution of caustic soda, and a hot-water wash treatment removes the caustic solution from the fiber. The caustic solution remaining on the fiber is neutralized with acid, followed by a number of rinses to remove the acid. Wastewater from mercerizing is highly alkaline, since it contains caustic soda. The recommended pollution prevention and control technique involves the recovery and reuse of alkali from mercerizing effluent, particularly rinsing water, subject to color limitations that may apply to mercerized cloth woven from dyed yarn.

Dyeing: Wastewater from dyeing may contain color pigments, halogens (especially in vat, disperse, and reactive dyes), metals

⁴ European Commission, 2003b

⁵ The degree of bioelimination should be >80 percent after 7 days based on OECD test method 302 B, recommended in the IPPC BREF resource document for the textile industry (European Commission, 2003b).

⁶ This agent should be considered only for flax and bast fibers that cannot be bleached with hydrogen peroxide. Consider use of a two-step process with a hydrogen peroxide stage to remove impurities, which would act as a precursor for AO_x formation, followed by elemental chlorine-free bleaching.

(e.g. copper, chromium, zinc, cobalt, and nickel), amines (produced by azo dyes under reducing conditions) in spent dyes, and other chemicals used as auxiliaries in dye formulation (e.g. dispersing and antifoaming agents) and in the dyeing process (e.g. alkalis, salts, and reducing / oxidizing agents). Dyeing process effluents are characterized by relatively high BOD and COD values, the latter commonly above 5,000 mg/l. Salt concentration (e.g. from reactive dye use) may range between 2,000 and 3,000 ppm. The recommended pollution prevention and control techniques include the following:

- Use of automatic systems for dosing and dispensing dyes;
- When applicable, use of continuous and semi-continuous dyeing processes to reduce water consumption with respect to more traditional batch dyeing processes;
- Use of bleaching systems (e.g. jet and package dyers and pad batch techniques), that reduce liquor-to-fabric ratios;
- Use of machinery with automatic controllers of temperature and dyeing cycle parameters;
- Optimization of machine size related to the size of fabric lots processed;
- Implementation of mechanical liquor extraction to reduce dye liquor carryover and improve washing efficiency;
- Adoption of optimized process cycles and procedures to reduce cycle duration; reuse of rinse water for subsequent dyeing, or countercurrent rinsing in continuous machines; and reconstitution and reuse of dye bath;
- Substitution of conventional dye carriers and finishing agents with less toxic compounds based on benzylbenzoate and N-alkylphthalimide. Carriers containing chlorinated organic compounds, phenyls, and biphenyls should be avoided;
- Use of non-carrier dyeable polyester fibers;

- Conduct dyeing in high temperature conditions without carriers;
- Replacement of sodium dithionite with reducing agents based on sulfinic acid derivatives;
- Replacement of conventional powder and liquid sulfur dyes with stabilized non-pre-reduced sulfide-free dyestuffs or with pre-reduced liquid dye formulations with a sulfide content of less than 1 percent;
- Adoption of systems and measures capable to allow that only the lowest amount needed of reducing agent is consumed to reduce the dyestuff;
- Use of disperse dyes that can be cleared in alkaline medium by hydrolytic solubilization instead of reduction;
- Use of dye formulations that contain highly biodegradable dispersing agents (e.g. based on fatty acid esters or modified aromatic sulfonic acids);
- Substitution of chrome dyes with reactive dyes. Benzidine-based azo dyes, dyes containing heavy metals, and chlorine-based dyes should be avoided. Azo dyes that may produce carcinogenic aromatic amines should also be avoided;
- Adoption of low-salt dyeing techniques, especially for reactive dyes;
- Adoption of a pH-controlled drying process (use of pH-controllable acid and basic dyes that allow control of pH);
- Treatment of dyeing wastewater at treatment plants using commonly available techniques, such as electrolysis, ultrafiltration and reverse osmosis, activated sludge, flocculation, and oxidation/reduction.

Printing: Print paste components consist of color concentrates, solvents, and binder resins. Color concentrates contain pigments (insoluble particles) or dyes. Organic solvents are used exclusively with pigments. Defoamers and resins are aimed at increasing color fastness. Printing blankets or back grays (fabric backing material that absorbs excess print paste),

⁷ Cotton batch dyeing operations typically use quantities of salt ranging from 20 to 80 percent of the weight of fabrics dyed.

which are washed with water before drying, may generate wastewater with an oily appearance and significant volatile organic compound (VOC) levels from the solvents (mineral spirits) used in print paste. The recommended pollution prevention and control techniques include the following:

- Reduce printing paste losses in rotary screen printing by minimizing the volume of printing paste supply and by recovering and recycling printing paste at the end of each run;
- Reuse rinsing water leftover from cleaning the printing belt;
- Use transfer printing for synthetic fabrics and digital ink-jet printing machines to produce short runs of fabrics;
- Avoid the use of urea by controlled addition of moisture or by two-step printing methods;
- Use printing pastes with no or low VOC emissions (e.g., water-based, APEO-free, and reduced-ammonia-content printing pastes).

Mothproofing: Mothproofing agents can be based on permethrin, cyfluthrin and other biocides, which are potentially highly toxic compounds to aquatic life. The recommended pollution prevention and control techniques include the following:

- Implement handling procedures during dispensing and transport of mothproofing agent concentrates to minimize spillage within the dyehouse;
- Implement operating techniques to ensure maximum efficiency (transfer of insect resist agent to the fibre) and lowest residues of active substance in the spent dyeing liquor and rinse water, such as:
 - Ensure that a pH value lower than 4.5 is reached at the end of the process. If this cannot be achieved, the insect resist agent should be applied in a separate step, re-using the bath,

- Avoid the use of dyeing auxiliaries (e.g. leveling agents) that can retard the uptake of mothproofing agents.

Process Wastewater Treatment

Since textile manufacturing operations use a myriad of raw materials, chemicals and processes, wastewater treatment may require the use of unit operations specific to the manufacturing process in use. Techniques for treating industrial process wastewater in this sector include source segregation and pretreatment of wastewater streams as follows: (i) high load (COD) streams containing non-biodegradable compounds using chemical oxidation, (ii) reduction in heavy metals using chemical precipitation, coagulation and flocculation, etc. and (iii) treatment of highly colored or high TDS streams using reverse osmosis. Typical wastewater treatment steps include: grease traps, skimmers or oil water separators for separation of floatable solids; filtration for separation of filterable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; biological treatment, typically aerobic treatment, for reduction of soluble organic matter (BOD); biological nutrient removal for reduction in nitrogen and phosphorus; chlorination of effluent when disinfection is required; dewatering and disposal of residuals in designated hazardous waste landfills. Additional engineering controls may be required for (i) advanced metals removal using membrane filtration or other physical/chemical treatment technologies, (ii) removal of recalcitrant organics, residual pesticides and halogenated organics using activated carbon or advanced chemical oxidation, (iii) residual color removal using adsorption or chemical oxidation, (iv) reduction in effluent toxicity using appropriate technology (such as reverse osmosis, ion exchange, activated carbon, etc.), (v) reduction in TDS in the effluent using reverse osmosis or evaporation, and (vi) containment and neutralization of nuisance odors.

Management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. Through use of these technologies and good practice techniques for wastewater management, facilities should meet the Guideline Values for wastewater discharge as indicated in the relevant table of Section 2 of this industry sector document.

Other Wastewater Streams

Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the **General EHS Guidelines**. Contaminated streams should be routed to the treatment system for industrial process wastewater.

Water Consumption

Water consumption in textile manufacturing has a significant environmental impact, in terms of freshwater needs, wastewater/sludge production, and energy used in heating. Recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**. Recommendations specific to this sector include:

- Reuse of dyebaths;
- Adoption of continuous horizontal washers and vertical spray washers or vertical, double-laced washers;
- Adoption of countercurrent washing (e.g. reuse the least contaminated water from the final wash for the next-to-last wash);
- Use of water flow-control devices to ensure that water only flows to a process when needed;
- Reuse of preparation and finishing water.

Emissions to Air

Textile manufacturing operations that may generate significant sources of air pollutants include the finishing processes (e.g. coating and dyeing operations). Other significant sources of air emissions in textile operations include drying, printing, fabric preparation, and wastewater treatment residues. Solvents may be emitted from coating / treatment finishing processes, drying ovens, and high-temperature drying and curing. Other potential emissions include formaldehyde, acids (especially acetic acid), and other volatile compounds, such as carriers and solvents, emitted during dyeing operations and from wastewater treatment operations. Solvent vapors may contain toxic compounds such as acetaldehyde, chlorofluorocarbons, dichlorobenzene, ethyl acetate, methylnaphthalene, chlorotoluene, among others.

Dust

Dust emissions associated with textile manufacturing occur during natural fiber and synthetic staple processing and yarn manufacturing. Fiber (especially cotton) handling and storage are sources of dust, particularly within work areas. The main sources are bale breakers, automatic feeders, separators and openers, mechanical conveyors, pickers, and cards. The recommended prevention and control methods for these main sources of dust emissions include:

- Enclosure of dust producing equipment, and use of local exhaust ventilation;
- Use of dust extraction and recycling systems to remove dust from work areas;
- Installation of fabric filters to prevent outdoor emissions.

The use of asbestos fibers as a source of natural fiber in the manufacturing of staple is no longer considered good industry practice and must be avoided.

Air Pollutants from Fiber Manufacturing

Regenerated fibers (viscose) and synthetic polymers (nylon and acrylic fibers) production processes involve the potential release of chemicals (e.g. carbon disulfide, hydrogen sulfide, hexamethylene diamine, and nitric acid). Pollution prevention and control measures include:

- Air removed from the processes by the exhaust ventilation should be transported to a recovery system;
- Use of emissions control techniques (e.g. absorption and chemical scrubbing).

VOCs and Oil Mists

Emissions of VOCs are related to the use of organic solvents in activities such as printing processes, fabric cleaning, wool scouring and heat treatments (e.g. thermofixation, drying, and curing). Another source of emissions is the evaporation or thermal degradation of chemicals used on the textile materials (e.g. oil-based antifoaming agents, plasticizers, and finishing agents). The main sources are often the stenter frames, which are used in drying. Other substances with significant air emission potential are used in printing processes, including ammonia, formaldehyde, methanols and other alcohols, esters, aliphatic hydrocarbons, and several monomers.

Pollution prevention and control techniques include the following:

- Installing and modifying equipment to reduce solvent use;
- Adopting water-based methods for removing oil and grease from fabric instead of using volatile solvents;
- Substituting cleaning solvents with less toxic solvents, particularly chlorinated solvents;
- Recovery of VOCs through vapor recovery units, and use of a fully closed-loop system, especially if cleaning with

halogenated organic solvents cannot be avoided (e.g. for fabrics that are heavily loaded with silicone oils);

- Using appropriate control technologies (e.g. diversion of stack emissions through boilers; installation of scrubbers with activated carbon slurries; installation of activated carbon absorbers; or incineration of extracted vapors in a combustion system).

Exhaust Gases

Combustion sources for power generation and process heating requirements are common in this industry sector. Guidance for the management of combustion products arising from sources with a heat input capacity of up to 50 megawatt including air emission standards, is provided in the **General EHS Guidelines**. Guidance applicable to larger emissions sources are presented in the **EHS Guidelines for Thermal Power**.

Odors

Odors may be generated in textile manufacturing, particularly during dyeing and other finishing processes, and use of oils, solvent vapors, formaldehyde, sulfur compounds, and ammonia. Techniques for the prevention or minimization of odor from these sources include:

- Substituting odor-intensive substances with less impacting compounds (e.g. sulfur containing dyestuffs and reducing agents with non-pre-reduced sulphide-free dyestuffs; sodium dithionite in dyeing after treatment with aliphatic short-chain sulfinic acid derivatives);
- Installing and modifying equipment to reduce use of odorous chemicals;
- Capturing and recovering the off-gases from the processes (e.g. installation of heat recovery systems);
- Routing of stack emissions through boilers to reduce odor emissions.

Energy Consumption

Textile manufacturing may involve significant use of energy resources. Heat consumption is particularly significant in drying and curing operations and in activities involving wet treatments. In addition to energy conservation measures discussed in the **General EHS Guidelines**, the following techniques are specific to this sector:

- Adoption of low-bath-ratio dyeing (e.g. jet dyeing and package dyeing) to reduce energy consumption, which is dependent on bath volume;
- Use of pad batch (cold) dyeing for cotton, rayon, and blends to conserve energy and water (in addition to dyes and chemicals);
- Consider efficient combination of operations, such as scouring and bleaching, to save energy and water;
- Use of continuous knit bleaching ranges instead of batch preparation knitting equipment;
- Use of heat recovery from continuous dyeing / bleaching ranges to preheat incoming water and heat recovery through reuse of cooling water and by heat exchange from hot effluents discharged by batch dyeing machines.

Wastes

Wastes specific to the textile industry include trials, selvedge, trimmings, cuttings of fabrics, and yarns; spent dyes, pigments, and printing pastes; and sludge from process wastewater treatment containing mainly fibers and grease.

Solid and liquid wastes generated in textile industries should be effectively recycled or reused within the process or external (e.g. waste fibers, cuttings, and trimmings can be recycled as a feedstock for other operations, including low-grade products, non-wovens, insulation, and geotextiles). Management and disposal of hazardous and non-hazardous wastes should be

undertaken in accordance with guidance included in the **General EHS Guidelines**.

1.2 Occupational Health and Safety

Occupational health and safety hazards during the operational phase of textile manufacturing projects primarily include the following:

- Chemical hazards
- Physical hazards
- Heat
- Noise
- Ionizing and non-ionizing radiation

Chemical Hazards

Respiratory & Dermal contact hazards

Dust: Exposure to fine particulates is mainly associated with natural fibers and yarn manufacturing processes described in Section 1.1. of this document. Cotton dust is generated during the handling or processing of cotton and contains cotton fibers and other potential chemical and microbiological contaminants (e.g. bacteria, fungi, pesticides, and herbicides). Exposure to cotton dust can generate respiratory hazards (e.g. byssinosis in cotton manufacturing, chronic bronchitis, asthma, and emphysema).

Prevention and control of occupational health and safety hazards relevant to natural fiber dust include the following

- Installation of dust extraction, recycling and ventilation systems to remove dust from work areas, especially in cotton mills;
- Use of vacuum cleaning of surfaces instead of compressed air "sweeping" techniques;
- Implementation of regular housekeeping procedures, especially in the "flocking" area;

- Use of mechanical methods to handle cotton and cotton waste;
- Use of personal protective equipment (PPE) for exposed workers, such as masks and respirators, as necessary.

Workplace exposure to asbestos dust during fiber production represents a known risk of lung cancer (mesothelioma) and injury to the bronchial tubes. The use of asbestos fiber is prohibited.⁸ Appropriate dust extraction systems in facilities where inorganic natural fibers are processed should be implemented (e.g. filters using nano-whiskers).

Volatile Organic Compounds (VOC): Exposure to VOC emissions is related to the use of solvents in textile printing processes, fabric cleaning, and heat treatments (e.g. thermofixation, drying, and curing). Worker exposure can cause skin and respiratory impacts. Exposure to certain compounds (e.g. carbon disulfide in rayon manufacturing) may have significant toxic effects, including nervous system and heart diseases.

Prevention and control techniques to reduce VOC exposure hazards include the following:

- Use of hoods and enclosed equipment;
- Use of well-ventilated rooms, with a slight positive pressure, for process control operators, and as worker rest stations;
- Use of shift and task rotation strategies for workers to minimize VOC exposure;
- Installation of extraction and air recycling systems to remove VOCs from the work area with use of appropriate abatement technologies (e.g. scrubbers employing activated carbon absorbers) or routing the extracted vapors to the combustion system;

- Use of personal protective equipment (PPE), such as respirators, as necessary.

Chromium: is a major cause of allergic contact dermatitis among dyehouse workers and workers who perform dyeing operations and handle dyestuffs containing chromium.

Prevention and control of this potential hazard include reduction in the proportion of soluble chromium in dyestuffs and the use of adequate PPE to prevent dermal contact, as described in the **General EHS Guidelines**.

Explosion

Organic dusts, including cotton dust, are combustible and present a potential explosion hazard. This hazard is most effectively controlled through the measures for prevention of dust accumulation as above. In addition, all possible sources of ignition where organic dusts may form clouds or accumulate should be removed. VOC use, such as solvents, may form potentially explosive mixtures in air. Electrical equipment in these areas should be rated for ignition prevention.

Physical Hazards

Activities related to the maintenance operations of industry-specific equipment (e.g. cards, spinning machinery, looms, and stenters) may expose workers to physical impacts, particularly with reference to hot surfaces and moving equipment.

Prevention and control of these impacts include the implementation of general protection measures (e.g. machine guarding and lock-out-tag-out systems and procedures), as described in the **General EHS Guidelines**.

Heat

The most significant risk of exposure to heat and high humidity occurs during wet processing and dry finishing operations and is caused by the use of steam and hot fluids in these processes.

⁸ Use of asbestos is not considered good industry practice and is prohibited according to the IFC Exclusion List.

Prevention and control recommendations are presented in the **General EHS Guidelines**.

Noise

The main sources of noise in textile plants are associated with yarn processing (e.g. texturizing and twisting and doubling) and woven fabric production. Noise management, including the use of personal hearing protection, is described in the **General EHS Guidelines**.

Ionizing and Non-Ionizing Radiation

X-ray stations are sometimes used for continuous monitoring of the foam thickness in continuous foam dyeing and for tank level control systems. Operators of this equipment should be protected through the use of ionizing radiation protection measures to limit exposure doses, as described in the **General EHS Guidelines**.

1.3 Community Health and Safety

Community health and safety impacts during the construction and decommissioning of textile manufacturing plants are common to those of most industrial facilities, and are discussed in the **General EHS Guidelines**.

Specific potential impacts during operations include odors that are produced by several sources in textile manufacturing. Odors are usually generated during dyeing and other finishing processes by oils, solvent vapors, formaldehyde, sulfur compounds, and ammonia. They should be adequately controlled and contained, as discussed in Section 1.1, to avoid becoming a nuisance for the community.

An additional community health and safety issue concerns the use of chemicals and their potential risk to the health of consumers who purchase garments or home textiles produced by the textile industry. Specific consideration should be given to ensuring that these products are safe for human use. The

manufacturer should avoid using allergenic dyestuffs and dyestuffs that form carcinogenic compounds. Adequate testing for pH, pesticides, heavy metals, formaldehyde, chlorinated phenols, chloro-organic carriers, and biologically active finishes should be conducted to assess textile characteristics according to the typical conditions of their use prior to entry into the market.⁹

⁹ Specific guidance can be found in the Oeko-Tex Standards (2006a, 2006b, 2006c).

2.0 Performance Indicators and Monitoring

2.1 Environment

Emissions and Effluent Guidelines

Tables 1 and 2 present emission and effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document. These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the **General EHS Guidelines**.

Emissions guidelines are applicable to process emissions. Combustion source emissions guidelines associated with steam- and power-generation activities from sources with a heat input capacity equal to or lower than 50 MW are addressed in the **General EHS Guidelines** with larger power source emissions addressed in the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Table 1. Air emission levels for textile industry^d

Pollutants	Units	Guideline Value
VOCs	mg/Nm ³	2 / 20 / 50 / 75 / 100 / 150 ^{a,b}
Chlorine	mg/Nm ³	5
Formaldehyde	mg/Nm ³	20
Ammonia	mg/Nm ³	30
Particulates	mg/Nm ³	50 ^c
H ₂ S	mg/Nm ³	5
CS ₂	mg/Nm ³	150
NOTES: ^a Calculated as total carbon. ^b As the 30-minute mean for stack emission. Applicability of guideline values: - 2 mg/Nm ³ for VOCs classified as carcinogenic or mutagenic with mass flow greater than or equal to 10 g/hour; - 20 mg/Nm ³ for discharges of halogenated VOCs with a mass flow equal or greater than 100 g/hour; - 50 mg/Nm ³ for waste gases from drying for large installations (solvent consumption >15 t/a); - 75 mg/Nm ³ for coating application processes for large installations (solvent consumption >15 t/a); - 100mg/Nm ³ for small installations (solvent consumption <15 t/a). - If solvent is recovered from emissions and reused, the limit value is 150 mg/Nm ³ ^c As the 30-minute mean for stack emissions. ^d Guideline values are applicable to installations with a solvent consumption > 5t/a.		

Table 2. Effluent levels for the textile industry ^a

Pollutants	Units	Guideline Value
pH	--	6 – 9
BOD	mg/L	30
COD	mg/L	160
AOX	mg/L	1
TSS	mg/L	50
Oil and Grease	mg/L	10
Pesticides	mg/L	0.05-0.10 ^b
Cadmium	mg/L	0.02
Chromium (total)	mg/L	0.5
Chromium (hexavalent)	mg/L	0.1
Cobalt	mg/L	0.5
Copper	mg/L	0.5
Nickel	mg/L	0.5
Zinc	mg/L	2
Phenol	mg/L	0.5
Sulfide	mg/L	1
Total Phosphorous	mg/L	2
Ammonia	mg/L	10
Total Nitrogen	mg/L	10
Color	m ⁻¹	7 (436 nm, yellow) 5 (525 nm, red) 3 (620 nm, blue)
Toxicity to Fish Eggs	T.U. 96h	2
Temperature increase	°C	<3
Coliform bacteria	MPN/100ml	400

^a At the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use, potential receptors and assimilative capacity
^b 0.05 mg/L for total pesticides (organophosphorous pesticides excluded); 0.10 mg/l for organophosphorous pesticides.

Resource Use

Tables 3 and 4 provide examples of industry-specific indicators for resource and energy consumption and waste generation. These benchmark values are provided for comparative purposes only, and individual projects should target continual improvement in these areas.

Table 3. Resource and energy consumption ^a

Process	Electrical Energy (kWh/kg)	Thermal Energy (MJ/kg)	Water Consumption (l / kg)
Wool Scouring	0.3	3.5	2–6
Yarn Finishing	–	–	70–120
Yarn Dyeing	0.8–1.1	13–16	15–30 (dyeing) 30–50 (rinsing)
Loose Fiber Dyeing	0.1–0.4	4–14	4–15 (dyeing) 4–20 (rinsing)
Knitted Fabric Finishing	1–6	10–60 ⁽²⁾	70–120
Woven Fabric Finishing	0.5–1.5	30–70 ⁽³⁾	50–100
Dyed Woven Fabric Finishing	–	–	<200

^a European Commission (2003b). The data of "industry benchmarks" originate from only a limited number of installations.
^b The higher value is for mills also having spinning and coning sections.
^c The higher value is for mills also having spinning, twisting, and coning sections.

Table 4. Waste generation.^a

Outputs per unit of product	Unit	Industry Benchmark
Wastewater Wool Scouring	l/kg	2–6 ^b
Wastewater Yarn Finishing Wool	l/kg	35–45
Wastewater Yarn Finishing Cotton	l/kg	100–120
Wastewater Yarn Finishing Synthetic Fiber	l/kg	65–85
Wastewater Knitted Fabric Finishing Wool	l/kg	60–70
Wastewater Knitted Fabric Finishing Cotton	l/kg	60–135
Wastewater Knitted Fabric Finishing Synthetic Fiber	l/kg	35–80
Wastewater Woven Fabric Finishing Wool	l/kg	70–140
Wastewater Woven Fabric Finishing Cotton	l/kg	50–70
Wastewater Woven Fabric Finishing + Print Cotton	l/kg	150–80
Wastewater Woven Fabrics Finishing Synthetic Fiber	l/kg	100–180
Sludge from Wastewater Treatment	kg/m ³ treated wastewater	1–5 ^c

^a European Commission (2002b).
^b BAT is 2–4 l/kg of greasy wool for medium and large mills (15000 tons/year of greasy wool) and 6 l/kg for small mills.
^c Volume of sludge produced after dewatering 1–5 kg/m³ of treated wastewater.

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during both normal operations and unsettled conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. 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. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV[®]) occupational exposure guidelines and Biological Exposure Indices (BEIs[®]) published by American Conference of Governmental Industrial Hygienists (ACGIH),¹⁰ the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),¹¹ Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United

¹⁰ Available at: <http://www.acgih.org/TLV/> and <http://www.acgih.org/store/>

¹¹ Available at: <http://www.cdc.gov/niosh/hpg/>

States (OSHA),¹² Indicative Occupational Exposure Limit Values published by European Union member states,¹³ or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)¹⁴.

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals as part of an occupational health and safety monitoring program.

Facilities should also maintain a record of occupational accidents and diseases and of dangerous occurrences and accidents.¹⁵ Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

¹² Available at:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARD&p_id=9992

¹³ Available at: http://europe.osha.eu.int/good_practice/risks/ds/oel/

¹⁴ Available at: <http://www.bls.gov/iif/> and
<http://www.hse.gov.uk/statistics/index.htm>

¹⁵ Accredited professionals may include certified industrial hygienists, registered occupational hygienists, certified safety professionals, or their equivalent.

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Annex A: General Description of Industry Activities

The textile industry includes the production of yarn, fabric, and finished goods. Textile manufacturers receive and prepare raw fibers; transform fibers into yarn, thread, or webbing; convert the yarn into fabric; and dye, finish, and assemble these materials at various stages of production. Raw materials used in textile manufacturing include natural fibers (organic or inorganic), chemical and manufactured fibers, chemicals, water and energy. (See Table A-1).¹⁶

Categories / Sub- Categories			Examples
Natural Fibers	Organic	Vegetable Fibers	Cotton Flax, Hemp Jute, Sisal, Broom
		Animal Fibers	Wools Silk
	Inorganic	Mineral Fibers	Basalt Asbestos
Man-made Fibers	Organic Regenerated Natural Fibers		Regenerated cellulose Viscose Cupro Cellulose acetate Cellulose triacetate
	Organic Synthetic Polymers		Polyamide Polyester Polyolefins Polyacrylic
	Inorganic Fibers		Glass Carbon

Fiber Manufacturing / Preparation

The textile industry uses two general categories of fibers, namely natural and manmade. Natural fibers, known as staple fibers when harvested, include vegetable and animal fibers (e.g. cotton, silk, and wool). Before these fibers can be spun into yarn, a series of preparation phases, including ginning, opening, blending, scouring, carding, combing, and drafting are

¹⁶ Specific terms and definition used in textile manufacturing can be found in Textile Terms and Definitions 11th Edition, 2002

undertaken. Natural mineral fibers including basalt fibers (both continuous filaments and staple fibers) and asbestos (a staple fiber) are known. Manmade fibers include synthetic organic materials from the petrochemical industry (e.g. polyamides, polyesters, polyolefins, and polyacrylic fibers), and regenerated natural organic fibers, including regenerated cellulose (viscose and cupro form), cellulose acetate, and triacetate manufactured from wood fibers. Manmade fibers may be processed into filament yarn or staple-length fibers to facilitate spinning. Manmade inorganic fibers include glass and carbon fibers, which are continuous filaments and staple fibers. The staple fibers of both of these materials are used in felts and composite. The continuous filament of glass is processed by spinning, twisting, and sizing. The continuous filaments of carbon are produced by pyrolysis.

Yarn Manufacturing

Staple (including natural, regenerated natural, and manmade) fibers are transformed into yarn through grouping and twisting operations. Other fibers are processed using spinning operations. Yarn manufacturing typically includes the following operations:

- Vegetable fibers: ginning, fiber blend, carding, combing, spinning (that is, ring and open end), and twisting
- Animal fibers: scouring, fiber blend, carding, combing, spinning (ring), and twisting
- Mineral fibers: spinning, twisting, and sizing
- Regenerated natural fibers: carding, combing, spinning (ring), and twisting
- Manmade fibers: carding, combing, spinning (ring or open end), and twisting

Continuous filament yarn may be used directly or after the following operations:

- Natural fibers (for example, silk): twisting
- Regenerated natural fibers: spinning and twisting
- Manmade fibers: spinning, twisting, and texturizing
- Inorganic fibers: spinning (glass) or pyrolysis (carbon), twisting, and sizing

Fabric Production

Winding

Winding involves transferring yarn from one type of package to another to facilitate subsequent processing. Precision winders are used primarily for filament yarn and produce packages with a diamond-patterned wind. Drum winders are used mainly for spun yarns.

Warping

Warping involves winding a portion of the total number of ends of a warp in full width onto a back beam.

Section Warping

Section warping is a machine method of preparing a warp on a beam. The process involves winding a warp in sections on a reel and beaming off the complete warp from the reel onto a warp beam.

Beaming

Beaming is an activity during warp-making in which ends, withdrawn from a warping creel, are wound onto a beam to a length that is a multiple of the loom warp length. Several similar beams (known as a set of back beams) provide the total number of ends required in the woven warps. Beaming is usually implemented for bulk production of grey warp. Direct beaming is a specific single-stage method.

Sizing

Sizing involves applying sizing compounds to warp yarn to bind the surface fiber together and protect the yarn against abrasion

during weaving. The primary sizing compounds include starch, gelatin, oil, wax, and manufactured polymers (such as polyvinyl alcohol, polystyrene, polyacrylic acid, and polyacetates).

The beam-to-beam sizing method transfers a warp from a warp beam to a loom beam. The sized warp is dried by hot air or by

contact with steam-heated cylinders during its transfer to the loom beam.

Fabric Manufacture

The most important methods for fabric manufacture are weaving and knitting. Weaving is done using looms (any set of devices permitting a warp to be tensioned and a shed to be formed with the aid of heddles). There are many kinds of looms including shuttle, projectile, rapier, and fluid jet. The shuttle loom uses a weft insertion device that propels the filling yarn across (over and under) the warp yarns. The projectile loom uses a projectile that conveys the weft through the shed and leaves a trail of yarn behind it. The rapier-type loom conveys a weft yarn from a stationary package through the shed. Rapier looms are simpler and more versatile than dummy-shuttle looms, however their weaving speed is slower. The two types of fluid-jet looms are air jet and water jet.

Knitting is a method of converting yarn into fabric by intermeshing loops, which are formed with the help of needles. Two weft-knitting technologies are used including flat bed (used for heavier gauge material) and circular. Warp-knitting technologies include chain (e.g. lace, light tricot), raschel (e.g. lace, velvet, technical fabrics), and crochet (e.g. technical fabrics).

Tufting is a process used to make carpets. Non-woven fabrics are produced using mechanical-bonding, water-bonding, and air-bonding machines. Braiding is an interlacing technology in

which two sets of continuous fibers are interwoven symmetrically around an axis.

Finishing Processes

Woven and knit fabrics are not normally processed into apparel or other finished goods until the undyed and unfinished fabrics, known as gray (woven) or greige (knit) fabrics, have passed through several water-intensive wet-processing stages. These processes convert them into finished fabrics, enhancing their appearance, durability, and serviceability. Wet processing or finishing processes include the main processes of fabric preparation, namely dyeing, printing, and other specific treatments. These phases treat fabrics with chemical and liquor baths and often require several washing, rinsing, and drying steps.

Preparation

Preparation (also known as pretreatment) of dyed, printed, or finished fabrics consists of a series of treatment and rinsing steps, which are critical for the results in subsequent textile finishing processes. Mills are used to remove natural impurities or processing chemicals that may interfere with dyeing, printing, and finishing. Typical preparation treatments include desizing, scouring, and bleaching, as well as other processes (e.g. gassing or singeing and mercerizing) designed to chemically or physically alter the fabric. Some pollutants generated during this phase may result from the removal of previously applied processing chemicals and agricultural residues. Wastewater may include metals, organics, and phosphorus contained in the surfactants and detergents.

Desizing

Desizing is the preparation step used to remove size materials applied before weaving. As manmade fibers are generally sized with water-soluble sizes, removal is usually done by hot water wash or in the scouring process. Natural fibers are most often

sized with water-insoluble starches or mixtures of starch and other materials. Desizing is often conducted through the use of enzymes capable of breaking starches into water soluble sugars. Sugars are then removed by washing before fabric scouring.

Gassing or Singeing

Gassing or singeing involves passing protruding fibers from yarn or fabric over a flame or heated copper plates to burn them off..

Spinning

Spinning involves creating yarn from raw fiber material. Compact or condensed spinning is a modification of the ring-spinning process, which allows lower fiber waste production, greater exploitation of fiber tenacity, enhanced appearance, and lower hair content of spun yarn.

Mercerizing

Mercerizing consists of the treatment of cellulosic textile fibers (both yarn and fabric) with a concentrated solution of caustic alkalis. The treatment allows fibers to swell and increases the strength and dye affinity of the materials. An alternative process uses liquid ammonia treatment produces some of the effects of mercerization.

Bleaching

Bleaching is a process to improve the whiteness of textile material, commonly using chlorine-based bleaches (sodium hypochlorite and sodium chlorite) or hydrogen peroxide. Peracetic acid bleaching is sometimes used for synthetic fibers that cannot be bleached using hydrogen peroxide (e.g. polyamide).

Dyeing

Dyeing is the application and fixing of a dye to a substrate. The textile industry uses several dyeing techniques (e.g. yarn package dyeing, piece dyeing, spray dyeing, top [stock] and

hank [skein] dyeing) and machines (e.g. winch, jet, paddle, overflow) to dye the fabric through a liquor. Dyeing is conducted in the textile manufacturing plant or by specialty dyehouses.

Textiles are dyed using a wide range of chemicals and dyestuffs. Dyes are normally synthetic molecules and are sold as powders, granules, pastes, and liquid dispersions. Dyeing can be performed using batch or continuous processes. In batch dyeing, a quantity of the textile is loaded into a dyeing machine and put in contact with the dye liquor. Auxiliary chemicals and bath conditions are used to accelerate the dyeing action. The dye is then fixed using heat and / or chemicals, and a wash removes unfixed dyes and chemicals from the textile fiber or fabric. The liquor ratio (the weight ratio between the total dry material and the total liquor) of the equipment used is an important parameter in discontinuous dyeing. This ratio ranges from 3:1 (less water needed per unit weight of textile material) to more than 50:1 (typical of low-affinity dyes and less efficient or more demanding dyeing processes). Dying winches and hank machines use higher ratios than jet drying, package dyeing, and pad batch techniques. Continuous dyeing processes feed the textiles into a dye machine where dye application in a bath, dye fixation with chemicals or heat, and washing are conducted at speeds between 50 and 250 meters of fabric per minute.

Printing

Printing produces designs or motifs on the fabric by applying a colorant or other reagent, usually in a paste or ink. Techniques include screen printing (in which a print paste is forced through a mesh, in contact with the substrate), sublimation printing (in which dyes that sublime readily are applied), and ink-jet printing.

Stentering

Stentering straightens and dries products using hot air, resulting in the desired width for finished products.

Coating and Laminating

Coating involves the application of semiliquid material on one or both sides of a textile material. Drying and curing, as necessary, of the coating material forms a bond with the fabric. Techniques include direct coating (e.g. spreading the coating with a knife); roller coating (e.g. application through a roller to the moving substrate fabric); and transfer coating (e.g. application to a temporary substrate and the addition of an adhesive coating, the tie coat, to allow transfer to the desired substrate). Flame lamination is widely used with thin, thermoplastic foam sheet (e.g. polyurethane) exposed to a wide flame burner located before the laminating rolls.

Wet processing produces the most significant amounts of emissions and waste in textile operations. Additionally, significant quantities of energy are needed for heating and cooling baths and for drying fabrics and yarn. Methods used vary depending on end products and applications, site-specific manufacturing practices, and fiber type. Natural fibers typically require more processing steps than synthetic fibers. Processing methods may differ based on the final properties desired, such as tensile strength, flexibility, uniformity, and luster.

Manufactured textiles are often shipped from textile mills to dyeing and finishing shops for wet processing, although large textile manufacturing plants may have integrated wet processing into their operations.

Manufacturing of End Products

Manufacturing of textile end products includes finished fabric decoration, such as embroidery, garment assembly, home interiors, and other industrial uses of finished fabrics.

Embroidery is the art of decorating fabric or other materials with designs stitched in strands of thread or yarn using a needle.

Embroidery may also incorporate other materials such as metal strips, pearls, and so on. Garment assembly may be a labor-intensive activity.