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The Textile Industry and the Environment

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FOREWORD

Textile production is an important contributor to many national economies. Its diverse operations can also have significant impacts on the local environment, and present health and safety risks to its workforce. With adequate care these impacts can however be reduced to acceptable levels.

As for all industrial developments it is essential to consider the potential for environmental impacts in the planning phase which might be costly and difficult to mitigate at a later stage.

This Technical Report aims to provide guidance on measures to prevent pollution and save raw materials through a cleaner production approach both at the conception stage and for ongoing operations.

This document is intended to provide an overview of the many specific elements which contribute to good environmental performance. As such it does not detail any particular matter. For readers who require specific design and operational details, further consultation of the references is recommended.

The guide will be useful to readers from several different backgrounds and areas of responsibility, in particular:

- Industry personnel will find descriptions of procedures and technologies that minimise environmental impacts as well as policy and management guidelines for ensuring low impact operations.
- Government personnel and industry regulators will find indications of the level of environmental performance that can be expected from the industry, together with a description of technical, planning and management tools that foster its achievement.
- The general reader will find an overview of environmental impacts related to the textile industry and recommended strategies for regulating these effects.

UNEP IE hopes that this document will assist in environmentally sound decision-making and thus contribute towards further development of a cleaner and sustainable textile industry. As many concrete examples show, good environmental performance is usually associated with economic savings coming from minimal treatment costs and effective use of energy and raw materials.

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TABLE OF CONTENTS

FOREWORD	3
ACKNOWLEDGEMENTS	5
TABLE OF CONTENTS	7
LIST OF TABLES	9
LIST OF FIGURES	11
GLOSSARY OF KEY TERMS	13
SUMMARY	17
1.0 INTRODUCTION	19
1.1 Cleaner Production	19
1.2 Pollution Control Strategies	20
1.3 About this Report	20
2.0 OVERVIEW OF TEXTILE WET PROCESSING OPERATIONS	21
2.1 Wool Scouring	22
2.2 Wool Finishing	22
2.3 Dry Processing	22
2.4 Woven Fabric Finishing	26
2.5 Knit Fabric Finishing	26
2.6 Carpet Manufacture	29
2.7 Stock and Yarn Dyeing and Finishing	29
3.0 ENVIRONMENTAL IMPACT OF THE TEXTILE INDUSTRY	33
3.1 Sources of Impact	33
3.2 Water Pollution Sources and Characteristics	38
3.3 Air Emissions Sources and Occupational Safety	41
4.0 CLEANER PRODUCTION TECHNIQUES AND PROCESSES	43
4.1 Water and Energy Conservation	43
4.2 Optimisation of Chemical Usage	48
4.3 Choice and Modification of Processes and Equipment	49
4.3.1 Washing Operations	52
4.3.2 Optimisation of Sizing-Desizing Systems	54
4.3.3 Pad-Batch Dyeing	54
4.3.4 Solvent Processing	55
4.3.5 Transfer Printing	56
4.3.6 Foam Processing Technology	58

5.0	END-OF-PIPE TREATMENT	59
5.1	Liquid Effluent Treatment	59
5.1.1	Screening	60
5.1.2	Equalisation and Neutralisation	60
5.1.3	Oil and Grease Separation	62
5.1.4	Chromium Removal	62
5.1.5	Biological Treatment	63
5.1.6	Colour Removal	65
5.2	Sludge Treatment and Disposal	66
5.3	Air Emissions Control	66
6.0	POLICY, MANAGEMENT AND LEGAL FRAMEWORK	69
6.1	Policies and their Implications	69
6.2	Managing and Auditing Resource Consumption	70
6.3	Environmental Regulations	73
ANNEXES		
A.	References and Further Reading	77
B.	International Textile Research Organisations and Journals	81
C.	Case Studies on Cleaner Production	83
D.	Safe Handling of Textile Chemicals	91
E.	Waste and Emission and Energy Audits	105
F.	US EPA, BAT and BPT Effluent Limits for the Textile Industry	115
G.	About the UNEP Industry and Environment Centre	119

LIST OF TABLES

1	Typical Chemicals Stock in a Textile Mill	34
2	Characteristics of Textile Effluents	39
3	Effluent Generation Load Factors in Textile Wet Processing	40
4	Partial List of Typical VOCs and Corresponding Potential Sources	41
5	Water Use in Textile Wet Processing	44
6	Check-list for Water Re-use	47
7	5-Day BOD for Some Textile Chemicals	50
8	Check-list of Possible Chemical Substitutions	51
9	Partial List of Cleaner Production Process Modifications	52
10	Highlights of Water Conservation Measures in Dyeing Equipment (Results of NORDIC Study)	53
11	Overview of Effluent Treatment Technologies	60
12	Anticipated Treatment Removal Efficiencies	61
13	(a) Typical Water Consumption at Different Processing Stages	71
	(b) Preferred Preparatory Sequence for all Cotton Fabrics	72
14	Effluent Standards for Discharge of Textile Wastewaters into Receiving Waters	74
15	Air Emission Requirements for Textile Dyeing and Finishing Plants in Victoria, Australia	75
16	List of Banned, Withdrawn and Restricted Chemicals	76

LIST OF FIGURES

1	Emissions Sources in Wool Scouring Mill	23
2	Emissions Sources in Wool Finishing Mill	24
3	Emissions Sources in Dry Processing Mill	25
4	Emissions Sources in Woven Fabric Finishing Mill	27
5	Emissions Sources in Knit Fabric Finishing Mill	28
6	Emissions Sources in Carpet Mill	30
7	Emissions Sources in Stock and Yarn Dyeing and Finishing Mill	31
8	Recommended Counter-Current Flow of Washing on a Soaper Range	44
9	A Water Re-use Scheme for Cotton Cloth in Continuous Bleaching by J-Box Method	45
10	Recommended Use of Water in Kier Processing	46
11	A Water Re-use Scheme in Batch-type Conventional Bleaching for Cotton Cloth	46
12	Influence of Design Parameters on Improved Washing	53
13	Schematic Sequence of Conventional Recleaning and Perchloroethylene Recleaning in Cold-Pad Batch	57
14	Schematic Diagram Showing Differences between Conventional Textile Printing and Transfer Printing Technology	57
15	Typical Flowsheet for Removal of Chromium from Textile Effluents	63
16	Typical Flowsheet for Treatment of Woven Fabric Effluents Using Activated Sludge Process	64

GLOSSARY OF KEY TERMS

Accelerators: Chemicals used to increase colour development in textile dyeing operations or to promote cross-linking between two chemicals on a fibre or between a chemical and a fibre.

Acetate: A manufactured fibre made from cellulose.

Acetic Acid: A weak acid used in wool, nylon, polyester, etc. dyeing. Can be replaced normally by ammonium sulphate.

Acid Dye: A type of dye commonly used to colour wool and nylon but may be used on other fibres.

Acrylic: A manufactured fibre in which the fibre forming substance is any long-chain synthetic polymer composed of at least 85% by weight acrylonitrile units. Made in both filament and staple form.

Adsorption: The adhesion of an extremely thin layer of molecules to the surfaces of solids or liquids with which they are in contact.

Aerobic: A biological process active only in the presence of oxygen.

Ageing: Use of heat, acid or some other means to age a fabric.

Anaerobic: A biological process active only in the absence of free oxygen.

Azoic: A type of dye used to colour cotton, rayon, polyester and cotton/polyester blends but not commonly used.

Basic Dye: Also known as a cationic dye. Used to colour synthetic fibre or cotton/polyester blends.

Beam: Any of a series of machines for dyeing which use a perforated beam through which the dye bath is circulated.

Beck: Any of a series of machines for scouring (cleaning), dyeing, etc., goods while in the form of rope or continuous belt. A roller gradually moves the cloth through the bath in a slack condition.

Bleaching: The treatment of textile fibres, yarn or cloth to destroy the natural colouring matter and leave the material white. Hydrogen peroxide is a widely used bleaching agent.

Blend: The combination of two or more types of fibres and/or colours in one yarn.

Blow down: Periodic or continuous draw-off of a mixture from a system to prevent build-up of contaminants.

BOD: Biochemical Oxygen Demand. A method of measuring the rate of oxygen usage due to biological oxidation. BOD₅ of 1000 mg/litre means that a sample (1 litre) is capable of consuming 1000 mg of oxygen in 5 days.

BTU: British Thermal Unit. The amount of heat required to increase the temperature of 1 pound of water by 1 degree Fahrenheit.

Calender: A machine using heavy rollers to impart a variety of effects on the finishing of fabrics, particularly cotton and rayon.

Carbonising: A phenomenon where the carbonaceous material decomposes leaving a residue of essentially black carbon, e.g. soot.

Carding: Fibres are separated and aligned in a thin web, then condensed into a continuous, untwisted strand called a 'sliver'.

Carrier: A water-insoluble organic compound which accelerates the absorption of dyes by a fibre. Disperse dyes used with polyester most commonly utilise carriers.

Cellulose: A plant material forming a major component of cotton and rayon. Also used as the base for acetate fibre.

CMC: Carboxymethyl cellulose. Synthetic size used in cotton fabric manufacture.

COD: Chemical Oxygen Demand. The amount of oxygen required to chemically oxidise organics in a liquid.

Combing: Processing cotton or wool stock through a series of needles (or combs), to remove short fibres and foreign matter.

Complex: Simple manufacturing with additional operations such as printing, dyeing and printing.

Creel: See slashing.

Desize: Removal of size material from greige (gray) goods to prepare for bleaching, dyeing, etc.

Desuinting: Removal of natural impurities and dirt in wool fibre.

Developers: Chemicals used in dyeing process where colour is developed by reaction on cotton.

Direct Dye: Anionic water-soluble dye used primarily for dyeing full shade ranges on cotton and rayon.

Disperse Dye: Water-insoluble dye used to colour several synthetic fibres. Applied as a fine dispersion using a carrier.

Drawing: Straightening and paralleling the fibres after combing or carding.

Dry Cleaning: Cleaning of dyed yarn or fabric with a solvent rather than scouring in water solution.

Felt: A fabric made without a system of threads and constructed by interlocking of fibres, most commonly, wool or cotton.

Fibre Reactive: A type of dye used to colour cotton, nylon and polyester/cotton blend. This dye gives bright shades, good all-round colour fastness and is easy to apply.

Filament: A man-made continuous strand of yarn of near infinite length.

Fleece: Quantity of wool cut from individual sheep at shearing time.

Floc: An agglomeration of finely divided or colloidal particles.

Framing: Dyeing or impregnating fabric with a resin or starch and drying at the correct width.

Fulling: A shrinking process for wool utilising moisture, heat, friction and pressure. Also known as felting and milling.

Greige: Fabrics in unbleached, undyed state prior to finishing. Also referred to as "gray" or "grey" goods.

J-Box: A J-shaped device often used in continuous bleaching. The cloth is held in a J-shape arrangement for the required time at a designated temperature.

Jet Dyeing: A tubular machine utilising water jets to circulate fabric in a dye bath.

Jig: An open vat which passes full width cloth from a roller through a dye liquor and then on to another roller.

Kier: A piece of equipment in which cotton is boiled with dilute caustic soda to remove impurities or a pressure vessel used for yarn and fabric dyeing.

Knitting: Process for making a fabric by interlocking in series the loops of one or more yarns. Types include: jersey (circular knits), tricots (warp knits), double knits.

Mercerising: A process given to cotton yarns and fabric to increase lustre, improve strength and dye ability. Treatment consists of impregnating fabrics with cold concentrated caustic soda solution.

Metalised Dye: Two acid dyes (anionic, water-soluble) joined together to make a larger molecule which has greater light and wet fastness. Used primarily for dyeing nylon and wool where high fastness is required.

Milling: A shrinking process for wool utilising moisture, heat, friction and pressure. Also known as felting and fulling.

Naphthol: An azo whose colour is formed by coupling with naphthol. Used chiefly on cotton.

Nip: A squeeze performed by two rolls under pressure.

Nutrient: Any substance assimilated by an organism which promotes growth and replacement of cellular constituents.

Nylon: Generic name for "a manufactured fibre in which the fibre forming substance is any long chain synthetic polyamide in which less than 85% of the amide in linkages are attached to two aromatic links".

Package Dyeing: The dyeing of yarns in the form of a package of various kinds and sizes. Packages wound on to perforated tubes or springs are placed on perforated spindles in a closed vat and the dye bath is circulated in and out of the package.

Pad: A machine for impregnating fabrics with chemicals. It consists essentially of a trough followed by two or more pairs of squeeze rolls.

PET: Polyethylene terephthalate (polyester).

pH: Unit used to describe acidity or alkalinity. pH 7 is neutral; above 7 is alkaline and below 7 is acidic.

Polyester: A manufactured fibre in which the fibre forming substance is any long chain synthetic polymer composed of at least 85% by weight of an ester of dihydric alcohol and terephthalic acid.

Printing: Process of producing designs of one or more colours on a fabric. There are several methods, such as rollers, block, screen, etc. and several colour techniques, such as direct, discharge and resist.

PVA: Polyvinyl Alcohol. Synthetic size used in sizing process in cotton fabric manufacturing.

Rayon: A generic name for man-made monofilament and continuous filaments fibres, made from regenerated cellulose. Fibres produced by both viscose and cupra-ammonium process are classified as rayon.

Recuperator: An enclosed wash box utilising low pressure steam. Most often found on the mercerising range.

Resin: A chemical finish used to impart a property desired in a fabric, such as water repellency etc.

Retardants: Chemicals applied typically to fabrics or fibres to retard burning etc.

Rope Soaper: A piece of equipment used for scouring fabric to remove impurities, processing oils, excess dye, etc.

Saturator: A box used to impregnate fabric with chemicals in a continuous range.

Scouring: Removal of foreign components from textiles. Normal scouring materials are alkalis (e.g. soda ash) or trisodium phosphate, frequently used in the presence of surfactants. Textiles are sometimes scoured using solvents.

Simple: Processes such as desizing, fibre manufacturing preparation and dyeing.

Singeing : Cloth is passed across an open gas flame at a high speed to burn off the loose surface fibres.

Sizing : Applying starch, PVA or CMC to warp yarns to minimise aberration during weaving.

Slashing: A number of beams from the warper placed into a creel, run through a size solution and dried on a series of drying cans.

Spinning : A process by which a large strand of fibres is drawn out to a small strand and converted into a yarn. After drawing out (or drafting), twist is inserted, and the resulting yarn is wound into a bobbin.

Starch: Organic polymer used as a size, highly biodegradable.

Suint: Dried sheep perspiration.

Sulphur Dyes: A class of dyes which dissolve in aqueous sodium forming a product with a marked affinity for cotton; the dyes are regenerated by air oxidation.

Tentering: Open width fabric is run through a tenter frame which holds it at the desired width, fabric is dried and wound onto a roll.

Textured: Bulked yarns that have greater volume and surface interest than conventional yarn of the same fibre.

Top: A continuous untwisted strand or sliver of wool fibres wound on to a large ball.

Tufted Yarn: Very coarse yarns, usually plied, designed for the tufting trade. Most tufting yarns are made from nylon, acrylic or polyester fibre.

Vat Dye: A type of insoluble dye applied from a liquor containing alkali and a powerful reducing agent, generally hydrosulphite. The dye then becomes soluble and completely permeates the cotton fibre. It is then oxidised and again becomes insoluble.

Warp: Set of lengthwise yarns in a loom through which the crosswise filling yarns (weft) are interlaced. Sometimes called 'ends'.

Weaving: Manufacture of a fabric by interlacing a series of warp yarns with filling (weft) yarns at right angles.

Winch: A machine for scouring (cleaning), dyeing, etc., goods while in the form of a rope or endless belt. A roller gradually moves the cloth through the bath in a slack condition.

Winding: Yarn is wound on to one of the several different types of large packages and most of the slubs or thick places are taken out.

Worsted: A wool fabric which uses finer grades of wool with finer yarns and higher weaving construction than a woollen fabric.

Yarn: A combination of fibres or filaments, either manufactured or natural, twisted or laid together so as to form a continuous strand which can be used in weaving or knitting or can be made into a textile material.

SUMMARY

The textile industry is a significant contributor to many national economies, encompassing both small and large-scale operations worldwide. Textile manufacturers use raw materials such as cotton, wool, and synthetics to produce a diverse range of products for consumers at home and abroad. Nevertheless most operations are highly standardized, and the environmental options for manufacturers can be conveniently studied from the point of view of a few common processes.

The impacts on the environment of this industry have been recognized for some time, both in terms of the discharge of pollutants and of the consumption of water and energy.

Pollutants arise from the dirt and grease that is removed from raw natural fibres, as well as from process chemicals and dyestuffs that are lost during operations. The extensive use of synthetic chemicals in particular can lead to serious environmental and occupational impacts if proper precautions are not taken. Air pollution can arise from dyeing and finishing agents, and in the form of oil mists from machinery. Land pollution may occur from the uncontrolled dumping of chemical residues and treatment plant sludges. Direct contact during handling of chemicals may give rise to occupational illnesses.

The discharge of pollutants and wastes also represents an economic cost to the company. Inefficient processes lead to loss of expensive chemicals, wastage of water and energy, and give rise to undesirable quality variations and off-specification products. Opportunities may be missed for recovery of valuable by-products from washing and cleansing operations, or recovery of size. Finally, the cost of wastewater treatment itself depends directly on the quantity of waste produced - less waste means smaller treatment plants and lower operating expenses.

These impacts can be addressed in number of ways, depending on the local situation. The application of Cleaner Production concepts to textile processing brings an overall view of the operation, and considers not only improved process equipment, but also alternative chemicals, and improved operating procedures.

For older plants there are usually many possibilities for immediate optimization of operations through more effective housekeeping, keeping plant in good working order, improved methods of handling, and minor process changes to reduce losses. The use of energy, waste and emissions audits can pinpoint the areas that particularly need attention. Audit procedures have become standard practice in many companies. UNEP and UNIDO have published guidance documents on how to perform such audits.

The possibility of replacing older plant by more efficient new equipment should also be thoroughly investigated, as often there are economic benefits to such an upgrading, and the investments have often very short paybacks. Where new plant is installed this should be assessed from the outset on environmental as well as technical criteria.

Careful handling and use of processing chemicals can only be achieved if proper workplace procedures are introduced and shop-floor personnel is adequately trained. There are a number of specialized organizations, both intergovernmental and industry-based, that can advise companies on the necessary procedures. Information on chemical hazards can also usually be obtained from such organizations. Many chemical companies now supply alternative reagents and dyes that are safer to use and less polluting to the environment.

Even with more efficient processes and better handling there will generally remain some effluent, and some waste residues. Adequate treatment processes exist for most common pollutants, with only colour removal sometimes presenting any real difficulty. Because effective control of fugitive emissions remains an expensive operation, air pollution control is preferably achieved through selection of less volatile finishing chemicals and completely enclosed processes. Disposal of chemical residues and empty containers is a further consideration which, while seemingly of minor importance, can have serious impacts if carelessly carried out. Safe disposal depends on adequate pre-treatment of residues, and if possible the use of special industrial landfills for the stabilized residues.

The range of potential environmental impacts and issues is now so large that addressing them one at a time is no longer effective. Textile companies need to adopt, at a high level, an integrated environmental management plan that is clearly explained to employees. Environmental and safety training should be provided to allow all employees to contribute to environmental programmes. Regular environmental audits and reporting should be carried out by management itself, with prompt action taken to address any problems that arise. The company should also participate in industry-wide initiatives to raise environmental awareness, and join cooperative action on research, training, information exchange and communication. The use of industry guidelines and self-regulatory procedures can do much to encourage better performance across the entire textile sector, and may reduce somewhat the need for regulatory action.

Within the government a clear policy framework for environmental control should be developed. This should include an explicit statement of what environmental standards apply to companies, covering all environmental and safety issues. Government policy and regulations should wherever possible encourage a preventive cleaner production approach as a complement to the traditional discharge and emission standards, and also consider incorporating monitoring and reporting requirements as a part of such systems.

1

INTRODUCTION

In terms of its output or production and employment, the textile industry is one of the largest industries in the world. It can be classified into cotton, woollen and synthetic fibre sectors. Operations typically vary in scale from large mechanised plants to small scale traditional units, but all are characterised by the vast quantity of water required and by the variety of chemicals used in a long sequence of wet processing stages that generate many waste arisings. Variations in the fabric profiles also produce wide fluctuations in flow rates and waste concentration.

Environmental problems associated with the textile industry are typically those associated with water pollution caused by the discharge of untreated effluents. Liquid wastes arising from washing operations contain a substantial organic and suspended pollution load such as fibres and grease. Effluents are generally hot, alkaline, strong smelling and coloured by chemicals used in dyeing processes. Some of the chemicals discharged are toxic and can lower the dissolved oxygen of receiving waters, threaten aquatic life and damage both aesthetic value and overall water quality downstream.

Other environmental issues now considered equally important and relevant to the textile industry include air emissions, notably Volatile Organic Compounds (VOC) and excessive noise or odour as well as work-space safety.

■ 1.1 CLEANER PRODUCTION

Complex environmental issues demand a comprehensive integrated approach to tackle the problems of pollution. Reductions in the use of energy, water and other raw materials along with waste minimisation and elimination, whenever and wherever possible, should be the highest priority. Cleaner production, covering both products and manufacturing processes, is both necessary and beneficial. This implies that all types of resources, along the entire product life cycle, should be used as optimally as possible to reduce environmental impacts. In a textile process, this can mean substituting a non-toxic raw material, reducing water flows, or changing operational parameters and so on.

Simple good housekeeping measures can deliver cleaner processes, but a review of the existing process technology may be needed to evaluate the choice of process, a processing sequence and equipment used. Examples of such options include water conservation by counter-current washing, recovery of chemicals such as size, caustic, dyes and grease, replacement of high BOD (Biochemical Oxygen Demand) chemicals by low BOD ones, heat recovery from effluents, etc.

Textile equipment manufacturers are becoming more aware of the need to conserve water, chemicals, and energy. Many new production technologies have been spawned, at least in part, by that aware-

ness. This same awareness is also influencing the design of textile manufacturing equipment without impairing the product quality. Examples of such process and equipment changes include modifications in equipment for washing, dyeing, drying and for fabric printing.

■ 1.2 POLLUTION CONTROL STRATEGIES

Having reviewed and improved production processes to eliminate and reduce waste as much as possible, it is then necessary to select the best effluent treatment strategy. If pollution avoidance, recycling and waste treatment are carefully chosen, then there should be little residue requiring treatment and disposal. Nevertheless, all these stages must be carried out bearing in mind possible environmental impacts, worker safety and the welfare of any neighbouring community.

Segregation and separate treatment of specific effluent streams is more efficient than attempting to treat combined and complex effluents. Such a strategy will often provide opportunities to reuse or recover heat or chemicals and reduce the size of the treatment plant facility. Combined chemical and biological treatment is one of the most commonly employed methods of liquid waste treatment in the textile industry. In such instances, flow equalisation tanks and appropriate pre-treatment units must be constructed to remove toxic substances such as chemical additives and dyestuffs in the waste streams and to ensure the proper operation and maintenance of any biological treatment unit. Residues from textile operations include sludges from biological or physico-chemical units and waste materials from the production process. Disposal alternatives include a range of options such as compaction and landfilling, anaerobic digestion or incineration.

For practical implementation, the relative emphasis on these various strategies would vary. For example, existing old textile mills with mostly batch or semi-mechanised operating methods might find few opportunities for new, cleaner equipment. Better housekeeping, the minimisation of chemical usage, water reuse and low cost technologies for end-of-pipe treatments such as land application or aerated lagoons may be the most practical approach, at least initially. For large new textile mills using continuous methods of operation, environmentally sound processes and equipment options could be more attractive.

■ 1.3 ABOUT THIS REPORT

This report deals in detail with the complementary strategies of cleaner production and pollution control in three sections:

- An overview of textile wet processing operations and the wastes generated.
- A description of various cleaner production options.
- A review of technological options for end-of-pipe treatment.

Additional information is provided in the appendices including a list of reading materials and journals, cleaner production case studies and important addresses of textile research organisations, etc.

This report has been written for several audiences, each with different responsibilities:

- For industrialists, to review the impacts of different processes and cleaner options.
- For regulators, to provide an outline of environmental considerations and an integrated pollution control strategy.
- For operators and technicians, to provide details about the environmental implications of common processes, cleaner manufacturing operations, and check-lists for management decision-making.

This report *will not serve* as a complete and independent reference for readers wishing to develop and implement a detailed environmental management system. Readers are urged to refer to the additional reading material listed in the reference sections for more exhaustive and detailed guidance.

2 OVERVIEW OF TEXTILE WET PROCESSING OPERATIONS

Textile manufacturing comprises a group of interrelated industries, each making use of a wide variety of natural or synthetic fibres to produce fabrics.

Subdivision of the textile industry into its various components can be approached from several angles. The accepted method for defining the textile industry consists of categorising manufacturing plants according to the type of fibre they process, i.e. cotton, wool or synthetic fibre. This is useful when describing the individual processes involved in the production of fabric, together with the waste produced by the operation of each unit but offers insufficient detail to provide insight of any practical value.

It is also possible to categorise the industry on the basis of the processing operations used. For example, knit and woven fabrics are processed differently from carpet, yarn or other processed fibre. Although various types of material are produced in different ways, there is a distinct similarity between the range of products in each of the separate categories.

A typical categorisation suggested by the US Environmental Protection Agency (1978) on this basis is given below:

1. Wool Scouring
2. Wool Finishing
3. Dry processing
4. Woven Fabric Finishing
5. Knit Fabric Finishing
6. Carpet Manufacture
7. Stock and Yarn Dyeing and Finishing

This report is based on these process categories and what now follows is a brief description of them in terms of the waste generated by each.

■ 2.1 WOOL SCOURING

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 fibres 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 fourth 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 fibres (used for wool yarn) and long fibres (used for wool top). Figure 1 shows the manufacturing processes and sources of emissions arising out of the wool scouring mill.

Since raw sheep wool contains from 25 to 75% suint (which includes water soluble excretions and secretions of the sheep such as urine, faeces, sweat, blood, dirt, grease, etc.), the production of one kilo of scoured wool fibre produces one and one half kilos of waste impurities. Because of this, the scouring process contributes to more than half or even up to two-thirds of pollution load in terms of BOD.

■ 2.2 WOOL FINISHING

This category of the textile mill includes wool finishing along with processes such as carbonising, fulling, 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 and sources of emissions are depicted in Figure 2. 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 one process is described below.

If the greige goods are 100% wool, then they are first cleaned to remove vegetable matter by carbonising. Later, spinning oils and any weaving sizes are removed with the use of a light scour. 100% woollens are then dimensionally stabilised, principally by felting. Worsted and most wool synthetic blends are generally not fullled because worsted blends are hard, tightly woven and dimensionally stable when they arrive at the finishing plant. Woollens are loosely woven, soft and are hence firmed up by fulling.

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 moth-proofing.

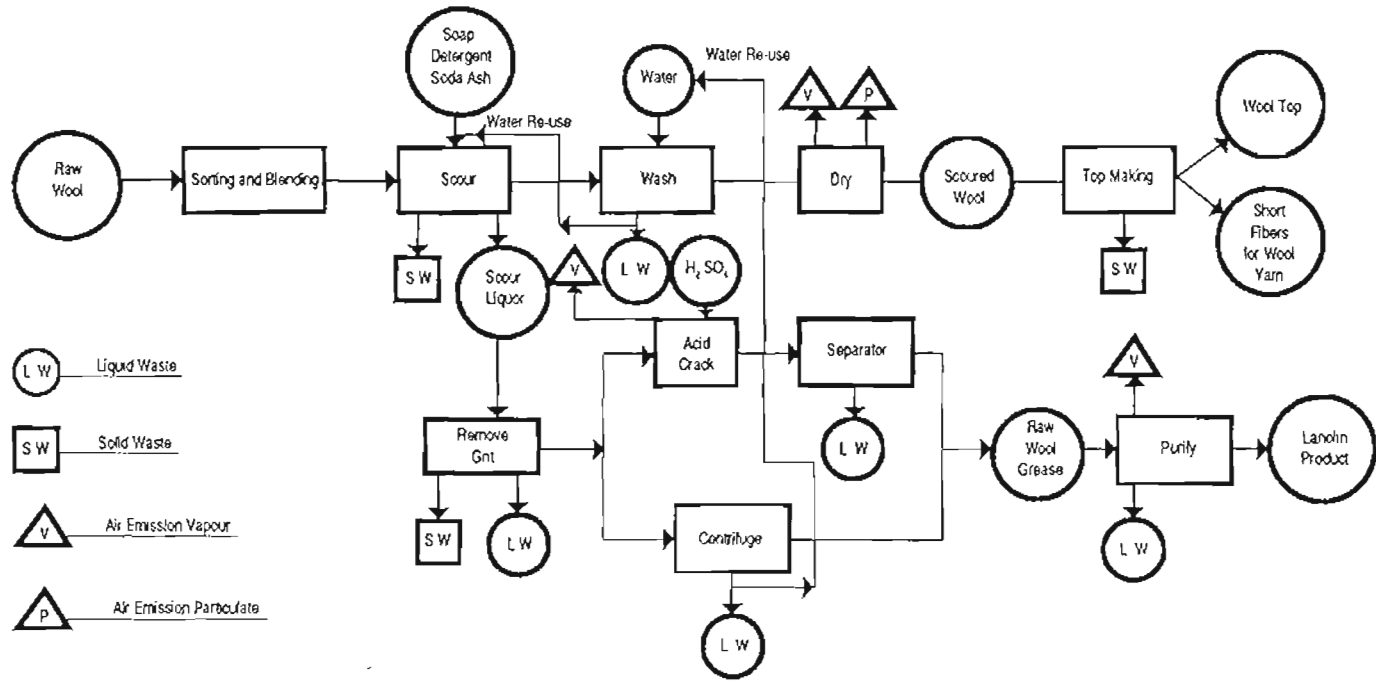
■ 2.3 DRY PROCESSING

This category of the textile mill includes yarn manufacturing, yarn texturing, unfinished fabric manufacturing, fabric coating, fabric laminating, fire 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 3 shows operations generally performed at this type of greige mill along with sources of emissions.

Mills within the dry processing category typically carry out dry-type operations, however, some waste is produced by spillage and vessels or 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

Figure 1: Emissions Sources in Wool Scouring Mill



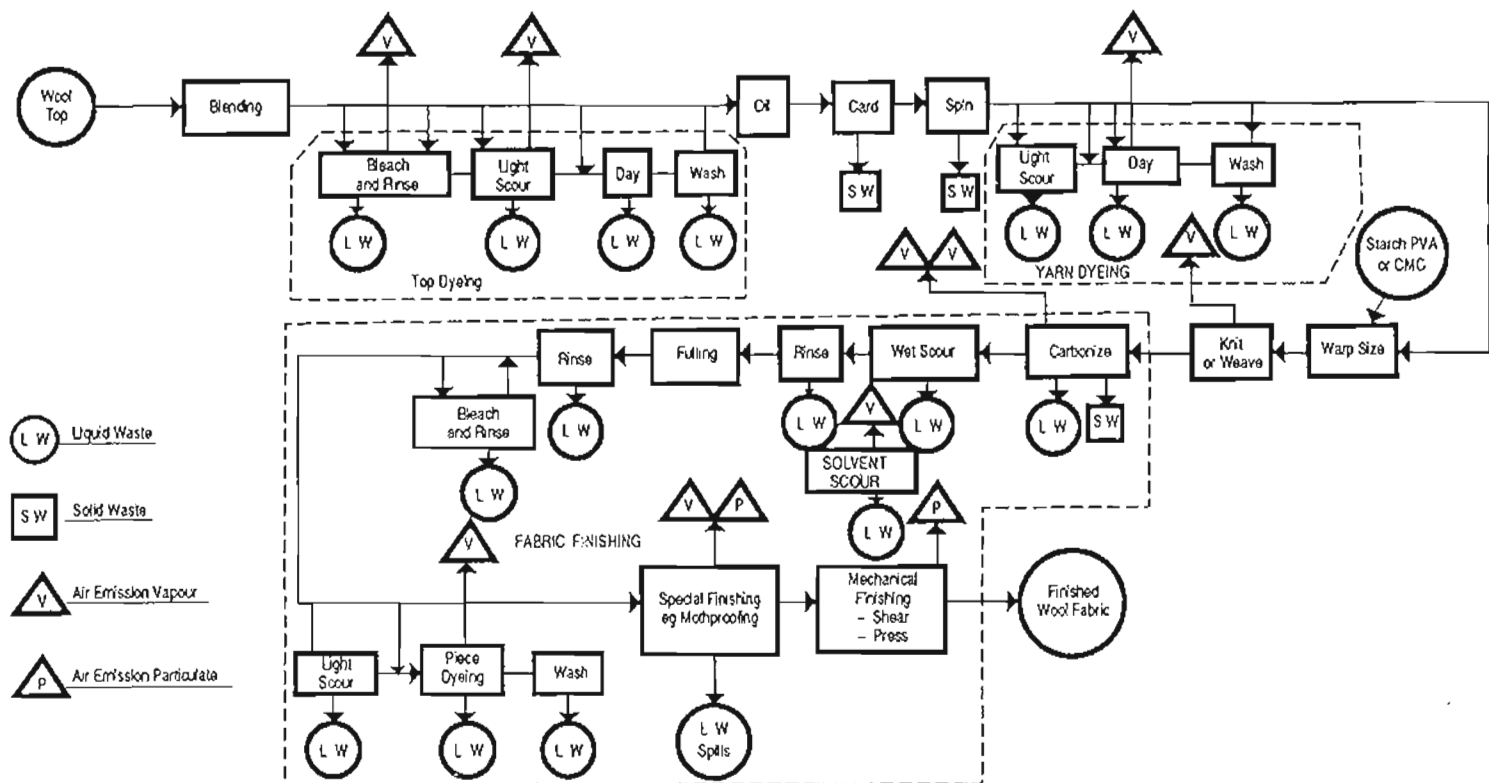


Figure 2: Emissions Sources in Wool Finishing Mill

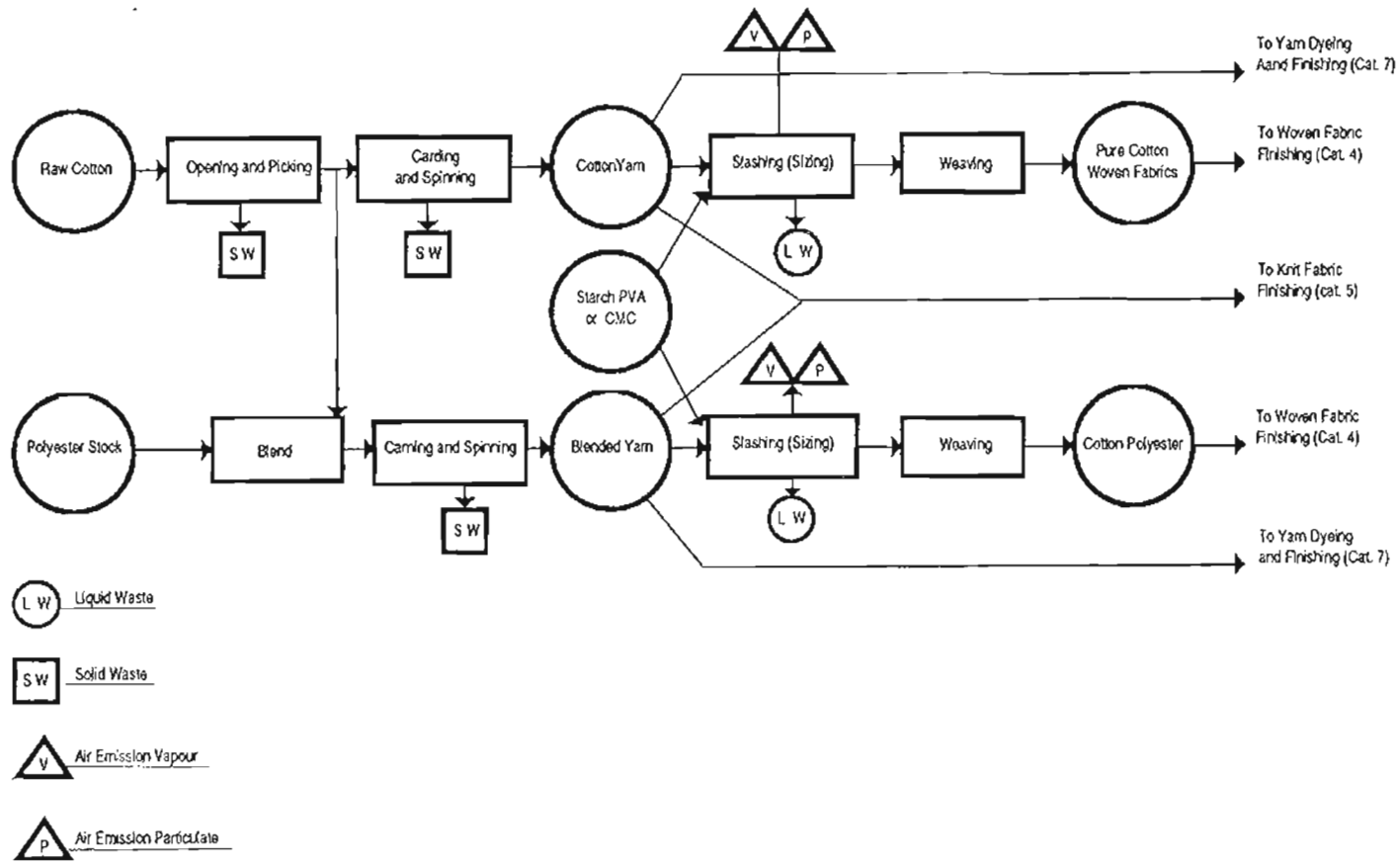


Figure 3: Emissions Sources in Dry Processing Mill

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. Under these conditions, the size film is flexible and yarn breaks on the loom are minimised. Yarns sized with Polyvinyl Alcohol (PVA) may be woven at a somewhat lower humidity than yarns sized with starch. 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.

■ 2.4 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, mercerising). 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 from 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 fibres (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 fibres contain only those impurities that were necessary for manufacture of the fibre and spinning to obtain the yarn. A flow sheet for woven fabric finishing is given in Figure 4 along with sources of emissions.

■ 2.5 KNIT FABRIC FINISHING

The knit fabric industry is characterised by a large number of plants and an organised structure, including specialised products segments such as knit fabric goods, hosiery, outerwear and underwear. This category is characterised by operational units such as bleaching, dyeing, printing, resin treatment, water proofing, flame proofing, and the application of soil repellency application or special finishes.

The wet processing operations performed in knit fabric finishing and sources of emissions are shown schematically in Figure 5. This is only a generalised flow sheet, as the specific operations employed in a given facility will vary from 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 agents, anti-oxidants, bacteriostats 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.

Figure 4: Emissions Sources in Woven Fabric Finishing Mill

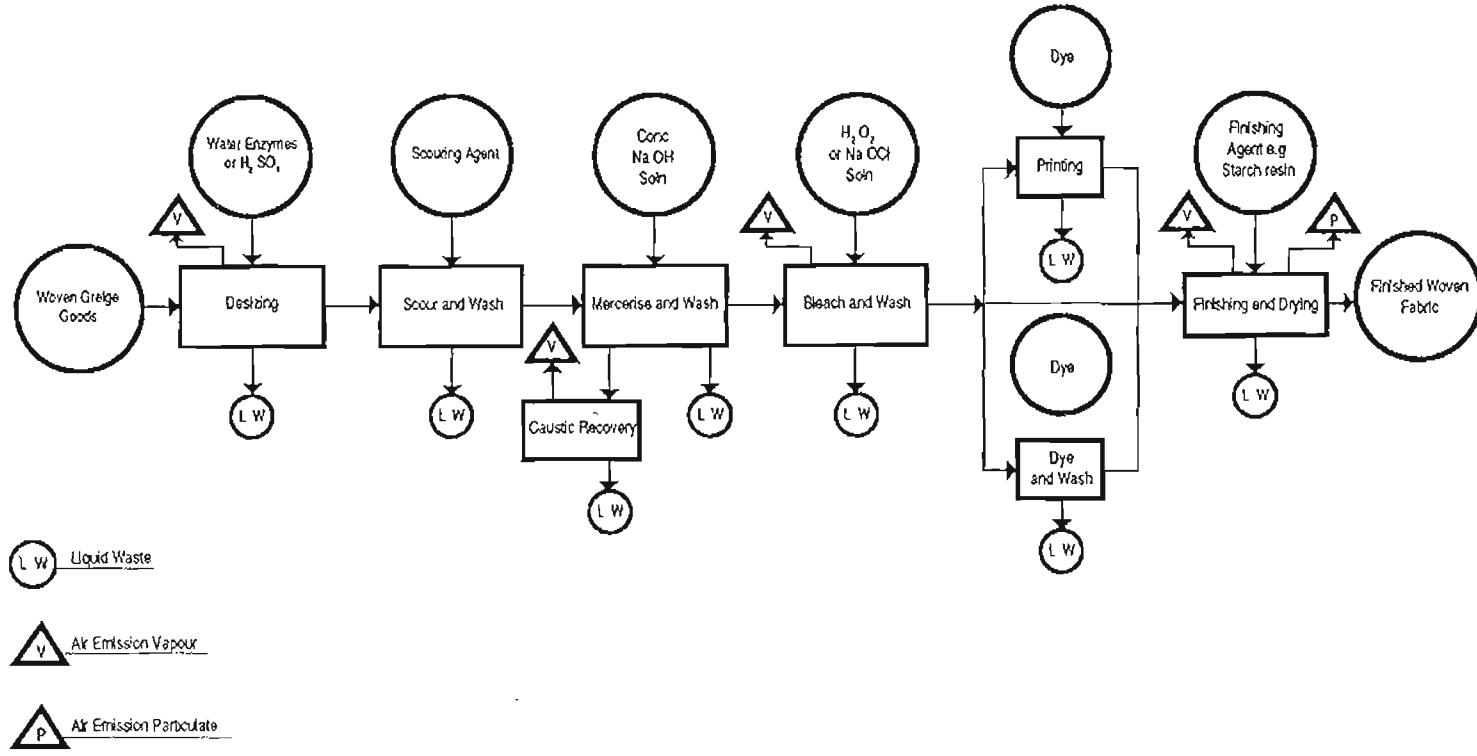
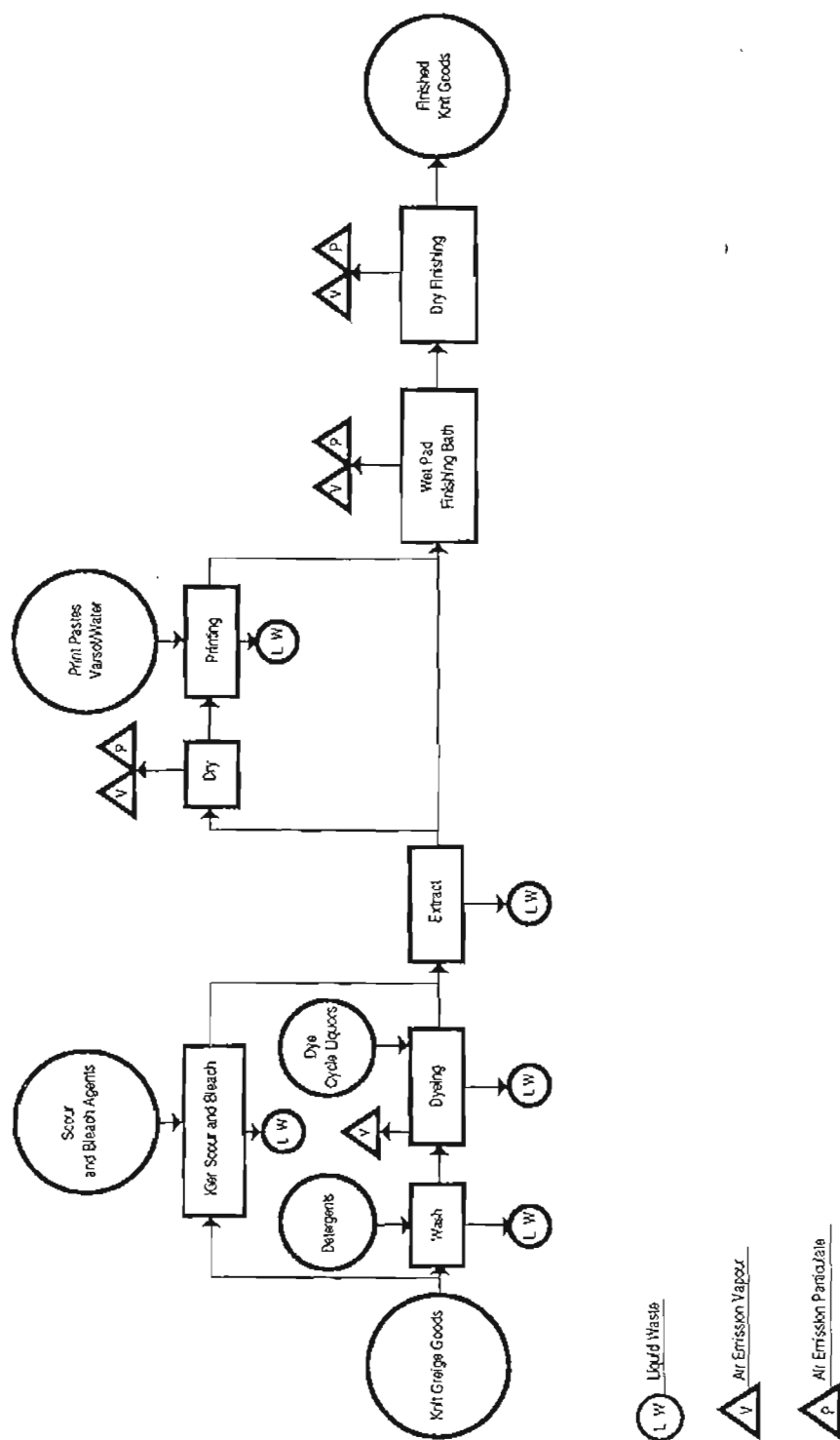


Figure 5: Emissions Sources in Knit Fabric Finishing Mill



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

■ 2.6 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 6 shows the various process details and sources of emissions.

Carpet mills use mostly synthetic fibres (nylon, acrylic and polyesters), but some wool and cotton is also processed. This category is characterised by any or all of the following operational units: bleaching, scouring, carbonising, 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 backing 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 fibres in carpets differs little from dyeing fabric, the dyeing descriptions for these fibres given in other categories applies here as well.

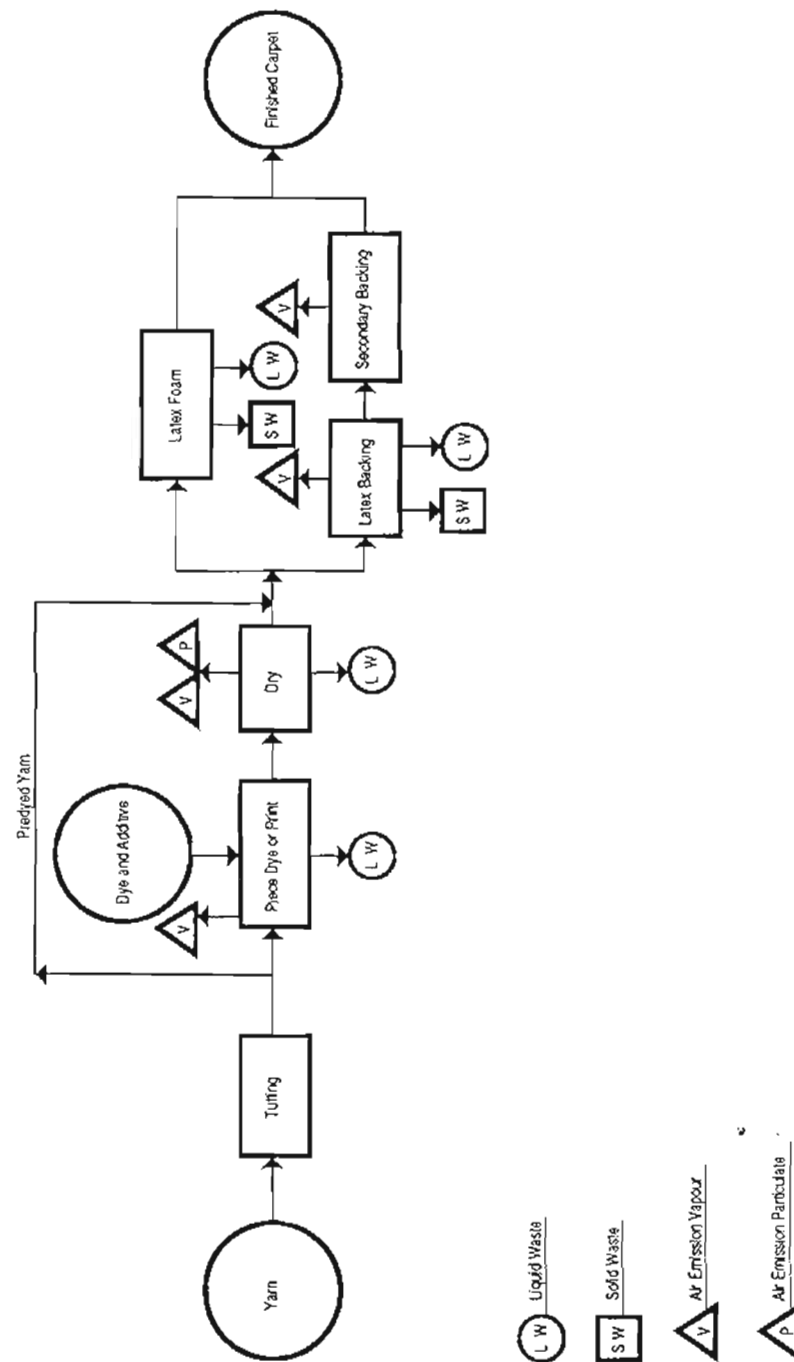
The yarn is tufted into a woven or synthetic non-woven polypropylene or jute primary backing in a dry operation. Following this, the tufted carpet can be either printed or dyed. If printed, a semi-continuous screen printing operation is performed, followed by a wash and rinse step in the same machine. 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.

■ 2.7 STOCK AND YARN DYEING AND FINISHING

Yarn dyeing and finishing are different from woven fabric finishing because there is no sizing and desizing operation. They are different from knit fabric finishing because of their mercerising operations and water use. These differences alone are sufficient to justify a separate category.

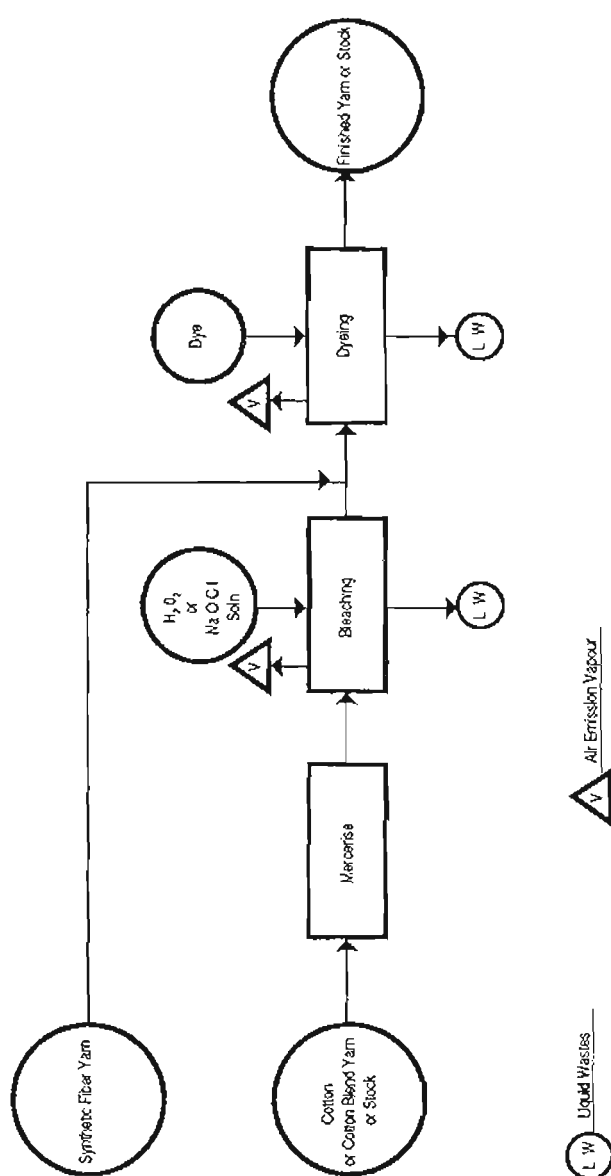
This category is typically characterised by operational units such as cleaning, scouring, bleaching, mercerising, dyeing and special finishing. This category includes plants which clean, dye and finish fibre stock of yarn. Sewing thread, textile and carpet yarn are typical products in this category. 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 unravelled 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 mill, showing the sources of emissions.

Figure 6: Emissions Sources in Carpet Mill



27

Figure 7: Emissions Sources in Stock and Yarn Dyeing and Finishing Mill



3

ENVIRONMENTAL IMPACT OF THE TEXTILE INDUSTRY

■ 3.1 SOURCES OF IMPACT

In typical textile operations both chemical and mechanical treatments are used on the raw materials to produce a finished product. Unwanted by-products arise from many points in this cycle, the majority of which are discarded.

Unwanted raw material components, such as grease and dirt, can constitute a major part of the raw pollution load arising from many textile operations. Waste chemicals, from the process or washed from finished textiles, constitute a second source of potential pollutants. Due to the range of chemicals used, the composition of the effluent stream may also vary considerably.

Chemical companies market a huge range of products such as dye formulations and colorants to the textile industry, many under trade names rather than by chemical composition. Table 1 shows an inventory of the 30 base chemicals and a wide variety of auxiliary chemicals used in a Ghanaian textile mill. Many of these are listed only under their trade name, making the full identification of their associated environmental and health risks more difficult. Many chemicals used may be dangerous to handle unless proper safety precautions are used. Some present a fire risk if incorrectly stored and handled. Others, including a range of caustic or oxidising chemicals, can be either corrosive or acutely toxic. Some solvents and colorants present a chronic health risk if prolonged exposure takes place.

Many dyes and colorants are difficult to treat but their high visibility in waste discharges means these materials attract particular attention. Occupational safety and exposure during handling is however an equally important issue which needs to be managed just as closely as impacts on the external environment. To provide users with more precise guidance, the Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers (ETAD) has prepared guidance documents covering safe handling as well as environmental issues such as risk assessment. Relevant references are

► Table 1 Typical Chemicals Stock in a Textile Mill

Base Chemical			Auxiliaries		
	Year Consumed	Comments	Base Chemical	Year Consumed	Comments
Caustic soda	344000 kg	General chemical	Biolase	PC 20	410 kg Desizing agent
Soda ash (sodium carbonate)	33900 kg	General chemical	Bactosol	TK liquid	400 kg Desizing agent
Common salt	1060 kg	General chemical	Sandopan	CBH	4620 kg Detergent/Wetting agent
Urea 46%	6700 kg	General chemical	Sandopan	DTC	8200 kg Detergent/Wetting agent
Hydrogen peroxide	2930 kg	General chemical	Invatex	KR	4290 kg Boiling-out aux.
Acetone	165 kg	General chemical	Tinoclarite	G	370 kg Bleaching stabilizing
Ammonia 25%	60 kg	General chemical	Contavan	CBS	625 kg Bleaching agent
Ammonium sulphate 21% 505	150 kg	General chemical	Ofnapon	ASN	300 kg Protective colloid
Calcium hypochlorite	5940 kg	General chemical	Solidegal oil	GL	480 kg Levelling agent
Diamonium phosphate	50 kg	General chemical	Setamol	WS	65 kg Colloid & dispersing agent
Magnesium sulphate	50 Kg	General chemical	Peregal	P	60 kg Levelling agent
Sodium acetate	6300 kg	General chemical	Irgasol	NA	1800 kg Levelling agent
Sodium bicarbonate	4400 kg	General chemical	Lyogen	WL	50 kg Levelling & Wetting agent
Sodium hydrosulphite	4000 kg	General chemical	Primazol	FP	1130 kg Wetting agent
Sodium nitrite	1430 kg	General chemical	Ruco wet	RNE	625 kg Wetting agent
Sodium silicate	1970 kg	General chemical	Turpex	ACN	60 kg Finishing agent
Sodium sulphide	400 kg	General chemical	Invadine	MC	50 kg Wetting agent
Hydrochloric acid	7406 kg	General chemical	Invadine	LU	505 kg Wetting agent
Sulphuric acid 66 Be'	5670 kg	General chemical	Invalon	PR	40 kg Sequestering agent
Acetic acid	12980 kg	General chemical	Diseron	ITH	2275 kg Rewetting agent
Tartaric acid	100 kg	General chemical	Leonil	GA-E	125 kg Wetting. Washing aux.
Glyezin A	600 kg	Solvent agent	Sapamine	OC	480 kg Softener
Trilon TB	575 kg	Sequestering agent	Sapamine	WL	40 kg Softener
Wood rosin	9400 KG	Wax	Avivan	RA	1860 kg Softener
Shea butter	1925 kg	Softener	Sandozol	CP LIQ. GF	20 kg Softener
Talcum powder	1475 kg	General chemical	Albatex	FFC	20 kg De-aerating agent
Lyoprint RG grains	495 kg	Printing, vat dyes, Kier boiling	Levamin	46040	20 kg Printing aux.
Polyron T	100 KG	Phosphate based aux.	Respumit	3300	2200 kg De-foamer
P3-T 288 (water treatment)	75 kg	Water treatment agent	Fumexol	AS	1170 kg De-foamer
Turkey red oil 50/70%	2000 kg	General chemical (protective colloid)	Levasol	TR	180 kg Solvent agent

► Table 1 Typical Chemicals Stock in a Textile Mill (continued)

Auxiliaries (cont.)				Thickeners			
Base Chemical		Year Consumed	Comments	Base Chemical		Year Consumed	Comments
Iriodine 101	Rutisilver	140 kg	For printing	Vinarol	ST	400 kg	For adhesive
Blankophor	BBU LIQ.	740 kg	Whitener	Ultrabind	SS10	100 kg	For adhesive
Uvitex	CF 530%	545 kg	Whitener	Indalca	PA/I 3%	100 kg	For ph. blue IBN
Nekal	BX DRY	100 kg	Whitener	Indalca	PA/16 3%	375 kg	For heavy metal salts
Emulsifier	WN	420 kg	Emulsifier	Meypro gum	R600 9%	1000 kg	For reactive dyes
Emulsifier	3240	100 kg	Emulsifier	Diaprint	AF/E 3.5%	4925 kg	For fast salts. Plant see gum
Emulsifier	VA	1201 kg	Emulsifier	Monagum (587)	W 9%	50 kg	For rotary screen printing
Acramin	SLN 130%	10000 kg	Binder	Dialgin	HV/A 9%	5875 kg	Na.alginates
Acramin	BA	1380 kg	Binder	Solvitose	OFA 4%	825 kg	Guar gum ether
Acrafix	MP	320 kg	Crosslinking agent	Solvitose	C.5.10%	100 kg	Guar gum ether
Acrafix	CO	50 kg	Crosslinking agent	Solvitose	H.4 15%	800 kg	For adhesive. Starch ether
Acrafix	UC	100 kg	Combiner	Printex	S 33%	125 kg	Based on starch
Acracome	B	270 kg	Dispersing of crosslinking	Polyprint	A-231	3350 kg	Guar gum
Vibratex	KN	2730 kg	Starching agent	HV 3%		7800 kg	For starching
Appretan	MB	5160 kg	Finishing agent	Wheat starch		2500 kg	Na.alginates
Ratifix	F Liquid	120 kg	Finishing agent, for resin	Lamitex	HV-VT	1500 kg	Na.alginates
Finish	MH Liq. (661)	215 kg	Finishing agent, for resin	Lamitex	LV-VT		
Sandolub HVN	(NV, KVN) 662	200 kg	Finishing agent				

► Table 1 Typical Chemicals Stock in a Textile Mill (continued)

Dyestuffs							
Base Chemical		Year Consumed	Comments	Base Chemical		Year Consumed	Comments
Acramin white	DR	30 kg	Pigment	Cibanone yellow	3R	50 kg	Vat
Acramin yellow	FGG	30 kg	Pigment	Cibanone yellow	GC MD	111 kg	Vat
Acramin yellow	F-7GC	55 kg	Pigment	Cibanone golden orange	3GF	60 kg	Vat
815		35 kg	Pigment	Cibanone br. orange	GF	60 kg	Vat
Acramin red	FFG	490 kg	Pigment	Cibanone br. orange	3R	55 kg	Vat
Acramin g. yellow	FGRN	80 kg	Pigment	Cibanone red	2B HD	80 kg	Vat
Acramin orange	F5G	80 kg	Pigment	Cibanone brown	BG	428 kg	Vat
Acramin red	FFG	200 kg	Pigment	Cibanone brown	BR	165 kg	Vat
Acramin red	FRC	30 kg	Pigment	Cibanone brown	2BR MD	30 kg	Vat
Acramin brown	FRL	50 kg	Pigment	Cibanone br. green	BF	190 kg	Vat
Acramin green	F3GC	30 kg	Pigment	Cibanone blue	FG	150 kg	Vat
Acramin green	FB	30 kg	Pigment	Cibanone blue	GF	545 kg	Vat
Acramin violet	FFR 816	10 Kg	Pigment	Cibanone blue	RS MD	30 kg	Vat
Acramin blue	FFG	40 kg	Pigment	Cibanone olive	S	35 kg	Vat
Acramin black	FPV	65 kg	Vat	Cibanone black	B	23 kg	Vat
Indanthren yellow	F3 GC	40 kg	Vat	Youhaoctive br. red	K2BP	75 kg	FR
Indanthren g. yellow	RK	45 kg	Vat	Youhaoctive grey	G	100 kg	FR
Indanthren brown	R	30 kg	Vat	Printofix black	HB	270 kg	Vat
Indanthren brown	NG 8059	35 kg	Vat	Immedial carbon	CMR	1100 kg	Sul
Indanthren brown	BRN	50 kg	Vat	Indigo pure base 20%		666 kg	Vat
Indanthren r. brown	SRF	45 kg	Vat	Antioxidant diresul	B liquid	150 kg	Dir
Indanthren bl. brown	NT	95 kg	Vat	Diresul black	RC liquid	1850 kg	Dir
Indanthren olive green	B	80 kg	Vat				
Indanthren olive	GG	111 kg	Vat				
Indanthren olive	MW	35 kg	Vat				
Indanthren khaki	GG	25 kg	Vat				
Indanthren grey	GL	45 kg	Vat				
Indanthren blue	BG	150 kg	Vat				
Indanthren blue	BC						

► Table 1 Typical Chemicals Stock in a Textile Mill (continued)

Dyestuffs							
Base Chemical		Year Consumed	Comments	Base Chemical		Year Consumed	Comments
Naphtol	AS-G	50 kg	Azoic coupling component	Drimarene yellow	R-GN	50 kg	Cotton fibre reactive dyes
Naphtol	AS	12298 kg	Azoic coupling component	Drimarene g. yellow	R-2RL	1100 kg	Cotton fibre reactive dyes
Naphtanilide	RC (AS)	3000 kg	Azoic coupling component	Drimarene scarlet	R-3G	130 kg	Cotton fibre reactive dyes
Naphtanilide	CB SUPRA	50 kg	Azoic coupling component	Drimarene br. orange	R-R	323 kg	Cotton fibre reactive dyes
Naphtanilide	LRG	1036 kg	Azoic coupling component	Drimarene br. red	R-4BL	513 kg	Cotton fibre reactive dyes
Youhaqthol	AS-OL	50 kg	Azoic coupling component	Drimarene d. brown	R-BL	175 kg	Cotton fibre reactive dyes
Fast yellow	CG salt	100 kg	Azoic diazo component	Drimarene turq.	R-BL	400 kg	Cotton fibre reactive dyes
Fast orange	GC base	2235 kg	Azoic diazo component	Drimarene violet	R-2RL	15 kg	Cotton fibre reactive dyes
Fast scarlet	GGG base	350 kg	Azoic diazo component	Drimarene blue	R-GL	400 kg	Cotton fibre reactive dyes
Fast red	B base	450 kg	Azoic diazo component	Remazol yellow	GR	295 kg	Cotton fibre reactive dyes
Fast bordeaux	GP base	1850 kg	Azoic diazo component	Remazol br. g. yellow	R	150 kg	Cotton fibre reactive dyes
Fast blue	B base	683 kg	Azoic diazo component	Remazol br. orange	RR 389	100 kg	Cotton fibre reactive dyes
Fast blue	BB base	210 kg	Azoic diazo component	Remazol br. orange	3R	20 kg	Cotton fibre reactive dyes
Fast red	KL salt	200 kg	Azoic diazo component	Remazol br. red	5B 426	255 kg	Cotton fibre reactive dyes
Fast black	K salt	100 kg	Azoic diazo component	Remazol brill green	6B	415 kg	Cotton fibre reactive dyes
Ruco dye blue	B base	365 kg	Azoic diazo component	Remazol turquoise	G	150 kg	Cotton fibre reactive dyes
Viamine blue	B	394 kg	Azoic diazo component	Remazol turq. blue	G 133	325 kg	Cotton fibre reactive dyes
Diazo fast yellow	GC salt	20 kg	Azoic diazo component	Remazol br. violet	5R 848	150 kg	Cotton fibre reactive dyes
Diazo fast orange	RD salt	1180 kg	Azoic diazo component	Remazol brown	GR	50 kg	Cotton fibre reactive dyes
Diazo fast orange	GGD	200 kg	Azoic diazo component	Remazol blue	3R	50 kg	Cotton fibre reactive dyes
Salt		615 kg	Azoic diazo component	Somazin turq. blue	G 133	900 kg	Cotton fibre reactive dyes
Diazo fast scarlet	GG salt	288 kg	Azoic diazo component	Somazin black	B	210 kg	Cotton fibre reactive dyes
Diazo fast red	RC salt	100 kg	Azoic diazo component	Procion turquoise	SP-2G	1403 kg	Cotton fibre reactive dyes
Diazo fast violet	B salt	550 kg	Azoic diazo component	Phthalogen blue	IBN	1200 kg	Phthalogen dye
Diazo fast blue	B salt	3250 kg	Azoic diazo component	Phthalogen br. blue	1F3G	300 kg	Phthalogen dye
Diazo fast black	K 150%	1975 kg	Azoic diazo component	Phthalogen br. blue	1F3GM	700 kg	Phthalogen dye
Diazo fast black	K 100%	1800 kg	Cotton fibre reactive dyes	Rapidamin blue	G	700 kg	Azoic diazo component
Cibacron yellow	2125	80 kg	Cotton fibre reactive dyes	Ronasal red	G	450 kg	Azoic diazo component
Cibacron g. yellow	2R	75 kg	Cotton fibre reactive dyes	Remazol printing green	3GT	300 kg	Cotton fibre reactive dyes
Cibacron yellow	GG	30 kg	Cotton fibre reactive dyes	Imperon white	BF new	120 kg	Pigment
Cibacron turq.	GR	30 kg	Cotton fibre reactive dyes	Imperon blue	KRR	10 kg	Pigment
Cibacron navy blue	T2 RP	27 kg	Cotton fibre reactive dyes				
Cibacron print black	G	235 kg	Cotton fibre reactive dyes				
Cibacron yellow	F-3R	50 kg	Cotton fibre reactive dyes				
Cibacron yellow	F-4G	18 kg	Cotton fibre reactive dyes				
Cibacron orange	F-R	270 kg	Cotton fibre reactive dyes				
Cibacron red	F-B	432 kg	Cotton fibre reactive dyes				
Cibacron blue	F-GF						

included in Annex A. ETAD's address is found in Annex D. Workplace issues are also comprehensively reviewed in a separate document prepared by ILO, as shown in the references.

Ancillary operations such as machine cleaning, boilers, water treatment plant and effluent treatment facilities may also cause further environmental impacts if they are not properly controlled. Sadly, these operations are often seen simply as adjuncts to textile processing, with discharges and emissions not subject to the same degree of scrutiny as the more major processes.

To identify all sources of pollution systematically a waste audit in the plant should be undertaken. This will provide a comprehensive view of the processes on the site, enhance understanding of material flows, and focus attention on areas where waste reduction is possible. The methodology for waste audits is explained in a UNEP/UNIDO technical report. A summary taken from this report is shown in Annex E.

■ 3.2 WATER POLLUTION SOURCES AND CHARACTERISTICS

Textile effluents are generally grey in colour, have a high BOD, high total dissolved solids and a high temperature. Natural impurities extracted from 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.

Effluents from each individual process therefore vary, depending on the variety of fibre blends produced. Each fibre process produces effluent with its own distinctive characteristics. For all textile mills processing the same fibre effluent characteristics are broadly similar but quantities may vary. Differences also arise between different plants processing the same fibre, due usually to variations in the production technology.

Wool effluents are characterised 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 colour content due to cotton dyeing operations. They also have a high BOD (although this is much lower than that found in wool scouring effluents), contain no grease and have a relatively low solids content. Synthetic finishing effluents are generally lower in volume than those generated in cotton finishing, but may contain toxic substances, especially from the dyeing streams where chemical dyes with a metallic ion content are used more widely.

Typical textile processing operations can include the use of several non-process chemicals such as machine cleaners, shop chemicals, biocides, insecticides and boiler treatments, the use of which is rarely as well controlled as that of most process chemicals. If any of these non-process chemicals enter the waste stream, they will greatly increase the pollution load of the total effluent. In addition, process chemicals can enter the effluent stream through spillage, leakage, clean-up (drums, tanks), batch chemical dumping and poor housekeeping.

Table 2 shows the approximate concentrations of pollutants generated from various textile processing operations. It is clear that the BOD from wool scouring effluents is the highest amongst all other categories, indicating its severe impact on receiving waters.

The ratio between BOD and COD generally represents the degree to which the wastes are refractory or difficult to biodegrade. Ratios ranging between 1:2 and 1:3 would imply good potential biodegradability. For most textile effluents the ratio lies in this range. For wool scouring effluents the ratio may be as high as 1:5, indicating that biological treatment of these effluents is exceptionally difficult. Their chemical pollution content is compounded by the high levels of suspended solids, oil and grease.

Textile mill wastes are also highly coloured due to the application of dyes with colour units ranging

► Table 2 Characteristics of Textile Effluents †

Sub-category	Concentrations in mg/l						
	BOD	COD	TSS*	O&G**	Phenol	Cr***	Sulphide
1. Wool Scouring	6,000	30,000	8,000	5,500	1.5	0.05	0.2
2. Wool Finishing	300	1,040	130	-	0.5	4.00	0.1
3. Dry Processing	350	1,000	200	-	-	0.014	8.0
4. Woven Fabric Finishing	650	1,200	300	14	0.04	0.040	3.0
5. Knit Fabric Finishing	350	1,000	300	53	0.24	0.24	0.2
6. Carpet Finishing	300	1,000	120	-	0.13	0.13	0.14
7. Stock and Yarn Finishing	250	800	75	-	0.12	0.12	0.09

* TSS: Total Suspended Solids
 ** O&G: Oil and Grease
 *** Cr: Chromium
 † Adapted from US EPA, *Environmental Pollution Control, Textile Processing Industry*, October, 1978.

between 300 to 1,000 for non-wool operations and as high as 2,000 in the case of effluents from wool scouring. Direct discharge of such effluent can lead to a significant deterioration in the aesthetic value of downstream water quality.

In addition to the major pollutants discussed above, trace constituents that are washed into effluents such as dyes, oils, surfactants and other substances, are also of increasing concern. Concentrations will often be quite low but these substances may still present a residual health risk, especially if receiving waters are to be used downstream for drinking water in major population areas.

A recent Canadian report † regarding priority pollutants in textile effluents concluded:

- 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. chlorophenols, methylphenol and nitrophenol), chloroethylenes, chloroethanes, chloroform and phthalates such as bis (2-ethylhexyl) phthalate and di-n-butylphthalate. These pollutants may come as trace or additives in dyes, dye carriers and raw materials as well as from 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 from the mills surveyed all had a loading of total phenols below 0.05 kg per 1000 kg of product. This is below the limit set by the EPA Textile Mill Effluent Guidelines.
- Metal priority pollutants commonly found in textile effluents are zinc, copper chromium, lead and nickel; individual concentration of these metals tends to be below 1 mg/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 as suggested by EPA, effluents from 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.

† Source: *Environmental Assessment of the Canadian Textile Industry*, Environment Canada, 1989.

■ 3.3 AIR EMISSIONS SOURCES AND OCCUPATIONAL SAFETY

Emissions from textile processes (excluding boiler emissions) fall into four general categories: oil and acid mists; dust and lint; solvent vapours; odours.

Oil mists are produced when textile materials containing oils, plasticisers and other materials that evaporate or degrade thermally are subjected to heat. The most common source of oil mists is the tenter frame, which produces oil mists with a droplet concentration of 0.030-0.045 grains/ACF corresponding to an emissions factor in the range of 25-200 lbs/day of oil released.

Acid mists are produced during wool carbonisation and during some types of spray dyeing and acetic acid mist dyeing. These mists are corrosive.

Solvent vapours generally contain a large number of toxic chemicals in varying concentrations depending on the substances used in dyeing and finishing operations. Examples of these compounds are acetaldehyde, chlorofluorocarbons, p-dichlorobenzene, ethylacetate, chlorobenzene, hexane, styrene, etc.

Two components normally found in these emissions are acetic acid and formaldehyde. Acetic acid can be emitted from bulk storage tanks through the vents, during filling and due to breathing losses, and to a lesser extent it may be emitted from dyeing machines and/or dryers. Formaldehyde may be emitted from bulk resin storage tanks, fabric warehouses, dryers and curing ovens.

Some process chemicals end up in the fibre and later evaporate away from the material in the dryers as airborne VOC. Examples of chemicals which behave this way include methyl naphthalene, chlorotoluene, trichlorobenzene, ortho dichlorobenzene, perchloroethylene, methyl ester of cresotinic acid, butyl benzoate, biphenyl, etc. Table 4 lists typical VOC and corresponding potential sources in textile processing operations.

Odours are often associated with oil mists or solvent vapours and are overcome by removal of these mists and vapours. The most common problem of this type arises from carrier odours associated with aqueous polyester dyeing and the processes subsequent to it. Resin finishing also produces odour, mainly of formaldehyde. Sulphur dyeing on cotton and cotton blends, dye reduction or stripping with hydrosulphite, bonding, laminating, back coating and bleaching with chlorine dioxide are other common sources of odour.

► Table 4 Partial List of Typical VOCs and Corresponding Potential Sources †

Chemical	Potential Source
Chlorine	Shop, Water Treatment
Ethylene Oxide	Dryer Stacks (Wetting Agents)
Hydrochloric Acid	Dryer Stacks (Catalyst)
Methylene Chloride	Shop, Paint Stripper
Perchloroethylene	Dry Cleaner, Scour Carrier
Toluene	Becks, Dryers
Xylene	Becks, Dryers
Ammonia	Shop, Storage Tanks
Tetrachloroethane	Shop, Inspection
Trichloroethylene	Shop, Inspection

† Adapted from B. Smith, *Identification and Reduction of Pollution Sources in Textile Wet Processing*, Pollution Prevention Program, North Carolina Department of Environment, Health and Natural Resources, 1986

Dust and lint are produced in the highest quantities by the processing of natural fibre and synthetic staple prior to and during spinning, by napping and by carpet shearing. To a lesser extent, most other textile processes produce lint. While this is not a pollutant itself the presence of lint can interfere with other pollution abatement processes.

4 CLEANER PRODUCTION TECHNIQUES AND PROCESSES

Implementation of cleaner production techniques at any manufacturing plant can help to reduce effluent characteristics and volume considerably. It will also reduce the overuse of raw materials and energy. The economic advantages gained by implementing cleaner production are twofold: it will reduce both the costs of production and the need for costly end-of-pipe pollution control facilities. At the same time, health and environmental impacts on plant workers and the surrounding community are reduced. Cleaner production techniques may be classified into three groups: water and energy conservation, optimisation of chemical usage and process or equipment modifications.

■ 4.1 WATER AND ENERGY CONSERVATION

Table 5 details some interesting statistics about water usage (per unit of production) in different sectors of the textile industry. This data clearly shows a significant variation in water usage even within each plant category, due to the differences in the washing cycles, washing equipment employed and extent of water re-use. Where a large difference exists between the median and maximum values this probably reflects instances of indiscriminate water use including bad housekeeping. Sharp differences between the median and minimum values may indicate instances of strict control over water use and better housekeeping, water re-use or the selection of improved washing equipment.

Water conservation significantly reduces effluent volume. It is not unusual to find situations where a reduction of more than 25% in water usage can be achieved by following water conservation practices. Common sources of water waste are excessive water use in washing operations and poor housekeeping measures such as broken or missing valves, unattended leaks from pipes and hoses, instances when cooling waters are left running when machinery is shut down, etc. Implementation of strict housekeeping measures such as plugging leakages, checks on running taps and the installation of water meters or level controllers on major water carrying lines are examples of simple water conservation

► Table 5 Water Use in Textile Wet Processing †

Sub-category	Amounts of Water Typically Used in l/kg (gallons/pound) of Product Produced		
	Minimum	Median	Maximum
Wool Scouring	4.2 (0.5)	11.7 (1.4)	77.6 (9.3)
Wool Finishing	110.9 (13.3)	283.6 (34.1)	657.2 (78.9)
Dry Processing	0.8 (0.1)	9.2 (1.1)	140.1 (16.8)
Woven Fabric Finishing			
Simple Processing	12.5 (1.5)	78.4 (9.4)	275.2 (33.1)
Complex Processing	10.8 (1.3)	86.7 (10.4)	276.9 (33.2)
Complex Processing plus Desizing	5.0 (0.6)	113.4 (13.6)	507.9 (66.9)
Knit Fabric Finishing			
Simple Processing	8.3 (0.9)	135.9 (16.3)	392.8 (47.2)
Complex Processing	20.0 (2.4)	83.4 (10.0)	377.8 (45.2)
Hosiery Products	5.8 (0.7)	69.2 (8.3)	289.4 (34.8)
Carpet Finishing	8.3 (1.0)	46.7 (5.6)	162.6 (19.5)
Stock & Yarn Finishing	3.3 (0.4)	100.1 (12.0)	557.1 (66.9)

† Adapted from *Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills*, US EPA, October, 1979

strategies. Other reasons for large effluent volume is the choice of inefficient washing equipment, excessively long washing cycles and use of fresh water at all points of water use.

One simple idea for water conservation is to segregate water used for cooling purposes and set up an independent closed loop system for its possible direct and repeated use. One example of such a system could involve the diversion of non-contact cooling water to a clear well for direct re-use or to the influent water line of the textile mill. Such a practice can result in significant water conservation.

Most of the effluent volumes arising from a textile mill come from washing operations, primarily the preparation of fibre and dyeing operations. Since most of the washing cycles are in a series, used water in the various washing stages can be re-used. This method of the water recycling is called counter-current washing. With this method the least contaminated water from the final wash is re-used for the next-to-last wash and so on until the water reaches the first wash stage, where it is finally discharged. Direct counter-current washing is now generally built into the process flow sheet of new textile mills. It is also easy to implement in existing mills where there is a synchronous processing operation. Figures 8 and 9 show recommended counter-current washing strategies for a soaper range and during continuous bleaching for the cotton textile industry.

Figure 8: Recommended Counter-Current Flow of Washing on a Soaper Range

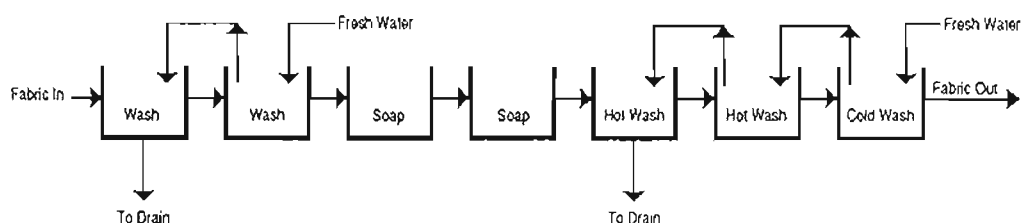
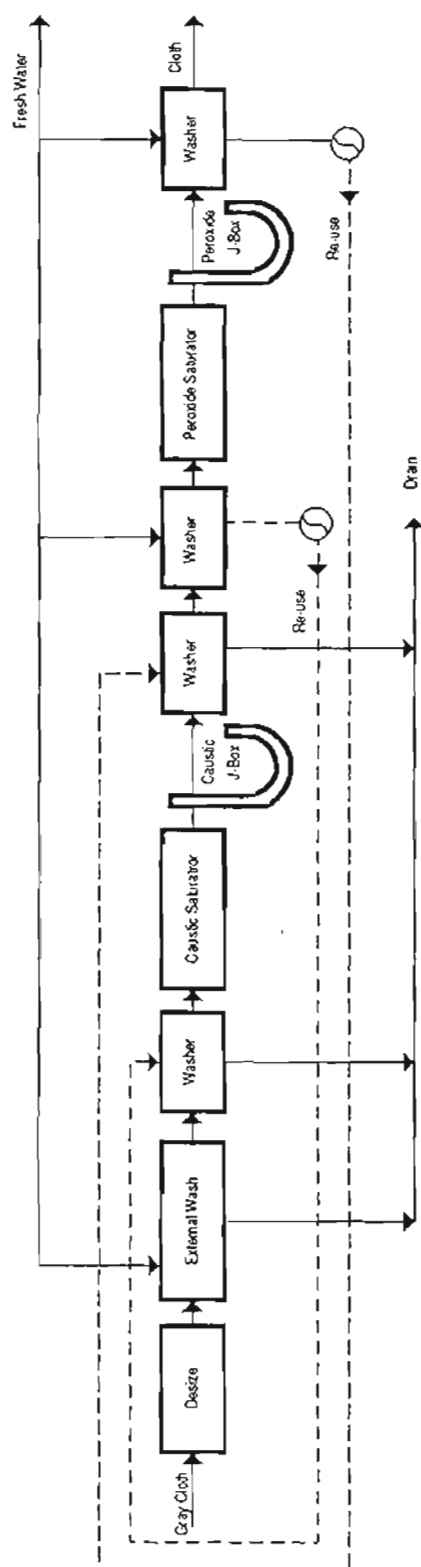


Figure 9: A Water Re-use Scheme for Cotton Cloth in Continuous Bleaching by J-Box Method



In a non-synchronised processing system such as that normally found in conventional rope form processing using kiers, the use of a counter-current flow principle for washing from the following washing machine to the preceding one may become difficult. In such a case, the reusable water could be collected in a common sump and then the water from the sump could be pumped to appropriate washing machines used on earlier cycles. Figures 10 and 11 show such schemes used in the case of kier processing and conventional batch bleaching. It has been found that apart from savings in fresh water consumption, there are additional benefits of effluent blending to yield neutralisation and equalisation effects.

Figure 10: Recommended Use of Water in Kier Processing

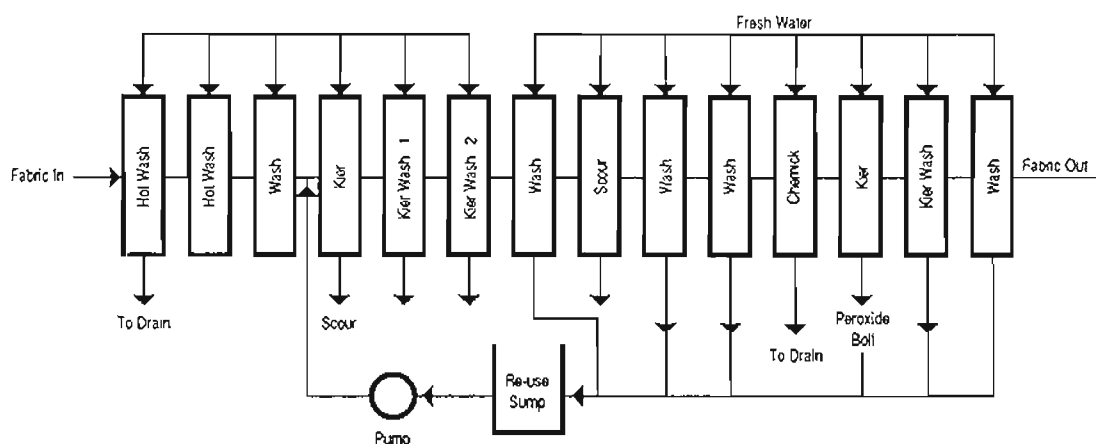


Figure 11: A Water Re-use Scheme in Batch-Type Conventional Bleaching for Cotton Cloth

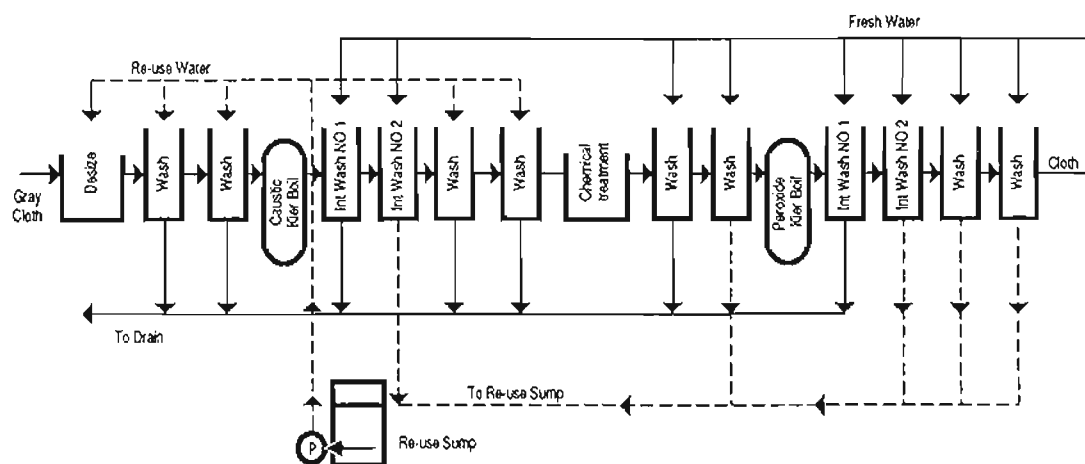


Table 6 shows a typical check-list for implementing water re-use in a textile mill. Before implementing water reuse, it is always advisable to discover whether the chosen method has already been implemented in another plant. If so, then it may be worth visiting or making enquiries about this facility to discover whether the industry faced any operational problems or product quality as a result of water re-use. It is also important that pipes in the plant are properly colour-coded to clearly label fresh water lines and used water lines. Training should also be given to operators to explain the revised water flow and to ensure that the used water treatment plant functions at the required efficiency.

As with water conservation, attention paid to reductions in energy use can deliver cost savings and lower emissions from boilers or generating plants simultaneously. Textile plants can be prodigious energy users. Minimising losses from unlagged pipes and cutting down excessive consumption can give good results. For large plants a formal energy audit may help to pinpoint where the most effective savings can be made. In some cases investment in energy recovery may also be justified, as the case study below shows.

► Table 6 *Check-list for Water Re-use*

1. Establish the average volume of water used in various wet processes and for miscellaneous non-process related purposes over a shift basis.
2. For the major water consuming wet processes, identify the level or levels of water quality required to maintain product quality.
3. Estimate water quality after use either by wet sampling or by setting up an approximate mass balance for all the wet processes considered in step 2.
4. Prepare a number of practical alternatives for water re-use based on information obtained in steps 1, 2 and 3. Practical considerations would include layout of the processes and existing pipe work, technological limitations on water treatment and the sensitivity of the fabric or the process to the used water quality. (The latter consideration is important in wet processes such as dyeing).
5. Evaluate the costs of all the alternatives. Costs should include both installation, operating and maintenance, bearing in mind:
 - a) Possible reduction in fresh water consumption and subsequent decrease in the costs of water billing. In some instances fresh water saved may be used for more productive purposes.
 - b) Possible reduction in the effluent volume and the resulting costs of effluent treatment and perhaps in the pollution fees.
 - c) Possible increase in effluent concentrations, due to reduced volume, and the probable effect of this on increased pre-treatment costs to protect the effectiveness of the effluent treatment plant. Consideration should be also given to the occasional bleeding and handling of used water required after several use cycles.
 - d) Additional costs of new pipelines, used water storage equipment, pumping, additional treatment of waste water, operating costs (energy and chemicals) and miscellaneous items.

Energy Savings from Textile Heat Exchanger

A heat exchanger, specially designed for an Irish wool and fabric dyeing company to recover heat from liquid used in the dyeing process, is saving the company about 13.2 MJ of heat per year.

Fabric dyeing requires large amounts of hot water - often more than 50 times the weight of the fabric processed. The recovery of heat from used water is difficult because the water contains fabric particles that clog conventional heat exchangers. To overcome this problem, a heat exchanger was designed in which there was a turbulent water flow through the machine to prevent fibres settling on the heat exchange surfaces. This also improved heat transfer.

Some 23 cubic metres of hot water per hour pass through the heat exchanger and its temperature is reduced from 95°C to 38°C. Incoming cold water is heated from about 10°C to 67°C. Energy savings arising from the new system paid for installation costs in less than two years.

■ 4.2 OPTIMISATION OF CHEMICAL USAGE

The choice of process chemicals used is a key decision for reducing impacts. Processing chemicals have a range of potentially hazardous properties. The wide choice of substances now available on the market means that often it is possible to substitute safer chemicals for those used traditionally. This is particularly true for some of the toxic dyestuffs, but opportunities also exist in other areas. The higher cost of some safer substances can usually be justified through benefits such as lower worker illness and savings from the reduced cost of required safety measures.

Some toxic chemicals are now banned or severely restricted in certain countries in order to encourage the use of safer substitutes. The International Register of Potentially Toxic Chemicals (IRPTC) in Geneva, provides an up-to-date list (for IRPTC's address see Annex D). Table 16 in Chapter 6 shows an extract from the 4th edition of this list.

In addition to acute toxicity, the possibility of long-term exposure effects such as carcinogenicity should also be kept in mind. This can be a concern for chemicals which have been inadequately tested and where the low acute toxicity may give managers a false sense of security. The International Agency for Research in Cancer (IARC) has classified over 700 chemicals for carcinogenic risk to humans. No dye has yet been included in Group 1 (carcinogenic to humans) but Annex D includes a list of dyes classified in Group 2A (probably carcinogenic to humans) and Group 2B (possibly carcinogenic to humans). Some national and regional organizations may also keep lists of chemicals subject to local restrictions.

In all cases process chemicals must be carefully handled in accordance with the safety advice of the manufacturer or any other authoritative source. Safety advice can be found in the Materials Safety Data Sheet (MSDS) which is available from manufacturers, or in health and safety guidance relating to specific chemicals where it is published by other institutes. A sample MSDS is shown in Annex D along with international sources of information on toxic chemicals.

In addition to problems of possible toxicity, textile processing uses a variety of chemicals with considerable BOD and COD. It is possible to lower these pollution problems by reducing the chemical loads, since very often a large margin of safety is employed. In many cases, knowingly or unknowingly, these safety margins may be applied more tightly at a textile mill to eliminate the need for reprocessing.

For this reason a careful study of the various textile processes, with respect to the minimum requirement of different chemical recipes, can be particularly important. It is possible to reduce the amount of process chemical by 20-50% by adopting such measures which will in turn reduce the effluent load in terms of BOD by about 30-50%. Another obvious benefit is lower operating costs.

One strategy to achieve chemicals and effluent reduction, especially in the context of large textile processing mills, is to use automated chemical dispensing. Many large and modern mills have implemented automated chemical and dye dispensing systems. Such systems will form one of the textile dyeing industry's major innovations over the next few years.

An automated chemical dosing system offers some important advantages over the manual method. Flexibility is gained by running smaller lots. Automation also offers faster delivery times, better laboratory-to-dye house correlation, a wider variety of styles and higher quality. Handling of some chemicals is hazardous so an automated system also minimises the chances of worker injury.

The effluent load can also be reduced by effective recovery practices and the re-use of process chemicals to the maximum possible extent. Preparation chemicals (including optical brighteners and tints) must however be selected in such a way that their re-use does not create quality problems such as spotting.

Four important areas where chemical recovery and re-use have proved most effective are:

- Re-use of dye solutions from the dye-bath
- Recovery of caustic in mercerising
- Recovery of size in cotton processing
- Recovery of grease in wool processing.

Caustic soda can be recovered from mercerising wash waters using membrane technology or by effective evaporation. Size can be recovered from desizing effluents using technologies such as ultra-filtration. Wool grease can be recovered from wool scouring effluents either by acid cracking, by centrifuging or by solvent extraction.

One method for reducing the BOD load in the effluent is to substitute low BOD process chemicals for those having high BOD values. Again, by referring to the BOD list of textile chemicals, the processor can determine which chemicals can be exchanged for those with high BOD values, while maintaining product quality. Table 7 shows the BOD values for many commonly used textile chemicals.

Three classical examples of process chemical substitution exist in the cotton textile industry. The substitution of synthetic warp sizes (1-3% BOD) for starch (50% BOD) and gelatin (100% BOD) used in cotton slashing operations; substitution of ammonium sulphate/chloride or mineral acids (0% BOD) for acetic acid (33-62% BOD) and the substitution of low BOD synthetic detergents (0-22% BOD) for soaps (140% BOD). In wool processing, the traditional carding oils, olive oil, etc. have 100% BOD values and may be replaced by mineral oils with non-ionic emulsifiers that have only 20% BOD value. Other possible substitutions include the use of sulphuric acid in place of soap in wool fulling. Table 8 shows a detailed check-list of possible chemical substitutions for reduction of BOD at source. Aspects of process and fabric specificity along with resource/technology constraints should however be considered carefully when assessing options suitable for each specific situation.

The substitution of low BOD process chemicals for high BOD ones does however have two drawbacks. Firstly, the increased cost usually associated with the low BOD products and secondly, while these chemicals have low five-day BOD values, little is known about their long-term biodegradability. Generally, the low BOD chemicals are found to be associated with low biodegradability and hence their use may demand prolonged periods of effluent aeration in biological treatment plants.

A careful study of the ultimate decomposition of these chemicals is therefore necessary before they are indiscriminately substituted for high BOD compounds. For example, the substitution of synthetic detergents for soap presented treatment problems for textile wastes in the early 1960s. The typical synthetic detergent used was Alkyl Benzene Sulphonate (ABS) surfactant type. This synthetic detergent exerted almost no BOD (10%) on the receiving aquatic body, but was non-biodegradable and therefore escaped into the receiving stream unaltered, leading to long-term ecological impacts. Soap, on the other hand, is thoroughly decomposed by biological treatment and hence did not pose such a threat. ABS is no longer used but has been replaced by Linear Alkyl Benzene Sulphonate (LABS) which has benefits of both low BOD and good biodegradability.

■ 4.3 CHOICE AND MODIFICATION OF PROCESSES AND EQUIPMENT

Often it is possible to change a textile production process in such a way that waste arisings are greatly reduced or eliminated. This change is usually very site-specific. It also depends on which products are being produced, the product quality required and effluent standards that apply. Textile equipment manufacturers are becoming more and more aware of the need to conserve water, chemicals, and energy. In fact, many new machine technologies have been influenced by that awareness, at least in parts. Table 9 provides a partial list of candidate process/equipment modifications which may be considered to reduce effluents at source.

► Table 7 5-Day BOD for Some Textile Chemicals †

Presented below is an abbreviated list of 5-Day BOD values for many chemicals used in textile processing. These values are based on the weight of the chemical as received, i.e. if a chemical has a BOD of 100%, then it would imply that 1 gm of the chemical would lead to 1gm of BOD.

Name	Composition	Use	BOD percent
Acetic Acid, 56%	CH ₃ COOH	dyeing, scouring	33,36
B-2 Gum	starch dextrins	printing ink, size	61
Dyes			
Alizarine Cyanine		acid dye	Near 0**
Green GHN			
Calcogene Black (GXCF Conc.)		sulphur dye	10
Celliton Fast (Blue AF100%)		acetate colour	3
Erie Brilliant (Black 5150%)		direct dye	8
Fast Red Salt 3GL	insoluble azo compound		2
Khaki Carbanthrene (2G)		vat dye	0
Naphthol AS-BR		prepare	10
Nyaform Blue 2B		direct dye (formaldehyde after treatment)	Near 0**
Ethanol	C ₂ H ₅ OH	solvent	93*,125
Ethyl Acetate	C ₂ H ₅ CO ₂ CH ₃	solvent	66*
Formic Acid 85%	HCOOH	scouring	2
Globe Easy Flow	starch	size	65
Gelatin	gelatin	sizes	100
Glue	glue	sizes	66
70% Hydroxyacetic Acid	HOCH ₂ COOH		7
Hydroxy Ammonium Sulphate	NH ₂ OH ₂ SO ₄		4
Monochlorobenzene	C ₆ H ₅ Cl	swelling agent in dyeing of Dacron	3
Morning Star	starch	dyeing assistant sizes, spinning, carding	47
Oxalic Acid	H ₂ C ₂ O ₄ ·2H ₂ O	rust removal	14
Phenol	C ₆ H ₅ OH	dyeing	200
Picking Oil		sizes, spinning, carding oils	13
Red Oil	sulphonated castor oil	soap making, carding	68 +
Salicylic Acid	C ₆ H ₄ (OH)COOH	dyeing	141
Soap Nonpareil	fatty acid soap	scouring, fulling washing	140
Sodium Alginate	size	thickening agent	36
Sodium Hydrosulphite	Na ₂ S ₂ O ₄	reducing, stripping	22

► Table 7 5-Day BOD for Some Textile Chemicals † (continued)

Name	Composition	Use	BOD percent
Special Textile Flake	sodium salt of fatty acid	detergent	112
Surfactant DN-40	scouring	15	
Sulphonated Castor Oil	castor oil		52
Sulphuric Acid	H ₂ SO ₄	dyeing	0
Tall Oil Soap		soap	147
Tallow	tallow	soap making	152
Tergitol 4	C ₄ H ₉ CH(C ₂ H ₅) C ₂ H ₄ CH(SO ₂ Na) CH ₂ CH(CH ₃) ₂		0
Triethanolamine	(HOCH ₂ CH ₂) ₃ N	emulsifier, dispersing agent	10
Wheat Starch	starch	printing inks, size	55
Wool Oil	(mineral oil + base)	spinning	3

† Adapted from the *Proceedings of the American Association of Textile Colourists and Chemists*, August 29, 1966, pp. 685-688.

* Calculated from the theoretical BOD and the published percent of theoretical.

** Interfered with the dye colour during determination.

► Table 8 Check-List of Possible Chemical Substitutions

1. Use synthetic warp sizes (based on PVA and acrylates) in place of the conventional starch-based size preparations.
2. Use mineral acids for acid-desizing in place of enzymatic desizing.
3. Use synthetic detergents in place of soaps.
4. Use sodium acetate in place of soda ash for neutralising scoured goods so as to convert mineral acidity into volatile organic acidity.
5. Use ammonium sulphate in place of acetic acid for pH adjustment in disperse dyeing and pigment printing. Although the salt concentration of the effluent would increase in this substitution, ammonium would serve as a nutrient in the biological treatment process.
6. Substitute emulsion-thickening - fully or partially - for gum thickening in textile printing.
7. Use sodium bicarbonate (in place of acetic acid) in conjunction with peroxide or perborate for the oxidation of vat dyestuffs.
8. Use permanent adhesive on tables and screen-printing machines (Flat Bed and Rotary types) in place of conventional gumming.
9. Use durable resin finishes in place of temporary finishes based on starch materials.
10. Use single-class dyestuffs like Indigosol, pigments, etc. for dyeing blended varieties in pale shades in place of two stage dyeing using two different classes of dyes (e.g. polyester using disperse and cellulose using vats, reactives, etc.)
11. Use all-aqueous phthalogen blue dyeing in place of solvent-based phthalogen blue dyeing which requires speciality auxiliary products.
12. Use monochlorobenzene in the place of other carriers for dyeing Dacron
13. Substitute formic acid for acetic acid in dye baths (acetic acid 0.64 kg BOD/kg; formic acid 0.12 kg BOD/kg.)
14. Replace carding oils and anti-stat lubricants with non-ionic emulsifiers.

► **Table 9** *Partial List of Cleaner Production Process Modifications*

1. Single-stage desizing-scouring-bleaching processes for the processing of cellulose and their blends with synthetics.
2. Solvent-aided scouring and bleaching processes.
3. Activated peroxide bleaching taking chemically treated goods straight into a peroxide bath through the washing machine.
4. Dyeing-sizing of warp yarns for denim style products.
5. Hot mercerisation in place of conventional cold mercerisation, often enabling the elimination of separate scouring treatment.
6. Combined Disperse and Reactive/Direct colour-dyeing of blended fabrics containing low percentages of cellulose.
7. Use of padding method in place of exhaust methods for dyeing, wherever possible.
8. Use of bicarbonate in a peroxide bath for vat oxidation to convert the caustic alkalinity into carbonate alkalinity for its easier removal; caustic alkalinity requires a plentiful supply of water.
9. Electrolytic process for the dyeing of vat colours and reduction-clearing of disperse colour printed synthetic fabrics.
10. Dry-heat fixation techniques for the development of Rapidogen prints in place of the conventional acid-steaming method.
11. Direct finishing of pigment printed goods and direct carbonising of disperse printed goods without intermediate washing.

□ 4.3.1 **Washing Operations**

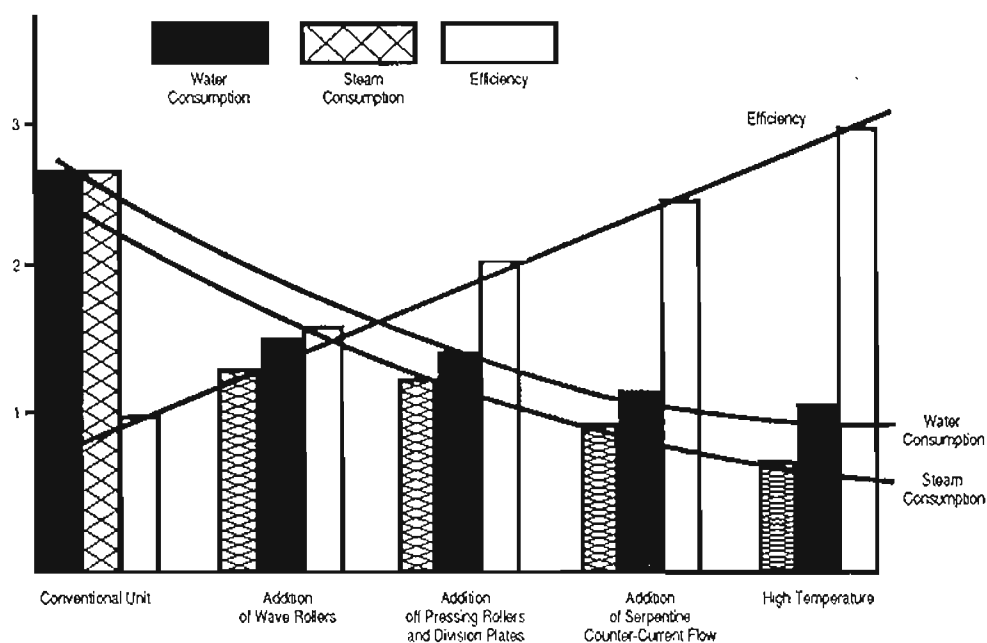
Popular avenues for exploring process/equipment modification have been found in fabric washing and drying (water extraction) operations. For example, fabric can be washed with different types of equipment, each with different unit water consumption and efficiency rates. Some of the parameters affecting washing efficiency are water application per unit weight of fabric, method of application viz. spraying, pulsing, cascading, water temperature, contact time and/or fabric speed, number of washes and duration of the washing cycle, intermediate water extraction methods such as squeezing, suction, beating etc. Figure 12 shows a typical qualitative picture of how various design parameters influence water and steam consumption as well as overall washing efficiency.

Understanding these equipment and efficiency related parameters greatly helps reduce water consumption in washing. For example, use of hot water instead of cold water alone has in some cases halved water consumption for a comparable rate of washing efficiency. Similarly, horizontal washing configurations have demonstrated performance comparable to two conventional vertical configurations.

In some instances, changes in rinsing practices can also save significant amounts of water. The use of hot water instead of cold (with heat energy often recuperated from merceriser and kier), more efficient design of nozzles and optimisation of the washing sequence can all improve washing efficiency and save water.

Between 1976 and 1981 a water care project examined options for water conservation in the Danish, Finnish, Swedish and Norwegian textile industries. This project found that water consumption in dyeing could be significantly reduced by improved rinsing practices and modifications to washing equipment. Table 10 highlights the main findings of this project.

Figure 12: Influence of Design Parameters on Improved Washing



► Table 10 Highlights of Water Conservation Measures in Dyeing Equipment (Results of NORDIC Study) †

Batch Operations

- 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 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 (ranging from 15% to 79%) were possible by switching from the practice of overflow to stepwise rinsing. Rinsing with spray technique, which was tried on a laboratory scale, was also effective.
- Cheese Dyeing: A reduction of around 70% was possible following intermittent rinsing.

Continuous Operations

A 20-30% saving was realised by introducing automatic water stops. Counter-current washing proved to be the most effective method. Horizontal washing equipment delivered the same performance as two vertical washing machines, using the same amount of water.

† Adapted from Asnes H., *Reduction of Water Consumption in the Textile Industry*, IFATTC Conference, London, 1984

□ 4.3.2 Optimisation of Sizing-Desizing Systems

Size represents the largest single group of chemicals used in the textile industry which, in most cases, does not become a permanent part of the product. Size recovery therefore presents one of the greatest opportunities for savings. This is most convenient in vertically integrated mills where the recovered size can be returned directly to the make-up kettles at the slashing operations. The common types of sizes used on textile warp yarns are:

1. Starch
2. Carboxymethyl cellulose (CMC)
3. Polyvinyl alcohol (PVOH)
4. Polyacrylic acid (PAA)
5. Polyvinyl acetate (PVAc)
6. Polyester (PET)
7. Modified cellulose and starches

Of these, starch is the most commonly used size material, especially in developing countries like India and Thailand. Starch is removed from the fibres using dilute acids or enzymes. Because starch is degraded in this desizing process, no recovery is possible. The other types of size such as PVA, CMC, etc. are mostly recoverable. Starch size can contribute up to 50% of the total BOD loading from processing of woven fabrics so there is frequently a powerful economic incentive to switch from starch to the recoverable sizes such as PVA to reduce effluent BOD.

The recoverable sizes are however more expensive than starch so it is difficult for a non-vertical textile mill to use them because another independent processor must recover them at a later stage. Therefore, size recovery systems are more popular in vertical operations. (Ultra-filtration technology is one of the promising methods employed to recover size.)

For textile mills using starch as the size, innovative desizing methods offer another option. Starch is traditionally removed using amylase enzymes. Typically, this will generate about 60 kg of BOD per 1000 kg of fabric, which can lead to a substantial BOD in the final effluent.

One alternative to this problem is to use an oxidation system instead of an enzyme system to desize the starch from the fabric. 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. It is expected that smaller producers will begin to use this oxidative desizing technology in the future.

While oxidative desizing is not a new technology, it is not widely practised due to problems that can arise from oxidation damage of the cotton itself, producing oxycellulose. Temperatures, dwell times and chemical concentrations must be controlled extremely well to carry out oxidation desizing successfully. Until recently this has not been practical but, with microprocessor-controlled chemical feeds and temperature sensing equipment, the necessary degree of control can now be accomplished far more readily.

Another innovative desizing method uses newer enzymes developed for the home laundry market. Some of these degrade the starch size to ethanol instead of anhydroglucose. The ethanol can then be recovered by distillation for use as a solvent or fuel, thereby reducing the BOD load in the desized effluent considerably.

□ 4.3.3 Pad-Batch Dyeing

One potential improved process for dyeing is pad-batch dyeing. This method is one of the most reliable and controllable available today and has been used quite successfully in a wide variety of applications. Benefits include the elimination of the need for salt or chemical specialities from the dye bath, with associated cost savings and waste reduction.

In the pad-batch dyeing, prepared fabric is impregnated with liquor containing premixed fibre reactive dyestuff and alkali. Excess liquid is squeezed out on the mangle. The fabric is batched on to rolls, or into boxes, and covered with plastic film to prevent absorption of carbon dioxide from the air or evaporation of water. It is then stored for two to twelve hours. The goods can then be washed in any of several conventional ways, depending on equipment available in the mill.

This method is interesting because it offers several significant advantages, primarily in waste reduction, simplicity and speed. Production case histories have shown that pad-batch dyeing for cotton, rayon and blends conserves energy, water, dyes, chemicals, labour and floor space. Salt consumption is reduced from about 100% for each weight of goods to zero. Water consumption for pad-batch dyeing with beam wash-off is typically under two gallons per pound of dyed fabric, compared to typically 20 gallons or more on atmospheric becks for the same fibre reactive dyed shades. Energy consumption is similarly reduced from about 9000 BTUs per pound of dyed fabric for becks to under 2000 BTUs per pound for pad batch with beam washing. Chemical use (including alkali as well as speciality chemicals), with associated BOD and COD loadings for waste streams, can be reduced by up to 80% compared with atmospheric becks. Labour costs are also reduced. For example, two workers per shift can dye 200,000 pounds of fabric per five-day week. In general, the quality of pad-batch dyeing is equal to or better than other dyeing systems with benefits that include:

1. Reduced effluent waste loads
2. Low capital outlay
3. Low energy requirements
4. High production speed
5. Reduced labour requirements
6. High colour yields
7. Outstanding reproducibility
8. Excellent penetration, and levelling characteristics
9. Rapid fixation
10. Substantial overall cost savings (dyes, chemicals, labour, water, etc.)

□ 4.3.4 Solvent Processing

At one time, during the 1970s, great interest was expressed in solvent systems other than water for processing textiles. Solvent preparation, dyeing, finishing, and drying were closely examined by the industry. Advantages claimed for solvent technology are:

1. Elimination of a pre-scour
2. Smaller, less costly equipment
3. Flexibility of making short, continuous runs
4. Low utility requirements
5. Considerable water usage reduction
6. Better levelling and uniformity
7. Better reproducibility between runs
8. Possibility to integrate dyeing and finishing

However, solvent technology did not meet wide acceptance due to two factors. Firstly, chemical systems, dyes, specialities, etc. appropriate to solvent use were not available at a commercially competitive cost. Secondly, environmental regulations for airborne emissions from solvent processing equipment, storage facilities, and hazardous waste regulations on recovery by-products (still bottoms, etc.) made many solvent processes uneconomic. A tight control over solvent systems is required to keep solvent losses below 5% of the fabric weight. There are also other problems associated with solvent vapours in a textile plant. Drawing solvent-laden air to dryers or tenter frames may result in their

conversion to hydrochloric acid gas. Fabric weakening, browning of cellulose, or dye degradation are some of the possible difficulties which should be anticipated.

For a plant deciding to employ solvent processing, a reasonable approach is to buy both solvent processing and solvent recovery systems from one supplier. This is usually the most economical route from a capital cost and installation standpoint. It also tends to help ensure successful operation alongside easier maintenance and repair. Consideration should also be given to fixed detection units located at the entry and exit ends of the production equipment and near the recovery unit. A portable detection unit should be on hand and any area indicated to be susceptible to leaks should be considered for a fixed detector.

Assuming that the quality of goods is the same when solvent procedures are compared to conventional ones, the following list gives some key factors which should be considered in an economic evaluation:

1. Is new equipment needed or can the existing equipment be converted?
2. Would the installation of solvent equipment reduce the load on the effluent treatment plant significantly?
3. Is a comparison between water and utility costs and the costs of solvents along with their availability favourable in economic terms?

The diagram provided in Figure 13 compares a conventional process with solvent processing technology based on perchloroethylene.

□ 4.3.5 Transfer Printing

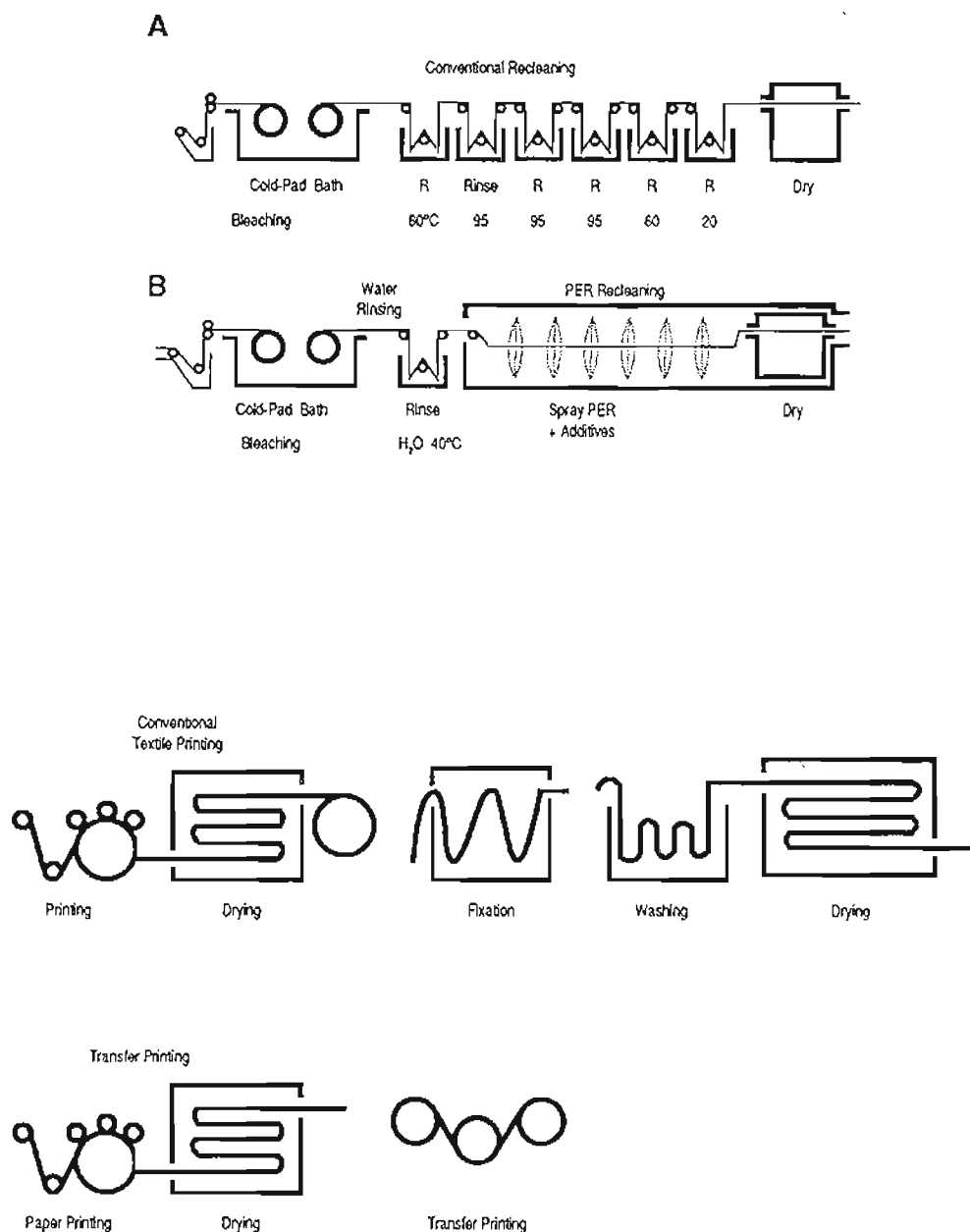
In normal textile processing, colour pastes are applied to a textile material. These pastes contain dyestuff, a thickening agent, water, and other chemicals. After printing and dyeing, the dyestuff fixation occurs by steaming. After steaming, an intensive washing process is necessary to remove the thickening agent, residual dyestuff, and other chemicals. This washing process produces a large amount of effluent. The after-washes of printed textiles also use considerable energy, incurring a high cost.

Transfer printing has important advantages in comparison to normal textile printing. In transfer printing, paper is first printed with volatile disperse dyes. The printed paper is heated together with a textile material in a thermopress at up to 200°C for thirty seconds. Under these conditions, the dyestuff is transferred from paper to textile material by sublimation. The transferred dyestuff has a good washing fastness.

In contrast to normal printing, in transfer printing only the dyestuff, and no other chemical, is deposited on the textile material so no after-washing is required and no effluent is generated. For conventional printing, 250 kg of water per kg of textile is required. In transfer printing only 2 kg is needed. Disadvantages of transfer printing include low rates of production as well as the limitation to volatile dyes (and to fibres which have affinity with these dyes). Figure 14 compares conventional printing and transfer printing technology. Important advantages are that dyestuff consumption is considerably lower than with direct printing on textiles. A dye yield of 80% can be realised with printed paper transfer, and penetration can be better controlled. With no need for after treatment, hardly any water is consumed leading to less effluent generation. Considerably less energy is consumed during drying. Approximately one-half ounce of water per square yard is used in transfer printing compared with between seven to 32 ounces of water per square yard used in direct printing. No after treatment such as steaming, washing, or drying is required. Thus transfer printing is cheaper. It demands less production space, fewer skilled staff and creates less pollution.

In its present form, transfer printing is only suitable for some synthetic fibres and can not yet be used for natural fibres. It has been particularly successful with polyester. Some transfer printing

Figure 13: Schematic Sequence of Conventional Recleaning and Per-chlorethylene Recleaning in Cold-Pad Batch



has been done on acrylic, nylon 66, and triacetate. Some wool has been successfully printed by means of the so-called Fastran process after a pre-treatment. Due to the nature of the present transfer process as well as the low quantity of dyestuff delivered to the paper, the penetration of the dye into the fibre is also limited. This is a particular problem with knit goods as the base colour of the substrate becomes visible when the cloth is stretched.

□ 4.3.6 Foam Processing Technology

Textile chemicals processing solutions can be diluted using air in place of part of the water by forming foams. There are several common commercial applications of foam processing, notably carpet dyeing, coating operations (backcoating), foam dyeing and foam finishing.

The basic types are stable and unstable foams. Each type requires a different chemical system and mechanical arrangement for producing, handling, and applying the foam. Use of these techniques can result in energy and cost savings, since there is less water to evaporate when drying the fabric. However, foam processing on continuous equipment (e.g. backcoating), has the disadvantage that, when the production line stops, the foam must be disposed of. This can be very difficult, especially when stable foams (e.g. backcoating) get in the wastewater, producing suspended solids which are hard to treat and will not settle. Possible ways to destroy excess foam include spraying it on to heated plates or dry cylinders where it can be rapidly dried, scraped off and recovered as a solid waste for disposal. Prior to setting up a foam operation, it is important to plan how foam disposal will occur other than by discharge to the process effluent stream.

5 END-OF-PIPE TREATMENT

■ 5.1 LIQUID EFFLUENT TREATMENT

Methods used for liquid effluent treatment in the textile industry can be classified into primary or mechanical, biological and advanced physico-chemical processes.

Primary treatment includes processes such as screening, neutralisation, equalisation and gravity sedimentation. The purpose of primary treatment is to remove suspended matter (including oil and grease) and to achieve uniform flows and concentrations. As the suspended matter is removed, the BOD or COD is also reduced.

Biological treatment is used to achieve a major reduction in the soluble effluent load (also measured in terms of BOD/COD) to meet effluent limits.

Advanced physico-chemical processes are used to remove suspended matter that cannot be stabilised easily, i.e. substances such as chromium and phenols. Examples of such processes include chemically assisted sedimentation, mixed media filtration, adsorption and ozonation. Physico-chemical processes may be preceded by biological treatment to enhance their effectiveness or may be used after biological treatment to meet specific discharge limits.

To select the optimal end-of-pipe treatment scheme, a few points should be considered to check both the cost-effectiveness and reliability of any facility:

1. Identify print paste, grease and solvent wastes for segregation to separate streams.
2. Identify all sources of chemicals (such as dyes, solvents, carriers and finishes) which may be toxic to biological treatment systems.
3. Identify sources of shock loads (such as finishing bath dumps) to estimate the flow accurately and load equalisation basins accordingly.
4. Identify any source of high concentration, refractory and non-biodegradable waste (such as carriers and finishes) for possible segregation to physico-chemical treatment.
5. Identify sources of foam-producing materials (such as detergents) and any measures required to protect the operation of aerobic biological treatment systems.

6. Evaluate how and whether to segregate high strength wastes (as measured by BOD, COD, colour or alkalinity) for separate treatment, e.g. by low cost anaerobic treatment.

Table 11 provides an overview of processes normally considered for reduction of parameters such as BOD, COD, solids, pH, chromium, phenols, sulphides and metals. Table 12 shows the anticipated treatment removal efficiencies for some of these treatment processes. Some commonly used treatment processes are also described in more detail after these tables.

► *Table 11 Overview of Effluent Treatment Technologies*

Type of Effluent	Processes Normally Employed	Strategy
Wool scouring	Screening - Equalisation - Flotation - Chemical Assisted Sedimentation - Biological Treatment	Segregation of rinse water for volume reduction
Wool finishing	Screening - Equalisation - Biological Treatment - Residual Chromium Removal by Chemically Assisted Sedimentation	Segregation and pretreatment of chrome bearing stream
Dry processing	Screening - Equalisation - Biological Treatment	Segregation of latex stream for separate treatment
Woven and knit fabric finishing	Screening - Equalisation - Biological Treatment - Residual COD Removal by Chemical Assisted Sedimentation	
Carpet mill	Screening - Equalisation - Biological Treatment	Segregation of latex stream for separate treatment
Stock & yarn dyeing	Screening - Equalisation - Biological Treatment	
Equalisation may include neutralisation for the adjustment of pH. Chemically assisted sedimentation is normally performed with lime and alum. Use of polyelectrolytes has proved beneficial in some instances.		

□ 5.1.1 Screening

A troublesome factor in the treatment of cotton and woollen textile effluents is fibre within the waste. This may come from improperly operated scouring equipment, washdown or other sources. In the case of wool scouring effluents, the fibres degrade, cause odours and may also cause mechanical problems in pumps and other treatment equipment. Carpet mills discharge short fibres, strings, lint, fluffy yarns and small solids. If not removed, these materials impair subsequent biological treatment, particularly in low-flow plants. It is usually necessary to provide coarse and fine mesh screening to remove the fibres. Devices such as fine mesh vibrating screens have proved excellent wool fibre removers.

□ 5.1.2 Equalisation and Neutralisation

An equalisation tank or basin is generally necessary to blend waste batch dumps and the surges or other flow variations which would upset downstream treatment processes. Generally a retention time of 24 hours or volume corresponding to daily effluent flow through the mill is provided. For small

► Table 12 Anticipated Treatment Removal Efficiencies†

Treatment Process Unit	Range of Removal Efficiency in %				
	BOD5	COD	TSS	Grease	Colour
Primary Treatment					
Screening	0-5	-	5-20	-	-
Equalisation	0-20	-	-	-	-
Neutralisation	-	-	-	-	-
Chemical Coagulation (removals vary with chemicals and dosage used)	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	20% colour removal for biological treatment units
Extended Aeration and Clarification	70-94 +	50-70	85-95	0-15	
Aerated lagoon & Clarification	60-90	45-60	85-95	0-10	
Aerobic Lagoon	50-80	35-60	50-80	0-10	
Packed Tower	40-70	20-40	-	-	
Roughing Filter	40-60	20-30	-	-	
Colour Removal for biological treatment units 20%					
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
Ozonation	-	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	-	-

† Adapted from US EPA *Environmental Pollution Control Textile Processing Industry*, October, 1978.

effluent volumes (less than 1 million litres per day), two tanks, each providing a 12-hour retention volume may also be used on a fill and draw basis. In such cases pH adjustments could be conveniently done using a batch neutralisation practice.

Equalisation basins should be equipped with an aeration and mixing mechanism that is adequate to prevent the deposition of solids and septicity. Mixing requirements may be typically 0.02 - 0.04 HP/100 gallons of the capacity. Air supply at the rate of 1.15-2.0 cubic ft/min/1000 gallons may be adequate to maintain aerobic conditions.

A neutralisation facility may be required when effluents exhibit a widely fluctuating pH due to changing yarn types. When cotton yarns are processed, sodium hydroxide used in mercerising may give rise

to a mill effluent with a pH 11-14. Raw stock or synthetic yarns do not require mercerising, so the mill effluent is about pH 8.0. While activated sludge systems can treat textile wastes entering with a high pH (up to 10.5), these systems are easily upset by pH changes of one or two units. Acidic pH is rarely encountered in textile effluents, except in the manufacture of polyester knits. In cotton processing units practising acid desizing as well as mercerising, the pH of the combined effluent is between 7.0-8.0.

Neutralisation can be effectively achieved using alkalis such as lime and caustic or acids like hydrochloric and sulphuric acid. It may be more practical to identify, collect and re-use waste acid and alkali streams separately to save on the addition of fresh chemicals. Another novel method is to use the flue gas from the boiler house, containing carbon dioxide and sulphur dioxide, to neutralise caustic streams. Normally a reaction time of 5-30 minutes is adequate with longer retention times for slowly reacting chemicals such as lime. Mechanical high speed mixers should be provided to achieve instantaneous blending of neutralising agents and effluents.

□ 5.1.3 Oil and Grease Separation

The problem of oil and grease separation is more relevant in the context of the woollen textile and knit fabric sector. Generally, flotation is used to remove substantial quantities of grease remaining after in-plant grease recovery processes.

Floated grease may be returned to the grease recovery system and settled sludge can be dewatered with other treatment plant sludge. Another technique uses ultra filtration to concentrate oil from its emulsified form. With ultra filtration, it may be possible to produce a permeate containing less than 5 mg/l oil and re-usable as process water. The concentrated oil also has a potential use as a fuel for plant boilers.

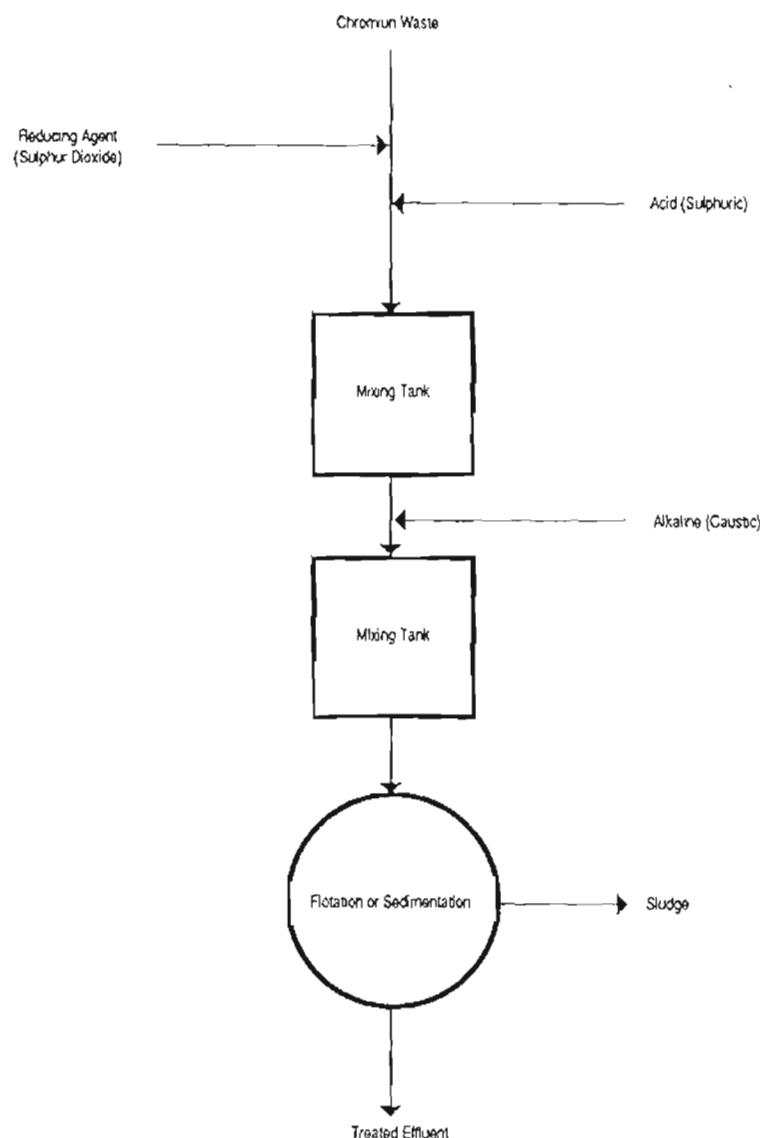
In the case of wool scouring wastewaters, it has been found that costs of ultra filtration could be quite high. In addition, the long term problems with filtration membrane failure may be a major drawback in using the process. Equipment such as solid bowl centrifuges are recommended for oil and grease removal from scouring wastewaters.

□ 5.1.4 Chromium Removal

Chromium is usually used for oxidation in cotton and rayon dyeing and for chemical fixation in wool dyeing. Usually, sodium dichromate, the hexavalent or oxidized form of chromium, is used and a small percentage of chromic (trivalent) chromium is produced on reduction. The yellow hexavalent form is highly toxic, and soluble at any pH, while the trivalent form is greenish and insoluble above pH 6.5.

In cotton and synthetic dyeing, other oxidants (peroxide, air, steam) may be used in place of dichromate, and hence contamination of chromium is prevented at source.) In wool dyeing, excessive chrome add-ons are often used so a considerable reduction in the total effluent chromium concentration may be obtained by reducing the add-ons.

When removal is desired, the soluble hexavalent chromium must be reduced to insoluble chromic form. After reduction, the trivalent chrome may be precipitated as hydroxide and removed as a sludge. The reduction of chrome is pH dependent and a lower retention period is required at a pH less than 4.0. Sulphur dioxide may be used as a reducing agent and agents such as sodium metabisulphite or ferrous sulphate are also used. Precipitation of trivalent chrome is also a pH dependent process, optimum at about pH 9.0. Lime is used generally to raise the pH and precipitation rates. A typical chrome removal flow sheet is shown in Figure 15.

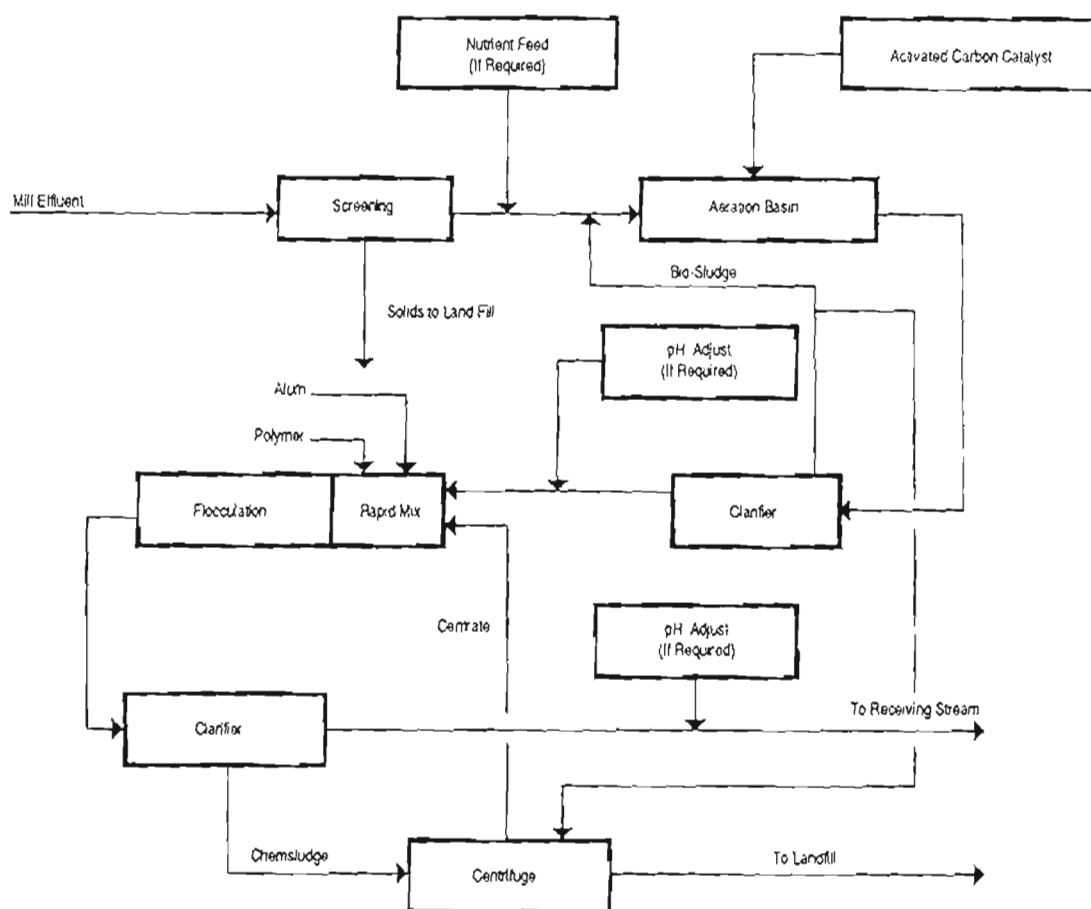
Figure 15: Typical Flowsheet for Removal of Chromium from Textile Effluents

□ 5.1.5 Biological Treatment

Biological treatment involves the development and cultivation of micro-organisms on food or substrate available in the effluent to lower the effluent BOD. This process may be achieved either in the presence of oxygen (aerobically) or in the absence of oxygen (anaerobically).

Amongst various aerobic biological treatment processes, activated sludge treatment has proved popular for the secondary treatment of textile effluents. A typical activated sludge system consists of a primary sedimentation tank, an aeration tank and a secondary sedimentation tank in series. Provision is made to recycle settled biological sludge from the underflow of the secondary sedimentation unit into the aeration tank to maintain the desired microbial population. In the aeration tank microbial population is generally expressed in terms Mixed Liquor Suspended Solids (MLSS). To lower or remove

Figure 16: Typical Flowsheet for Treatment of Woven Fabric Effluents Using Activated Sludge Process



BOD effectively, it is desirable to maintain a MLSS of 2500-3500 mg/l. Aeration devices such as mechanical aerators or air blowers are used to supply the necessary oxygen to maximise the use of substrate in the aeration tank by its micro-organisms. Figure 16 shows a typical treatment flowsheet for woven fabric finishing effluents employing activated sludge process.

Low food to micro-organism ratios (less than 0.3 kg BOD per kg of MLSS per day) are recommended for aeration tanks. Clarifiers for use following aeration are best designed for low overflow rates (10-15 m³/m²/hr) to give a better settling efficiency.

For woven fabric effluents, a retention time of 1-2 days is sufficient. For wool scouring and wool finishing effluents much longer times are required (up to 5 days). Anaerobic upflow filter technology has been found quite satisfactory for these high BOD effluents.

Apart from the activated sludge, aerated lagoons are also used for the treatment of textile effluents. Aerated lagoons are shallow (2 to 3 metres deep) and have provisions for oxygen supply with the help of floating or fixed-type aerators. Unlike the activated sludge process, it is not necessary to recycle the underflow of secondary sedimentation in the aerated lagoons. The retention time varies

between 2 to 10 days; 5 days is most common. Aerated lagoons are therefore cost-effective only when mills have a large area of land at their disposal.

Another popular aerobic treatment process is biological filtration. Both fixed media trickling filters and rotating media biological contactors have been used although the rotating type is more popular.

Textile effluents are generally deficient in nutrients although phosphorus content is usually adequate for activated sludge systems. For aerobic treatment systems operating on low food to micro-organism ratios, a BOD:N:P ratio of at least 100:2:0.3 is recommended. Sanitary sewage can provide a suitable source of nutrients but whenever nutrient deficiencies are found, aqueous or anhydrous ammonia may be added to effluent before it enters the aeration basins.

Foaming problems are common in the aeration basin and cannot always be controlled by conventional water sprays. Anti-foam agents may be used to alleviate them. Powdered, activated carbon or de-foaming agents can also be introduced to reduce or eliminate foams. Activated carbon is not as effective as a foam remover, but it will also act as a catalyst improving BOD, COD and colour removal efficiency of the biological system. Foaming problems are not common unless a large percentage of the fibre processed is cotton.

□ 5.1.6 Colour Removal

Colour removal is a pertinent problem for all categories of textile effluents due to the variety of chemicals used in fabric dyeing and printing. In the non-woollen category, effluents have colour units ranging between 300 and 1000. For woollen production units they can be as high as 2000. Apart from the deterioration in the aesthetic value of the receiving water body, the presence of colour makes water re-use difficult.

When colour removal is necessary, the following list provides useful guidance with regard to end-of-pipe treatment technology.

- Segregate all print paste wastes and dispose of each separately to landfill or incineration.
- Reduce colour shop losses by careful hand cleaning of all brushes, troughs, doctor blades, cans, tanks and screens.
- In weaving mills, reduce the use of fugitive tints in weaving.
- Try to exhaust dyes more thoroughly in the dye process.
- Use dye processes that cause less colour loss; for example solvent, pad and stream, microfoam, methanol and ammonia dyeing methods.

Colour removal may be achieved by techniques such as chemical coagulation, activated carbon adsorption, ozonation and hyperfiltration. Some incidental colour removal is also possible in biological treatment processes such as activated sludge.

Chemical coagulation is generally applied to remove colour arising from dyes such as dispersed, vat and sulphur vats. Coagulants such as alum and ferric sulphate applied at a dose of 300-600 mg/l and lime at a dose of approximately 300-600 mg/l will remove 75-90% of colour. Chemical coagulation cannot however achieve satisfactory removal of soluble dyes.

Adsorption is an efficient and popular method of colour removal. Several adsorbents are known to be capable of removing dyes from textile effluents. These include activated carbon, fullers earth, fly ash, fired clay, baggasse pith, etc. Techniques to regenerate adsorbents include the use of boiler water, organic solvents, catalytic oxidation. The pH must be adjusted to near neutral and suspended particulates must be removed for the adsorption unit to function properly.

Colour removal in biological treatment can be improved by adding activated powdered carbon (as a catalyst) to aeration basins in activated sludge systems. This treatment will not remove colour as efficiently as absorption. However, an additional 20-55% reduction in colour can be realised from

this process. Additional benefits from the use of powdered carbon include an increase in the efficiency with which BOD, COD and foaming problems are removed.

Other promising techniques for colour removal are ozonation and hyperfiltration.

■ 5.2 SLUDGE TREATMENT AND DISPOSAL

Small amounts of wasted sludge from activated sludge systems can be treated in lagoons. Where waste sludge arisings are more substantial, aerobic digestion is more suitable. Digested sludge may be thickened by a gravity thickener. Supernatant from this process should be returned to the aeration tank and thickened sludge should be dewatered before final disposal. Both biological and chemical sludge may be dewatered in a horizontal solid bowl-type centrifuge or decanter. The liquid taken off may be returned to the rapid mix tank of the chemical coagulation process. Sludge from the centrifuge is best disposed of to a sanitary landfill facility, on- or off-site.

Apart from sludges, other residues from textile processes include solid wastes such as cans, rejected fabric, willow dust, etc. These are generally carted away to a landfill or incinerated off- or on-site. In the latter scenario, adequate air pollution control measures must be taken to control particulates and scrub flue gases.

■ 5.3 AIR EMISSIONS CONTROL

The conventional source of air pollution from 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 emission control methods commonly installed at textile mills include cyclone separators, bag filters and wet scrubbers.

Oil mists 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 vapours 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 tackled at the effluent treatment plant.
3. Mist removal from air, using equipment such as electrostatic precipitators. When oil mists contain water, high efficiency fibre mist eliminators are better than electrostatic precipitators (where water droplets can cause arcing and short circuiting). The disadvantage of mist elimination is that pressure drops substantially around 10 to 30 cm of water. 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 odourless.
4. Collection and disposal of the contaminant. This is achieved by ducting to stacks with adequate

dispersal height. Since the mists are corrosive, material for ducting and control equipment must be carefully chosen.

The other major source of air emissions is from organic solvent vapour releases during and after drying, finishing and solvent processing operations. These vapours cannot be treated by scrubbing because they have a limited solubility in water. Incineration is expensive and emissions from incineration also need to be handled separately. For example, for chlorine derived chemicals, hydrogen chloride gas is released by incineration which needs to be treated. Particulate removal techniques are also not applicable since the solvents are present entirely in the vapour phase. The only effective way to solve this problem is to use activated carbon for vapour adsorption and attempt some form of solvent recovery.

6 POLICY, MANAGEMENT AND LEGAL FRAMEWORK

■ 6.1 POLICIES AND THEIR IMPLICATIONS

In most cases the policies adopted by a government, industry or trade association will influence both the technology used and the environmental management standards applied in that particular industry. These policies can affect the choice of raw materials or production processes, the equipment selected and the product design, so in many instances policy shapes manufacturing management practice. It is therefore important for managers to maintain close contact with national and international policy, regulations and debate.

In the textile industry (especially over the last three decades), there have been several changes with regard to policy and regulation at both a national level in many countries and on an international level. For instance, certain types of chemicals and dyes are now banned in many countries due to their known hazardous nature or impacts, e.g. the use of benzidine, a known carcinogen, has been banned in dye formulations. For similar reasons much of the industry has resisted the adoption of solvent processing using perchloroethylene. In many countries, kerosene use has been banned in pigment printing due to the generation of VOC during use. Severe fuel restrictions have also been imposed on boiler houses, especially for production units operating in cities. In many loom modernisation projects, preference is given to machinery which produces less noise while guaranteeing improved throughput.

An example of a voluntary agreement between the industry and government on environmental performance is shown in the case study below. The proposed agreement was put forward in 1992 by a Thai Working Group for Establishment of Permit Criteria for Establishing or Expanding of Textile Dyeing, Printing and Finishing Industry.

Proposed Supplemental Agreement Between Ministry of Industry and the Association of Thai Textile Bleaching, Dyeing, Printing and Finishing Industries (ATDP) under the Textile Club, Federation of Thai Industries

1. Evaluate safety data sheets for high volume dyestuffs for unreasonable risk to workers or environment.
2. Assess performance and cost of colour removal technologies including chemical coagulation, chlorination and activated carbon adsorption. Evaluate analytical methods for colour.
3. Determine appropriateness of whole effluent toxicity testing methods for predicting unreasonable risk.
4. Promote transfer of appropriate industrial effluent licensing procedures and protocols from USA to Ministry of Industry.
5. Continue transfer of pollution prevention know-how and clean production equipment through assistance, training, and demonstration.
6. Adopt a Textile Club (FTI) commitment to encouraging environmental excellence among member companies to protect workers and the environment.

Periodic review of progress of these activities will be conducted under the FTI-IEM programme by representatives of the Association of Thai Textile Bleaching, Dyeing, Printing and Finishing Industries (ATDP) and Ministry of Industry.

Special Conditions:

1. New establishment or expansion of textile dyeing, printing and finishing industries is not allowed to use chromium-based and benzidine-based dyes.
2. In an area where receiving water is used as a source for municipal water supply, the establishment of new textile dyeing, printing and finishing industries is not allowed within 2 km above the intake, and expansion of existing textile dyeing, printing and finishing industries will require special effluent considerations.
3. Electricity consumed by wastewater treatment facilities must be registered in a separate meter. The meter must be installed in accessible and readable conditions.

■ 6.2 MANAGING AND AUDITING RESOURCE CONSUMPTION

Many industry associations have developed norms for manufacturing which dictate the desirable usage of resources such as water, labour, electricity and common chemicals (e.g. peroxide, caustic) for each unit of product. While these norms are rarely imposed legally, the member industries are encouraged to follow them as closely as possible, and this has brought a more professional approach to the overall management of various operations. As an illustration, Tables 13 (a) and 13 (b) show typical 'norms' developed by four textile research associations in India to serve as a guide to the Indian textile industry.

To assess whether manufacturing operations are comparable to or fall within such norms, managers should audit operations periodically. These audits should include a thorough examination of all emissions and environmental impacts and produce drawings that show processing sequences, indicate all stages at which raw materials and energy are used and highlight all locations where pollution arises.

► Table 13 (a) *Typical Water Consumption at Different Processing Stages*

Machine/Process	Litres/kg of Cloth
Desize saturator	2.0
Caustic/Peroxide Saturator in J-Box Range	1.0/saturator
Kier	4.0/operation
Washing Machines	
Rope Washing	10.0
Tenstriol Type	15.0
Open Width Scouring/Peroxide Range	15.0/range
Mercerising	Machines
(with counter-current washing)	20.0
Jigger Scouring/Bleaching	30/operation
Heavy Duty Jumbo Jigger (preparation of PC blend)	30.0
Ordinary Jiggers	25 to 35
Open Width Dyeing Soaper (5 compartments)	15.0
Continuous Dyeing Range	25.0
Yarn Dyeing Plant (all operations)	100.0 kg/yarn
Beam Dyeing (including washing subsequent to dyeing)	
Conventional	25.0
Modified	15.0
Jet Dyeing (including washing subsequent to dyeing)	
Conventional	20.0
Rapid	15.0
Neutral	2.0
Water Mangle	2.0
Starch Padding Mangle	2.0
Pre-shrinking Range (with water re-use)	1.0
Carbonising	30
Notes: For all operations including screens, blankets and print washing, water consumption is as follows for all types of printing machines:	
i) Pigment printing > 4 litres/kg	
ii) Other classes of printing > 80 litres/kg	
For washing of screens, water consumption is 100 litres/screen	

The next exercise should create simple material balances that attempt to explain the usage and wastage of various resources. For example, it is extremely useful to set up a water balance for printing and washing units to establish the efficacy of water usage. Similarly, an ability to understand and quantify the usage of caustic in kier and mercerising units can indicate whether it is possible to re-use caustic streams or recover them for re-use via concentration.

Material balances need not be confined to processing sequences alone. It is worth examining the record of the store-keeper and the dye-master to track losses of expensive and/or hazardous dyeing chemicals during handling and preparation. This exercise can be especially useful when an inventory of volatile chemicals, such as hydrogen peroxide, is made for the bleaching operations.

Auditing and the preparation of material balances is a phase which needs to be supplemented by carefully planned monitoring exercises. This involves measuring flows in pipes and open channels, gas flows up stacks and vents, collection and analysis of liquid, gaseous and solid samples.

While of no direct value in material balance studies, an in-situ analysis of parameters such as VOC in air from finishing operations and noise levels amid the looms should be done periodically to assess

► Table 13 (b) Preferred Preparatory Sequence for all Cotton Fabrics

Sequence	Consumption/kg of Cloth		
	Steam (kg)	Water (litres)	
FABRIC - Poplin and Coating			
Conventional (Kier Processing) Bleaching System:			
(a) Full Bleached, Low Coverage Prints and Light Shades Dyed Sorts: Stitch - Shear & Crop - Singe & Desize - Hot Wash - Wash - Pressure Boil - Kier Wash - Wash - Scutch - Dry - Mercerise - Wash - Chemick - Wash - Peroxide Bleach - Kier Wash - Wash - Dry.	7.5	90	
(b) Dyed/Printed Sorts: Stitch - Shear & Crop - Singe & Desize - Hot Wash - Wash - Pressure Boil - Kier Wash - Wash - Scutch - Dry - Mercerise - Wash - Chemick - Wash - Sour - Wash - Wash - Dry.	7.0	100	
J-Box Pad Roll Bleaching System:			
(a) Stitch - Shear & Crop - Singe & Desize - Hot Wash - Wash - Scour - Wash - Scutch (J-Box treated cloth only) - Dry - Mercerise - Wash - Chemick - Wash - Peroxide Bleach - Wash - Dry.	J-Box Pad Roll	7.0 8.75	90 80
(b) Stitch - Shear and Crop - Singe & Desize - Hot Wash - Wash - Scour - Wash - Chemick - Wash - Peroxide Bleaching - Wash - Dry - Mercerise - Wash - Dry.	J-Box Pad Roll	90 8.75	90 80
FABRIC - Voile Lawn, Cambric			
Stitch - Singe & Quench - Grey Mercerise - Wash - Scour - (Kier Wash) - Chemick - Wash - Peroxide Bleach - (Kier Wash) - Wash - Dry.	Kier J-Box Pad Roll	5.5 5.0 6.5	70 70 55
FABRIC - Colour Woven Sorts			
Stitch - Shear and Crop - Singe & Desize - Hot Wash - Wash - Scutch - Dry - Mercerise - Wash - Chemick - Peroxide Bleaching - (Kier Wash) - Wash - Dry.	Kier J-Box Pad Roll	6.25 6.25 7.0	65 65 65
Note: Fabric drying prior to mercerisation should be avoided as far as possible.			

their impact on occupational health and safety. Another important and routine monitoring exercise is the assessment of effluent treatment plant and air pollution control equipment performance.

Managers would be well advised to anticipate diverse environmental monitoring activities because this will influence to some extent the layout of underflow drains and equipment, pipework and fixtures such as meters and valves. It is important to ensure that locations for measuring water consumption are accessible, that underflow drains and manholes are constructed to allow liquid sampling for analysis and that holes are drilled for collecting stack emission samples. Managers must also procure the equipment and fixtures necessary for at least simple in-house monitoring exercises. This will include meters on all major water lines, and weir construction for measuring flows in open channels (especially

downstream from chemical processing equipment). Likewise managers must procure stack monitoring kits and equip a wet analysis laboratory to analyse routine parameters such as BOD, COD and suspended solids, etc.

In addition to adequate planning and infrastructure, it is necessary in most operations to employ a full-time professional environmental team or train senior staff and workers to undertake monitoring and environmental audit tasks. Commitment to this exercise and participation by top managers helps to establish a sound environmental management system. In most cases it will also improve the productivity and hence the prosperity of the company.

Careful auditing and an accurate materials balance often identifies room for improvement and cleaner production options (see Section 4.0). Some of the strategies identified can be "low cost, low waste" solutions effected through improved housekeeping, equipment re-conditioning and better mechanical maintenance. Other observations may show how optimisation of various sequences (especially washing) or changes in process operating parameters (e.g. in batch dyeing) will deliver savings.

The key point here is that managers must have baseline data for similar operations in other industries against which to compare and interpret the results of their own materials balance work with an open mind. They must also allow discussion between staff and encourage team members to bring forward innovative ideas. These ideas must then be evaluated from a technical and economic perspective because they must lead to cleaner production without impairing productivity and product quality. For reference sources on process auditing and cleaner production, see Annex A.

After exploring options fully during an audit exercise, the next step should be to check the adequacy of pollution control equipment for residue handling. This must be done by evaluating each residue stream individually, in order to develop a strategy of separate or combined handling.

The performance of the control equipment in relation to the environmental standards must also be evaluated. For example, the boiler stack height must meet the minimum requirement imposed by regulation and ensure satisfactory pollutant dispersal; the pre-treatment of the effluents especially with respect to pH, temperature and toxic substances must be achieved with a sufficient margin of safety to protect the performance of the main biological effluent treatment unit; the proper supply of chemicals (e.g. for oxidation, precipitation and pH correction) and materials (such as activated carbon) must also conform to environmental standards. If the supplies are uncertain, adequate storage must be allocated to cover emergency requirements.

■ 6.3 ENVIRONMENTAL REGULATIONS

The limits on liquid effluents, gaseous emissions, noise levels and solid wastes have always been a dynamic phenomenon but in general they have been made increasingly specific in recent years to enhance environmental protection standards.

Limits are generally made specific to each industry and discharge location but differ between countries. Normally, the standard quantitative limiting parameters for textile effluents are flow, BOD, COD, suspended solids, pH and temperature. In some cases additional parameters are specified such as colour and chromium. Rules for air emissions refer to concentrations or mass emissions of particulates, sulphur dioxide and in some instances to specific VOCs. Solid waste regulations are normally prescriptive and generally refer to the safe disposal of empty chemical bags, rejected barrels and used cleaning materials. Table 14 shows a typical compilation of discharge standards in several countries for the textile industry.

The federal requirements in the USA and Canada are framed in terms of pollution load per unit weight of fibre processed rather than absolute concentrations. Different requirements apply for the various

► Table 14 Effluent Standards for Discharge of Textile Wastewaters into Receiving Waters

	Germany	Indonesia	Japan	Venezuela	India
pH		6 - 9	5.8 - 8.6	6 - 9	5.5 - 9
Temp.					
BOD ₅	40	85	160	60	100/150
COD	280	250	30/120 ⁽¹⁾	350	
SS	40	60	200	60	100
Oils		5	5/35	20	10
Colour				500 ⁽²⁾	
Phenol		1	5	0.5	5
Cr	2	2 (total)	0.5 (CrVI) 2 (total)	0.5 (CrVI) 2 (total)	0.1 (CrVI) 2 total
(1) COD (Mn)					
(2) Pt/Co Unit					

unit processes in textile manufacture. Annex F shows a summary of the final discharge limits in the USA for a number of processing operations using *Best Practicable Technology Currently Available* (BPT) and *Best Available Technology Economically Achievable* (BAT). (These are standards that can be achieved by a combination of efficient production plant coupled with modern treatment facilities.) For complete information or periodic updates, the US federal authorities should be consulted.

In addition to control of normal air emissions, there may be special requirements to reduce odours and other emissions from dyeing and finishing operations. Table 15 is taken from a 1982 Schedule of the State Environment Protection Policy (Air) of the State of Victoria, Australia.

As well as the requirements of the policy, individual plants require a permit for air emissions which also specify:

- all heat setting equipment must be vented to a chimney
- only machines which are closed, or are enclosed, may be used
- products containing more than 15% of methyl naphthalene, biphenyl, or orthophenyl phenol are prohibited
- the minimum height of stacks is set
- on-line monitoring equipment must be fitted to the stack, with an alarm if the smoke levels exceed those set in the permit
- the owner must keep a record of the amount of dye carrier used in the plant
- no offensive odours or excessive smoke may be discharged
- the owner must undertake a permanent monitoring programme of emissions (details given in the permit)

As was explained earlier, the use of certain chemicals is also becoming more tightly regulated. In addition to national regulations concerning the safe transport, storage and handling of chemicals, the actual use of some of the more toxic substances has been restricted in some countries. Table 16 shows a recent UN compilation of such substances.

► Table 15 *Air Emission Requirements for Textile Dyeing and Finishing Plants in Victoria, Australia*

Process or Equipment	Basic Requirements
All	<ul style="list-style-type: none"> (a) Every emission of waste to have free vertical discharge via a chimney. (b) Discharge velocity shall not be less than 8 metres per second for new plant or equipment unless otherwise specified. (c) Chimney heights shall be designed in accordance with the requirements of Schedule E. (d) The preparation of chemicals which give rise to emissions of waste during preparation shall be performed in an area(s) where emission capture facilities are provided. (e) Records shall be kept, detailing the quantities and types of dye carriers^(a) used per month.
Heat Setting Machines	<ul style="list-style-type: none"> (a) Basic requirements plus equipment to capture and duct all emissions of waste from the heat setting machine to a chimney (s). (b) Goods containing excess volatiles^(b) shall not be heat set or heat dried^(c).
Atmospheric Batch Dyeing Machines	<p>It is preferable that dyeing be carried out using pressure dyeing machines. Where this is not possible, the following shall apply:</p> <ul style="list-style-type: none"> (a) During dye carrier^(d) and/or sulphur dyeing operations, the basic requirements apply plus: <ul style="list-style-type: none"> (i) only machines which are capable of being completely enclosed, including machines with ducted outlets, shall be used; (ii) machine doors shall remain closed during dyeing cycle except when sampling, or servicing is required; (iii) each machine must be provided with adequate seals to prevent the escape of emissions; (iv) seals must be inspected at least once every month and repaired if necessary. (b) If venting of waste is necessary during production, it must be via a flue(s) from each machine. All flues are to be ducted to a chimney(s).^{(c), (e)} (c) Every atmospheric dyeing machine shall have a permanently fixed identification number for EPA reference, until that machine is permanently removed from the premises. (d) Where specified by EPA the dye house area shall be provided with forced ventilators with the emissions ducted to a discrete discharge point(s). The exhaust system shall be designed to efficiently capture all emissions. Emissions are not permitted via roof ridges, windows and other openings which are not connected to a chimney.
Levelling or Stripping with Carriers	<p>It is recommended that levelling or stripping be performed only in pressure vessels. Where this is not practical the conditions for enclosed atmospheric dyeing machines must be strictly adhered to.</p>
<ul style="list-style-type: none"> (a) A dye carrier is defined as a compound used to increase the rate of dye uptake and diffusion at a given temperature. (b) Excess volatiles are defined as greater than 0.3% (w/w) of volatile material in the textile goods excluding water. Where the volatile content cannot be accurately estimated then measurements shall be made. The reference temperature for volatility is the maximum process temperature to which the goods will be subjected. (c) Unless the exhaust gases are passed through a control device acceptable to EPA. (d) Minimising dye carrier usage and using a less odorous dye carrier will significantly reduce the emissions. (e) This requirement will not be applicable to operations not causing emissions of odorous waste to air. The Authority will accept submissions from companies seeking to be excluded from the requirements. 	
Source: <i>State Environment Protection Policy (Air)</i> , 1982, Victoria, Australia.	

► Table 16 List of Banned, Withdrawn and Restricted Chemicals

Chemicals that may be used as dyes or for the manufacture of dyes or used as flame retardants and which are listed in the 4th edition of the United Nations Consolidated List of Products whose Consumption and/or Sale have been Banned, Withdrawn, Severely Restricted or not Approved by Governments.

Antimony and compounds	o-Aminoazotoluene
Arsenic and compounds	p-Aminoazobenzene
Auramine	Phenyl-beta-naphthylamine
Benzidine	Yellow fatty dye
β-Naphthylamine	3,3' Dichlorobenzidine
Dianisidine	4-Dimethylaminoazobenzene
Lead and some compounds	Bis(2,3-Dibromopropyl)phosphate
Lead carbonate	DDTB
Magenta	p-Phenylenediamine
Naphthalenes	Picric acid
N,N'-Diacetylbenzidine	Tris(Aziridinyl)phosphine oxide
	Tris(2,3-Dibromopropyl)phosphate

ANNEX A

REFERENCES AND FURTHER READING

LITERATURE REFERENCES USED TO PREPARE THE TEXT

- ARCEIVALA S., 1978, "Water Reuse in India", *Water Reuse*, Ed H. Shuval, Academic Press.
- ASNES H., 1984, *Reduction of Water Consumption in Textile Industry*, IFATCC Conference, London.
- CENTRAL BOARD FOR THE PREVENTION AND CONTROL OF WATER POLLUTION, 1981, *Report on Pollution Control Measures and Standards for Effluents from Textile Industry*, Prepared by Environmental Engineering Consultants, Bombay.
- DIXIT M.D., 1972, "Practical Reuse of Water in Textile Industry", *Colourage (India)*, Vol. 19, No. 6.
- DOSHI S.M., G.R. PILLAI and M.G. NAIR, 1982, *Water Pollution and Its Control in Textile Industry*, Bombay Textile Research Association Publication, Bombay.
- DOSHI S.M. and G.R. PILLAI, 1983, *Control of Air Pollution in Textile Industry*, Bombay Textile Research Association Publication, Bombay.
- ENVIRONMENT CANADA, 1989, *Environmental Assessment of the Canadian Textile Industry*.
- FEDERAL MINISTER FOR RESEARCH AND TECHNOLOGY, 1984, *Environmental Protection Technologies*, Germany.
- NORTHERN INDIA TEXTILE RESEARCH ASSOCIATION, Ghaziabad, India 1991, *Norms for the Textile Industry*, on behalf of Textile Research Associations at Bombay, Ahmadabad and Coimbatore, India.
- SMITH B., 1986, *Identification and Reduction of Pollution Sources in Textile Wet Processes*, Pollution Prevention Pays Program, Department of Natural Resources and Community Development, Raleigh, North Carolina, USA.
- SMITH B., 1988, *A Workbook for Pollution Prevention by Source Reduction in Textile Wet Processing*, Pollution Prevention Pays Program, Division of Environmental Management, North Carolina, USA.

US ENVIRONMENTAL PROTECTION AGENCY ENVIRONMENTAL RESEARCH INFORMATION CENTRE, Technology Transfer, 1974, *In-Plant Control of Pollution and Upgrading Textile Operations to Reduce Pollution*, Institute of Textile Technology.

US ENVIRONMENTAL PROTECTION AGENCY ENVIRONMENTAL RESEARCH INFORMATION CENTRE, Technology Transfer, 1978, *Environmental Pollution Control in the Textile Processing Industry*.

US ENVIRONMENTAL PROTECTION AGENCY ENVIRONMENTAL RESEARCH INFORMATION CENTRE, Technology Transfer, October 1979, *Development Document for Effluent Limitations Guidelines and Standards for Textile Mills, Environmental Pollution Control in Textile Processing Industry*.

GENERAL REFERENCES

Environmental Auditing

BOLAND E.W., 1988, "Environmental Auditing Can Minimize the Risk of Not Being in Compliance and of Knowing It, A Self Appraisal", *American Dyestuff Reporter*, Vol. 3, No. 27.

CUTLER R.W., 1985, *Environmental Auditing: The Keystone to a management compliance, control and risk assessment program*, *Environmental Auditing Fundamentals and Techniques*, John Wiley and Sons.

HARRISON L.L., 1984, *The McGraw-Hill Environmental Auditing Handbook, A Guide to Corporate and Environmental Waste Management*, McGraw-Hill Book Company, U.S.A.

HARVEY H., May 1978, "Your Mill Can Profit From Energy Audit", *Textile World*, p. 143.

NEWTON J., 1989, *Environmental Auditing*, Pudvan Publishing Co., Northbrook, Illinois, USA.

ONTARIO WASTE MANAGEMENT CORPORATION, 1981, *Industrial Waste Audit and Reduction Manual*, Canada.

UNITED NATIONS ENVIRONMENT PROGRAMME - INDUSTRY AND ENVIRONMENT OFFICE, January 1989, *Environmental Auditing*, Technical Report Series No. 2, Paris France.

UNITED NATIONS ENVIRONMENT PROGRAMME - INDUSTRY AND ENVIRONMENT OFFICE, and UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, 1991, *Audit and Reduction Manual for Industrial Emissions and Wastes*, Technical Report Series No. 7, Paris, France.

Chemical Safety, Occupational Safety and Chemical Transport

ETAD, 1992, *Colorants and the Environment - Guidance for the User*, ETAD Information Notice No.4.

ETAD, 1989, *Guidelines for Safe Handling of Dyes*.

ETAD, 1983, *Guidelines for the Safe Handling of Dyestuffs in Color Storerooms*.

ETAD, *Reactive Dyes - Mode of Action and Safe Handling*.

ETAD, 1987, *Safety Instructions for Handling of Colorants*.

ETAD, 1992, *Information Notice No. 3 (in Italian, English, French)*.

ETAD, 1993, *ETAD Dye Care Initiative, Slide Presentation*, Prepared by US Operating Committee.

ETAD, 'Pollution Prevention Guidance Manual for the Dye Manufacturing Industry.' A cooperative project between the US Environmental Protection Agency and USOC of ETAD (although more relevant to manufacturers it has some interest also for dye users).

INTERNATIONAL LABOUR OFFICE, 1984, 11th Session of the Textiles Committee, Report III, *Occupational Safety and Health in the Textiles Industry*.

INTERNATIONAL LABOUR OFFICE, CIS, *Information Sources on the Textile Industry - Occupational Safety and Health* (regularly updated).

LITTLE A.D., for ETAD, *Azo Dyes: Evaluation of Data Relevant to Human Health and Environmental Safety*.

NIOSH/OSHA, 1981, *Occupational Health Guidelines for Chemical Hazards*. USA.

PARMEGGIANI L. (Ed), 1983, *Encyclopedia of Occupational Health and Safety*, 2 volumes, International Labour Office, Geneva.

SAX N.I., 1988, *Dangerous Properties of Industrial Materials*, 7th Edition, Van Nostrand Reinhold, New York.

SRI International, 1983, *Anthraquinone Dyes and Related Chemicals: Review and Assessment of Potential Environmental and Health Aspects*.

SRI International, 1987, *Non-azo/Non-anthraquinone Dyes: Review and Assessment of Potential Environmental and Health Aspects*.

UNITED NATIONS ECONOMIC AND SOCIAL COUNCIL, *Transport of Dangerous Goods - Recommendations prepared by United Nations Committee of Experts on the Transport of Dangerous Goods*.

UNITED NATIONS, 1991, *Consolidated List of Products Whose Consumption and/or Sale Have Been Banned, Withdrawn, Severely Restricted or Not Approved by Governments*, 3rd Issue.

Pollution Control Technology

ATKINS M.H. et al, 1979, *Case Studies in Pollution Control Measures in the Textile Dyeing and Finishing Industries*, Pergamon Press.

BRANDON C. et al, 1978, "New Technology of Hyper-filtration Promises Sizable Saving to Textiles", *Textile World*, Vol. 128.

CHEN E.C., 1989, *Environmental Assessment of the Canadian Textile Industry*, Report published by Environment Canada.

COPPER S.G., 1978, *The Textile Industry, Environmental Control and Energy Conservation*, Noyes Data Corporation, Park Ridge, New Jersey, USA.

DARUWALLA E.H., January 1976, "Savings in Use of Chemicals in Dyeing", *Colourage* (India), Vol. 23, No. 1.

EUROPEAN ECONOMIC COMMISSION, 1986, *Final Report: Treatment of Raw Wool Scouring Liquors*, Prepared by Wira Technology Group, Leeds, UK

GHOSH M.M. et al, 1978, "Treatability Studies and Design Considerations for Textile Waste Waters", *Journal of Water Pollution Control Federation*, Vol. 50, No. 8.

GREN J.M., 1985, "Using Ozone to Decolorize Dyeing Plant Waste Waters", *American Dyestuff Reporter*, Vol. 74, No. 4.

IEC INTERNATIONAL ENVIRONMENTAL CONSULTANTS LTD., 1989, *Survey of Textile Wet Processing and Pollution Abatement Technology*, Ontario.

PORTER J.J. et al, 1976, "Long Term Biodegradability of Textile Chemicals", *Journal of Water Pollution Control Federation*, Vol. 48.

SHELLY M.L. et al, 1978, "Evaluation of Chemical - Biological and Chemical - Physical Treatment for Textile Dyeing and Finishing Waste", *Journal of Water Pollution Control Federation*, Vol. 48, No. 4.

US ENVIRONMENTAL PROTECTION AGENCY ENVIRONMENTAL RESEARCH INFORMATION CENTRE, Technology Transfer, 1971, *State of the Art of Textile Waste Treatment*, prepared by J. Porter, Clemson University

US ENVIRONMENTAL PROTECTION AGENCY ENVIRONMENTAL RESEARCH INFORMATION CENTRE Technology Transfer, 1974, Wastewater Treatment Systems, *Upgrading Textile Operation to Reduce Pollution*, prepared by Metcalf and Eddy Inc.

WEETER D.W., 1977, "Alternatives for Biological Waste Treatment of Dye - Waste Waters", *American Dyestuff Reporter*, Vol. 66, No. 8.

ANNEX B

INTERNATIONAL TEXTILE RESEARCH ORGANISATIONS AND JOURNALS

B.1 INTERNATIONAL ORGANISATIONS ENGAGED IN TEXTILE RESEARCH

Commonwealth Scientific and Industrial
Research Organization
Division of Textile Industry
Belmont, Victoria 3216
AUSTRALIA

Bundes-Lehr-und Versuchsanstalt f.
Textilindustrie
Textilinstitut Dornbirn
6850 Dornbirn
AUSTRIA

Centre Scientifique et Technique de l'Industrie
Textile Belge
Rue Montoyer 24
B-1040 Bruxelles
BELGIUM

Ontario Research Foundation
Textile Department
Sheridan Park, Ontario
CANADA

Dansk Textil Institut
Stokhuagade 5
Copenhagen
DENMARK

Tekstiiliteknikan saatio - Tutkimuslaboratorio
(The Foundation for Textile Technical
Research - Laboratory)
Eerikinkatu 36, Helsinki 18
FINLAND

Institut Textile de France
35, Rue des Abondances
92 Boulogne-sur-Seine
FRANCE

Ahmedabad Textile Industry's Research
Association (ATIRA)
Post Polytechnic
Ahmedabad - 15, Gujarat
INDIA

The Textile Research Institute
Fukui University
3-9-1 Bunkyo
Fukui Prefecture
JAPAN

Vezelinstituut TNO (Toegepast
Natuurwetenschappelijk
Onderzoek: Applied Scientific Research)
Schoemakerstraat 97, P.O. Box 110
Delft
NETHERLANDS

Pakistan Institute for Cotton Research and
Technology
Moulvi Tameezuddin Khan Road
Karachi - 1
PAKISTAN

Wool Research Division
P.C.S.I.R., Laboratories
P.O. Peshawar University
Peshawar, West Pakistan
PAKISTAN

Department of Chemistry - Department of
Textile Industries
College of Technology
Belfast, Northern Ireland
UNITED KINGDOM

The Cotton, Silk and Man-Made Fibres
Research Association
Shirley Institute
Didsbury, Manchester M20 8RX
UNITED KINGDOM

Wool Industries Research Association
Headingley Lane
Leeds LS6 1BW
UNITED KINGDOM

Arthur D. Little Inc.
25, Acorn Park
Cambridge, Massachusetts 02140
UNITED STATES OF AMERICA

Research Triangle Institute
Post Office Box 12194
Research Triangle Park, North Carolina 27709
UNITED STATES OF AMERICA

North Carolina State University
115, Davis Clark Lab.,
Raleigh, North Carolina 27607
UNITED STATES OF AMERICA

B.2 JOURNALS

America's Textile International
210 Powers Ferry Road
Atlanta GA 30339
UNITED STATES OF AMERICA

Australian Textiles
Box 286, Belmont
3216 Victoria
AUSTRALIA

International Textile Bulletin
ITS Publishing International Textile Service
Univer Haus,
Kesslerstrasse 9 Ctl 8952
Schlieren - Zurich
SWITZERLAND

JTN The International Textile Magazine
Osaka Senken Ltd.
3-4-9 Bingomachi,
Chow Ku Osaka 541
JAPAN

Textil Praxis International
Konradin Verlag
Postfach 10
0252 7022 Leinnfelden - Echterdingen
GERMANY

Textile Asia
The Asian Textile & Apparel Monthly
California Tower, 11th Floor
30-32 D'Aguilar Street
HONG KONG

Textile Month
World Textile Publications Ltd.
Caidan House, Canal Road
Timperley, Altrincham
Cheshire WA14 1TD
UNITED KINGDOM

Textile World
4170 Ashford Dunwoody Road, Suite 420
Atlanta, Georgia 30319
UNITED STATES OF AMERICA

Textiles and Textile Horizons
The Textile Institute
10, Blackfriars Street
Manchester M3 5DR
UNITED KINGDOM

ANNEX C

CASE STUDIES ON CLEANER PRODUCTION

CASE STUDY 1

Water Conservation at Binny Textile Mills, Madras, India.

Major water pollution is generated by the following departments:

- Process and treatment
- Captive power generation unit (coal fired thermal power station)
- Sizing
- Yarn dyeing and printing

Wastewater and re-use measures undertaken include:

a) Re-use of pressure filter backwash water

Easily settleable suspended solids is the main pollutant in the pressure filter backwash water. By collecting this in a pond with a minimum hydraulic retention time of 12 hours the supernatant free from suspended solids can be re-used for gardening purposes. Periodically the retained suspended solids will be removed from the pond and disposed of as solid waste in a landfill site. The net effect is conservation of 20 m³/day of fresh water used at present for gardening.

b) Re-use of wastewater from the dyeing and finishing department

About 1200 m³/day of fresh water (including evaporation loss) is used for quenching hot ash from the boiler house before disposal. Laboratory experiments have confirmed that it is feasible to re-use the hard-to-treat wastewater from the dyeing department, instead of fresh water, for quenching purposes. It was also confirmed that due to adsorption of colour/dyes on the ash particles, there will be about 20% reduction in BOD content in the re-used dye-house wastewater. The net effect of this approach is conservation of around 1200 m³/day fresh water and a reduction of around 520 kg BOD/day.

c) Re-use of wastewater from sizing activities

To avoid spontaneous combustion and to reduce the fines loss, fresh water is used for wetting coal in the yard. By collecting the low volume high organic strength wastewater from the sizing operation in a pond with facilities to prevent septicity, the entire wastewater arisings can be used for coal wetting. The net saving is a total elimination of wastewater from sizing and conservation of around 27 m³ per day of fresh water.

Additional savings/reduction occur in capital investment and annual operational and maintenance costs for wastewater treatment plant. These avoided costs include the facility for pH neutralisation, pumps and pipe line costs as a result of the 31% overall reduction in wastewater quantity along with a 25% cut in BOD load.

Source: Mr L. Paneerselvam, Director (PC), National Productivity Council, Lodhi Road, New Delhi 110003, India.

CASE STUDY 2

Elimination of Sulphide Problems by Chemical Substitution at Century Textiles and Industries Ltd, Bombay, India.

Sulphur dyes, like vat dyes, are water-insoluble compounds. Before they can be applied to textiles, they have to be converted into a soluble (leuco) form which has affinity for cellulosic compounds. Traditional methods for this conversion involve treatment with aqueous sodium sulphide solution. Again, as with vat dyes, the reduced form of the sulphur dye absorbed on to the fibres has to be converted into its original water-insoluble form. This is generally carried out either by exposure to air or by using a chemical oxidizing agent.

Black dye is an important member of the sulphur series on account of its cheap cost alongside its excellent washing and light fastness, but Maharashtra State pollution limits prescribe no more than 2 ppm sulphide in treated mill effluents.

Sulphur black dyeing methods and effluent treatment options were therefore reviewed carefully including the possibility of reducing the sulphide concentrations in the waste load by chemical substitution of sodium sulphide with another reducing agent.

Studies found that alkaline solution of glucose can reduce black sulphur colours satisfactorily but the high cost of glucose might impose a practical constraint. A market survey was therefore done into where it might be possible to procure glucose at a competitive price. This led to liquid glucose, a by-product of the starch industry.

It was also observed that in sulphur black dyeing, 100 parts of sodium sulphide (50%) can be replaced by 61 parts of glucose (80% solids) plus 26 parts of caustic soda. Despite special arrangements for emptying the thick glucose solution from drums, this option was found to provide a cost-effective substitution of sodium sulphide.

From April 1990 this substitution was gradually implemented. The depth, shades, fastness and quality of the dyeing were equivalent to those obtained conventionally.

The results of this substitution on the effluent plant were also good. Not only was sulphide in the effluent reduced but the aeration system worked better, in turn improving settling characteristics in the effluent. The foul smell associated with sulphur dyeing was also curtailed.

At present around 3500 kg cotton is being dyed every day in this way. It should be noted that while this substitution was studied for sulphur black, it is also suitable for other colours in the sulphur series. Furthermore, no capital expenditure is required in this substitution.

Source: Mr Mahesh A. Sharma, Chief Chemist, Century Textiles and Industries Ltd, Worli, Bombay 400025, India.

CASE STUDY 3

Heat Recovery in Textile Manufacturing, Ellen Knitting Mills, Spruce Pine, USA.

The temperature of dye bath water, when discharged to the municipal sewer was 132° F causing breakages in the terra cotta sewage pipes.

In 1981 the company invested \$100,000 in a heat exchange system which had a payback period of two years. To achieve the heat recovery, dye water is discharged into a holding vat from which it enters a stainless steel heat exchanger. Heat removed from the water is used to heat incoming feed water from the dye tubes, almost doubling its temperature from 55° F to 105° F. This pre-heating operation saves around 200,000 litres of fuel oil per year.

Source: Profits of Pollution Prevention: A compendium of North Carolina case studies, North Carolina Department of Natural Resources and Community Development, NC, USA.

CASE STUDY 4

Recovery and Re-use of Water in Wet Textile Processing at a BTRA Textile Mill, Bombay, India.

Diagnostic studies were undertaken to examine the conservation and re-use of water in wet processing. A range of measures was suggested:

- Reduced rate of water flow and throttling on water supply to washing machines.
- Counter-current flow of washing water on soapers, mercerising machines, J-box, etc.
- Effective re-use of washwater earlier in the sequence via a common sump and pump.
- Collection of steam condensation for re-use via boiler feed water.
- Application of static washes on jiggers in place of overflow washes.
- Use of sodium bicarbonate in place of acetic acid for the oxidation of vat-dyed goods for easy removal of the caustic soda.
- Recycling of water for washing of blankets on printing machines.
- Reducing the number of washing steps in the processing sequence by giving appropriate treatment to fabrics.

The bulk trials for such conservation and re-use measures were carried out for mills processing a number of fabric varieties, e.g. bleached long cloth, dyed poplin, bleached mills/voiles and dyed mulls and voiles.

Fabric sort and production/day	1	2	3
Bleached longcloth (1000 kg)	76,500	22,500	47,250
Dyed Poplin (2000 kg)	121,500	45,000	74,000
Bleached Mulls/Voiles (500 kg)	35,000	8,000	21,750
Dyed Mulls/Voiles (500 kg)	28,000	8,000	10,750
Bleached Dhoti (250 kg)	7,500	1,700	3,800
Total	268,500	85,299	157,550

1-Water volumes used in processing (l/day)

2-Volumes re-used before the study (l/day)

3-Volumes re-used after the study (l/day)

Total freshwater consumption before the survey was 183,350 l/day, and afterwards 110,950 l/day. Over a year the reduction was 21,710,000 l, giving a cost saving of 60 Rs/10,000 l of water.

Source: Seminars on Avenues for Cost Reduction in Chemical Processing of Textiles, Feb 26, 1985, Bombay Textile Research Association, Bombay 400086. BTRA Paper No 06.3.1

CASE STUDY 5

Potential Water and Energy Savings in Textile Bleaching at Du Pont, Chemical Pigments Department, Delaware, USA.

There is a strong correlation between water and energy use in textile bleaching, since a high proportion of the energy is used to heat washwater. By reducing water consumption, significant energy savings are easily realized.

A typical open-width bleach range consists of three (desize, caustic, and peroxide) bleach stages. Each washing train has a major water feed, usually 50-75 gal/min which is counterflowed through all the washers in that stage. (Data in this discussion are based on 60 gal/min at desize washers and 50 gal/min at caustic or bleach washers.) Water temperatures vary but are almost always at least 180° F.

► *Table 1 Water and Energy Use by 3-stage Open-Width Bleach Range*

	Water (gal/hr) (incl. steam)	Energy (lb steam/hr)		
		useful	losses	total
Saturators	550	300	400	700
Steamers & J-Boxes	150	1,150	150	1,300
Washers				
Desize	3,700			
Caustic	3,100	8,100	2,250	10,350
Bleach	3,150			
Dry Cans	450	3,600	500	4,100
Total	11,100	13,150	3,300	16,450

Of the total 16,450 lb steam/hour required to run the bleach range, 10,350 are used in washing systems including the 8,100 lb of steam needed to achieve 180° F and 2,250 lb steam/hour to compensate for heat losses. Energy losses are mainly evaporative and could be reduced substantially if enclosed washers were used. There is also an obvious opportunity to save water and energy by reducing water flows and temperatures on the bleach range.

Reduced water temperature:

Bleach washers remove a relatively small share of impurities in the fabric so temperature reductions are best considered here. As shown in Table 2, at the end of the discussion, a decrease in 10° F from 180° to 170° would cut energy needs by 250 lb/hour steam without reducing water requirements. For most bleach ranges this is a relatively safe change. In fact many mills run 150-160° F water for bleach washing.

Reduced water flow rates:

For the desize and caustic stages, temperature reduction is not advisable because the materials being removed (caustic, sizing polymer, waxes) become more viscous or fall below their melting points. However, a reduction in water flow rate by 5 gal/min would save 300 gal/hour of water and 300 lb/hour steam. This is attractive if it can be determined reliably that more water than necessary is being used to remove the impurities. There are some potential problems though which make lower flow rates difficult:

- Few mills control flow rates well and would be unable to recognize a reduction if it occurred. the bleach range operator often controls the flow valve at his own whim. Flow rates should not be lowered until they are controlled and until fabric quality has been monitored with present rates.

- No automatic monitors are available to measure the concentration of impurities in the wash water or on the fabric. Data on the effects of change must be gathered by painstaking laboratory work.
- In the absence of other controls, the water flow is set to be sufficient for the most difficult fabrics processed. It is generally changed for more easily washed fabrics. (A control was recently introduced which allows automatic variation of wash water flow with the lb/hour of fabric produced which assumes that the difficulty of washing is proportional to the fabric weight, something that is true for most fabric types.)

One valid way to reduce water flow is to use more efficient washers. Horizontal washers use about one third to one quarter as much as vertical washers for the same washing job. Water and energy use is reduced accordingly.

Reduce the number of water feeds:

a) Counterflow between stages

As stated earlier the standard open-width continuous bleach range has three separate water feeds. Counterflowing water from the bleach washers to the caustic washers could eliminate 3,000 gal/hour water feed and could save 2,600 lb/hour steam. A mass energy balance of a typical bleach range has shown that the total impurities in the bleach water when it is discharged are about 0.03 lb/gal or 0.34% by weight. It is clean enough for re-use in the desize or caustic stages for most mills, and many of them have recently begun to take advantage of this.

It is possible to recycle the same water through all three stages but this is rarely done. Wash water used in both the bleach and caustic stages will contain around 1.3% impurities by weight and its re-use in desizing might lower efficiency too much. Coagulation of impurities due to cooling during the counterflowing is another risk. In spite of the high incentive (6,000 gal/hour and 5,300 lb steam/hour) full counterflow is practiced on very few ranges.

b) Reduce the number of stages

Elimination of bleach range stages would save 3,100 gal/hour and 3,700 lb steam/hour. For this there are three options:

1. Combining desize and caustic functions, something especially attractive for cotton polyester blends because PVA desize can be removed by hot water washing and caustic must be kept low to protect the polyester. The system becomes in a sense a non-desize one. A small addition of hydrogen peroxide stabilized with epsom salt can help remove PVA and other minor sizing polymers which may be present.
2. Combining caustic and bleach functions. If the caustic is eliminated, the result is a desize bleach system. Du Pont introduced this concept during the 1950s as the Solo Matic process. The most popular configuration is rope desizing in bins followed by a single J-Box to perform both the caustic and bleaching stages. It is intended mainly for lightweight open weave fabrics including soft-filled sheeting, polyester cotton shirting and preparation for non-critical dyeing. Its major limitations are development of absorbency and removal of moles, both of which require strong caustic treatment.

The bleach bath in a desize bleach system uses a high alkali content and requires sodium silicate buffering to pH 10.8-11.00;

3. Single stage bleaching. The prospect of cutting out two stages is attractive. Present applications include knit goods, bedsheets, terry cloth and lightweight polyester cotton shirting.

There are very few open-width single-stage bleach ranges because of the limited steaming times available. Few plants run corduroy and other fabrics for non-critical dyeing use on a single stage range as results are often marginal. The conveyer steamer with 15-20 minutes steaming time is of greatest interest here, although few such applications are currently running.

Pre-washing:

In any single stage system and in many other abbreviated bleach configurations it will be beneficial to use a pre-washing train with recycled water from the bleach stage - something which might be called a 1.5 stage range. Pre-washing can remove significant quantities of sizing and natural impurities which would otherwise have to be removed in the final washes and which might affect the stability of the bleach bath. Since pre-washing with recycled water does not affect water consumption and rarely affects energy use, it is always recommended.

Water costs including waste treatment can exceed \$1/1,000 gallons. Energy for an oil fired range can cost around \$7/1,000 lb steam, so careful selection of the optimum bleach range configurations for the fabric being processed can save a great deal. For example, counterflow from bleach washers to caustic washers (see Table 2) can save around \$20,000/year in water costs, \$110,000/yr in energy costs.

► Table 2 Water and Energy Savings Available by Process Changes

Change	Savings	
	Water (gal/hr)	Energy (lb steam/hr)
Reduce water temp by 10° F at bleach stage washers	0	250
Decrease water flow by 5 gal/min at caustic washers	300	300
Counterflow from bleach washers to caustic washers	3,000	2,600
Fully counterflow wash water	6,000	5,300
Eliminate one stage	3,100	3,700
Single stage bleach	6,200	7,000

Source: Bruce A Evans, E.I. Du Pont de Nemours & Co Inc, Chemical Pigments Dept, Chestnut Run, Wilmington, Delaware, USA.

CASE STUDY 6

Recycling Spent Nylon Hosiery Dyebaths to Reduce Raw Material and Disposal Costs, Dominion Textiles Inc, Valleyfield, Quebec

A pilot operation was established to recycle spent nylon hosiery dyebaths containing disperse dyes and chemical auxiliaries (scouring, levelling and wetting agents). The dyebaths are pumped from the rotary drum drying machine to a holding tank for analysis and reconstitution with dyestuff. An average of 30 batches can be dyed before discharge.

Capital costs for the conversion and analytical equipment required in 1980 were \$28,441. Operating costs for wet processing fell by \$0.044/kg, giving a disposal and feedstock saving of \$12,240/year along with a 19% reduction in dye consumption, 35% in auxiliaries use and 57% energy savings. Volumes entering the waste stream fell because spent and contaminated dyes were being recycled.

Source: Catalogue of Successful Hazardous Waste Reduction/ Recycling. Energy Pathways Inc and Pollution Probe Foundation. Prepared for Industrial Programs Branch, Conversion and Protection, Environment Canada, March 1987, page 91.

CASE STUDY 7

Cleaner Production at a UK Woollen Textile Mill

This large firm employs over 1,500 people and processes a significant part of the raw wool imported to the UK from Australia. It is involved in the scouring of raw wool, in spinning, dyeing of wool and synthetics. Throughput is roughly 100 tonnes of wool and a similar amount of synthetic fibre per 120 hour week.

Water consumption runs at: 1,600 m³ for dyeing and scouring, 180 m³ for raw wool scouring, 220 m³ lost as steam. After treatment the effluent is discharged to a municipal sewer for which limits apply of 800 ppm for grease and 1,000 ppm for suspended solids. There is also a maximum discharge rate of 113.5 m³/hour and maximum volume of 2,000 m³/day. The total mass of grease discharged is thus estimated at 1,500 kg/day. Discharge consent costs are also rising significantly as environmental standards tighten.

The highest pollution load originates from the scouring of raw wool at a temperature of 45° C with soap and alkali to remove grease and other impurities. Untreated effluent contains 36,000 ppm of grease and 50,000 ppm other suspended solids. This, together with its alkalinity (pH 9) makes direct discharge illegal. Dye house effluent accounts for 90% of the process water but is potentially less polluting. It contains 1,000 ppm grease and 5,000 ppm suspended solids, is highly acidic (pH 4) and hot (100° C). Yarn washing produces a fairly clean effluent containing large amounts of fibre that is difficult to remove. Substantial measures are therefore essential to bring the effluents up to the discharge consent conditions.

£1m was spent on new scouring systems that use one rather than three bowls, to reduce water consumption and effluent volume by 30%. A heat exchanger costing £30,000 was installed to reduce the temperature of dye house effluent to meet discharge consent conditions and heat incoming water. Grease is also recovered inside the plant by centrifuging to extract pure lanolin. This can be highly profitable in its own right.

90% of the remaining grease is recovered by acid cracking but the overheads of this are high and this is one pollution control measure that is not profitable. Through spending 4% of the value added in dyeing on pollution control the company meets its discharge consent standards by treating its own effluents, and recovering useful cash products. Capital expenditure is considerable to achieve this but as environmental standards tighten so will discharge consent conditions.

Source: Case Studies in Pollution Control Measures in Textile Dyeing and Finishing, M.H. Atkins and J. F. Lowe, Pergamon Press.

ANNEX D

SAFE HANDLING OF TEXTILE CHEMICALS

INTERNATIONAL ORGANIZATIONS PROVIDING ADVICE ON HAZARDOUS CHEMICALS

UNEP International Register of Potentially Toxic Chemicals (IRPTC)

Palais des Nations, CH 1211 Geneva 10, Switzerland

Tel:(41) 22 979 9111; Telex: 28877 Geneva; Telefax:(41) 22 797 34 60

Provides information on chemicals, waste disposal and discharge regulations, including the current international list of chemicals banned or severely restricted.

UNEP/WHO/ILO International Programme for Chemical Safety (IPCS)

c/o World Health Organization CH 1211 Geneva 27, Switzerland

Tel:(41) 22 791 21 11; Telex:27821 OMS; Telefax:(41) 22 791 07 46

Contact for toxicological information on chemicals

International Labour Organisation (ILO)

4 route des Morillons, CH 1211 Geneva 22, Switzerland

Tel:(41) 22 799 61 11; Telex: 22 271 BIT CH; Telefax:(41) 22 798 86 85

Contact for occupational health and safety information.

International Safety and Health Information Centre (CIS)

c/o International Labour Office,

4 route des Morillons, CH 1211 Geneva, Switzerland

Tel: (41) 22 799 67 40; Telex: 22 271 BIT CH; Telefax: (41) 22 798 86 85

Contact for information on hazardous materials and workplace safety.

International Agency for Research on Cancer (IARC)

150 Cours Albert Thomas

69008 Lyon, France

Tel: (33) 72 73 84 85; Telefax: (33) 72 73 85 75

Ecological and Toxicological Association of Dyes and Organic Pigment Manufacturers (ETAD)

Clarastrasse 4, Basel - PO Box ETAD

CH-4005 Basel, Switzerland

Tel: (41) 61 681 22 30; Telefax: (41) 61 691 42 78

EXAMPLES OF MATERIALS SAFETY DATA SHEETS - MSDS

MSDS can be obtained from a number of sources. In the first instance these sheets should be requested from the chemical supplier, together with other information on safe handling of the product. In addition a number of commercial publishing houses produce MSDS for general use. Finally, some national and international authorities produce guidance notes and advice on chemical hazards. Examples of safety data sheets prepared by Genium, and by the International Programme on Chemical Safety (IPCS) are shown here.

HYDROGEN PEROXIDE		ICSC: 0164	
CAS # 7722-84-1 RTECS # MX0900000 ICSC # 0164 UN # 2015 EC # 008-003-00-9		Hydroperoxido H_2O_2 Molecular mass: 34	
		HAZARD SYMBOLS <i>Consult national legislation</i>	
TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/ SYMPTOMS	PREVENTION	FIRST AID/ FIRE FIGHTING
FIRE	Not combustible but enhances combustion of other substances. Many reactions may cause fire or explosion	NO contact with flammable substances. NO contact with hot surfaces	In case of fire in the surroundings all extinguishing agents allowed
EXPLOSION	Risk of fire and explosion when reacting with other substances		In case of fire, keep drums, etc., cool by spraying with water
EXPOSURE		AVOID ALL CONTACT!	
<input type="checkbox"/> Inhalation	Cough, dizziness, headache, laboured breathing, nausea, shortness of breath, sore throat	Ventilation, local exhaust, or breathing protection	Fresh air, rest, half-upright position, and refer for medical attention
<input type="checkbox"/> Skin	Redness, skin burns, pain	Protective gloves, protective clothing	Remove contaminated clothes, rinse skin with plenty of water or shower, and refer for medical attention
<input type="checkbox"/> Eyes	Redness, pain, blurred vision, severe deep burns, ulceration of cornea, perforation	Face shield	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor
<input type="checkbox"/> Ingestion	Abdominal pain, nausea, sore throat, vomiting, abdominal distension		Rinse mouth, give plenty of water to drink, do NOT induce vomiting, and refer for medical attention
SPILLAGE DISPOSAL	STORAGE	PACKAGING & LABELLING	
Ventilation, wash away spilled liquid with plenty of water, do NOT absorb in saw-dust or other combustible absorbents. Do NOT let this chemical enter the environment (extra personal protection; complete protective clothing including self-contained breathing apparatus)	Separated from combustible and reducing substances, strong bases, metals, cool, keep in the dark, store only if stabilized	Special insulated container in upright position UN Haz Class 5.1 UN Subsidiary Risks 8 UN Pack Group 1 FURTHER INFORMATION ON LABELLING <i>Consult national legislation</i>	
<div>ADDITIONAL INFORMATION</div>			
SEE IMPORTANT INFORMATION ON BACK			
ICSC: 0164 V 1.0 IMPORTANT LEGAL NOTICE ON BACK		Prepared in the context of cooperation between the IPCS and the Commission of the European Communities © CEC, IPCS, 1991.	

I M P O R T A N T D A T A	PHYSICAL STATE; APPEARANCE COLOURLESS LIQUID. CHEMICAL DANGERS: The substance decomposes on warming producing oxygen which increases fire hazard. The substance is a strong oxidant and reacts violently with combustible and reducing materials causing fire and explosion hazard particularly in the presence of metals. Attacks many organic substances, e.g. textile and paper. OCCUPATIONAL EXPOSURE LIMITS: TLV, 1 ppm; 1.4 mg/m ³ (ACGIH 1987-1977) ROUTES OF EXPOSURE: The substance can be absorbed into the body by inhalation of its vapour and by ingestion. EFFECTS OF SHORT-TERM EXPOSURE: The substance is corrosive to the eyes, the skin, and the respiratory tract. Inhalation of vapours may cause lung oedema (see Notes). The effects may be delayed. Medical observation is indicated.	EFFECTS OF LONG-TERM OR REPEATED EXPOSURE: May cause genetic damage in humans.
	PHYSICAL PROPERTIES Boiling point: 115-157 °C Melting point: < 50 °C Relative density (water = 1): 1.3 Solubility in water: Miscible Vapour pressure, kPa at 30 °C: 0.7 Relative vapour density (air = 1): 1.2 Relative density of the vapour/air-mixture at 20 °C (air = 1): 1.06	
	ENVIRONMENTAL DATA	
	NOTES	
<div style="display: flex; justify-content: space-between;"> <div> The symptoms of lung oedema often do not become manifest until a few hours have passed and they are aggravated by physical effort. Rest and medical observation are therefore essential. Immediate administration of an appropriate spray, by a doctor or a person authorized by him/her, should be considered. Albion is a trade name. </div> <div> Transport Emergency Card TEC (R): 51G05 NFPA Code: H2 F0 R3 </div> </div>		
ADDITIONAL INFORMATION		
<div style="display: flex; justify-content: space-between;"> <div>ICSC: 0164</div> <div>© CEC, IPCS, 1991</div> <div>HYDROGEN PEROXIDE</div> </div>		
<small> IMPORTANT LEGAL NOTICE: Neither the CEC or the IPCS nor any person acting on behalf of the CEC or the IPCS is responsible for the use which might be made of this information. This card contains the collective views of the IPCS Peer Review Committee and may not reflect in all cases all the detailed requirements included in national legislation on the subject. The user should verify compliance of the cards with the relevant legislation in the country of use. </small>		

Material Safety Data Sheet

From Genium's Reference Collection
Genium Publishing Corporation
1145 Catalyn Street
Schenectady, NY 12303-1836 USA
(518) 377-8855



No. 312
TRICHLOROETHYLENE
(Revision E)

Issued: July 1979
Revised: August 1987

SECTION 1. MATERIAL IDENTIFICATION

MATERIAL NAME: TRICHLOROETHYLENE

DESCRIPTION (Origin/Uses): Prepared from sym-tetrachloroethane by way of eliminating HCl by boiling with lime. Used to manufacture organic chemicals, pharmaceuticals; in degreasing and dry cleaning; and as a solvent for fats, waxes, rubbers, oils, paints, varnishes, ethers, and cellulose esters

OTHER DESIGNATIONS: Ethylene Trichloride; TCE; Trichloroethene, 1,1,2-Trichloroethylene, C₂HCl₃; NIOSH RTECS #KX4550000; CAS #0079-01-6

MANUFACTURER/SUPPLIER: Available from several suppliers, including:
Dow Chemical USA, 2020 Dow Center, Midland, MI 48640,

Telephone: (517) 636-1000; (800) 258-CHEM

COMMENTS: Trichloroethylene is a toxic solvent and a suspected occupational carcinogen

HMIS

H 2

F 1

R 1

PPE*

R 1

I 3

S 1

K 0

SECTION 2. INGREDIENTS AND HAZARDS

Trichloroethylene, CAS #0079-01-6; NIOSH RTECS #KX4550000

%

HAZARD DATA

$$\begin{array}{c} \text{Cl} & & \text{Cl} \\ & \diagdown & / \\ & \text{C} = \text{C} \\ & / & \diagdown \\ \text{H} & & \text{Cl} \end{array}$$

- The TLV-TWA is set to control subjective complaints such as headache, fatigue, and irritability.
- The TLV-STEL is set to prevent incoordination and other beginning anesthetic effects from TCE. These levels should provide a wide margin of safety in preventing liver injury.
- The OSHA PEL is 300 ppm for 5 minutes in any 2 hours

ACGIH Values 1987-88

TLV-TWA*, 50 ppm, 270 mg/m³

TLV-STEL**, 200 ppm, 1080 mg/m³

OSHA PEL 1986***

8-Hr TWA, 100 ppm

Ceiling, 200 ppm

NIOSH REL 1986

10-Hr TWA, 25 ppm

TOXICITY DATA

Human, Oral, LD₅₀: 7 g/kg

Human, Inhalation, TC_{Lo} 6900 mg/m³

(10 Min)

Human, Inhalation, TC_{Lo}: 160 ppm/

83 Min

Human, Inhalation, TD_{Lo}: 812 mg/kg

SECTION 3. PHYSICAL DATA

Boiling Point ... 188.6°F (87°C)

Vapor Pressure ... 58 Torr at 68°F (20°C)

Water Solubility ... Insoluble

Vapor Density (Air = 1) ... 4.53

Evaporation Rate ... Not Listed

Specific Gravity ... 1.4649 at 68°F (20°C)

Melting Point ... -120.64°F (-84.8°C)

Molecular Weight ... 131.40 Grams/Mole

Appearance and odor: Colorless, nonflammable mobile liquid; sweetish odor like chloroform

COMMENTS: TCE is highly soluble in lipids. A high vapor pressure at room temperature provides the potential for TCE vapors to contaminate use areas.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air	LOWER	UPPER
Not Listed	770°F (410°C)	% by Volume	8%	10.5%

EXTINGUISHING MEDIA: TCE has no flash point in a conventional closed tester at room temperature, but it is moderately flammable at higher temperatures. Use dry chemical, carbon dioxide, alcohol foam, or other extinguishing agents suitable for the surrounding fire.

OSHA Flammability Class (29 CFR 1910.106): Not Regulated

UNUSUAL FIRE/EXPLOSION HAZARDS: During fire conditions TCE emits highly toxic and irritating fumes, including hydrochloric acid and phosgene. **SPECIAL FIRE-FIGHTING PROCEDURES:** Wear a self-contained breathing apparatus with a full facepiece operated in a pressure-demand or another positive-pressure mode. At TCE vapor levels of 300-1000 ppm, fire fighters who lack the proper respiratory equipment may experience incoordination and impaired judgment.

DOT Flammability Class (49 CFR 173.115): Not Regulated

SECTION 5. REACTIVITY DATA

Trichloroethylene is stable. Hazardous polymerization can occur under certain circumstances (see Conditions to Avoid and Comments, below)

CHEMICAL INCOMPATIBILITIES include magnesium or aluminum powder, NaOH, KOH, or other strong alkaline materials. Reactions with alkaline materials may lead to the formation of dangerous explosive mixtures of chloroacetylenes.

CONDITIONS TO AVOID: When TCE is heated (as in the case with vapor degreasers) or exposed to sunlight, it requires extra stabilization against oxidation, degradation, and polymerization. It is slowly decomposed by light when moist.

PRODUCTS OF HAZARDOUS DECOMPOSITION include hydrochloric acid and phosgene under certain conditions at elevated temperatures.

COMMENTS: TCE is stable under normal handling and storage conditions, and hazardous polymerization is not expected to occur. However, failure of the stabilizer at elevated temperatures or other extreme conditions may allow polymerization to take place..

**LIST OF DYES CLASSIFIED BY THE INTERNATIONAL AGENCY FOR RESEARCH ON
CANCER AS GROUP 2A OR 2B CARCINOGENS**

Group 2A Probably carcinogenic to humans
 Benzidine-based dyes

Group 2B Possibly carcinogenic to humans

CINR Name	CAS No.
11000: Solvent Yellow 1	60-90-3
11020: Solvent Yellow 2	60-11-7
11160: Solvent Yellow 3	97-56-3
12100: Solvent Orange 2	2646-17-5
12156: Solvent Red 80	6358-53-8
16150: Acid Red 26, Food Red 5	3761-53-3
16155: Acid Dye B, Food Red 6	3564-09-8
23635: Acid Red 114	6459-94-5
23850: Direct Blue 14	72-57-1
24400: Direct Blue 15	2429-74-5
41000: Basic Yellow 2	2465-27-2
42500: Basic Red 9	569-61-9
42510: Basic Violet 14	632-99-5
42640: Acid Violet 49, Food Violet 2	1694-09-3
64500: Disperse Blue 1, Solvent Blue 18	2475-45-8
HC Blue 1	2784-94-3

LIST OF COLORANTS TO BE CLASSIFIED AS TOXIC

R. Anliker, G. Dürig, D. Steinle and E.J. Moriconi
ETAD, PO Box, CH-4005, Basel 5, Switzerland

This paper presents a list of colorants that must be classified as toxic on the basis of their acute peroral LD₅₀ value, applying the criteria of the EEC 6th amendment. For each product the list includes: C.I. generic name and number, CAS number and name, concentration of active ingredient, toxicological data and recommended labelling.

The EEC Council Directive 79/831 of 18 September 1979 (6th amendment) requires that "Dangerous substances be... provisionally labelled by the manufacturer or his representative in accordance with the rules laid down in Articles 15 to 18 and with the criteria in Annex VI"^[1]. The latter also specifies unequivocal limits for the classification of "very toxic", "toxic" and "harmful" substances. Thus, for a product with an LD₅₀ ≤ 200 mg/kg (rat, oral), a specific labelling recommendation would be "very toxic" or "toxic".

Further, both the 6th amendment and the West German "dangerous substances law"^[2] require skin testing (rabbits) to determine the applicability of the hazard labels "corrosive" and "irritant". These regulations were intended to achieve reasonable assessment of both occupational and consumer hazards. In 1983 a Commission directive defined precisely the translation of these criteria into R- (risk) and S- (safety) phrases^[3].

In 1974 the Ecological and Toxicological Association of the Dyestuffs Manufacturing Industry's (ETAD) member companies began a programme to generate a systematical toxicological and ecotoxicological database on all their commercial dyes. These appear on the market almost exclusively as preparations. Differences in analytical and assessment methodology have, however, led to varying acute toxicity data and irritation potential, with consequent conflicting labels from different manufacturers for identical toxic substances. Furthermore, different commercial dyestuff formulations containing an identical toxic dye may also be labelled differently, depending on the nature of formulating components, dye concentration and possible variation in toxic by-products resulting from differing manufacturing and/or purification processes.

To avoid such possible conflicts and to provide labelling help for companies that do not have their own toxicological data, the ETAD board of directors decided in 1986 to voluntarily publish a list of colorants which, based on their acute peroral LD₅₀ value, must be classified as toxic (colorants which in the future must be listed in Annex I of the 6th amendment). Each ETAD member company (currently 28) was asked to provide toxicological information on purified samples of these colorants. Table 1 is a compilation showing all colorants that are classified as toxic, based on the requirements of the 6th amendment. For each it includes C.I. generic name and number, CAS number and name, concentration of active ingredient, toxicological data (LD₅₀ and results of rabbit skin and eye irritation tests) and recommended labels (symbol; R- and S- phrases).

REFERENCES

1. Off. J. Europ. Commun., 22 (L29) 10. (6th amendment of Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances.)
2. Bundesgesetzblatt, Part I (58) 1718. (Law dated 16 Sept. 1980 concerned with protection against dangerous substances.)
3. Off. J. Europ. Commun., 26 (L257) 1. (Commission directive dated 29 July 1983 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances (83/467/EEC).)

Reprinted with permission from: *Journal of the Society of Dyers and Colourists*, 104, May/June 1988, 223-225.

► Table 1 List of colorants to be classified as toxic

C.I. generic name and No.	CAS No.	CAS name	Active ingredient ^(a) in test sample (%)	Toxicological results ^(b)		Recommended labelling ^(c)		
				LD ₅₀ (mg/kg rat)	Imitation ^(d) Skin Eye	Symbol	R-phrase	S-phrase
C.I. Acid Orange 156 C.I. 26501	68555-86-2	Benzenesulphonic acid, 4-[[[5-methoxy-4-[[4-methoxyphenyl]azo]-2-methylphenyl]-azo]-, sodium salt	95	120-200 ^(e)	- -	T	23 ^(g) /25	44
C.I. Acid Orange 165 C.I. 23682	85030-26-8	Benzenesulphonic acid, 3-[[[4-[[3,5-dimethyl-1H-pyrazol-4-yl]azo]-2,5-dimethoxyphenyl]azo]-, sodium salt	100 ^(f)	60 ^(f)	- +	T	25,36	26,44
C.I. Basic Blue 3 C.I. 51004 (chlorozincate)	63589-47-9	Phenoxazin-5-ium, 3,7-bis(diethylamino)-, (7-4)-tetrahydrozincate (2-)(2-1)	95	100	- +	T	25,42	22,26,44
C.I. Basic Blue 7 C.I. 42595	2390-60-5	Ethanaminium, N-[[4-(diethylamino)-phenyl]-4-[[4-(diethylamino)-1-naphthalenyl]methylene]-2,5-cyclohexadien-1-ylidene]-N-ethyl-, chloride	>98	100	- +	T	25,41	22,26,44
C.I. Basic Blue 81 C.I. 42598	73309-46-3	Ethanaminium, N-[[4-(diethylamino)-phenyl]-4-[[4-(4-methoxyphenylamino)-1-naphthalenyl]methylene]-2,5-cyclohexadien-1-ylidene]-N-ethyl-, chloride	>98	205	- +	T ^(g)	25,41	22,26,44
C.I. Basic Red 12 C.I. 48070	6320-14-5	3H-Indolium, 2-[3-(1,3-dihydro-1,3,3-trimethyl-2H-indol-2-ylidene)-1-propenyl]-1,3,3-trimethyl-, chloride	>98	25 ^g 31 ^g	- +	T	25,41	22,26,44
C.I. Basic Violet 16 C.I. 48013	6359-45-1	3H-Indolium, 2-[2-[4-(diethylamino)phenyl]-ethenyl]-1,3,3-trimethyl-, chloride	94	90	- +	T	25,36	22,26,44
C.I. Basic Yellow 21 C.I. 48060	6359-50-8	3H-Indolium, 2-[2-[2,3-dihydro-2-methyl-1H-indol-1-yl]ethenyl]-1,3,3-trimethyl-, chloride	>98	171	- +	T	25,36	22,26,44
C.I. Direct Orange 62 C.I. not available	70304-37-9	Benzenesulphonic acid, 2,2'-[[1,2-ethenediyl]-bis[5-[[[2-methoxy-5-methyl-4-[[4-sulphophenyl]azo]phenyl]-azoxy]-, tetrasodium salt	96	150	- -	T	25	44
C.I. Azoic Diazo Component 20 C.I. 37175	120-00-3	Benzamide, N-(4-amino-2,5-dimethoxyphenyl)-	90	49	- -	T	23/24/25 33	28,36/37 44
C.I. Azoic Diazo Component 24 C.I. 37155	6268-05-09	Benzamide, N-(4-amino-2,5-dimethoxyphenyl)-	90	70	- -	T	23/24/25 33	28,36/37 44
C.I. Azoic Diazo Component 41 C.I. 37165	99-21-8	Benzamide, N-(4-amino-5-methoxy-2-methylphenyl)-	90	115	- -	T	23/24/25 33	28,36/37 44

(a) The purified test samples contained water and such inert ingredients as sodium chloride, sodium sulphate, etc.

(b) Based on test procedures according to OECD guidelines for testing of chemicals, "Acute oral toxicity" (No. 401), "Acute dermal irritation/corrosion" (No. 404) and "Acute eye irritation/corrosion" (No. 405).

(c) Symbol T = toxic

Risk (R) phrases

- 23 - toxic by inhalation
- 24 - toxic in contact with skin
- 25 - toxic if swallowed
- 33 - danger of cumulative effects
- 36 - irritating to eyes
- 41 - risk of serious damage to eyes

Safety (S) phrases

- 22 - do not breathe dust
- 26 - in case of contact with eyes, nose immediately with plenty of water and seek medical advice
- 28 - after contact with skin, wash immediately with plenty of soap and water
- 36 - wear suitable protective clothing
- 37 - wear suitable gloves
- 44 - if you feel unwell seek medical advice (show the label if possible)

(d) + = irritant - = non-irritant

(e) Acute inhalation toxicity (rat) LD₅₀ = 1 mg/l(f) Calculated to 100% active ingredient from the result of an animal trial with a sample containing 40% of the active ingredient and 60% of sodium sulphate (LD₅₀ = 150 mg/kg).

(g) This classification as toxic was based on delayed toxicity.

GUIDELINES FOR THE SAFE HANDLING OF DYESTUFFS IN COLOR STOREROOMS (Reprinted with the permission of ETAD)

Introduction

These suggested guidelines for the safe handling of dyestuffs are aimed at reducing the exposure of workers in color storerooms to dyestuffs. They are particularly applicable to those dyehouses in the textile, paper, leather and plastic industries where dyes are handled in a powder or similar form.

These guidelines are general in nature and are not intended to be an exhaustive list of precautions which cover every situation in a color storeroom or every chemical found there. Dye weighers and handlers should follow any advice or instructions received from the chemical supplier with respect to safety and health precautions for using and handling dyes and other chemicals in the color storeroom or elsewhere as well as comply with all applicable federal, state and local laws and regulations.

A large number of dyes are used by various industries, and information on the potential health effects of long term exposure to many of these is not available. In light of current knowledge, the vast majority of dyestuffs should be placed in the category of substances whose toxicity to man is not known.

There has been some suggestion of a connection between carcinomas of the bladder and exposure to certain dyes. Although this connection appears more clearly related to workers who have been exposed to certain intermediates used in the manufacture of these dyes, it is not reasonable, at this time, to discount a possible risk to dye users.

It would also appear that there is some relationship between a few dyestuffs and an asthmatical condition from sensitization whereby the sensitized worker will become subject to attacks of asthma following subsequent exposure to very low concentrations of the sensitizing agent. Additionally, excess exposure to dyes and, more particularly, to certain chemicals used in the dyeing industry may cause dermatitis, especially on the hands and forearms of dyeworkers.

Accordingly, it is strongly advocated that a general precautionary policy be adopted for controlling the handling of dyestuffs, and this should be directed towards keeping worker exposure to these substances as low as is reasonably practicable. In order to do this, it must be recognized that substances can enter the human body through inhalation, ingestion or skin absorption and that this is most likely to occur when dyestuffs are handled in powder form, whether in color storerooms or elsewhere. Dyes are produced for industrial use in several physical forms. In addition to powders and granules, some specific dyes are available in liquid or paste forms. Although the potential for the inhalation and ingestion of dyes is reduced by the use of liquid or paste dyes, there is a possibility that some dyes can be absorbed through the skin following spills or splashes. Therefore, care must be exercised when handling liquid and paste dyes.

These guidelines attempt to set out procedures for reducing worker exposure to dyes and seeks to do this by considering the following:

- Good Housekeeping
- Dyestuff Storage
- Weighing Station Ventilation
- Respiratory Protection
- Personal Protective Clothing
- Washing and Showering
- Eating, Drinking and Smoking
- First Aid
- Information, Training and Supervision
- Construction of Color Storerooms

The term "color storeroom" is synonymous with the terms color shop, drug room, dye preparation area and dye weighing station.

Good housekeeping

The walls, floors and furnishings of the color storerooms should be kept clean by suitable non-dust producing methods, such as vacuum cleaning or the use of dust absorbent materials and adequate standards of tidiness should be maintained. Aisles and passages should be clear at all times. Spillages should be kept to a minimum and should be cleaned up immediately, again by suitable non-dust producing methods.

Dyestuff storage

The containers for all dyes should be kept in good condition, and they should be stored on pallets or platforms so that the cleaning of the floor of the color storeroom is facilitated and to keep the containers dry. Containers should be stored at suitable heights for handling, and where racking is used, it should be of sound construction with easy access. Lids should be kept on containers at all times, to prevent contamination and moisture absorption, except when necessarily removed for access to the contents. Any scoops used to transfer powdered dyes should enclose the powder to the greatest practical extent; that is, they should be designed on the coal scuttle principle with a curved base and a partial canopy.

Weighing station ventilation

Wherever reasonably practical, the weighing station should be enclosed and provided with a low level of exhaust ventilation sufficient to create a negative pressure at the feed opening. The level of such ventilation should account for the use of dyes in powder form, as it is possible that strong air currents may extract too much of the dyestuff and/or affect the sensitivity of the weighing scales. Exhausted air should be directed to a scrubber system.

Respiratory protection

In the following circumstances, the employer should ensure that NIOSH/MSHA approved respiratory protective equipment is provided and used:

- on the recommendation of the dyestuffs manufacturer;
- where persons are exposed to quantities of dust, for example during the cleaning of the color storerooms or following spillages of dyestuffs;
- when dyestuffs in powder or other physical forms likely to generate dusts are actually being scooped, weighed and dispersed;
- when required by applicable federal, state or local law or regulation.

Generally, dyestuff dusts are classified as nuisance dusts by OSHA in the Code of Federal Regulations, Title 29, Chapter XVII Occupational Safety and Health Administration (OSHA), Part 1910.1000. If compliance with the nuisance dust standard cannot be achieved through the use of feasible administrative and engineering controls, then NIOSH/MSHA approved respiratory protective equipment of adequate efficiency should be provided. When not in use, such equipment should be stored in suitable holders or boxes to protect against contamination. They should be cleaned, inspected and maintained by a designated person, and this should be done as frequently as necessary to ensure that proper protection is provided for the wearer. Further advice on the cleaning and maintenance of respiratory protective equipment should be obtained from the manufacturer.

Personal protective clothing

Protective clothing should be provided and worn by color storeroom workers. This should include shirts and pants that cover the arms and legs or coveralls, head coverings, suitable footwear and gloves. It should be kept in good condition and regularly laundered. Safety glasses should be worn at all times.

Washing and showering

Adequate washing facilities, with an ample supply of clean running hot and cold water, soaps, and clean towels or other suitable means of drying for the hands and face, should be provided. Nail brushes should also be provided. Wherever practicable, these facilities should be situated so that they can be conveniently used by employees passing from the color storeroom to the lunchroom area.

Shower facilities should be provided conveniently accessible to the color storeroom for the use of the workers. The facilities should include separate lockers for outdoor clothing and working clothes, providing secure storage for clothing and personal possessions.

When chemicals and/or detergents are used to remove dyestains from the skin, procedures should be adopted to ensure the chemicals are properly removed by neutralization and rinsing before the skin is dried so as to prevent dermatitis.

Eating, drinking and smoking

Eating, drinking, smoking, the application of cosmetics and the preparation and keeping of food and drink in color storerooms should be prohibited. Any existing means of preparing refreshments in such places should be removed. A suitable lunchroom should be available to all workers. Notices should be posted requiring employees to wash their hands carefully before eating, drinking or smoking.

First aid

A first aid box, clearly identified and placed in the charge of a responsible person, should be readily accessible and, to prevent contamination, should be situated outside the color storeroom. It should contain suitable dressings to enable open wounds to be quickly covered after thorough washing; such wounds should receive proper medical attention subsequent to first aid treatment. Suitable eye washing and emergency shower facilities should be provided and maintained in an easily accessible area in good working condition.

Information, training and supervision

Dyestuff and other chemical suppliers generally provide their dye application customers with material safety information for their products. This information about precautions in handling and using dyes and other chemicals should be made available to employees working in the color storerooms and to any other employee exposed to such products.

Adequate training should be given to ensure that all persons working in the color storerooms have a clear understanding of the possible hazards associated with the materials they handle. In addition, they should be fully instructed in the precautionary measures set out in these guidelines.

Sufficient supervision should be provided to ensure that the precautionary measures are adopted and observed.

Construction of color storerooms

It is recognized that there may be difficulties in making immediate and substantial alterations to existing color storerooms. Nevertheless, this guideline includes recommendations on the design of new storerooms, and wherever possible, these should be incorporated in existing premises.

The walls and floors of color storerooms should be constructed of materials that can be easily cleaned. Walls should have smooth impervious surfaces capable of being washed down, and floors should be smooth but non-slip, preferably designed with a fall to a channel or drain so that when washed down the water can be easily removed. The floors should be corrosion resistant, and have adequate strength to withstand vigorous treatment from containers of all kinds. Color storerooms should be well lit and of sufficient size to afford easy and unimpeded access to the stored materials. They should

be well ventilated. Account should be taken of any fire hazard that may exist, and there should be appropriate consultation with the plant fire brigade and the local fire department.

Chemicals other than dyestuffs

Dyestuffs are not the only substances kept in or near color storerooms or handled by the workers in the color storerooms. Frequently, other chemicals used in the dyeing processes are stored and handled in the area. Much of what has been said in the foregoing parts of this guideline applies equally to these materials. In many instances, additional precautions are necessary in order to deal safely with the special properties that may be associated with them. It is not possible in this document to identify these chemicals individually, but from a hazard point of view, they do fall into broad groups, each of which presents its own particular dangers. These groups are classified as corrosives, flammables and oxidizing agents and toxics, and the general precautions to be taken or made available in respect to each of them are set out below. It must be emphasized that these precautions are not exhaustive, and users should take careful note of labelling and detailed information on proper usage and handling provided by the suppliers (e.g. Material Safety Data Sheets or OSHA Form 20s) and applicable federal, state and local laws and regulations.

Corrosives

Some alkalis and acids particularly fall into this category. Care should be taken to prevent skin contact by the provision of appropriate protective clothing, including approved eye protection. Emergency drenching showers including eye washers should be provided in places where there is a risk of serious or substantial contact with corrosive substances.

Flammables and oxidizing agents

Certain liquids used are flammable. These liquids should be clearly labelled, stored and used only in accordance with applicable instructions and regulations. Some powdered chemicals are susceptible to spontaneous combustion, while others are combustible on contact with small amounts of water; these materials should be kept in suitable metal containers with sealed lids. Oxidizing agents, though not themselves combustible, may in fire conditions increase the danger and should not be stored with flammable liquids. Education of all employees on these chemicals is extremely important. Periodic review of the dangers is important to prevent any chance of an accident.

Toxics

Many chemicals are toxic if inhaled, ingested or absorbed through the skin. Exposure to some of these chemicals has been regulated by governmental authorities (e.g. OSHA's permissible exposure limit (PEL) as found in 29 CFR 1910.1000 of January 1, 1977). In such cases, exposure should be maintained at or below government mandated levels. In addition some chemicals have been allocated Threshold Limit Values (TLVs[®]) and Short Term Exposure Limits (STELs) by the American Conference of Governmental Industrial Hygienists.* Exposure to such chemicals should be kept below the applicable TLV and STEL levels. If necessary, suitable respiratory and other protective equipment should be provided. Where the atmosphere in a chemical storeroom is likely to be contaminated, atmospheric analyses should be carried out periodically.

General precautions for chemical storeroom

The following general precautions should be observed in chemical stores, in addition to the precautions specific to the individual groups of chemicals already referred to above.

* Available from: Publications Office, ACGIH
6500 Glenway Avenue, Building D-5
Cincinnati, Ohio 45211, USA

- Separate storage areas should be provided for chemicals as distinct from dyestuffs, as spillages of chemicals require frequent floor washing operations which create a moist atmosphere not conducive to the good storage of dyes.
- Spillages should be avoided wherever possible by the provision and use of non-spill containers.
- When spillages or leakages do occur, they should be dealt with quickly, using methods recommended by the supplier of the chemicals.
- Chemicals which react violently together, such as acids and alkalis or oxidizing agents and reducing agents, should be kept in separately defined areas which should be clearly marked either by a color coding system or by the use of suitable labelling techniques.
- To prevent cross-contamination of incompatible chemicals, separate dispensing scoops and other handling containers should be provided.
- If, as a result of cross-contamination of incompatible chemicals, there is a possibility of release of toxic fumes or gas, then the recommended canister respirators or breathing apparatus should be readily available.
- Warning notices or safe methods of handling hazardous chemicals should be posted and clearly visible at the places where these chemicals are stored.

Conclusion

The above guidelines have set forth general recommendations about precautions which may be used to reduce exposure of workers in color storerooms to dyestuffs and other chemicals and to reduce any risks associated with such exposure. It is emphasized that such guidelines are intended neither to cover all conceivable situations nor to discourage the use of other precautionary measures which may be necessary or appropriate in some circumstances. Persons engaged in activities related to a color storeroom should carefully adhere to informational materials provided by suppliers or other qualified persons on the handling and use of individual chemicals and comply with all applicable federal, state and local laws and regulations. In light of the general nature of these guidelines, no warranty is given that compliance with the recommended precautionary measures will eliminate all risks which may be associated with the operation of a color storeroom.

Acknowledgement

These suggested guidelines are based on a document entitled "Safe Handling of Dyestuffs in Colour Stores," which was prepared in Great Britain by a committee whose members represented industry, trade unions and the UK Health and Safety Executive. This British document, published by the UK Health and Safety Executive, has been adapted to US terminology, and the order of the items discussed has been changed.

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ANNEX E

WASTE AND EMISSION AND ENERGY AUDITS

1. WASTE AND EMISSION AUDITING

This technique aims to identify all important sources of emissions and wastes within a plant, and in particular, to determine why they occur. In this way priority waste streams can be addressed in the most cost-effective manner.

A good waste audit:

- defines sources, quantities and types of waste being generated;
- collates information on unit operations, raw materials, products and water usage and wastes;
- highlights process inefficiencies and areas of poor management;
- helps to set targets for waste reduction;
- permits the development of cost-effective waste management strategies;
- raises awareness in the workforce regarding benefits of waste reduction;
- increases knowledge of the process;
- helps to improve process efficiency.

The technique is essentially a mass-balance approach which reconciles materials coming into the site with products and wastes leaving it. It is particularly well adapted to studying processing operations of a plant.

The waste audit consists of a number of discrete steps as shown in the attached diagram. The pre-audit phase is particularly important in gaining both management and worker support for the audit.

Following the second phase, i.e. the mass balance, the synthesis phase is the key to taking action. Here the obvious reduction measures are identified and immediately implemented. The segregation of waste streams for separate treatment is examined, and ways of avoiding the remaining waste streams are studied.

Experience in manufacturing and chemical industries has been that the first waste audit at a plant commonly leads to considerable cost-savings for the company because excessively wasteful practices and inefficient equipment is identified. Subsequent audits gradually deal with the more difficult problems some of which may lead to reinvestment in more efficient plant. Here the cost-savings are more often of a medium or long term nature. In all cases the methodology allows a concentration on the most important problems, and encourages cost-effective waste minimisation rather than aiming immediately at expensive treatment installations.

2. ENERGY AUDITS

A detailed study of energy use can be well worthwhile for many plants. Energy consumption can often be reduced by adopting more efficient operating procedures and equipment.

There is a double benefit to such a study. Not only does it identify major cost-savings to the company, it reduces a number of indirect environmental impacts from transport of fuel, and CO₂ emissions from fuel use. CO₂ is the major greenhouse gas implicated in global warming, and a number of legislative measures will soon be aimed at reducing such emissions from industry.

Energy audits are similar in concept to other audits. Careful preparation, a rigorous methodology and subsequent follow-up, remain the keys to success. Subsequent to the audit, it is of course necessary to identify appropriate conservation measures.

PROCEDURE FOR ENERGY AUDITS

Phase 1 An audit of historical data

Collect and analyze company records of energy use to determine:

- the cost and physical quantities of energy inputs used
- annual and seasonal trends in energy use and cost
- the energy use per unit of output

Phase 2 The screening survey

Undertake a screening study of energy use in the operation. This will be a fairly quick, low cost preliminary investigation of an operation using existing data to indicate:

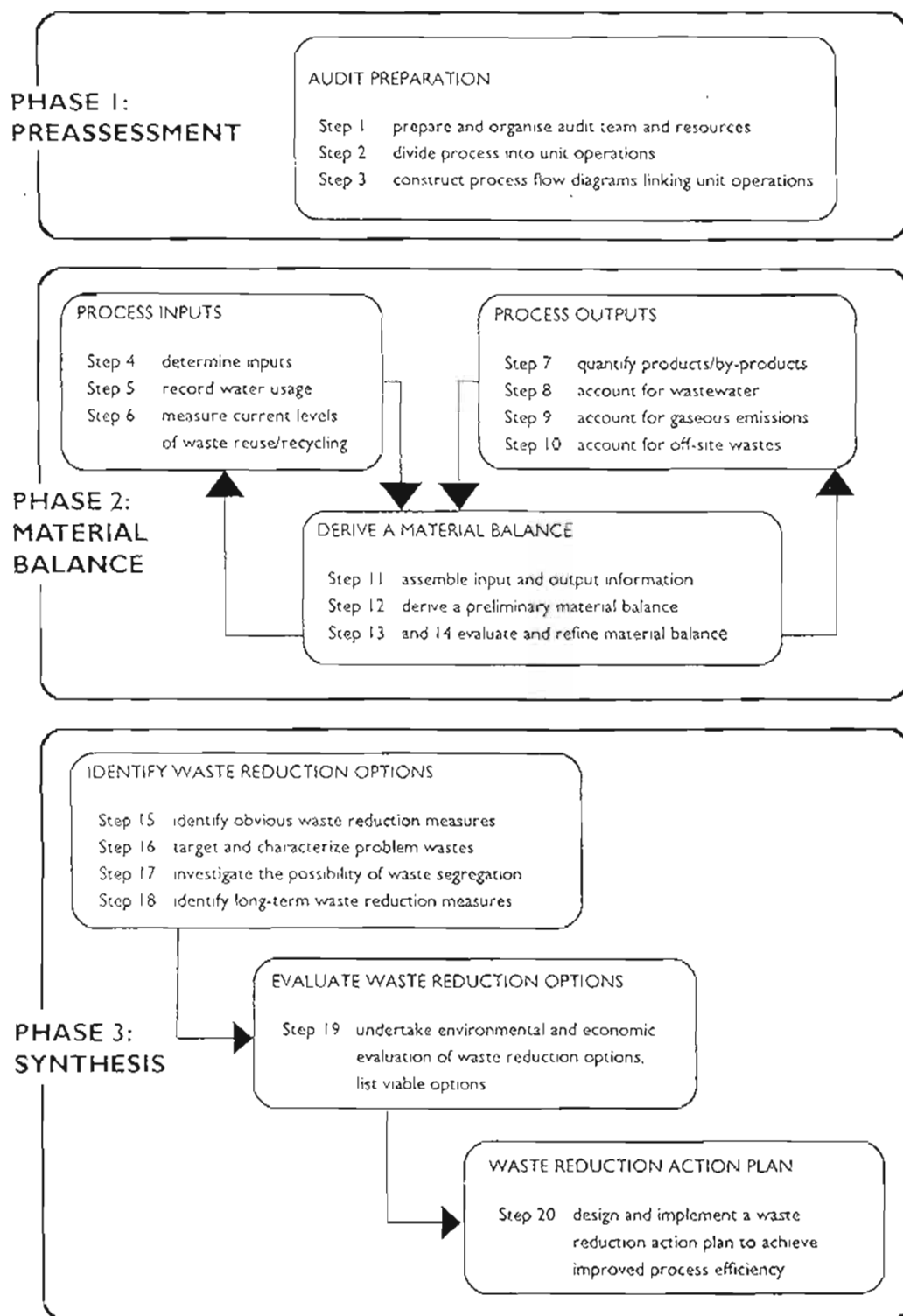
- major energy consuming plant and processes
- obvious energy waste and inefficiencies
- gaps in the metering and reporting of energy use
- priority areas for investigation of inefficient or inappropriate energy systems

Phase 3 Detailed investigation and analysis

Processes or plant identified by the screening survey as justifying further investigation will have to be examined in order to determine the size of avoidable energy losses and the cost of reducing this waste.

Detailed surveys may incur considerable cost and/or time, therefore it is vital to select only those processes, areas or plant which are most likely to yield significant cost-savings for a reasonable effort.

QUICK REFERENCE WASTE AUDIT GUIDE



EXAMPLE OF WASTE AUDIT AND REDUCTION IN A TEXTILE INDUSTRY

Background:

The mill is a medium sized unit which processes 100% cotton yardage and intermittent quantities of 50% cotton 50% polyester yardage. It has an average employment of 750 workers per shift and has three shifts a day. There are 300 additional employees comprising management and support staff during daytime hours. This mill processes on an average 150,000 metres a day with an average of 6 metres per kilogram.

The average water requirement at the time of the audit was 5,000 cubic metres of water a day. The pre-study gross water usage was 200 l/kg of cloth. This estimate includes steam usage.

This company decided to do an audit because the local government had increased the water pricing and had instituted a tiered fee schedule for the effluent flows based on volume and concentration of pollutants. The State mandate to reduce air emissions was also a consideration. A change in management had recently taken place and the new plant manager was more receptive to making in-house improvement.

Audit Team:

The auditing team consisted of the Environmental Officer, Chief Chemist, Plant Manager and two junior engineers. After the detailed plans were chalked out, an Employee Orientation Programme was organized to brief the workers, whose cooperation was essential in the entire task.

Identification of Processes:

As a first exercise, the auditing team walked through the plant to prepare a listing of unit operations. The available process flow sheets were found to be outdated, and had to be updated with respect to new processing lines and equipment. With the help of available drawings a block flow diagram was created, noting inputs of fabric, chemicals, water use and recycle and heat (steam). The outputs of wastewater, fabric, and streams to recycle were detailed. Drains locations were noted. An updated process flow diagram was developed from this data. It was reviewed with mill personnel at the management level and also with assistant supervisors who are more familiar with actual process conditions. Modifications were then made to the flow sheet.

Figure 1 shows the typical process flowsheet developed for the section of cotton cloth preparation and process house showing material movement for one batch.

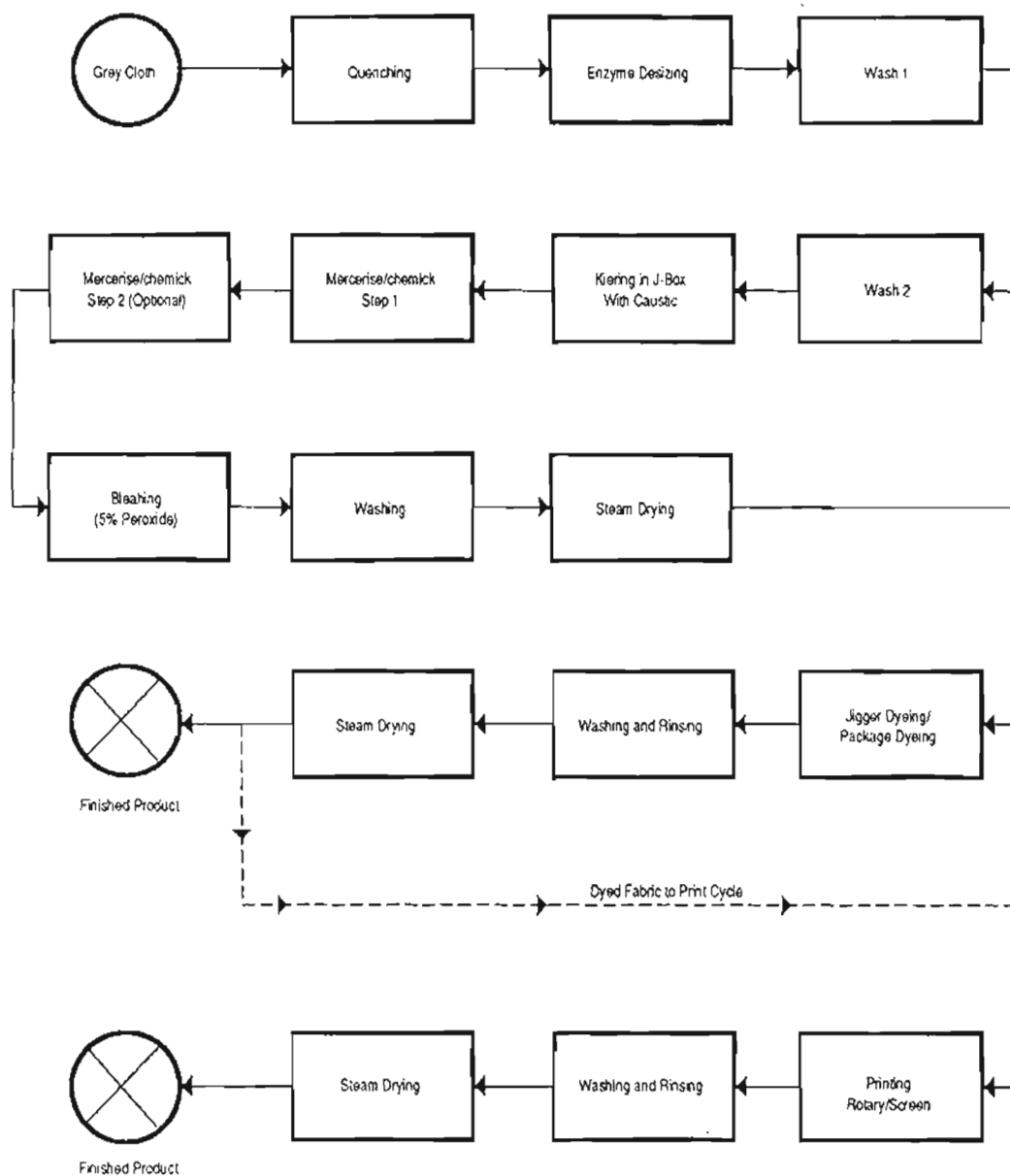
Cloth Preparation Sequence:

The company purchased grey cloth from another unit. Following processes were used:

1. Quenching
2. Desizing (with Enzymes)
3. Wash-1
4. Wash-2
5. Kiering in the J-Box with Caustic (5%)
6. Mercerising with concentrated Caustic (37%)
 - Chemick-1
 - Chemick-2

The chemicking sequence was done to add to the fabric a brilliant finish and luster. This was accomplished in one or two stages depending upon the nature of the finish expected.

7. Bleaching (with Peroxide concentration 5%)
8. Washing
9. Drying (with Steam) 2 kg Steam/kg fabric

Figure 1: Process Flow Sheet for the Textile Process House

The chemicals used in the process house included: caustic, enzymes for desizing, hydrogen peroxide for bleaching, stabilizing agents for bleaching, soaps, detergents for washing, chemicking.

Dye House Sequence:

The dye house was found to have the following important operations:

1. Yardage dyeing
 - Beck dyeing (rope) for yardage
 - High pressure reactor for cotton/polyester
 - Padding operation with aging
 - Jigger dyeing
2. Printing operations
 - Rotary screen
 - Semi-automatic flat screen
3. Washing and Curing
4. Drying

Steam was used for heating in process. This was generated from a boiler house using rice hulls, with fuel value of approximately 3150 kcal/kg. This unit produced 12 tonnes of steam from approximately 16 tonnes of water per hour. This amounted to a daily steam usage of 288 tonnes of steam per day.

The chemicals used in the process house include:

1. Dyestuffs: Reactive (cotton), Direct (cotton), Dispersed (for cotton/poly blend), occasionally some ingosal vat dyes are used for certain shades (this dyestuff was not in use during the course of this audit).
2. Chemical Auxiliaries for dyeing: Sodium chloride, sodium sulphate, caustic, surfactants, carriers are used for the cotton/poly blends, mineral acids, sodium bicarbonate, and urea.
3. Washing: Acetic acid, softeners, soaps
4. Boiler chemical for water treatment

The fabric preparation operation was continuous type and mostly automatic. Generally the process sequence did not alter much except for chemicking operation which was more or less dependant on the desired quality and finish of cloth. Accordingly, this operation was carried out in one or two steps. This was the sole influencing factor in the fabric preparation for the variation in resource consumption and quantity and quality of generated effluent. It was observed that the washing sequence was the most often used in the entire process and it consumed a substantial amount of water (70% of the total required for fabric preparation).

The sequence with the maximum chemical consumption was identified to be dyeing and printing. The most water intensive process here was once again that of washing. In the dye house, the processing was typically batch and semi-automatic. All available processing capacity was not always in use due to the changing demands of colour fashion and fabric design. The use of dye types and discharges varies with market conditions. These aspects of variability and non-operational equipment were given due consideration while interpreting the audit data.

Quantification of Process Inputs and Outputs (Material Balance Study):

Quantifying the process inputs and outputs is a very important part of the auditing programme. In order to enable this phase, initially a number of locations were examined to install flow measuring devices like V-notches or flow meters.

After finalizing the unit operations and process flow sheet the precise locations for installing the flow measuring instruments (for both water consumption and generated effluent), were decided and the works taken up accordingly. For example, the water meter on the main line was repaired for its minor defects and was checked for calibration. Also it was decided to install a new V-notch permanently

at the end on the main sewer line and monitor inflow and outflow for the entire unit throughout the year. Occasionally water was purchased by tanker during the dry season. This was also included in the calculation of water balance.

A method of stocking housekeeping records was introduced in the stores with regard to consumption of dyes and chemicals. Production of dyed cloth, chemical and dye usage was detailed from purchasing and store records. Housekeeping records were also examined. Handling losses were determined from interviews and observations. These were estimated at 2 to 5%.

The various sources of wastewater were identified. The plant had three major drains, one containing waste from the mercerising as well as dyeing and printing operations, and a second containing condensate, wash water from the various sections and the sanitary sewer. The third drain originated from the dye stock mixing kitchen that would periodically run out to a ditch and into the local roadway. This contained washdown water from the dye mixing room. Samples were collected from individual discharge sources and all wet processing equipment, and analyzed.

The stack from the boiler house constituted the main gaseous emission point. An outside consultant was called in to sample it for suspended particulate material (SPM), sulphur and nitrogen oxides (SO_x and NO_x), carbon monoxide (CO) and oxygen content. The consultant also determined the flow rates.

Off-site waste was composed largely of mill-ends which were sent to a processing unit where they were cleaned and cut into strips. These were supplied to manufacturers of durrie style carpets.

A detailed sampling schedule as prepared during the planning stage was followed to obtain raw data required to prepare material balance studies. Generally water input and output was noted for four months on a daily basis with the help of the installed flow measuring devices. Wherever there was no access for installing meters and V-notches, some water usage was estimated based on the dimensions of vessels and number of times in a given time period that it was filled. The wastewater from the unit dyeing and printing and washing operations was estimated by bath volume. The concentrations for dyestuffs and chemical remaining were determined analytically and by spectrophotonic method. Accordingly, average water consumption and effluent generation on per unit production per day was worked out. Further, the effluent characteristics were analyzed for four consecutive days over a period of four months and averaged as tabulated in the following tables.

► *Table 1 Water Consumption and Effluent Quantity and Quality for Cloth Preparation*

Unit Process	Water Consumed 1000 l/day
Desizing	150
Wash 1	250
Wash 2	250
Kiering	100
Wash	17.5
Chemick 1	27.5
Chemick 2	27.5
Peroxide Bleaching	27.5
Wash	275
Total	1125.0

► *Table 2 Water Consumption for Dyeing and Processing Per Day*

Unit Process Consumption	Water Consumed	Gross
	l/kg	1000 l
Jigger Dyeing	30	600
Dyeing and Soaping	15	300
Jet Dyeing	20	100
Pigment Printing	40	200
Regular Printing	80	800
Washing	10	250
Screen Washing *L/Screen	100	20
Total water consumption for dyeing and processing		2270

► *Table 3 Steam Usage*

Process	Steam Consumption tonnes/day
Jet Dyeing	40
Dyeing and Soaping	100
Bleaching	20
Scouring	30
Mercerising	40
Drying	50
Misc.	8
Total	288

Some additional work was required to obtain a good water balance. There was 20% unaccounted water. Some of this was attributed to evaporative losses and leaks in the boiler operation. It was postulated that rinsing and washdowns occurred on the third shift. This was verified and found to be true. The balance was reconstructed with these estimates and close agreement was found (less than 10%).

Based on this preliminary study, following recommendations were made with respective action plans.

RECOMMENDATIONS:

Housekeeping in the dye house:

The drain in the dye stock mixing kitchen was piped into the drain from the dye house. Much of the washdown water originated due to cleaning up the dye stock spillage. Operators in this location were given training in good housekeeping practices. New mixers were installed in this location. This reduced spillage and reduced the need to wash down the area. Chemicals were saved and COD in the effluent was reduced.

Water Re-use:

It was clear that a major part of fresh water consumption (i.e. 70%) was due to various washing stages which actually do not need fresh water. An intensive water reduction and re-use scheme was taken up. A consultant was appointed for this purpose and after discussion, both quality and quantity requirements were reviewed.

Following this, a scheme for recirculation and re-use of water was devised. An empty tank was re-stored after carrying out minor repairs. It was proposed to segregate washing process effluents to this tank for storage and blending. A pressure sand filter was provided with a pH adjustment unit. After treating the washing effluent in this way, this was recirculated to the different washing stages. The fresh water connections to the subsequent washes except first wash were removed and replaced by the reclaimed wash water. After this, a recirculation routine was operated for a few days and guidelines were laid down to estimate the schedule and quantity of required makeup fresh water. In this way, a 30% reduction in the fresh water consumption was achieved.

Washing of printed and dyed cloth was done in three stages. All water was being used in a once-through manner. Instead, counter-current washing was installed. This consisted of washing the finished cloth with clean water and pumping the water to the next wash bath, with "dirtiest" water being used to wash the cloth as it exited the dye bath or directly from the curing operation.

Chemical Re-use:

The effluent stream from the Kiering J-Box contained large amounts of dirt and caustic. It was proposed to set up a caustic concentrator recovery unit in the mill. The monthly requirement of caustic for the mill was thus reduced from 34,000 kg to 20,000 kg.

ANNEX F

US EPA, BPT* AND BAT** EFFLUENT LIMITS FOR THE TEXTILE INDUSTRY

Wool Finishing Subcategory

i) BPT Limitations, kg/1000 kg of fibre

	Daily Maximum	Monthly average
BOD	22.4	11.2
COD	163.0	81.5
TSS	35.2	17.6
Sulphide	0.28	0.14
Phenols	0.14	0.07
Total Chromium	0.14	0.07
pH	6 to 9	6 to 9

ii) BAT Limitations, kg/1000 kg of fibre

	Daily Maximum	Monthly average
COD	163.0	81.5
Sulphide	0.28	0.14
Phenols	0.14	0.07
Total Chromium	0.14	0.07

* Best Practicable Technology Currently Available

** Best Available Technology Economically Achievable

Woven Fabric Finishing Subcategory

i) BPT Limitations, kg/1000 kg of product

	Daily Maximum	Monthly average
BOD	6.6	3.3
COD	60.0	30.0
TSS	17.8	8.9
Sulphide	0.20	0.10
Phenols	0.10	0.05
Total Chromium	0.10	0.05
pH	6 to 9	6 to 9

ii) BAT Limitations, kg/1000 kg of product

	Daily Maximum	Monthly average
COD	60.0	30.0
Sulphide	0.20	0.10
Phenols	0.10	0.05
Total Chromium	0.10	0.05

Knit Fabric Finishing Subcategory

i) BPT Limitations, kg/1000 kg of product

	Daily Maximum	Monthly average
BOD	5.0	2.5
COD	60.0	30.0
TSS	21.8	10.9
Sulphide	0.20	0.10
Phenols	0.10	0.05
Total Chromium	0.10	0.05
pH	6 to 9	6 to 9

ii) BAT Limitations, kg/1000 kg of product

	Daily Maximum	Monthly average
COD	60.0	30.0
Sulphide	0.20	0.10
Phenols	0.10	0.05
Total Chromium	0.10	0.05

Carpet Finishing Subcategory

i) BPT Limitations, kg/1000 kg of product

	Daily Maximum	Monthly average
BOD	7.8	3.9
COD	70.2	35.1
TSS	11.0	5.5
Sulphide	0.08	0.04
Phenols	0.04	0.02
Total Chromium	0.04	0.02
pH	6 to 9	6 to 9

ii) BAT Limitations, kg/1000 kg of product

	Daily Maximum	Monthly average
COD	70.2	35.1
Sulphide	0.08	0.04
Phenols	0.04	0.02
Total Chromium	0.04	0.02

Stock and Yarn Finishing Subcategory

i) BPT Limitations, kg/1000 kg of product

	Daily Maximum	Monthly average
BOD	6.8	3.4
COD	84.6	42.3
TSS	7.4	8.7
Sulphide	0.24	0.12
Phenols	0.12	0.06
Total Chromium	0.12	0.06
pH	6 to 9	6 to 9

ii) BAT Limitations, kg/1000 kg of product

	Daily Maximum	Monthly average
COD	84.6	42.3
Sulphide	0.24	0.12
Phenols	0.12	0.06
Total Chromium	0.12	0.06

ANNEX G

ABOUT THE UNEP INDUSTRY AND ENVIRONMENT CENTRE

The Industry and Environment centre (IE) was established by UNEP in 1975 to bring industry and government together to promote environmentally sound industrial development. IE is located in Paris and its goals are to:

- 1) Encourage the incorporation of environmental criteria in industrial development plans
- 2) Facilitate the implementation of procedures and principles for the protection of the environment
- 3) Promote the use of safe and clean technologies
- 4) Stimulate the exchange of information and experience throughout the world.

IE provides access to practical information and develops co-operative on-site action and information exchange backed by regular follow-up and assessment. To promote the transfer of information and the sharing of knowledge and experience, IE has developed three complementary tools: technical reviews and guidelines; *Industry and Environment* - a quarterly review; and a technical query-response service. In keeping with its emphasis on technical co-operation, IE facilitates technology transfer and the implementation of practices to safeguard the environment through promoting awareness and interaction, training activities and diagnostic studies.

About Cleaner Production activities and the Textile Working Group

In 1988, UNEP IE established a Cleaner Production Programme with the objective of promoting low or non-waste technologies among industry. As a part of this activity, four industry specific working groups were established for textiles, leather, metal finishing and solvent-using industries. A newsletter on Cleaner Production was also launched and an initiative to develop a data bank of case studies was created, called the International Cleaner Production Information Clearinghouse (ICPIC).

The idea behind the creation of working groups was to obtain expert input via literature, presentations and case studies about pollution prevention on a voluntary basis. Members of the working group

are also expected to serve as important nodes of information exchange on an international as well as inter-regional basis. The textile working group consists of 50 members from six countries and has contributed to a collection of more than 50 case studies on the ICPIC database, approximately 1,500 references and a network of more than 100 professional contacts.

To join the group or for more details, please contact Dr Prasad Modak, Coordinator - Working Group on Textile Industry, at Centre for Environmental Science and Engineering, Indian Institute of Technology, Bombay, India. Telex 031 71385 IITB IN; Fax 91 (22) 5783480.

Some Recent UNEP IE Publications

Industry and Environment (quarterly) deals with issues relevant to industrial development, such as auditing, waste management industry-specific problems, environmental news.

Directory of Information Sources on Air and Water Pollution - INFOTERRA/IEO, ISBN 92-807-1233-0, 387 p., 1989.

Environmental Aspects of the Metal Finishing Industry: A Technical Guide (Technical Report Series No. 1), ISBN 92-807-1216-0, 91 p., 1989.

Tanneries and the Environment (Technical Report Series No. 4), ISBN 92-807-1276-4, 119 p., 1991.

Environmental Auditing (Technical Report Series No. 2), ISBN 92-807-1253-5, 125 p., 1990.

Audit and Reduction Manual for Industrial Emissions and Wastes (Technical Report Series No. 7), UNEP/UNIDO, ISBN 92-807-1303-5, 127 p., 1991.

Storage of Hazardous Materials: A Guide for Safe Warehousing of Hazardous Materials (Technical Report Series No. 3), ISBN 92-807-1238-1, 80 p., 1990.

Climate Change and Energy Efficiency, UNEP/IPIECA, 1992.

Hazard Identification and Evaluation in a Local Community (Technical Report Series No.12), ISBN 92-807-1331-0, 86 p., 1992.

Companies Organization and Public Communication on Environmental Issues (Technical Report Series No. 6), ISBN 92-807-1304-3, 130 p., 1991.

From Regulations to Industry Compliance: Building Institutional Capabilities (Technical Report Series No.11), ISBN 92-807-1342-X, 62 p., 1992.

Company Environmental Reporting (Technical Report Series No.24), ISBN 92-807-1413-9, 118 p., 1994.